DATA BOOK OF WORLD LAKE ENVIRONMENTS

—A SURVEY OF THE STATE OF WORLD LAKES—

edited by

Lake Biwa Research Institute

and

International Lake Environment Committee

International Lake Environment Committee

United Nations Environment Programme

Otsu 1987-1989

Foreword to the First-Year Prints

This data book is the major output from a joint ILEC/UNEP project, Survey of the State of World Lakes. The International Lake Environment Committee (ILEC) and the Lake Biwa Research Institute (LBRI) are jointly responsible for the editorial work.
The whole three-year project includes, besides the publication of the data book, in-depth studies on some inportant lakes and lake environment issues and a synthetic report based on the data collected.

Despite increasing demand for a methodology for sustainable development of lakes, few principles or guidelines have been developed on environmentally sound management of lakes and their catchment areas. The collection of information and numerical data on the present status of lakes in the world is urgently required for the development of such principles and guidelines, which would be useful for lake management experts as well as for decision makers and planners, especially in developing countries.

This publication was intended to compile geographical, limnological, socio-economic and environmental data on as many lakes of the world as possible to provide a basis for environmentally sound management consistent with sustainable development policies related to lakes. Multidisciplinary analyses of the data collected are expected to contribute greatly to the formulation of lake management guidelines, which is the subject of another project being carried on by ILEC and UNEP.

On the occasion of the Shiga Conference '84 on Conservation and Management of World Lake Environment (LECS '84) held at Otsu, Shiga Prefecture, Japan in 1984, LBRI and the National Institute for Research Advancement (NIRA) first attempted to prepare an original version of such a data book. However, this "Data Book of World Lakes" covered only 52 freshwater lakes. The present volume is essentially a revised and greatly augmented version of the LECS book. The number of lakes is significantly increased to cover saline and brackish lakes also, while several data items are newly added.

The data and information compiled in this book were btained by asking scientists, research institutes and administrative offices in many countries to fill the standard questionnaire sheets. Relevant books and scientific papers were also consulted for additional information. There are of course limitations to such a method of data collection. Inevitably the data obtained do not always fit the standard form requested by the editors. Socio-economic, legislative and managerial data are always more difficult to collect than geographical and limnological data. The editors have to apologize that the data are so heterogeneous in form and that the completeness of data differs widely from one lake to another.

The original questionnaire sheets are reproduced here as an appendix for the users' reference. The editorial committee is sincerely grateful for the cooperation by those who kindly responded to the questionnaire and whose names are mentioned for respective lakes in the text. Thanks are also due to the authors of the books and/or scientific papers for permitting their partial citation or reproduction.

To balance the distribution of work and printing cost over the three-year period, it was decided to print the completed text successively at the end of each year. Therefore the book takes a filing form. Additional pages are successively printed and added to the file. Lakes are tentatively classified into six geographical groups, Asia (ASI), Oceania (OCE), Europe (EUR), Africa (AFR), North America (NAM), and South America (SAM), and numbered in each group according to the time order of manuscript preparation. The geographical and alphabetical indices of lake names will be prepared at the end of the project period.

Representing ILEC and the editorial committee, I would like to express our appreciation for financial aid from UNEP and the Prefectural Government of Shiga, and heartfelt thanks to Dr.

Mostafa Tolba, Executive Director of UNEP, the late Dr. Lazlo David of the Water and Lithosphere Unit of UNEP and Dr. M. Nakayama for their effective support and advice to the present project.

December 1987, Otsu

Tatuo Kira
Chairperson of ILEC
and Chief Editor

Q U E S T I O N N A I R E   S H E E T S

FOR THE COMPILATION OF

DATA BOOK OF WORLD LAKE ENVIRONMENTS

INSTRUCTIONS

GENERAL

1) Please fill in the following blank tables and answer the questions as far as relevant data and information are available.

2) If you do not have access to necessary data, please suggest the names of appropriate persons or organizations together with their mailing address so that we may be able to establish contact for requesting their assistance.

3) Part of the data or answers may be substituted by attaching publications or their photocopies containing required information.

4) Please supply data as numerical tables as far as possible, unless otherwise stated. To save publishing costs, graphic representation should preferably be limited to a minimum number of cases in which quantitative data are not available.

5) Drawings provided ought to be clear and concise. They need not be camera-ready, however, because they will be redrawn by a specialist in the editorial office.

6) Short supplementary comments may be provided to help explain the numerical data or to compensate the lack of quantitative data.

7) Please mention clearly the sources of data referred to so that editorial committee can obtain the necessary permission for citation.

PHYSIOGRAPHIC AND BIOLOGICAL DATA

8) Average values over the latest 3-5 years are preferable. However, the data for a latest available year may be used if longer term data are not available.

9) As far as physico-chemical properties of lake water are concerned, the data observed at or near the lake center are preferred. If the lake concerned is large and consists of sub-basins or parts having different water qualities, data at more than one station may be given, respectively, in separate tables.

SOCIO-ECONOMIC DATA

10) Data for the latest available year are requested.

11) If the data are based on only parts of the lake's catchment area or on administrative boundaries which do not overlap with the catchment exactly, specify the area to which the data pertains(if necessary, on a map).

EXAMPLES

12) For your reference, two examples of data set are attached; one for a lake with fairly abundant information and the other for a lake with relatively limited data.

PHOTOGRAPH

13) A copy of colored photo, a slide or a print(larger than about 12.5cm x 9cm in size), is requested. An aerial view of the lake is most preferred. If this is not available, please supply one that illustrates a typical landscape, either natural or cultural.

LAKE NAME ______________________________

A. LOCATION

*Administrative district(county or state, country)

____

____

*Approximate latitude and longitude(ranges for large lakes)

____°____'-____°____'N or S ____°____'-____°____'E or W

*Altitude __________ m above sea-level

B. INTRODUCTORY DESCRIPTION OF THE LAKE

[Note] Please prepare a brief description of the lake (about 500 words), including the lake's geological origin, characteristic features if any(topographical, geographical, biological, etc.), social values as resources, natural landscape, scientific monuments and the likes, history of relations with human activities, recent environmental issues, etc. In case of man-made lakes, add the purpose, the incurred costs of project development and construction, and the responsible body in charge of construction, and the year of completion.

C. PHYSICAL DIMENSIONS

*Surface area ______________________________ km^2

*Volume ____________________________________ m^3

*Maximum depth ______________________________ m

*Mean depth _________________________________ m

*Normal range of annual
water level fluctuation ____________________ m
Is the lake's water level artificially
controlled? Yes [ ] No [ ]

*Length of shoreline ________________________ km

*Residence time _____________________________ yr

*Catchment area[1] __________________________ km^2
[Note][1]The total sum of the catchment areas of rivers directly flowing into the lake. Not including the lake area.

D. PHYSIOGRAPHIC FEATURES

D_1 GEOGRAPHICAL

*Bathymetric map(attach as a separate sheet, if available. Mark the locations of meteorological station and observation points in the lake for cross referencing with the following tables or figures).

*Names and areas of main islands on the lake ____________________

____

*Number and names of outflowing rivers and channels

Number ________ Name(s) ____________________________________

D_2 CLIMATIC[1]

*Climatic data pertaining to a representative spot on or near the lake shore

Place name ______________________________

Period of observation ____________________

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp.[°C]													
Precipitation [mm]													

*Number of hours of bright sunshine per year ______ hr yr^{-1}

*Average solar radiation ______ MJ $m^{-2} day^{-1}$

*Water temperature [°C]
Station name(if necessary) ______

Period of observation ______

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface (m)												

*Freezing period(lake) From ______ to ______

*Mixing type(please mark appropriate word)

Meromictic Dimictic Monomictic Polymictic Others(   )

*Notes on water mixing and thermocline formation(if necessary)

______

______

[Note][1]In the case of large lakes which extend over different climatic regions, please give data at more than one spots.

E. LAKE WATER QUALITY

E_1 TRANSPARENCY[m]

Station name ______ Period of observation ______

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_2 pH

Station name ______ Period of observation ______

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_3 SS[mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_4 DO[mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_5 COD[mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

*Please mark the method used.

K_2MnO_4-method $K_2Cr_2O_4$-method

E_6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_7 TOTAL-N CONCENTRATION[1] [mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

[Note] [1] If not available, substitute NO_3-N and/or NH_4-N data.

E_8 Total-P CONCENTRATION[2] [mg l^{-1}]

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

[Note] [2]If not available, substitute PO_4-P data.

E_9 CHLORINE ION CONCENTRATION [mg l^{-1} or ‰](saline and brackish lakes only)

Station name ______________ Period of observation ______________

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

E_{10} PAST TRENDS OF THE ABOVE-MENTIONED WATER QUALITY VARIABLES (tabular or graphical data), IF AVAILABLE

F. BIOLOGICAL FEATURES

Station name and the year of observation
(if necessary, especially in large lakes)______________________

F_1 FLORA(mention the names of dominant or remarkable species)

*Emerged macrophytes ____

____

*Floating macrophytes ____

____

*Submerged macrophytes ____

____

*Phytoplankton(for different seasons, if necessary) ____________

____

F_2 FAUNA

*Zooplankton(for different seasons, if necessary) ______________

____

*Benthos(for different depths, if necessary) __________________

____

*Fish(mark economically important species with asterisks) ______

____

*Supplementary notes on the biota(endeminsm, distribution in the lake, etc., if necessary) ______________________________

____

F_3 PRIMARY PRODUCTION RATE[1]

Station name ____________ Period of observation ____________

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
Net production													
Dark respiration													
Gross production													

[Note] [1]Use units of the amount of carbon or dry matter produced, or oxygen released, per unit water surface area and time.

F_4 BIOMASS

Biomass data for the above taxa in units of dry matter per unit water or bottom area or plankton dry matter per unit volume of water; monthly and/or annual mean values.

F_5 FISHERY PRODUCTS

*Annual fish catch[metric tons]____________________ (in 19)

*Fishery products other than fish(shrimp, shellfish,etc., if any)

____

F_6 PAST TRENDS OF PRIMARY PRODUCTIVITY, BIOMASS AND FISHERY PRODUCTION(tabular or graphical data, if available)

F_7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE(if any, in recent years)

____

____

G. SOCIO-ECONOMIC CONDITIONS

G_1 LAND USE IN THE CATCHMENT AREA(in 19)[1]

	Area(km^2 or ha) [%]
Natural landscape	
Woody vegetation	
Herbaceous vegetation	
Swamp	
Others	
Agricultural land	
Crop field	
Pasture land	
Settlement area	
Others	
Total	

[Note] [1]If the data are based on an area not exactly the same with the catchment area, please describe the area concerned.

____

*Types of important forest or scrub vegetation(please mention only those which occupy large land areas)______________________

____

*Types of important herbaceous vegetation(do.)______________________

____

*Types of the other important vegetation(do.)______________________

____

*Main kinds of crops and/or cropping systems ______________________

____

*Levels of fertilizer application on crop fields(please mark appropriate word)

Heavy Moderate Light None

*Trends of change in land use in recent years, if any __________

____

G_2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE(in 19)

	Gross product Per year[2] (=US$1.00)	No. of persons engaged	No. of establishments	Main products or major industries
Primary industry				
Crop production				
Animal husbandry				
Fisheries[3]				
Others				
Secondary industry				
Tertiary industry				

[Note] [2]On monetary basis(provide the current conversation rate to US dollars)
[3]Fisheries on the lake concerned.

*Numbers of domestic animals in the catchment area

Cattle________ Sheep________ Swine________

Poultry_______ Others________, ________, ________

G_3 POPULATION IN THE CATCHMENT AREA(in 19)

	Population	Mean population density [no km^{-2}]	Names of major cities
Urban[4]			
Rural			
Total			

[Note] [4]Urban area defined here includes all the cities of which the population is greater than 30,000.

H. LAKE UTILIZATION

H_1 LAKE UTILIZATION(mark the appropriate boxes)

- [ ] Source of water(see below)
- [ ] Navigation and transportation
  *Tonnage(metric)of cargo per year(in 19) ______________
- [ ] Sightseeing and tourism
  *Number of visitors per year(in 19) ____________________
- [ ] Recreation
  [ ] Swimming [ ] Sport-fishing [ ] Yachting
- [ ] Fisheries
- [ ] Others(please specify) ____

H_2 THE LAKE AS WATER RESOURCE(in 19)

	Use rate[1]
Domestic water	
Irrigation	
Industrial water	
Power plant	
Others(please specify)	
______________	
______________	

[Note] [1]In units of m^3sec^{-1}, m^3day^{-1}, kw hr^{-1}, etc.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I_1 ENHANCED SILTATION

*Extent of damage(mark the appropriate box)

[ ] Serious [ ] Not serious [ ] None

*Supplementary notes,(rates of sedimentation and/or washout inflow, kinds of damage, recent history, local differences, etc. if necessary)

____

____

I_2 TOXIC CONTAMINATION

*Present status of toxic contamination(mark the appropriate box)

☐ Serious ☐ Detected but not serious
☐ None ☐ No information

*Main contaminants, their concentrations(year of determination) and sources

Station name(s) ______________________

Name of contaminants	Range of concentrations[ppm] in[1] Water	Bottom mud	Fishf[3]	Other organisms[4]			Main Sources[2]
	(19)	(19)	(19)	(19)	(19)	(19)	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	
	( )	( )	( )	( )	( )	( )	

[Note] [1] Please specify the basis of representation; volume basis, dry weight basis, wet weight basis, etc.

____

____

[2] Industrial, pesticide, airborne, waste dumps, etc.

[3] Species names and kinds of tissue ______________________

____

[4] Species names and kinds of tissue ______________________

____

*Environmental quality standards for contaminants in the lake, if any

____

____

*Food safety standards or tolerance limits for toxic contaminant residue (national or local), if any

____

____

*Past trends of the above concentrations(tabular or graphical data, if available)

*Supplementary notes(recent history and spacial distribution of contamination, countermeasures, etc., if necessary)

______

______

I$_3$ EUTROPHICATION

*Nuisance caused by eutrophication(mark the appropriate boxes)

- [ ] Unusual algal bloom
  Dominant species of algae ______
  ______
- [ ] Disturbed filtration in cleaning beds
- [ ] Foul odour of tap water
- [ ] Harms to fishery products
  Kinds of products damaged ______
- [ ] Others(Please describe) ______

*Nitrogen and phosphorus loadings to the lake(in 19)[5]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N					
T-P					

[Note] [5] Rates of loading on a whole lake basis or per unit lake surface area; e.g. kg day^{-1} , t yr^{-1}, kg m^{-2} day^{-1}, etc

*Supplementary notes on the recent history of eutrophication and countermeasures implemented

______

______

I$_4$ ACIDIFICATION

*Extent of damage(mark the appropriate box)

- [ ] Serious
- [ ] Detected but not serious
- [ ] None
- [ ] No information

*Kinds of damage(please describe) ______

______

*Past trends in hydrogen ion concentration in lake water, and, if available, rain/stream water(tabular or graphical data)

*Supplementary notes on the recent history of acidification and countermeasures implemented

______

______

I_5 OTHER HAZARDS(Please describe shortly, if any)

____

____

J. WASTEWATER TREATMENTS

J_1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA

Please mark the appropriate boxes.

*a. No major human settlements or activities producing significant pollution(pristine lake environments) ☐

*b. Location of pollution-generating human settlements or activities being restricted along the inflowing river basins or the coastal region of the lake, resulting in no major pollution of the lake(e.g. lake reserves) ☐

*c. Sporadic development of the catchment area with some provision for on-site wastewater treatment, municipal and/or industrial wastewater treatment, or agricultural runoff control, resulting in some discharge of pollution load into the lake ☐

*d. Significant development of the catchment area with some provision for municipal and/or industrial wastewater treatment or agricultural runoff control, resulting in measurable discharge of pollution load into the lake ☐

*e. Extensive development or exploitation of the catchment area with little or no provision for municipal and/or industrial wastewater treatment or agricultural runoff control, resulting in severe pollution of the lake ☐

*f. Other cases(please describe) ☐

____

J_2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	
Point sources	
Municipal	
Industrial	
Others(please specify)	
____________	
____________	
____________	
Total	100%

J_3 SANITARY FACILITIES AND SEWERAGE

*Percentage of municipal population in the catchment area provided with adequate sanitary facilities(on-site treatment systems) or public sewerage

*Percentage of rural(sparsely settled community) population with adequate sanitary facilities(on-site treatment systems)

*Municipal wastewater treatment systems

No. of tertiary treatment systems(specify typical systems adopted)

No. of secondary treatment systems(do.)

No. of primary treatment systems(do.)

No. of other types(specify, e. g., nightsoil treatment, etc.)

*Industrial wastewater treatment systems
How many? (specify typical system(s) adopted)

K. IMPROVEMENT WORKS IN THE LAKE(please mark the appropriate box and provide supplementary notes, if possible)

K_1 RESTORATION

☐ Notes __________

K_2 AERATION

☐ Notes __________

K_3 OTHERS

☐ Notes __________

L. DEVELOPMENT PLANS

Please describe the development plans in the lake and catchment area which have already been completed in recent years, or are now going on, or are being drawn up(period of operation, responsible body, purpose, cost, etc.)

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M_1 NATIONAL AND LOCAL LAWS CONCERNED

Please specify the names of laws dealing directly with control and restoration of lake environments and provide, in respective order, the information requested regarding each law.

*Names of the laws(the year of legislation)

(1) ____________________

(2) ____________________

(3) ____________________

*Responsible authorities

(1) ____________________

(2) ____________________

(3) ____________________

*Main items of control

(1) ____________________

(2) ____________________

(3) ____________________

*Supplementary notes, if necessary ____________________

____

M_2 INSTITUTIONAL MEASURES

Please mention the names, locations and year of establishment of public organizations responsible for monitoring, control and restoration of lake environments, with supplementary notes, if necessary.

(1) ____________________

(2) ____________________

(3) ____________________

M_3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

The same as above.

(1) ____________________

(2) ____________________

(3) ____________________

(4) ____________________

Supplementary notes, if necessary ________________________________

____

N. SOURCES OF INFORMATION

*Please identify the sources of data and information(reference documents, literature, etc.) in sequential numerical order in brackets, [ ], immediately following subject headings or subheadings for tables and figures, and list the details of these reference materials in corresponding order in the following space.

CONTENTS (1988)

Questionnaire sheets for the compilation of Data Book of World Lake Environments

Asia

ASI-1 Biwa-ko (Japan)
ASI-2 Lake Songkhla (Thailand)
ASI-3 Lake Rara (Nepal)
ASI-4 Lake Phewa (Nepal)
ASI-5 Chûzenji-ko (Japan)
ASI-6 Nagase-damu-ko (Japan)
ASI-7 Chao-hu (China)
ASI-8 Miyun Reservoir (China)
ASI-9 Lake Kinneret (Israel)
ASI-10 Danau Toba (Indonesia)
ASI-11 Dongting-hu (China)
ASI-12 Dong-hu (China)
ASI-13 Laguna de Bay (Philippines)
ASI-14 Inawashiro-ko (Japan)
ASI-15 Tasek Bera (Malaysia)
ASI-16 Shikotsu-ko (Japan)
ASI-17 Tôya-ko (Japan)
ASI-18 Sagami-ko (Japan)
ASI-19 Bung Boraphet (Thailand)
ASI-21 Akan-ko (Japan)
ASI-22 Mashû-ko (Japan)
ASI-23 Towada-ko (Japan)
ASI-24 Ogôchi-damu-ko (Japan)
ASI-25 Kawaguchi-ko (Japan)
ASI-26 Tai-hu (China)
ASI-27 Ozero Baykal (U.S.S.R.)
ASI-28 Tega-numa (Japan)
ASI-29 Inba-numa (Japan)
ASI-30 Ikeda-ko (Japan)
ASI-31 Suwa-ko (Japan)
ASI-32 Kizaki-ko (Japan)

Oceania

OCE-1 Lake Taupo (New Zealand)
OCE-2 Lake Burley Griffin (Australia)

Europe

EUR-1 Tjeukemeer (the Netherlands)
EUR-4 Lake Balaton (Hungary)
EUR-5 Lago Maggiore (Italy & Switzerland)
EUR-6 Zürichsee (Switzerland)
EUR-7 Lac Léman (Switzerland & France)
EUR-8 Loch Ness (U.K.)
EUR-9 Lake Skadar (Yugoslavia & Albania)
EUR-10 Lunzer See (Austria)
EUR-11 Windermere (U.K.)
EUR-12 Lake Trummen (Sweden)

Africa

AFR-1 Lake Chilwa (Malawi & Mozambique)
AFR-2 Lake Chad (Chad, Cameroon, Nigeria & Niger)
AFR-3 Lake Sibaya (South Africa)
AFR-4 Lake Kariba (Zambia & Zimbabwe)
AFR-5 Lake Victoria (Tanzania, Uganda & Kenya)
AFR-6 Lake Tanganyika (Tanzania, Zaire, Zambia & Burundi)
AFR-7 Lake Nakuru (Kenya)

North America

NAM-1 Lake Mendota (U.S.A)
NAM-2 Lake Tahoe (U.S.A)
NAM-3 Lake Michigan (U.S.A)
NAM-4 Lake Superior (Canada & U.S.A.)
NAM-5 Lake Huron (Canada & U.S.A.)
NAM-6 Lake Erie (Canada & U.S.A.)
NAM-7 Lake Ontario (Canada & U.S.A.)
NAM-8 Lake Winnipeg (Canada)
NAM-9 Lake Washington (U.S.A.)

South America

SAM-1 Represa do Lobo (Brazil)
SAM-2 Lake Nahuel Huapi (Argentina)
SAM-3 Ezequiel Ramos Mexia Reservoir (Argentina)
SAM-4 Lago Titicaca (Peru & Bolivia)

BIWA-KO (LAKE BIWA)

A northward view over the whole lake

Photo: Shiga Prefectural Government

A. LOCATION

§ Shiga Prefecture, Japan.
§ 34°58′-35°31′N, 135°52′-136°17′E; 85.6 m above sea level.

B. DESCRIPTION

Lake Biwa, the largest lake of Japan, is located in central Honshu and fills the bottom of an oblong tectonic basin. The lake was formed some five million years ago and is therefore one of the oldest lakes in the world geologically, though it was originally located some distance south and moved gradually to its present site about 700,000 years ago. The long history of isolation from other water bodies is suggested by the lake's biota, which is fairly rich for an island lake, containing about 50 species of fish, 40 species of mollusca and a number of indigenous species.

L. Biwa measures 63.5 km from north to south and is strongly constricted at about 16 km from its southern end reaching a minimum width of only 1.35 km. The deep main basin (average depth 44 m) north of the constriction is called the Northern Lake, while the shallow sub-basin (average depth 3.5 m) to the south is called the Southern Lake. The two basins differ considerably in water quality, physical conditions, flora and fauna.

The lake's catchment area is 4.7 times as wide as the lake itself, and corresponds closely to the administrative limits of Shiga Prefecture. Forest-covered hills and mountains accounts for nearly 60% of the land area of the Prefecture, and farmlands (mostly wet paddy fields) makes up additional 25%. The forest vegetation consists mostly of secondary forests of pine on low hills and of mixed deciduous hardwoods on marginal mountains, and plantations of conifers. There are several cities of moderate size, the largest being Otsu with a population of 240,000.

L. Biwa is also the biggest water resource in Japan that supplies city and industrial water for some 13 million residents in Osaka/Kyoto/Kobe megalopolis. The quality of lake water was profoundly influenced by economic development since the 1960's through rapid eutrophication. The legal control of waste water discharge from industries implemented by the National Government in 1970 slowed down the rate of eutrophication to a certain extent , but the steady increase of population, ever-rising standard of living, increased fertilizer application, etc. in the catchment area combined to result in a slow but steady march of lake water quality degradation.

The Shiga Prefectural Government enacted in 1980 the Ordinance for the Prevention of Eutrophication of Lake Biwa, which, for the first time in this country, prohibited the use of phosphate-containing synthetic detergents. The phosphorus content of lake water was thereby reduced considerably, but the effect of reduced phosphorus loading on biological processes in the lake is not yet apparent.

C. PHYSICAL DIMENSIONS (1)

	Northern Lake	Southern Lake	Total
Surface area [km²]	616	58	674
Volume [10⁹m³]	27.3	0.2	27.5
Maximum depth [m]	104	8	104
Mean depth [m]	44	3.5	41
Normal range of annual water level fluctuation (regulated) [m]	—	—	1
Length of shoreline [km]	—	—	235
Residence time [yr]	5.5	0.04	5.5
Catchment area [km²]	—	—	3,174

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-1-1).
§ Main islands (name and area): Oki-shima (1.5 km²), Chikubu-shima (0.14 km²), Take-shima.
§ Outflowing rivers and channels (number and names): 3 (Seta R., Biwako Canal I and II).

D2 CLIMATIC (3, 4)

§ Climatic data at Hikone (cf. Fig. ASI-1-1 and 2), 1951 1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	3.2	3.5	6.2	11.7	16.6	20.8	25.1	26.4	22.3	16.4	10.8	5.9	14.1
Precipitation [mm]	110	106	119	154	149	224	235	150	206	117	85	86	1,741

§ Number of hours of bright sunshine (Hikone, 1951-1980): 1,979.4 hr yr^{-1}.
§ Solar radiation (Hikone, 1967-1982): 13.1 MJ m^{-2} day^{-1}.
§ Average depth of maximum snow accumulation (Fig. ASI-1-3)

Fig. ASI-1-1 Bathymetric map (2).
● Observation station in the lake.
★ Meteorological observatory.

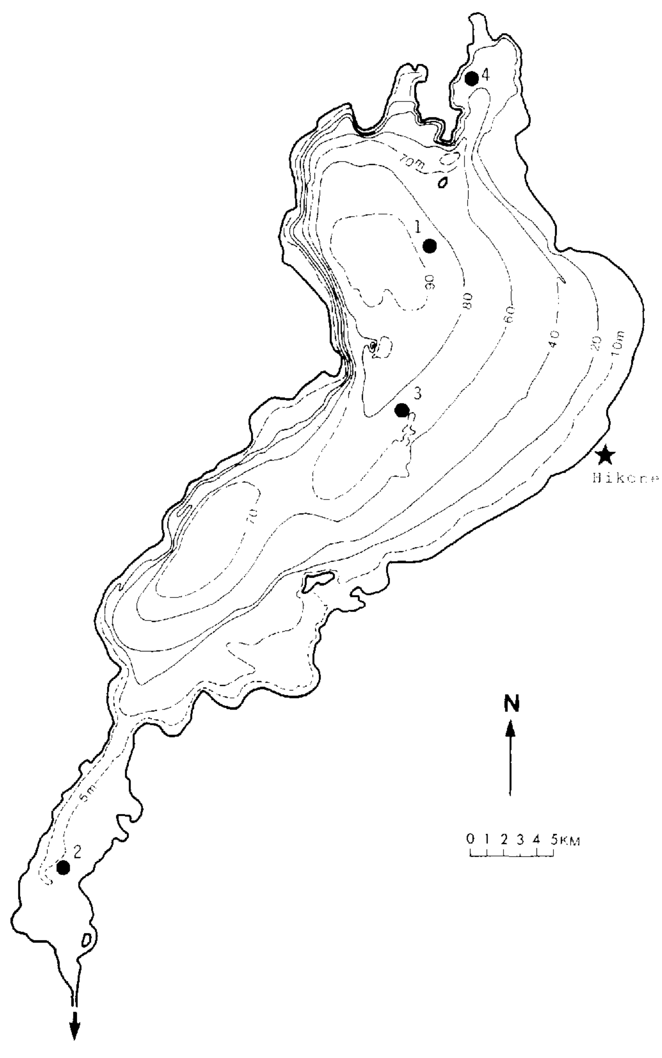


Fig. ASI-1-2 Distribution of mean annual precipitation [mm] in Lake Biwa Basin, with patterns of seasonal distribution of precipitation at representative stations (1931 1960) (5).

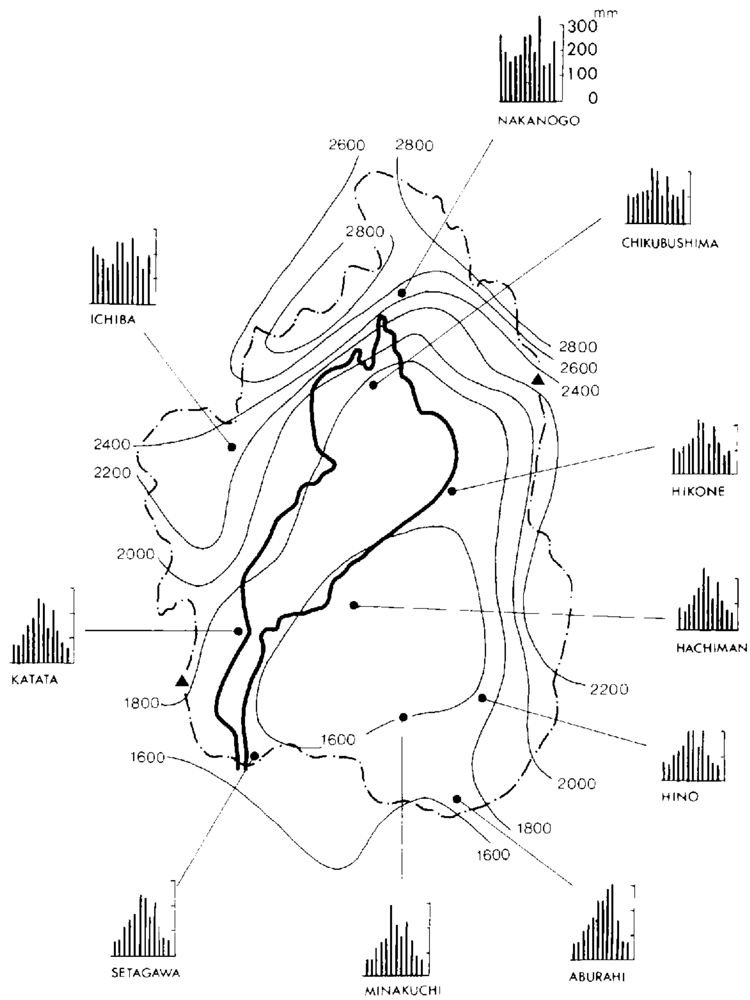
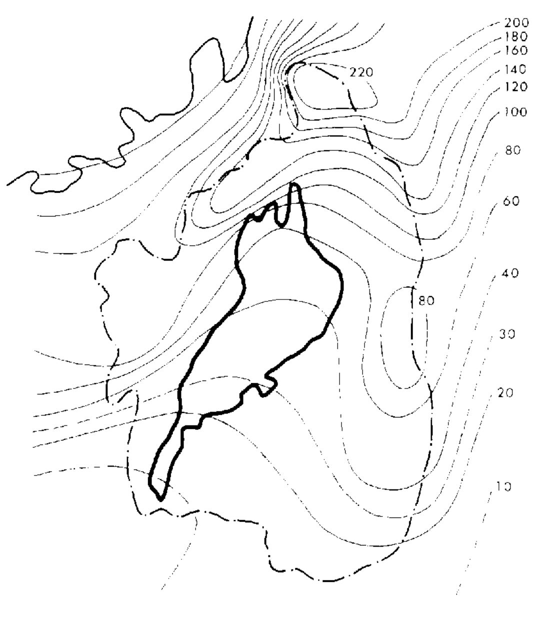


Fig. ASI-1-3 Average depth of maximum snow accumulation [cm] in Lake Biwa Basin (1931-1960) (6).



§ Water temperature [C] (7)

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	8.5	7.0	6.4	8.6	15.1	19.1	22.2	26.6	27.2	22.7	16.3	12.6
5	8.5	6.8	6.3	8.1	13.2	18.0	21.5	26.4	26.9	22.1	16.4	12.5
10	8.5	6.8	6.3	7.8	11.7	15.7	20.2	24.0	26.0	22.0	16.3	12.4
15	8.5	6.8	6.2	7.6	10.0	13.5	16.4	18.9	19.2	20.1	16.2	12.4
20	8.5	6.8	6.2	7.6	9.1	11.2	12.7	15.7	14.3	15.8	16.0	12.4
30	8.5	6.8	6.2	7.3	8.2	8.6	9.5	10.5	10.1	10.2	9.9	10.4
40	8.4	6.8	6.2	7.1	7.5	7.7	8.3	8.5	8.4	8.7	8.4	9.0
60	7.8	6.7	6.2	6.9	7.0	7.2	7.3	7.3	7.4	7.8	7.3	8.0
80	7.4	6.6	6.2	6.7	6.6	6.8	6.9	6.9	6.9	7.3	7.0	7.2
bottom	7.2	6.6	6.2	6.6	6.4	6.6	6.8	6.6	6.8	7.0	6.8	7.0

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	5.5	5.5	5.8	11.8	17.8	22.1	23.5	27.5	27.8	22.8	15.6	9.9
bottom	5.3	5.5	5.7	11.7	16.1	21.5	23.2	26.7	27.4	22.1	15.2	9.8

§ Freezing period : None.

§ Mixing type : Monomictic.

§ Notes on water mixing and thermocline formation : Thermocline formation is observed from May to November in the Northern Lake, but not in the Southern Lake.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], 1982-1986 (7)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Station 1	8.4	8.7	7.6	5.7	4.2	5.5	4.6	5.3	6.1	5.5	7.4	7.1
Station 2	2.0	2.4	1.5	2.4	2.1	2.1	2.4	2.4	1.8	1.5	1.7	1.7

E2 pH (7)

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	7.4	7.4	7.4	7.7	8.2	8.2	8.7	8.9	8.7	8.1	7.7	7.6
5	7.4	7.5	7.4	7.7	8.2	8.3	8.7	9.0	8.7	8.1	7.7	7.6
10	7.4	7.4	7.4	7.7	8.1	8.2	8.3	8.7	8.5	8.1	7.7	7.6
15	7.4	7.5	7.4	7.7	7.8	7.8	7.8	7.6	7.6	7.6	7.7	7.6
20	7.4	7.4	7.4	7.7	7.7	7.5	7.5	7.5	7.4	7.3	7.6	7.5
30	7.4	7.5	7.4	7.6	7.6	7.4	7.4	7.3	7.3	7.2	7.3	7.3
40	7.4	7.5	7.4	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1
60	7.2	7.4	7.4	7.6	7.6	7.4	7.4	7.3	7.3	7.2	7.0	7.0
80	7.0	7.4	7.3	7.6	7.5	7.4	7.4	7.1	7.1	7.1	6.9	6.9
bottom	6.9	7.4	7.4	7.5	7.4	7.3	7.2	7.0	7.0	7.0	6.9	6.9

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	7.6	7.6	7.5	8.0	8.7	8.9	8.5	8.8	8.7	8.8	8.0	7.8
bottom	7.6	7.6	7.5	8.1	8.6	8.8	8.6	8.8	8.7	8.6	8.0	7.7

E3 SS [mg l^{-1}] (7)

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.7	1.1	0.9	1.2	1.2	0.5	1.7	1.3	1.0	1.2	0.9	1.2
5	1.1	1.6	1.3	1.3	1.5	1.2	2.1	1.8	1.3	1.6	1.0	1.1
10	0.7	1.0	1.1	1.2	1.3	1.1	1.9	2.1	1.0	1.3	1.0	1.2
15	0.6	0.8	1.2	1.2	1.3	0.9	1.4	1.6	1.1	1.2	1.0	1.2
20	0.8	0.7	1.0	1.3	1.2	0.5	1.1	1.0	0.8	0.7	0.9	1.2
30	0.7	0.8	1.1	1.2	1.0	0.6	0.6	0.8	0.4	0.6	0.6	0.9
40	0.8	0.8	1.0	1.3	1.1	0.5	0.6	0.5	0.3	0.4	0.4	0.6
60	0.5	1.1	1.1	1.3	1.0	0.4	0.6	0.4	0.2	0.4	0.3	0.3
80	0.5	0.9	0.8	1.5	1.4	0.7	0.7	0.6	0.3	0.6	0.4	0.4
bottom	0.9	1.7	1.1	2.3	3.1	1.3	1.3	1.8	1.0	2.1	2.1	5.8

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	5.3	4.9	8.0	3.3	4.0	4.2	3.7	5.9	5.2	7.0	5.7	5.2
bottom	4.7	4.8	7.8	3.4	3.7	4.5	4.7	6.5	5.9	8.0	6.3	5.8

E4 DO [mg l^{-1}] (7)

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	10.2	10.5	10.8	11.1	10.7	9.4	9.3	8.8	7.9	8.4	9.2	9.8
5	9.9	10.7	10.9	11.0	11.1	10.0	9.9	8.6	8.2	8.4	9.4	9.7
10	9.9	10.7	11.0	11.0	11.0	10.0	9.1	8.4	8.0	8.2	9.3	9.6
15	9.9	10.6	11.0	11.0	10.8	9.9	8.8	6.9	6.3	6.8	9.1	9.7
20	9.9	10.5	10.9	11.1	10.5	9.8	8.9	7.2	7.0	6.2	8.9	9.6
30	9.9	10.5	11.0	10.9	10.6	10.0	9.3	8.4	7.8	7.4	7.4	8.1
40	9.6	10.4	10.8	10.9	10.4	10.1	9.7	8.9	8.5	7.9	7.3	7.6
60	7.6	10.4	10.8	10.8	10.5	10.2	10.0	9.1	9.1	8.1	7.0	7.3
80	6.7	9.6	10.7	10.4	10.4	10.1	9.8	8.9	8.2	7.1	5.7	6.1
bottom	5.6	9.6	10.0	10.2	9.8	9.0	8.3	6.5	5.1	3.1	3.2	4.0

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	11.5	11.1	11.3	10.5	11.0	9.9	8.8	8.5	8.5	9.6	9.8	10.8
bottom	11.3	11.0	11.4	10.5	11.0	9.5	8.9	8.4	7.8	8.9	9.8	10.7

E5 COD [mg l⁻¹] (7)

Determined by $KMnO_4$ method.

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	1.7	1.6	1.6	1.5	1.8	2.2	2.6	2.3	2.6	2.3	2.0	1.9
5	1.9	1.6	1.7	1.6	1.8	2.2	2.7	2.6	2.4	2.6	2.0	2.0
10	1.8	1.7	1.5	1.6	1.6	2.1	2.5	2.3	2.4	2.3	2.0	2.0
15	1.8	1.6	1.6	1.5	1.6	1.9	2.0	2.0	2.1	2.1	2.0	1.9
20	1.8	1.5	1.5	1.4	1.4	1.9	1.8	1.8	1.8	1.8	1.9	1.9
30	1.8	1.6	1.5	1.5	1.3	1.6	1.6	1.5	1.4	1.7	1.4	1.7
40	1.8	1.6	1.5	1.4	1.4	1.6	1.4	1.4	1.3	1.6	1.4	1.5
60	1.5	1.6	1.6	1.4	1.3	1.4	1.3	1.4	1.4	1.4	1.3	1.5
80	1.5	1.5	1.5	1.4	1.4	1.5	1.4	1.4	1.3	1.5	1.4	1.5
bottom	1.4	1.6	1.4	1.4	1.4	1.6	1.5	1.6	1.6	1.9	1.5	1.9

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	2.3	1.8	2.1	2.1	2.6	2.9	2.6	2.9	3.2	3.3	2.8	2.4
bottom	2.3	2.0	2.1	2.1	2.8	3.2	2.6	2.9	3.3	3.4	2.9	2.5

E6 CHLOROPHYLL CONCENTRATION [μg l⁻¹] (7)

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	2.8	2.3	2.5	1.7	4.7	2.5	7.2	4.8	4.4	6.3	5.6	6.4
5	2.9	2.3	2.8	2.9	6.5	3.3	8.7	5.6	4.9	6.9	6.3	6.8
10	2.9	2.2	2.8	2.9	4.2	3.6	8.6	9.7	5.6	7.1	5.9	6.3
15	2.9	2.2	2.6	2.9	3.1	3.5	5.4	7.1	5.4	6.2	6.0	6.2
20	2.9	2.1	2.7	2.9	2.6	3.1	3.0	3.9	3.8	4.1	5.7	6.0
30	2.7	2.1	2.5	2.6	1.8	1.5	1.2	1.6	1.6	1.3	1.7	3.4
40	2.5	2.0	2.5	2.6	1.5	1.0	0.7	0.8	0.9	0.7	0.7	1.0
60	1.1	1.9	2.7	2.4	1.5	0.7	0.6	0.3	0.5	0.4	0.5	0.4
80	0.5	1.7	2.7	2.4	1.9	0.8	0.6	0.4	0.6	0.4	0.4	0.3
bottom	0.5	2.4	2.6	4.2	2.8	1.6	1.2	1.4	1.0	1.2	1.2	1.9

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	3.7	3.4	4.2	6.5	13.3	9.7	7.0	7.9	11.7	17.2	13.4	12.8
bottom	4.0	3.6	4.3	7.2	14.9	10.9	8.8	8.5	14.3	20.9	14.2	12.7

E7 NITROGEN CONCENTRATION (7)

§ NH_4N [mg l⁻¹]

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
5	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
10	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.00	0.01	0.00	0.01
15	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00
20	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01
30	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
40	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01
60	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
80	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
bottom	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.04	0.01	0.00

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.02	0.02	0.03	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01
bottom	0.02	0.01	0.03	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01

§ NO_3-N [mg l^{-1}]

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.14	0.17	0.18	0.17	0.12	0.09	0.06	0.02	0.00	0.02	0.06	0.09
5	0.14	0.17	0.18	0.16	0.12	0.09	0.06	0.02	0.01	0.03	0.06	0.09
10	0.14	0.17	0.18	0.17	0.13	0.10	0.07	0.03	0.02	0.03	0.05	0.09
15	0.14	0.17	0.18	0.17	0.15	0.12	0.11	0.09	0.11	0.08	0.06	0.09
20	0.14	0.17	0.18	0.17	0.16	0.16	0.16	0.15	0.17	0.17	0.06	0.09
30	0.14	0.17	0.18	0.17	0.18	0.19	0.20	0.21	0.23	0.23	0.22	0.18
40	0.15	0.17	0.18	0.17	0.19	0.20	0.21	0.22	0.22	0.23	0.25	0.24
60	0.22	0.18	0.18	0.18	0.19	0.20	0.21	0.22	0.22	0.23	0.25	0.26
80	0.27	0.20	0.18	0.19	0.20	0.21	0.21	0.23	0.25	0.25	0.27	0.27
bottom	0.27	0.20	0.18	0.19	0.20	0.21	0.23	0.25	0.27	0.27	0.28	0.30

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.17	0.20	0.24	0.16	0.11	0.03	0.08	0.04	0.00	0.03	0.00	0.04
bottom	0.17	0.20	0.24	0.16	0.11	0.03	0.08	0.04	0.00	0.03	0.00	0.04

§ Total-N [mg l^{-1}]

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.28	0.30	0.30	0.31	0.31	0.25	0.25	0.26	0.18	0.19	0.21	0.24
5	0.31	0.30	0.34	0.34	0.34	0.30	0.28	0.29	0.24	0.23	0.23	0.25
10	0.29	0.31	0.31	0.34	0.31	0.31	0.28	0.27	0.22	0.22	0.22	0.25
15	0.31	0.32	0.31	0.33	0.33	0.29	0.30	0.33	0.30	0.27	0.21	0.26
20	0.31	0.31	0.30	0.34	0.32	0.31	0.33	0.33	0.34	0.31	0.23	0.24
30	0.33	0.32	0.30	0.35	0.31	0.31	0.32	0.37	0.36	0.34	0.33	0.32
40	0.29	0.30	0.31	0.32	0.31	0.30	0.30	0.35	0.35	0.33	0.35	0.37
60	0.37	0.30	0.32	0.34	0.32	0.31	0.29	0.34	0.34	0.33	0.30	0.36
80	0.39	0.33	0.30	0.33	0.32	0.31	0.30	0.35	0.37	0.35	0.37	0.39
bottom	0.42	0.33	0.34	0.35	0.33	0.34	0.33	0.41	0.43	0.47	0.39	0.46

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.37	0.36	0.45	0.37	0.37	0.29	0.30	0.25	0.31	0.34	0.25	0.26
bottom	0.39	0.39	0.45	0.39	0.40	0.34	0.35	0.30	0.34	0.36	0.26	0.28

E8 PHOSPHORUS CONCENTRATION (7)

§ PO_4-P [$\times 10^{-1}$mg l^{-1}]

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	.002	.003	.004	.002	.002	.001	.001	.001	.001	.001	.001	.001
5	.003	.005	.004	.002	.001	.002	.002	.001	.001	.001	.001	.001
10	.002	.005	.004	.001	.002	.002	.002	.001	.001	.001	.001	.001
15	.003	.004	.004	.001	.001	.002	.001	.001	.001	.001	.001	.000
20	.002	.004	.005	.001	.001	.001	.002	.001	.001	.002	.001	.000
30	.002	.004	.004	.002	.002	.002	.004	.002	.002	.002	.002	.001
40	.002	.004	.004	.002	.003	.003	.005	.003	.002	.003	.005	.003
60	.009	.004	.005	.002	.004	.004	.005	.008	.005	.008	.011	.012
80	.020	.008	.005	.005	.006	.007	.008	.016	.015	.019	.020	.020
bottom	.022	.009	.004	.005	.008	.011	.020	.026	.025	.031	.026	.022

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	.002	.003	.004	.002	.002	.002	.007	.004	.002	.002	.002	.003
bottom	.003	.002	.004	.002	.003	.002	.007	.004	.002	.002	.002	.004

§ Total-P [mg l^{-1}]

Station 1 (N. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	.006	.007	.007	.005	.009	.007	.008	.007	.007	.007	.005	.006
5	.006	.007	.008	.007	.010	.009	.011	.009	.009	.010	.006	.008
10	.006	.006	.008	.007	.011	.009	.011	.009	.008	.009	.006	.006
15	.006	.007	.007	.009	.010	.008	.009	.007	.010	.008	.007	.011
20	.006	.009	.008	.007	.008	.007	.007	.006	.006	.007	.006	.014
30	.005	.007	.007	.006	.006	.005	.005	.004	.005	.006	.004	.005
40	.005	.007	.007	.007	.006	.006	.004	.005	.005	.005	.006	.005
60	.006	.009	.008	.006	.006	.004	.004	.005	.005	.006	.007	.007
80	.010	.008	.008	.007	.007	.007	.006	.010	.009	.010	.011	.010
bottom	.011	.010	.007	.009	.012	.009	.013	.016	.014	.018	.017	.024

Station 2 (S. Lake), 1982-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	.012	.013	.017	.013	.019	.018	.018	.021	.022	.023	.017	.017
bottom	.013	.013	.017	.014	.018	.019	.018	.022	.024	.024	.018	.018

E9 PAST TRENDS

Fig. ASI-I-4 Trend of transparency in Northern Lake, Station 3 (8).

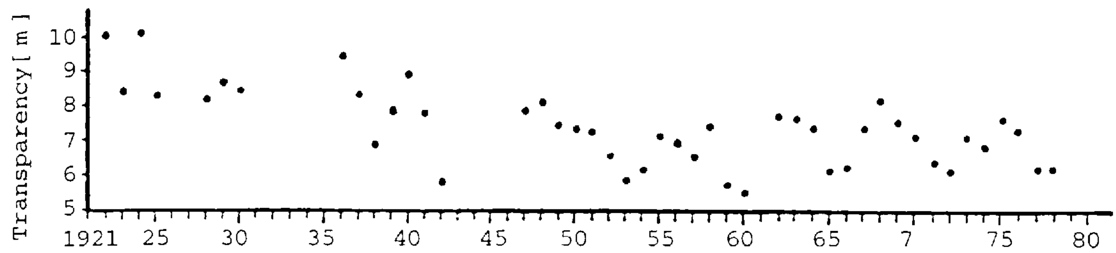


Fig. ASI-I-5 Trend of dissolved oxygen concentration in the hypolimnion of Northern Lake (Station 3, depth 70m) immediately before the circulation period in late autumn (9).

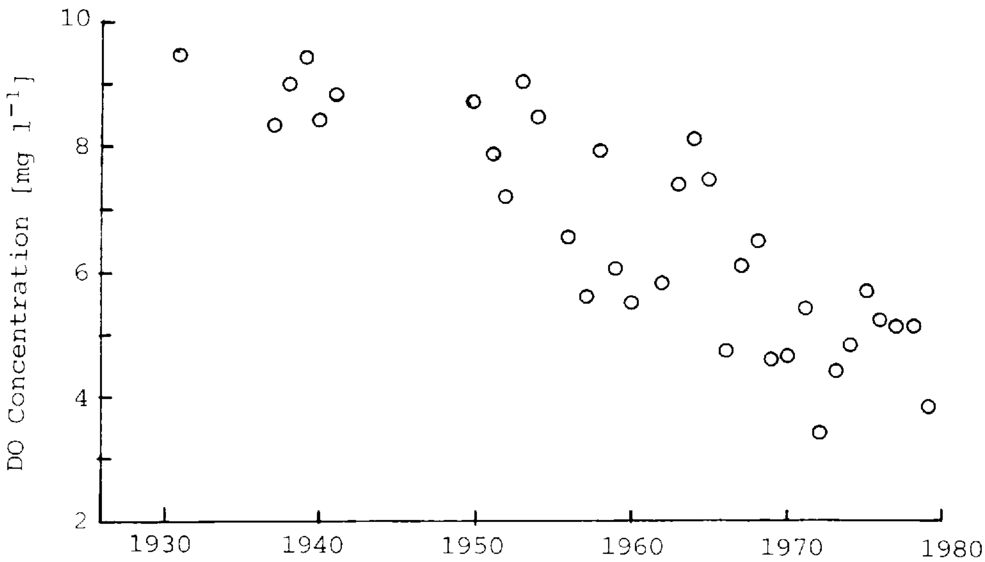


Fig. ASI-I-6 Trend of organic matter concentration (in terms of $KMnO_4$ consumption) in the water of Biwako Canal II flowing from Southern Lake (10).

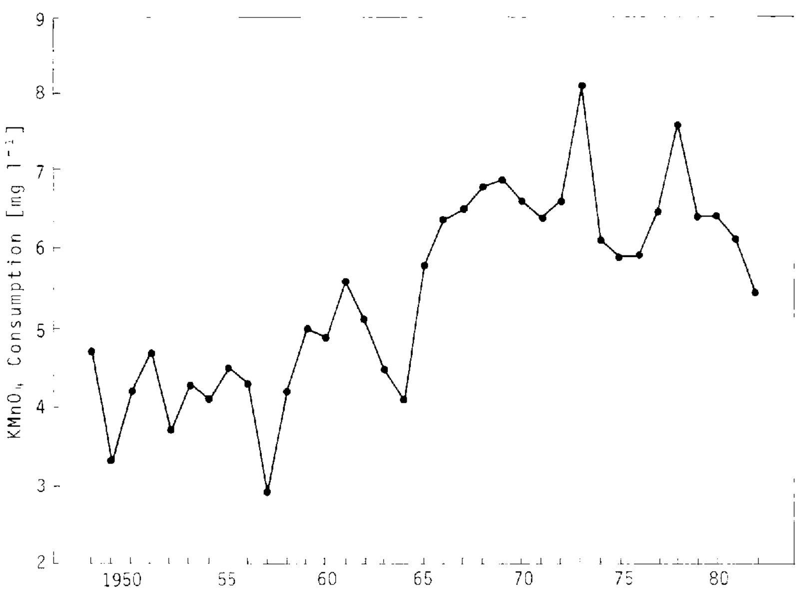


Fig. ASI-1-7 Distribution and time trend of BOD (7, 11, 12).
1967, 1972 and 1977 : means of spring and fall observations for Northern Lake and means of four seasons for Southern Lake.
1982 : means of monthly observations.

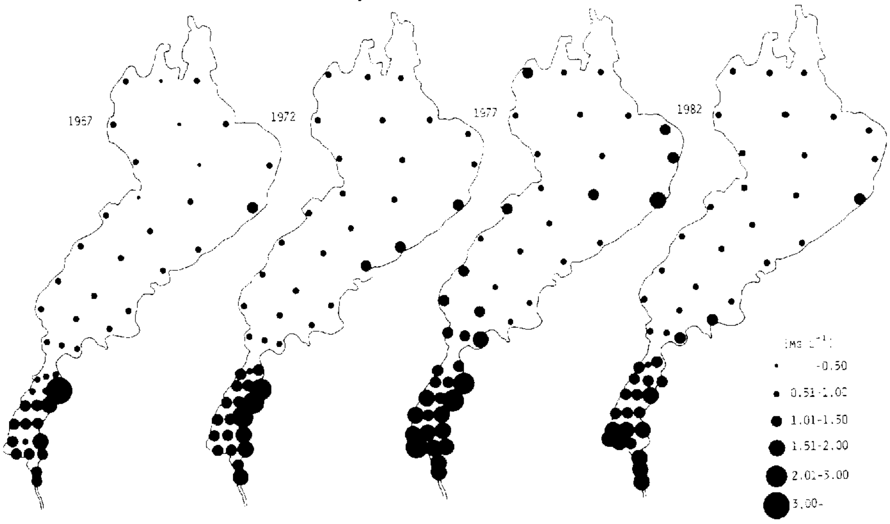


Fig. ASI-1-8 Trend of T-N concentration in Northern Lake, Southern Lake (averages for the whole area) and Seta River (flowing out from Southern Lake) (7).

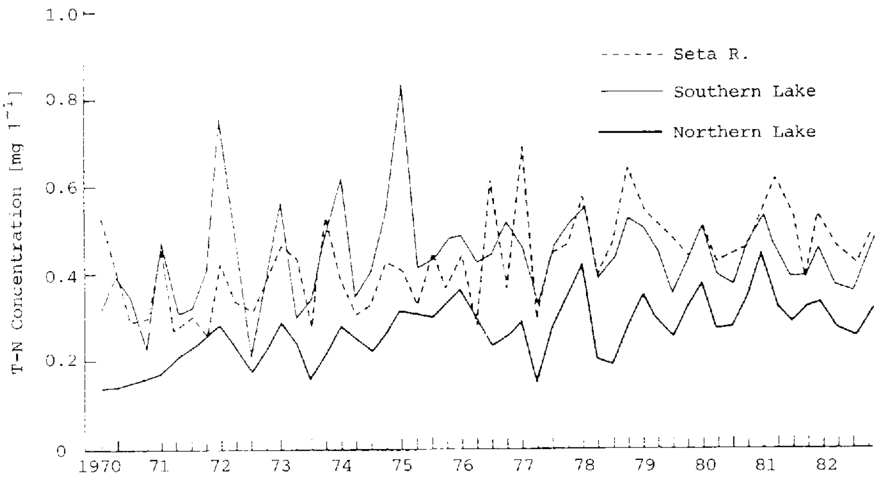
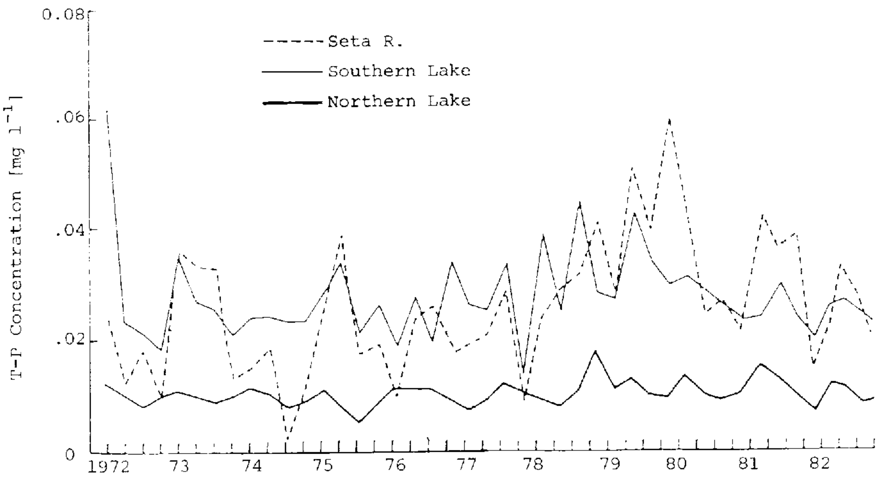


Fig. ASI-1-9 Trend of T-P concentration in Northern Lake, Southern Lake (averages for the whole area) and Seta River (flowing out from Southern Lake) (7).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes (13)

Northern Lake: *Phragmites communis, P. japonica, Zizania latifolia, Scirpus yagara, Carex dispalata, Cicuta virosa.*

Southern Lake: *Phragmites communis, Zizania latifolia, Typha angustata, Nelumbo nucifera, Scirpus tabernaemontani, S. yagara.*

§ Floating macropytes (on calm sheltered water surfaces) (15)

Trapa japonica, Hydrocharis dubia, Nymphoides indica, N. peltata, Spirodela polyrhiza, Lemna paucicostata, Eichhornia crassipes (15).

§ Submerged macrophytes (13)

Northern Lake: *Elodea nuttallii*⁺, *Hydrilla verticillata, Vallisneria biwaensis**, *Potamogeton crispus, P. maackianus, Egeria densa*⁺.

Southern Lake: *Ceratophyllum demersum, Egeria densa*⁺, *Vallisneria biwaensis**, *V. denseserrulata, Hydrilla verticillata, Potamogeton malaianus, Najas marina.*

§ Phytoplankton (14)

Northern Lake: *Fragilaria crotonensis, Uroglena americana, Planktosphaeria gelatinosa, Melosira solida, Staurastrum dorsidentiferum* var. *ornatum, Oocystis submarina, Stephanodiscus carconensis* var. *pusilla.*

Southern Lake: *Fragilaria crotonensis, Cryptomonas* sp., *Cyclotella glomerata, Uroglena americana, Planktosphaeria gelationsa, Pediastrum biwae**, *Melosira granulata, Dinobryon bavaricum, Chrysosphaella* sp., *Phormidium tenue.*

F2 FAUNA

§ Zooplankton (15, 16)

Northern Lake: *Polyarthra trigla, Collotheca* sp., *Keratella quadrata, Notommata* sp., *Eodiaptomus japonicus, Bosmina longirostris, Daphnia longispina, D. galeata, Strombidium* sp.

Southern Lake: *Tintinnidium fluviatile, Tintinnopsis cratera, Epistylis* sp., *Vorticella* sp., *Askenasia volvox, Difflugia brevicolla, Conochilus unicornis, Polyarthra trigla.*

§ Benthos (17)

Northern Lake:

Littoral zone (depth 5-10m): Gastropoda (*Heterogen longispira**, *Semisulcospira decipiens**, *S. decipiens reticulata**, *Radix auricularia japonica, R. onychia**, *Gyraulus perstriatulus**), Bivalvia (*Unio douglasiae biwae**, *Anodonta calipigos**, *Corbicula sandai**), Crustacea (*Anisogammarus annandalei, Palaemon paucidens, Macrobrachium nipponense*), Insecta (*Gomphus oculatus, Ephemerella longicaudata, Chironomus plumosus*).

Littoriprofundal zone (depth 20-40m): Gastropoda (*Valvata piscinalis biwaensis**, *Semisulcospira decipiens reticulata*), Bivalvia (*Pisidium kawamurai**), Oligochaeta (*Limnodrilus grandisetosus*), Hirudinea, Crustacea (*Palaemon paucidens*).

Profundal zone (depth 50-90m): Turbellaria (*Bdellocephala annandalei*), Oligochaeta (*Tubifex* spp.), Crustacea (*Palaemon paucidens, Anisogammarus annandalei*), Insecta (*Chironomus* spp.).

Southern Lake: Gastropoda (*Sinotaia quadrata histrica, Semisulcospira libertina, S. decipiens multigranosa**), Bivalvia (*Corbicula sandai**, *C. leana, Unio douglasiae*), Oligochaeta (*Tubifex* sp., *Brauchiura sowerbyi*), Hirudinea (Hirudidae), Crustacea (*Palaemon paucidens*), Insecta (*Chironomus plumosus, Tokunagayusurika akamusi*).

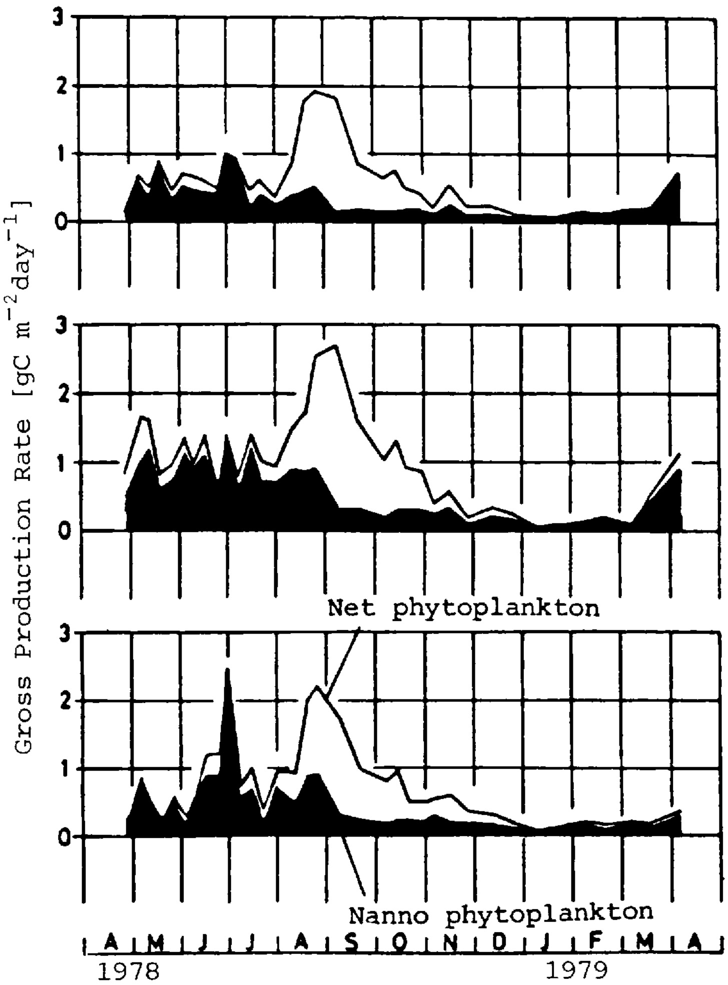
§ Fish (18)

*Plecoglossus altivelis, Rhinogobius similis, Carassius auratus cuvieri**, *C. auratus grandoculis**, *Acheilognathus lanceolata, Chaenogobius isaza**, *Gnathopogon caerulescens**, *Pseudocrasvora parva, Zacco platypus, Cyprinus carpio, Opsaiichthys uncirostris**, *Oncorhynchus rhodurus* f. *rhodurus**.

* : endemic taxa. + : exotic species.

F3 PRIMARY PRODUCTION RATE

Fig. ASI-1-10 Seasonal changes in gross primary production rate at three stations in Southern Lake. Net and nanno-plankton were separated by a 25 μm-mesh screen (19).



F4 BIOMASS

§ Biomass of submerged macrophytes in Southern Lake [metric tons, dry weight] (20)

Year	*Egeria densa*	*Elodea nuttallii*	Others	Total
1964	–	–	30	30
1969	–	460	97	557
1974	577	21	22	620
1979	94	+	24	118

§ Biomass of *Phragmites communis* around the lake [g m^{-2}, dry wt] (21)

Average of aboveground biomass at 13 stands: 731 (range 422–1,314).

F5 FISHERY PRODUCTS

§ Annual fish catch in 1977–1981: 3,246 [metric tons] (1).

§ Fishery products other than fish: Shellfish (mostly *Corbicula sandai*), shrimp (mostly *Palaemon paucidens*), freshwater pearl (cultured).

F6 PAST TRENDS

Fig. ASI-1-11 Trend of phytoplankton biomass in a surface 20m layer in Northern Lake, Station 3 (22).
Bars indicate ranges of monthly observations.

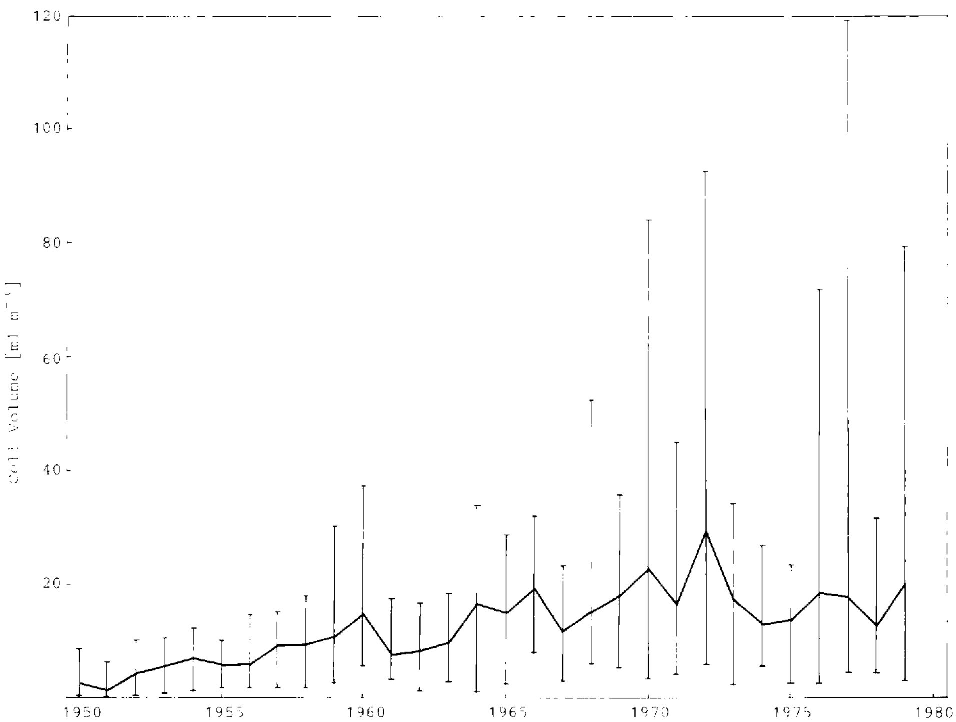
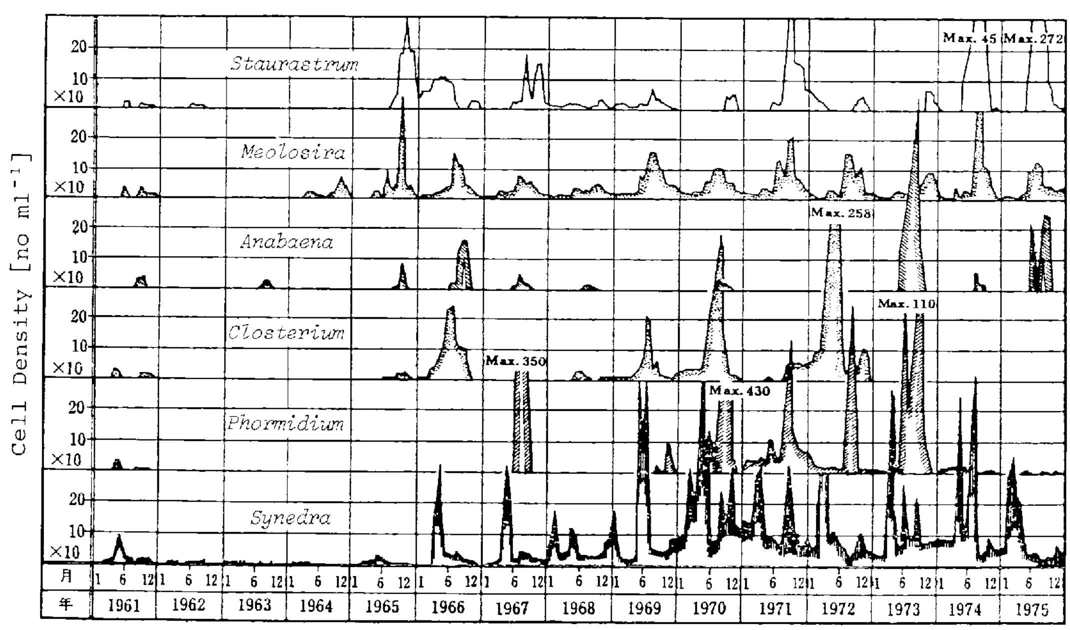


Fig. ASI-1-12 Trend of population densities of main phytoplankton taxa in the water of Biwako Canal I flowing from Southern Lake (10).



§ Trend of fishery production [metric tons] (23)

	1955	1960	1965	1970	1975	1980
Fish total	2181	1926	2938	3105	3262	3514
Oncorhynchus rhodurus	68	30	37	23	22	11
Plecoglossus altivelis	608	312	308	678	892	1345
Cyprinus carpio	57	70	131	154	202	164
Carassius	613	701	1104	615	616	791
Tribolodon hakonensis	46	29	27	50	64	67
Zacco platypus	11	13	33	37	40	39
Anguilla japonica	30	22	19	37	13	9
Chaenogobius isaza	10	5	436	473	377	411
Gnathopogon	230	285	352	476	323	233
Opsariichthys uncirostris	200	87	122	162	100	134
Others	308	372	369	400	613	310
Mollusca total	8205	5287	2957	2836	1412	950
Corbicula	5697	4226	2511	1725	992	700
Others	2508	1061	446	1111	420	250
Others	230	269	286	519	1329	725
Total	10616	7482	6181	6460	6003	5189

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Macrophytes

The area of reed (*Phragmites*) was reduced from 261 ha in 1953 to 163 ha in 1980 (21). Two species of exotic submerged macrophytes, *Elodea nuttallii* (since 1961) and *Egeria densa* (since 1969), invaded the lake and expanded vigorously (20).

Phytoplankton

Sphaerocystis schroeteri, Stephanodiscus carconensis, Surirella robustus, etc. decreased in Southern Lake (14, 24, 25). *Staurastrum dorsidentiferum, Closterium aciculare, Fragilaria crotonensis, Cryptomonas* sp., etc. increased in Northern Lake, and *Cryptomonas erosa, Anabaena macrospora, Lyngbya limnetica,* etc. did in Southern Lake (14, 15, 24, 25).

The outbreak of "freshwater red tide", or the bloom of *Uroglena americana*, started in 1977 and has been observed every year in spring and early summer except for 1986 (26, 27).

Zooplankton

Rotifers decreased in Southern Lake (24, 25). Ciliata, mainly *Halteria grandinella, Strombilidium* sp. and *Askenasia volvox*, increased in Northern Lake (15, 24, 25).

Benthos

An economically important endemic species, *Corbicula sandai*, decreased and almost disappeared in Southern Lake. *Heterogen longispira* and *Semisylcospira decipiens* also decreased in the southern area (28, 29). *Sinotaia quadrata histrica, Semisulcospira libertina, Corbicula leana, Radix auricularia japonica, Sphaerium japonicum biwaense,* etc. and also Oligochaeta and Chironomidae (*Tokunagayusurika akamusi* and *Chironomus plumosus*) also increased either temporarily or permanently (28, 29).

Fish

Such native species as *Oncorhynchus rhodurus* f. *rhodurus, Hemigrammocypris rasborella, Hymenophysa curta,* etc. tended to decrease (18). Exotic species such as *Channa maculata, Micropterus salmoides, Lepomis macrochirus,* etc. increased (18).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN SHIGA PREFECTURE* (1979) (30)

Vegetation and land use types	Area [km^2]	[%]
Woody vegetation	(2108.9)	(63.2)
Natural forests with little human disturbance	(92.2)	(2.8)
Cool-temperate deciduous broadleaf forest (*Fagus crenata, Acer* spp.)	59.3	1.8
Warm-temperate deciduous broadleaf forest (*Zelkova serrata, Carpinus* spp.)	18.3	0.5
Evergreen broadleaf forest (*Castanopsis cuspidata, Persea thunbergii, Quercus* spp.)	2.1	0.1
Evergreen conifer forest (*Abies firma*)	11.3	0.3
Swamp forest (*Salix chaenomeloides*)	1.2	<0.1
Secondary forest	(1608.6)	(48.2)
Cool-temperate deciduous broadleaf forest (*Quercus mongolica* var. *grosseserrata*)	511.7	15.3
Warm-temperate deciduous broadleaf forest (*Quercus serrata, Q. acutissima*)	144.6	4.3
Pine forest (*Pinus densiflora*)	817.0	24.5
Scrub	135.3	4.1
Others	(408.1)	(12.2)
Evergreen conifer plantation (*Cryptomeria japonica, Chamaecyparis obtusa*)	395.0	11.8
Bamboo forest (*Phyllostachys bambusoides*)	13.1	0.4
Herbaceous vegetation	(69.1)	(2.0)
Dwarf bamboo community (*Sasa* spp.)	7.2	0.2
Grassland (*Miscanthus sinensis*) and weeds	54.6	1.6
Swamp (*Phragmites communis*)	7.3	0.2
Agricultural land	(830.7)	(24.9)
Paddy field	767.7	23.0
Upland field	23.7	0.7
Mulberry plantation	4.5	0.1
Tea plantation	9.0	0.3
Orchard	5.6	0.2
Others	20.2	0.6
Residential and industrial area	(298.0)	(8.9)
Urban	175.4	5.3
Rural	50.5	1.5
Industrial	24.1	0.7
Others	48.0	1.4
Open water	33.3	1.0
Total (exclusive of L. Biwa)	3340.0	100.0

*The catchment area of L. Biwa equals 93% of the land area of Shiga Prefecture. The administrative limit of the Prefecture nearly coincides with the boundary of the lake's catchment except for the southernmost part.

§ Levels of fertilizer application on crop fields : Heavy.

§ Trend of agricultural land use in Shiga Prefecture [km^2] (7)

	Paddy field	Upland field	Orchard	Pasture	Total
1975	609	38.6	23.9	2.8	674
1976	603	38.5	22.7	3.1	667
1977	597	37.9	22.5	3.3	661
1978	593	37.6	22.0	3.3	656
1979	588	36.9	21.9	3.4	650
1980	583	36.7	21.7	3.3	645
1981	579	36.5	20.8	3.4	640
1982	575	36.2	20.3	3.2	635
1983	571	35.8	20.1	3.2	630
1984	569	35.4	19.2	3.2	627

G2 INDUSTRIES IN SHIGA PREFECTURE AND THE LAKE (1981) (31-36)

	Gross production during the year [10^6 yen]*	Number of persons engaged (1980)	Number of establishments	Main products and main kinds of industry
Primary industry				
Agriculture	104,847	58,300	N. A.	1)
Forestry	7,559	1,100	N. A.	2)
Fisheries	4,836	1,500	N. A.	3)
Secondary industry				
Manufacturing	3,081,699	167,000	9,249	4)
Mining	N. A.	500	58	5)
Others	N. A.	40,700	7,205	6)
Tertiary industry	N. A.	250,600	41,367	7)

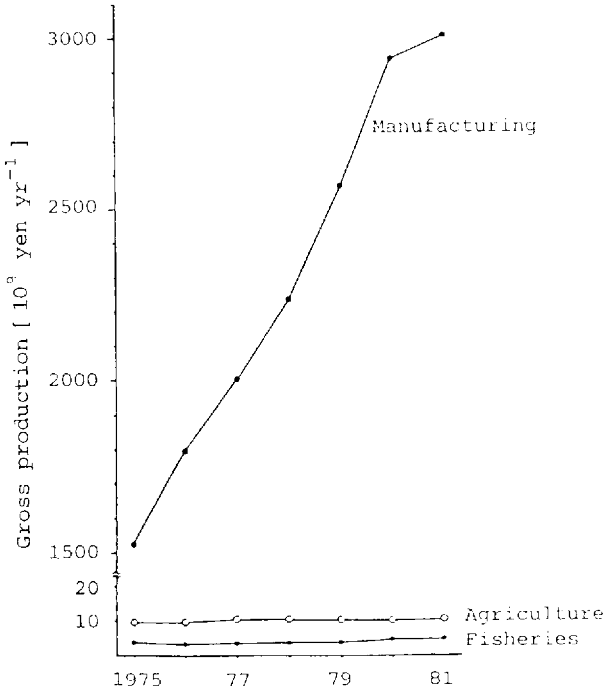
*ca. 250 yen = US$ 1 in 1981.
1) Rice, tea, fruit, vegetables, flowers, silk and domestic animals.
2) Timber, charcoal, firewood, mushroom, etc.
3) Fish, shrimp, corbicula (mussel) and freshwater pearl.
4) Electromechanical, mechanical, textile, chemical, metal, foodstuff and pottery industries.
5) Limestone, aplite and firebrick clay.
6) Construction, etc.
7) Wholesale retail, service, transportation, banking, communication, public service, etc.

§ Numbers of domestic animals in Shiga Prefecture: Cattle 26,500, swine 16,000, poultry 124×10^4.
§ Trend in the relative numbers of residents engaged in different kinds of industry in Shiga Prefecture [%] (31)

	1955	1960	1970	1980
Primary industry	51.4	43.5	27.6	11.7
Agriculture	49.0	42.0	27.3	11.2
Forestry	2.0	1.1		0.2
Fisheries	0.4	0.4	0.3	0.3
Secondary industry	20.5	25.7	35.2	40.0
Manufacturing	16.3	19.9	29.2	32.1
Mining	0.3	0.5	0.2	0.1
Others	3.9	5.3	5.8	7.8

Tertiary industry	28.0	30.8	37.3	48.3
Total	100.0	100.0	100.0	100.0
(Actual number)	(411,243)	(427,018)	(486,220)	(520,211)

Fig. ASI-1-13 Trend of industrial production in Shiga Prefecture (33-35).

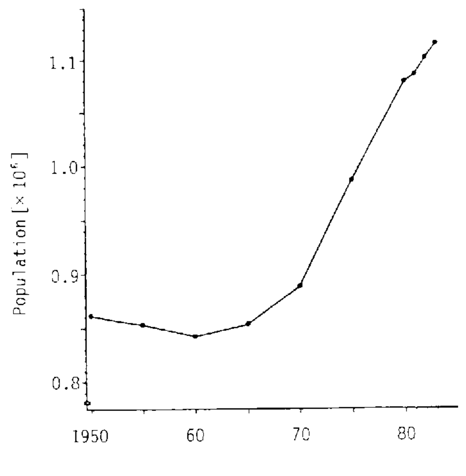


G3 POPULATION IN SHIGA PREFECTURE (1985) (31, 37)

Total population	Population density [km^{-2}]	Main cities (population)
1,155,844	277.8 (345.7)*	Otsu(234,551), Hikone, Kusatu, Omi-hachiman

*Land area basis.

Fig. ASI-1-14 Trend of population increase in Shiga Prefecture (31-37).



H. LAKE UTILIZATION

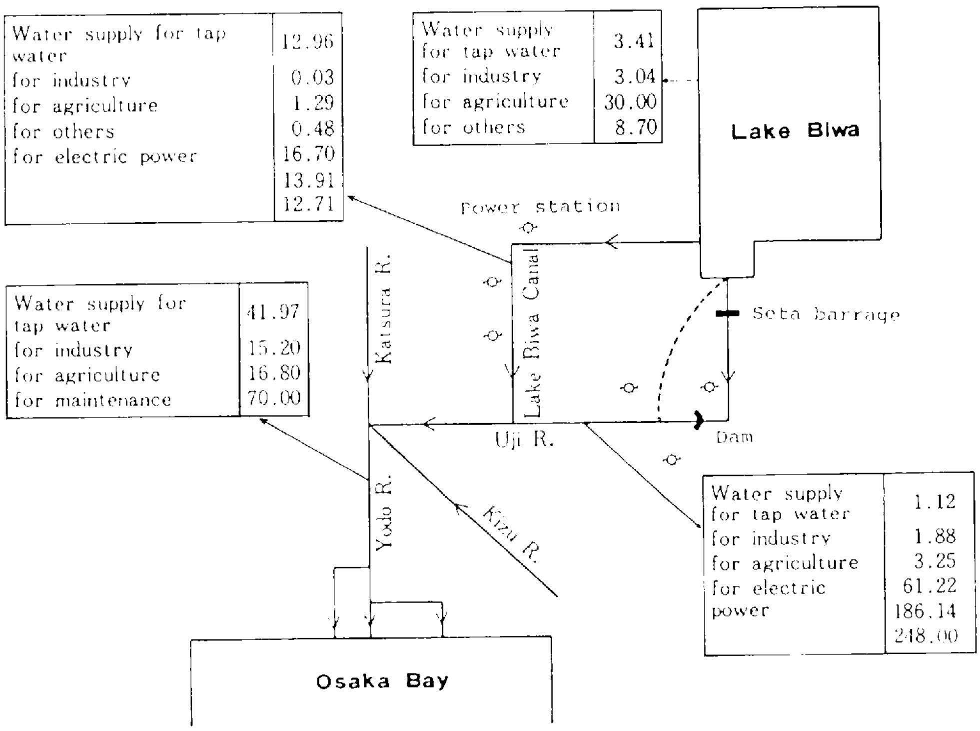
H1 LAKE UTILIZATION

Source of water, fisheries, tourism, recreation (swimming, yachting, sport-fishing, etc.) and navigation.

H2 THE LAKE AS WATER RESOURCE (1982) (38)

	Use rate [$m^3\ sec^{-1}$]		
	In Shiga Pref.	Biwako Canals	Total
Domestic	3.41	12.96	16.37
Irrigation	30.00	1.29	31.29
Industrial	3.04	0.03	3.07
Power plant	61.22	43.32	104.54
Others	8.70	0.48	9.18
Total	106.37	58.08	164.14
Power plant (Seta River)			186.14
Sum total			350.50

Fig. ASI-I-15 Utilization of water in the Lake Biwa/Yodo River system (38). Use rates in units of $m^3\ sec^{-1}$.



I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources (39-53)

Name of contaminant	Concentration [ppm]				Main source
	Water	Bottom mud	Fish	Other organisms	
Methyl Hg	—	—	0.013-0.79 (1969)	—	Pesticide
Total Hg	0.0005 (1981)	0.72-1.75 (1978)	0.020-1.61 (1969)	—	Pesticide
Cd	ND (1978)	0.3-5.5 (1979)	0.00-0.146 (1976)	0.20-0.59 (1970)	Industrial
Cr	0.002 (1981)	29.5-74.6 (1979)		–	Industrial
Pb	0.05 (1981)	32-134 (1979)	0.00-8.25 (1976)	0.00-25.1 (1976)	Industrial
Zn	0-0.007 (1978)	144-390 (1979)	9.8 88.1 (1976)	5.1-48.3 (1976)	Industrial
Sb	0.002-0.01 (1980)	0.0-0.51 (1977)	0.0-0.82 (1976)	0.0-1.62 (1976)	Industrial
Cu	0.002-0.019 (1980)	0.3-129 (1977)	0.37-15.1 (1976)	0.65-239 (1976)	Industrial
Ni	0.004-0.018 (1980)	0.29-7.19 (1977)	0.0-0.86 (1976)	0.18-1.24 (1976)	Industrial
F	0.08-0.12 (1975)	—	—	—	Industrial
As	0.02 (1981)	8.1-20.8 (1978)	—	—	Industrial
DDT	—	—	0.04 (1976)	0.029-0.14 (1963)	Pesticide
BHC	0.00004 (1979)	—	0.04 (1982)	0.013-0.075 (1963)	Pesticide
PCP	—	—	0.0 0.113 (1969)	—	Herbicide
PCB	0.1 (1975)	0.03-1.15 (1976)	0.2-2 (1976)	0.02-1 (1976)	Industrial
CNP	0.0-0.000015 (1984)	0.007-0.076 (1985)	0.06 (1981)	—	Herbicide

§ Accumulation of contaminants in bodies of organisms [ppm. wet weight basis] (39-53)

		Methyl Hg	Total Hg	Sb	Pb	Cu
Fish						
1	*Plecoglossus altivelis*	0.031-0.051	0.045-0.064	0.02-0.27	0.49-5.89	1.19 2.24
2	*Cyprinus carpio*		—	—	0.0-0.35	0.91-1.01
3	*Carassius carassius* (subsp. *cuvieri* ?)	—	—	0.0-0.05	0.0 1.98	1.26-2.53
4	*Tribolodon hakonensis*	0.13-0.23	0.25 0.40	—	—	—
5	*Parasilurus variegatus* (subsp. *microculus* ?)		—	—	0.08-0.12	0.63-0.73
6	*Chaenogobius isaza*	—		—	—	—
Shellfish						
7	*Sinotaia quadrata histrica*		—	0.0-1.11	0.0-8.36	26.0-98.3
8	*Unio douglasiae biwae*	—	—	0.06	—	1.7
Submerged macrophyte						
9	*Elodea nuttallii*		—	0.0-0.07	0.0-1.72	0.65-2.71
10	*Potamogeton malaianus*	-	—	0.02-0.08	0.10-0.71	1.38-5.07

	Cd	Zn	Ni	DDT	PCP	PCB	CNP
1	0.001-0.086	20.7-29.2	0.07-0.85	—	—	0.3-2	—
2	0.0-0.006	51.3-68.8	0.02-0.09		0.0 0.113	1 -10	
3	0.0-0.055	40.3-88.1	0.12-0.39	—	0.027-0.0995	1 20	—
4	—	—	—	—	—	—	—
5	0.009	14.9-31.8	0.0 0.01	—		—	—
6	—	—	—	0.04	0.018	0.03 0.8	tr-0.011
7	0.0-0.10	25.3-126	0.0-1.98	—	—	—	—
8	0.17	35.4	0.01	—		—	-
9	0.0-0.06	6.3-30.4	0.20-0.75	—	—	—	—
10	0.03-0.06	0.2-48.3	0.33-1.24	—	—	—	—

§ Effluent standards for the discharge from industrial plants and facilities (38)

A. Substances related to the protection of human health

	Maximum permissible limits [ppm]		
	Water Pollution Control Law*	More stringent prefectural standards	Environmental Pollution Control Ordinance (Shiga)*
Cd and its compounds	0.1	0.01	0.01
Cyanides	1	0.1	0.1
Organic P	1	ND	ND
Pb and its compounds	1	0.1	0.1
Cr^{6+} compounds	0.5	0.05	0.05
As and its compounds	0.5	0.05	0.05
Total Hg	0.005	—	0.005
Alkyl Hg compounds	ND	—	NG
PCB	0.003	—	0.003

B. Items related to the protection of the environment

	Maximum permissible limits [ppm]				
	Water Pollution Control Law*	More stringent prefectural standards		Environmental Pollution Control Ordinance (Shiga)*	
Water discharge rate [m^3 day^{-1}]	>50	30-50	>50	30-50	>50
pH	5.8-8.6	6.0-8.5		6.0-8.5	
BOD**	160	100 120 70	80 90 50	100 120 70	80 90 50
COD**	160	100 120 70	80 90 50	100 120 70	80 90 50
SS	200	90	70	90	70
Mineral oil	5	5		5	
Animal and vegetable fat	30	20		20	
Phenols	5	1		1	
Cu	3	1		1	
Zn	5	1		1	
Dissolved Fe	10	10		10	
Dissolved Mn	10	10		10	
Cr	2	0.1		0.1	
F	15	8		8	
B	–	–		2	
Sb	–	–		0.05	
No. of coliform group [cells ml^{-1}]	3,000	3,000		3,000	

*Japanese National Government enacted the Water Pollution Control Law (Statute No. 138) in 1971. It was allowed for local governments to set more stringent standards where necessary. The Prefectural Government of Shiga revised the Prefectural Environmental Pollution Control Ordinance (legislated in 1969) completely in 1973 to meet the growing threat to human health and water quality due to the pollution of Lake Biwa.

**BOD standards are applicable to industrial effluents discharged into rivers, and COD standards to those discharged into L. Biwa. Of the three figures mentioned in BOD and COD columns, the upper, middle and lower figures are for foodstuff industries, textile industries and the other kinds of industry, respectively.

Fig. ASI-I-16 Past trend of BHC concentration in the lake water (43).

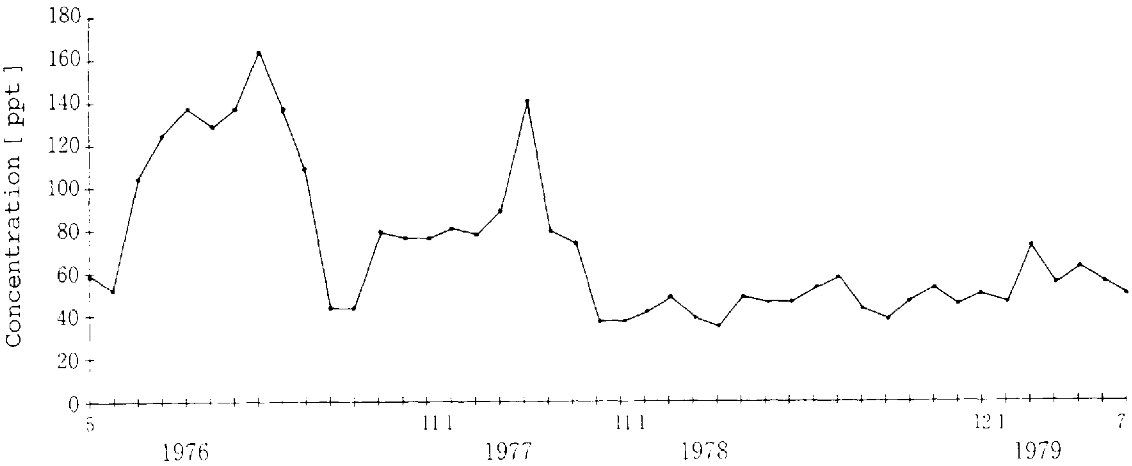


Fig. ASI-I-17 Past trend of BHC accumulation in the body of *Chaenogobius isaza*, with the annual amount of BHC shipment into Shiga Prefecture (43).

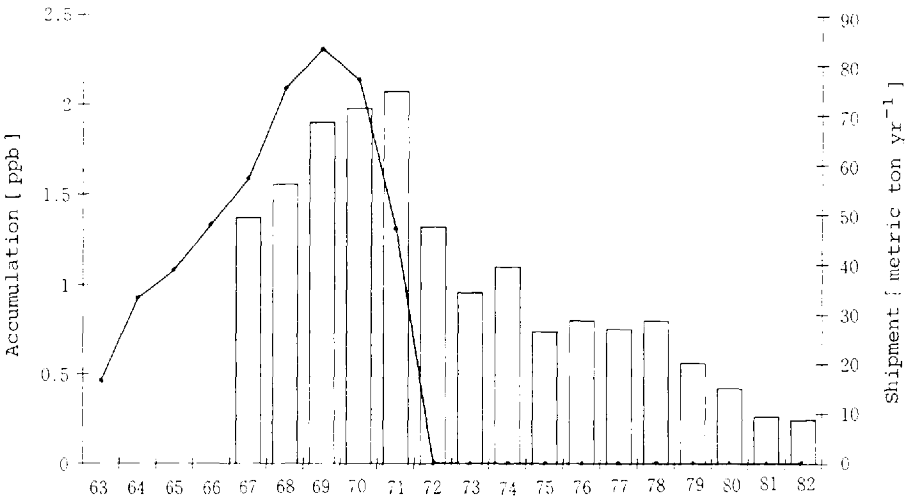
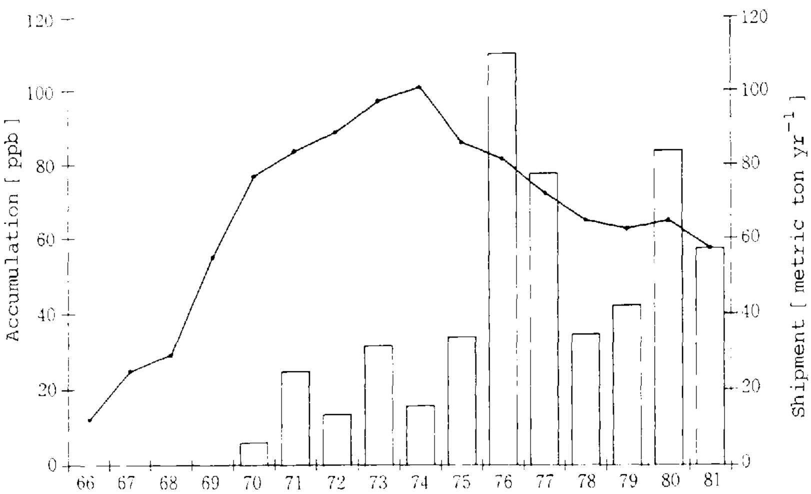


Fig. ASI-I-18 Past trend of CNP accumulation in the body of *Chaenogobius isaza*, with the annual amount of CNP shipment into Shiga Prefecture (43).



§ Supplementary notes

The first case of industrial pollution in L. Biwa took place in 1928, when the effluent from a rayon factory in Otsu City caused a serious damage on fishery products in the southernmost part of the lake. After World War II, the increased use of agricultural chemicals, especially organic P compounds and chlorinated hydrocarbons, poisoned fishes and shellfishes extensively several times in the 1960's and 1970's. The most serious post-war event was the contamination of Southern Lake and Seta River with PCB which escaped from a condenser plant in Kusatu City. High levels of PCB contents of bottom mud and fishes were revealed toward the end of the 1960's, but the disposal of contaminated soil and sediments was successfully carried out to lower the level of contamination in several years.

Currently, the accumulation of CNP, a herbicide that has been widely applied to paddy fields since ten years ago, in the lake ecosystem is approaching an alarming level (Fig. ASI-1-18). Slight contamination of ground water with trichloroethylene found in a few cities seems to offer another source of future concern.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual algal bloom: *Uroglena americana* (1977-1985), *Peridinium* spp. (since 1972), *Anabaena* spp. (since 1965), etc.

Overgrowth of exotic water weeds: *Elodea nuttallii* (1965-1970, 1980-) and *Egeria densa* (1971-1975).

Disturbed filtration in cleaning beds for city water: Since 1959.

Foul smell of tap water: Since 1969 ; mainly due to the generation of geosmin associated with the bloom of *Phormidium*, *Anabaena*, etc.

§ Nitrogen and phosphorus loadings to the lake [t yr^{-1}] (7, 26)

T-N

	Industrial	Domestic	Agricultural	Natural	Total
1960	405.5	1,021.3	2,047.7	1,986.9	5,461.4
1965	677.7	1,313.7	1,783.9	2,014.5	5,789.8
1970	1,281.4	1,821.3	1,804.0	2,033.9	6,940.6
1975	1,407.2	2,585.9	1,733.4	2,104.3	7,830.8
1980	2,089.2	3,248.0	1,726.9	2,131.9	9,196.0

T-P

	Industrial	Domestic	Agricultural	Natural	Total
1960	110.3	88.4	98.4	70.4	367.5
1965	119.0	200.4	101.0	71.4	491.8
1970	372.0	348.7	119.6	72.2	912.5
1975	249.0	407.6	118.6	74.8	850.0
1980	371.1	497.4	120.7	75.8	1,065.0

§ Supplementary notes

The Northern Lake remained oligotrophic until around 1955, though the eutrophication had already started in pre-war days as seen in the past trend of transparency in Fig. ASI-1-4. However, it was suddenly accelerated by the post-war industrialization of the lake's catchment area. The first clogging trouble in the sand filter of a city water supply to Kyoto took place as early as in 1959. Between 1960 and 1965, drastic changes in the biomass and species composition of plankters and benthic animals became apparent. The plankton biomass increased almost tenfold since 1950 (Fig. ASI-1-11), while the primary productivity in Northern Lake nearly doubled between 1965 and 1985. Algal blooms, particularly the so-called "freshwater red tide" caused by *Uroglena americana*, and the resultant unpleasant smell of tap water from the lake became a matter of keen social concern.

The Water Pollution Control Law legislated in 1970 abated the rate of eutrophication to a considerable extent through the regulation of nutrient level in industrial effluents, but the deterioration of lake water quality did not stop at all due to the steady growth of population and industrial activity in the catchment. The construction of an extensive sewerage network started in 1972 within the framework of the Lake Biwa Comprehensive Development Project, though its progress has been slow owing to the financial burden to local communities.

The residents' voluntary movement against the use of phosphate-containing synthetic detergents resulted in the ban of their use in 1980 by the enforcement of a prefectural ordinance for the prevention of eutrophication of L. Biwa. The P content of lake water was thereby somewhat reduced in past several years, but the effect of the ordinance has been only marginal. To prevent further eutrophication, it seems urgent to take new measures at least until the completion of the sewerage network.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF NUTRIENT LOADS (1979-1983) (7)

	N [%]	P [%]
Natural	27	9
Domestic wastewater	33	48
Industrial wastewater	18	29
Agricultural runoff	22	14
Total	100	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 100%.

§ Percentage of rural population with adequate sanitary facilities : Exact figure not available ; nearly 100%.

§ Municipal wastewater treatment systems

Number of tertiary treatment systems : 3 (activated sludge with denitrification and coagulation processes).

Number of secondary treatment systems : 1 (activated sludge).

Other types : Treatment plants of nightsoil collected from holding tanks are common, while the use of home septic tank is increasing. Small-scale wastewater treatment plants are also increasing in number on a local community basis.

§ Number of industrial wastewater treatment systems : ca. 3,100 (installed by individual industries ; various methods).

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION

Dredging is carried out locally along the lake shore.

L. DEVELOPMENT PLANS

Lake Biwa Comprehensive Development Project (54)

The Lake Biwa Comprehensive Development Project was set up in 1972 by the cooperation of

Japanese National Government and the prefectural governments concerned to develop and conserve the water resource of L. Biwa, to control flood disaster in the lake's drainage basin and the Yodo River system, to maintain good quality of the lake and river water, and to settle the conflicts of interest between upstream and downstream districts of the river. The Special Measures Act for Lake Biwa Comprehensive Development Project was legislated by National Government, firstly for ten years beginning in 1972, and later extended in 1982 for additional ten years.

This 20-year project contains, among others, two important operations; 1) to increase the supply of water from L. Biwa to downstream areas via Seta River by $40 m^3 sec^{-1}$ to meet increasing demands, and 2) to construct a large-scale sewerage system with treatment plants of advanced type over the catchment area of the lake to prevent further pollution of its water. The constant increase in water discharge from L. Biwa requires a wider range of fluctuation of the lake's water level, so that a continuous embankment along the lake shore is now being constructed. Two major public wastewater treatment plants with tertiary treatment processes have been constructed, but the completion of the whole sewerage network may need many years.

The total budget for the first ten years amounted to 562 billion yen. That for the second ten years is estimated at 963 billion yen in 1983. Main undertakings involved in the project are as follows.

Water resource development

Construction of new city and industrial waterworks; improvement of farm irrigation systems; improvement of fishery facilities; promotion of fishery studies

Flood control

Erosion control work; river conservation works; construction of several new dams; afforestation on watershed mountains; construction of roads for forestry

Water quality improvement

Construction of public sewerage systems; construction of sanitary facilities; improvement of wastewater treatment for livestock farming; construction of solid waste disposal facilities; promoting water quality monitoring

Conservation and use of natural environment

Providing lakeshore parks; providing facilities for visitors in natural parks; procurement of lands for nature reserves; construction of lakeshore road and embankment

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (1, 38, 55–58)

§ Names of the laws (the year of legislation)

(1) Basic Law for Environmental Pollution Control (1967)
(2) Water Pollution Control Law (1970)
(3) Shiga Prefecture Environmental Pollution Control Ordinance (1969, revised in 1973)
(4) Ordinance Concerning the Prevention of the Eutrophication of Lake Biwa (1979)

§ Responsible authorities

(1) and (2): National Government
(3) and (4): Shiga Prefectural Government

§ Main items of control

Toxic substances in the effluents from industries and facilities (Cd, Pb, Cr, As, Hg, PCB).
Pollutants in the effluents from industries and facilities (N, P, BOD, COD, SS, pH, mineral oil, fat, Cu, Zn, Cr, F, B, Sb, dissolved Fe, dissolved Mn, phenols, no. of coliform groups)
Use of phosphate-containing synthetic detergents

M2 INSTITUTIONAL MEASURES

Lake Biwa Comprehensive Development Project: cf. Item L.

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Lake Biwa Research Institute, Otsu
(2) Shiga Prefectural Institute of Public Health and Environmental Science, Otsu
(3) Shiga Prefectural Fisheries Experiment Station, Hikone
(4) Otsu Hydrobiological Station, Kyoto University, Otsu

(5) Laboratory for Control of Environmental Micropollutants, Kyoto University, Otsu
(6) Institute of Lake Sciences, Shiga University, Otsu

N. SOURCES OF DATA

* Printed in Japanese. The titles are tentatively translated into English with the original titles in romanized Japanese in parentheses.
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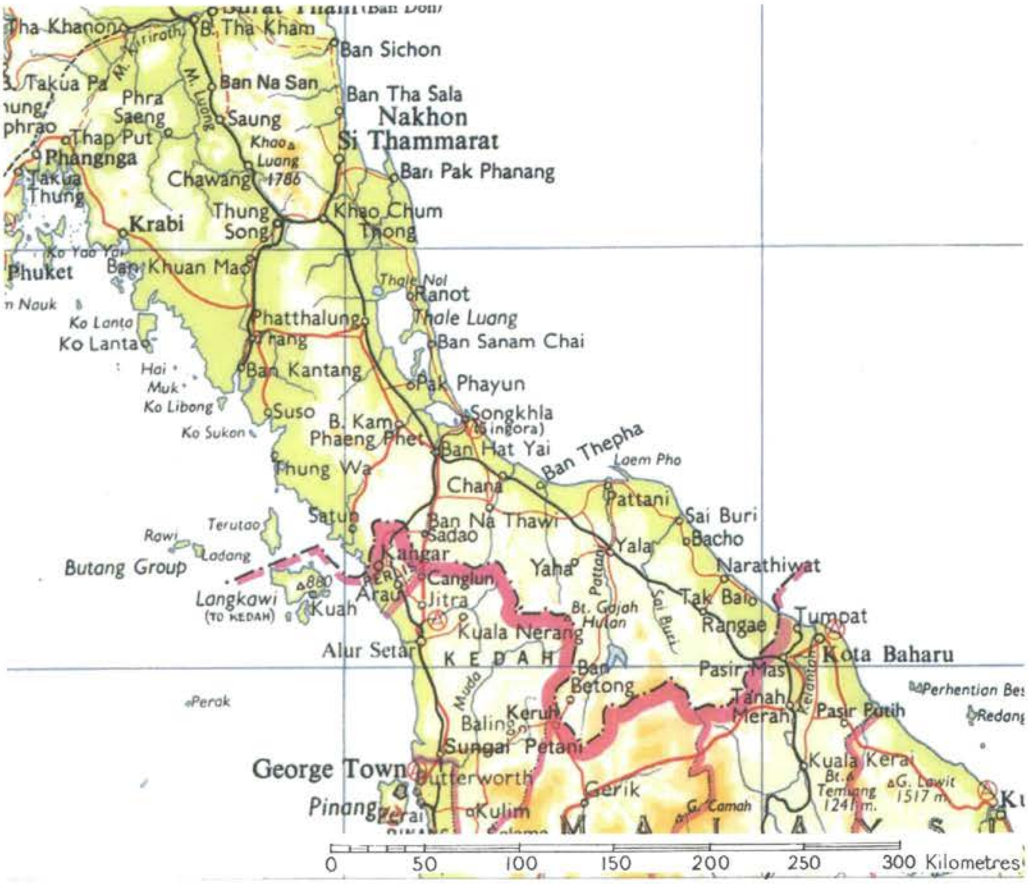
LAKE SONGKHLA

Fish culture on Thale Sap Songkhla

Photo: T. Kira



A. LOCATION

§ Phatthalung, Songkhla and Nakhon Si Thammarat, Thailand.
§ 7°08'-50'N and 100°07'-37'E ; nearly 0 m above sea level.

B. DESCRIPTION

Lake Songkhla, a coastal lagoon produced by sand-bar formation includes three lakes, Thale Noi (2,800 ha), Thale Luang (78,280 ha) and Thale Sap Songkhla (17,600 ha), from north to south, which are inter-connected by narrow channels. A narrow strait (minimum width 380 m) connects Thale Sap with the sea (Gulf of Thailand) at its southeastern end. A grandient of salinity exists, therefore, between the brackish water of Thale Sap and the pure freshwater of Thale Noi. The middle lake, Thale Luang, approaches a freshwater condition during the rainy season (October January), but is influenced by the invasion of seawater in other months.

The lakes are shallow throughout and moderately eutrophic, with a mean water depth of 1.2 -1.3 m in relatively dry seasons, but the water level rises by about one meter during the winter months. Thale Sap is known for its production of fish, shrimp and crabs, and is also intensively utilized for the aquaculture of seabass (*Lates calcarifer*). The fry produced and supplied by the National Institute of Coastal Aquaculture in Songkhla is grown in net cages by fishermen families. Thale Noi and the eastern branch of Thale Luang, called Kukut, have been designated as an area for waterfowl protection.

The catchment area of about 8,020 km^2 consists mostly of lowland rice fields, rubber plantations and forest-covered hills, and contains such rapidly growing cities as Hat Yai and Songkhla. The waste water from certain manufacturing and freezing factories has caused local pollution of the lake and some damage to the fisheries, but the complete and rapid turnover of water in the rainy season seems to prevent severe problems (Q, 1, 2).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	1,082
Volume [10^9m^3]	1.6 (MSL)
	3.8 (1.5 m MSL)
Maximum depth [m]	2.0
Mean depth [m]*	1.4
Luang	1.8
Sap Songkla	1.4
Normal range of annual water level fluctuation (unregulated) [m]	0.6-2.2
Residence time [yr]	0.3-0.5
Catchment area [km^2]	8,020

*The depth of the channels connecting Thale Sap with the Gulf of Thailand and with Thale Luang is approximately 6m. The average of monthly water depth observations at 35 stations in Thale Sap and Thale Luang (Oct. 1976-Sep. 1978) was 1.53 m (2).

D. PHYSIOGRAPHIC FEATURES

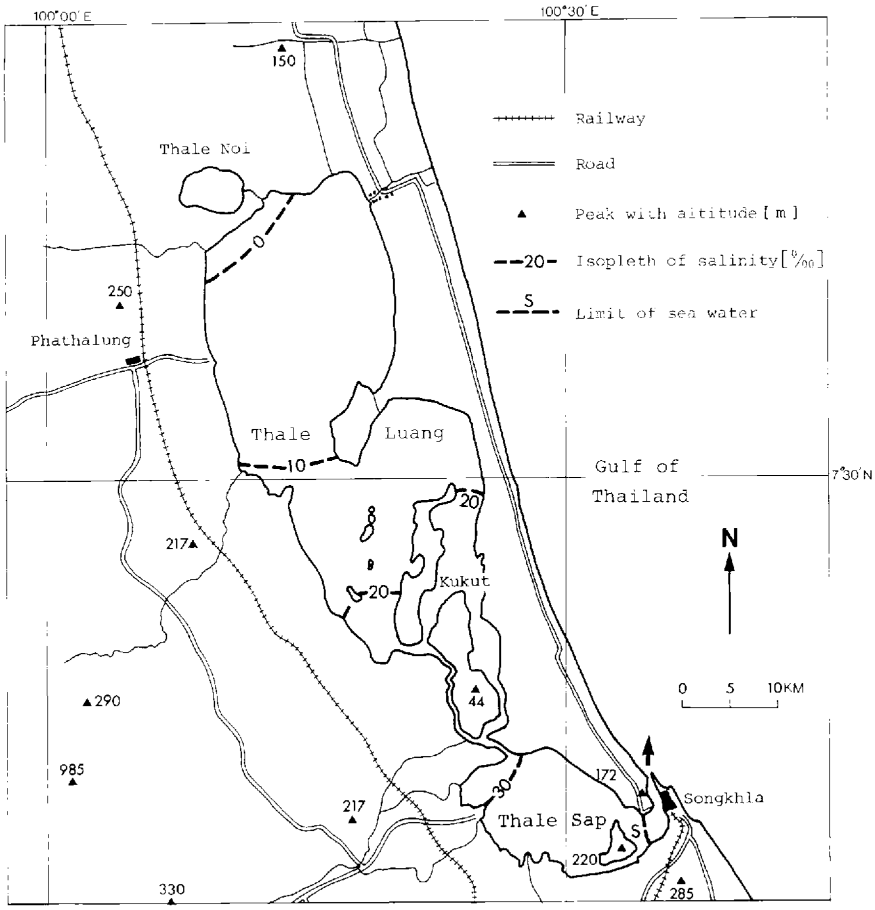
D1 GEOGRAPHICAL (Q)

§ Sketch map of the lake system (Fig. ASI-2-1).

§ Main islands (4 groups): Ko Yo; Ko Si, Ko Ha; Ko Khop, Ko Mak, Ko Nok; Mo Nu, Ko Maco.

§ Outflowing rivers and channels (number and names): 2 (channel connecting Thale Sap Songkhla with the Gulf of Thailand, and Ranot Canal).

Fig. ASI-2-1 Sketch map of L. Songkhla and surrounding areas, with isopleths of mean salinity (2).



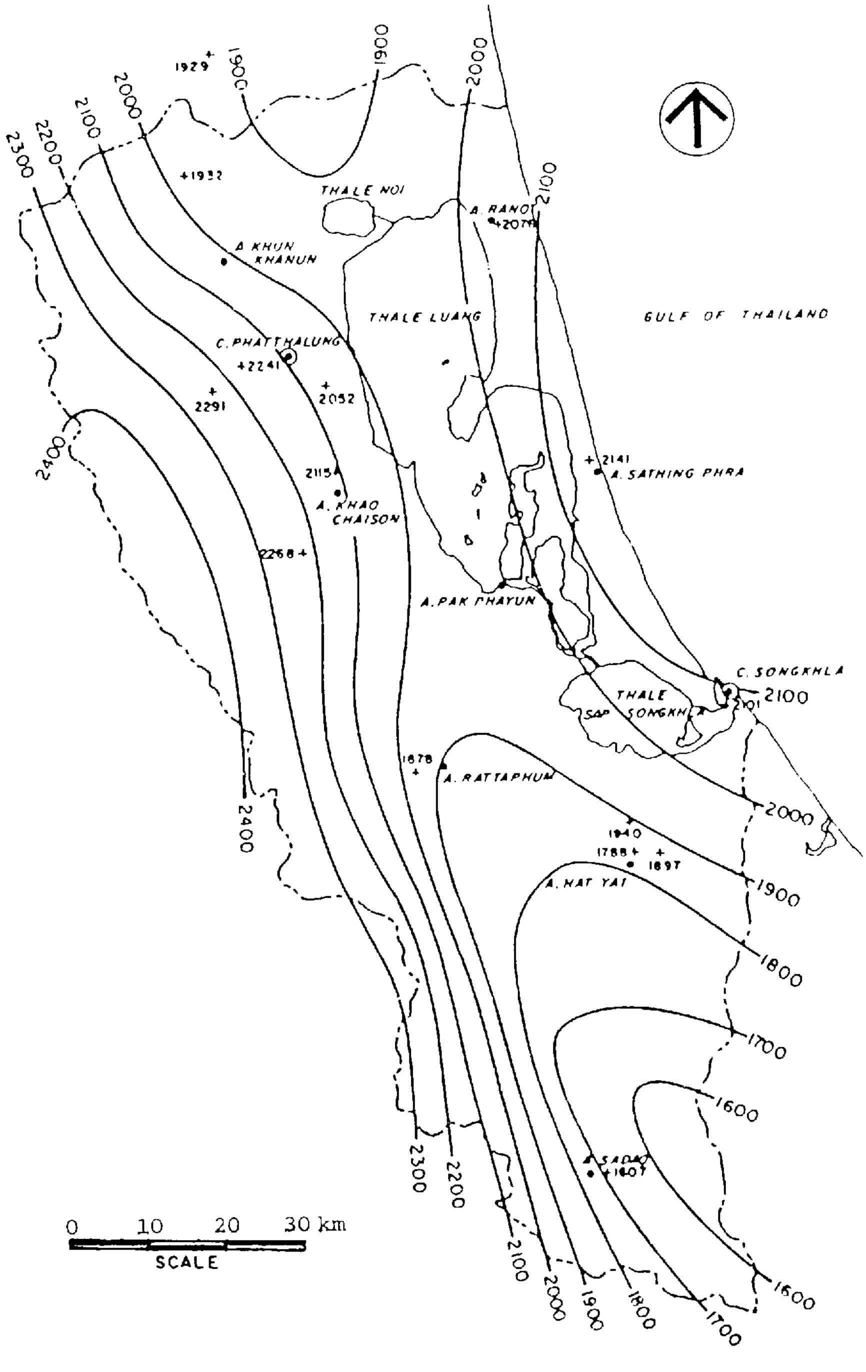
D2 CLIMATIC

§ Climatic data at Songkhla (Q, 2) (cf. Fig. ASI-2-2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp.* [°C]	26.9	27.4	28.0	28.7	28.4	28.1	27.8	27.8	27.5	27.0	26.6	26.6	27.6
Precipitation** [mm]	141	39	42	56	131	102	121	114	122	305	541	437	3149

*1951-1980. **1951-1970.

Fig. ASI-2-2 Distribution of mean annual rainfall (1959-1983) in the catchment area (Q).



§ Number of hours of bright sunshine (Q) : 2,625.0 hr yr^{-1}.

§ Surface water temperature [°C] (Q, 4)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thale Noi*	26.9	–	–	–	–	–	–	–	31.8	–	–	–
Thale Luang**	28.7	28.1	30.0	31.8	31.1	29.4	30.0	28.4	29.8	30.7	27.4	27.6
Thale Sap**	27.3	28.3	29.6	31.0	31.3	29.8	29.6	29.4	28.5	30.4	26.5	27.0

*May 1980-Jan. 1981. **Oct. 1976-Sep. 1978.

§ Notes on water mixing and thermocline formation (Q): Extensive mixing in Thale Luang; no thermocline formation.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], Oct. 1976-Sep. 1978 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thale Luang	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.5	0.4	0.7	0.6	0.4
Thale Sap	0.6	0.7	0.8	0.9	0.9	0.6	0.9	0.8	0.7	0.7	0.4	0.3

E2 pH, 1978-1979, average at 0.3m depth (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.8	7.8	8.1	7.9	7.2	7.3	7.8	7.3	7.5	6.9	6.9	7.2

E3 SS [mg l^{-1}] of surface water, May 1980-Jan 1982 (4)

	Jan	May	Sep
Thale Noi	26.2	176.7	49.9
Thale Luang (Kukut)	35.1	33.1	32.9

E4 DO [mg l^{-1}], 1978-1979, average at 0.3m depth (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.9	7.1	6.8	7.1	6.9	7.0	5.3	6.6	7.2	4.7	5.3	6.7

E5 COD [mg l^{-1}], 1983-1984, surface water of Thale Sap: 1-2(Q).

E6 CHLOROPHYLL CONCENTRATION [$\mu g l^{-1}$], 1978-1979, average at 0.3m depth (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.65	6.30	2.58	10.0	–	–	–	7.58	0.77	0.69	2.27	–

E7 NITROGEN CONCENTRATION [mg l^{-1}]

§ Total-N of surface water, May 1980-Jan. 1981 (6)

	Jan	May	Sep
Thale Noi	0.64	3.75	1.39
Thale Luang (Kukut)	0.46	0.89	0.96

§ NO_3-N, 1978-1979, average at 0.3m depth (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.20	1.96	2.58	2.59	–	–	–	–	1.95	1.97	2.29	2.33

E8 PHOSPHORUS CONCENTRATION [mg l^{-1}]

§ PO_4-P, 1978-1979, average at 0.3m depth (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.05	0.08	0.06	0.07	0.02	0.08	–	–	0.15	0.12	0.04	0.07

E9 SALINITY [ppt], 1978-1979, average at 0.3m depth (Q) (cf. Fig. ASI-2-1)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.9	3.3	5.9	6.9	1.2	1.1	1.3	3.1	9.3	11.0	3.5	2.2

F. BIOLOGICAL FEATURES

F1 FLORA

§ Mangrove plants : Kukut (*Sonneratia caseolaris, Nipa fruticans, Acrostichum aureum*) ; Thale Sap (*Rhizophora apiculata*) (6).

§ Emerged macrophytes : Thale Noi (*Phragmites communis, Scleris oryzoides, Cyperus grossus* and spp., *Eleocharis dulcis*) ; Kukut (*Paspalum* sp., *Eleocharis dulcis, Scirpus mucronatus, Cyperus tegetiformes* and spp., *Phragmites communis*) (6).

§ Floating macrophytes : *Eichhornia crassipes* (Q) ; Thale Noi (*Nymphoides indica, Salvinia cucullata*) ; Kukut (*Azolla* sp., *Lemna* sp.) (6).

§ Submerged macrophytes ; Thale Noi (*Chara* sp., *Blyxa echinosperma, Utricularia flexuosa, Ceratophyllum demersum*) ; Kukut (*Chara* spp., *Ceratophyllum demersum, Najas marina*) (6).

§ Phytoplankton : Kukut (*Phormidium* spp., *Oscillatoria* spp., *Anabaena* spp., *Nitzchia* spp., *Navicula* spp., *Diatoma* spp., *Scenedesmus* spp., *Spirogyra* spp.) (6) ; Thale Luang (*Pediastrum* sp., *Spirulina* sp., *Surirella* sp.) (2) ; Thale Sap (*Chaetoceros* spp., *Nitzchia* spp., *Rhizosolenia* spp., *Coscinodiscus* spp.) (2).

F2 FAUNA

§ Zooplankton : Thale Noi and Kukut (*Arcella* spp., *Difflugia* spp., *Brachionus* spp., *Lecane* spp., Cladocera, Podoplea) (6).

Cladocerans tend to be found in the upper part of the lake system, and copepods, urochordates, nauplius larvae and chaetognatha in the lower part, while fish larvae and malacostraca are more widely distributed (Q).

§ Benthos : Thale Noi and Kukut (Polychaeta (*Nereis, Dendronereis, Nephtys, Sabella, Meglomma*), Mollusca (*Melanoides, Idiopoma, Pila, Clea, Corbicula, Modiolus*), Crustacea (*Palaemon* spp., *Macrobrachium* spp., *Gammalus* sp.)); Thale Sap (Polychaeta (*Nephtys*, Nereidae, Orbiniidae, *Lambrinereis, Arbella*), Crustacea (*Upogebia, Cyathura, Apseudes, Gammalus, Penaeus, Metapenaeus*)) (2, 6). Arthropods are found at high density in the upper lake system, reaching the maximum level in dry season. Polychaetes increase their density toward the sea, flourishing in dry season. Nematodes are found at high density near the end of each lake, while nemerteans are abundant in the middle lake system (Q).

§ Fish (caught by fishing gears) : Thale Luang (*Tachysurus* spp., *Mystus* spp., *Fluta* sp., *Puntius* spp., *Ophicephalus* spp., *Ompox* sp.) ; Thale Sap (*Mugil dussumieri* and spp., *Lates calcarifer, Epinephelus* spp., *Eleutheronema* sp., *Gerres* sp., *Plotosus* sp.) (2).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (Q. 7)

Vegetation and land use types	Area [km²]	[%]
Forested area	1,726	24.7
Undisturbed	1,084	15.5
Disturbed	487	7.0
Swamp & Mangrove	155	2.2
Agricultural land	5,110	73.0
Paddy field (rice)	2,474	35.3
Rubber plantation	2,636	37.7
Settlement area	163	2.3
Total	6,999	100.0

§ Main types of woody vegetation (main species): Tropical rain forest; secondary forests at various stages of regeneration; mangrove forest (*Rhizophora apiculata, Sonneratia caseolaris, Nipa fruticans*); rear mangrove (*Melaleuca leucadendron*); brackish swamp forest; freshwater swamp forest (*Alstonia spathulata, Eugenia grata*); scrub on limestone hills, etc.

§ Main types of herbaceous vegetation: Grass swamps (*Paspalum scrobiculatum, Phragmites* spp., *Cyperus, Scirpus, Scleria,* etc.).

§ Main kinds of crop plants: Lowland rice, rubber and fruit trees.

§ Levels of fertilizer application on crop fields: Light.

§ Trends of change in land use (1974-1982) (1)

Land use types	1974 [%]	1978 [%]	1982 [%]
Forested area			
Undisturbed forest			
- Tropical evergreen forest	19.7	16.2	15.3
- Mangrove and swamps	–	–	2.2
- Scrub	–	–	0.2
Disturbed forest			
- Old clearing area	5.9	–	2.7
- New deforested area		–	4.2
- Rubber plantation mixed with forest	10.8	–	–
Non-forest area	–	83.8	–
Rice field	35.0	–	35.3
Rubber plantation	22.6	–	37.7
Residential area	6.0	–	2.3
Total	100.0	100.0	100.0

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1984) (1)

Kinds of industry	Units	No. of workers
Rice mills	950	1,462
Fishing industries (including ice)	89	2,605
Other food and beverages	69	775
Wood industries	61	769
Furniture	27	793
Printing	15	113
Rubber processing	30	1,913
Chemical products	14	168
Non-metallic minerals including building and construction materials	62	816
Metal products	57	375
Machinery including repair	154	1,024
Boat building and repair	6	150
Others (umbrellas, etc.)	2	55
Total	1,536	11,004

G3 POPULATION IN THE CATCHMENT AREA (1980) (1)

Total population	Population density $[km^{-2}]$	Main cities
1,199,000	171.2	Hat Yai Songkhla Patthalung

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, navigation and transportation, sight-seeing and tourism (477, 400 visitors in 1984), recreation (swimming, sport-fishing, yachting, bird-watching) and fisheries (including aquaculture).

H2 THE LAKE AS WATER RESOURCE (Q)

	Use rate $[10^6 m^3 yr^{-1}]$
Domestic water	50
Irrigation	450
Industrial water	55
Total	555

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : Not serious.

§ Rate of sedimentation (entering lake) : 500,000-600,000 [metric ton yr^{-1}].

12 TOXIC CONTAMINATION (Q)

§ Present status : Detected but not serious.

§ Pesticide residues in Thale Noi area (ppm)

Pesticide	Recorded maximum level	Location	Material
Gamma-BHC	0.03	Ban Thale Noi, Rhlong Mai	Sediment
Heptachlor	0.03	Thale Noi non-hunting area	Water
Dieldrin	0.10	Ban Thale Noi, Khlong Mai	Sediment
p, p' DDE	0.03	Khlong Mai	Sediment
p, p' DDD	0.08	Khlong Mai	Sediment
p, p' DDT	0.43	Ban Thale Noi	Water
Total DDT	0.45	Ban Thale Noi	Water
	0.25	Ban Thale Noi	Sediment
	0.06	Thale Noi	Catfish

§ Heavy metals in bottom sediments [ppm, dry wt. base] (1)

	Minimum	Maximum
Cd	1.9	16.1
Cu	130.6	260.2
Fe	16,000	48,000
Mn	199.8	733.5
Pb	31.5	78.5
Zn	29.0	88.6

§ Draft water quality standards for freshwater sources (1)

Characteristics [unit]	Percentile	Water class*** 1	2	3	4	5
Physical						
Floating solids		n	n	n	n	
Colour		n	n	n	n	
Taste & odour		n	n	n	n	
Temperature [°C]	-	n	n′	n′	n′	n′
pH	-	6-8	6-8	6-8	6-8	6-8
DO	80>	n	6	4	2	-
BOD_5 (20°C)	80<	Less than 2	1.5	2.0	4.0	-
Coliform bacteria						
Total coliforms [MPN $100ml^{-1}$>]	80>		5,000	20,000	20,000	-
Faecal coliforms [〃]	-		1,000	4,000	4,000	-
NO_3 as N [mg l^{-1}]	100	As occurs in natural waters		5.0	No other specific criteria listed	
NH_3 as N [〃]				0.5		
Phenols [〃]				0.005		
Cu [〃]				0.1		
Ni [〃]				0.1		
Mn [〃]				1.0		
Zn [〃]				1.0		
Radioactivity Alpha	100			0.1		
[picocuries l^{-1}] Beta	100			1.0		
Toxic substances	100					
As [mg l^{-1}]				0.01		
Cd [〃]				0.005*		
Cr [〃]				0.05** 0.05		
Cu [〃]				0.005		
Pb [〃]				0.05		
Hg [〃]				0.002		
Pesticides [〃]				0.05		

n : Natural condition.
n′ : Natural condition± 3 °C.
* In water having hardness less than 100 mg l^{-1} as $CaCO_3$.
** In water having hardness higher than 100 mg l^{-1} as $CaCO_3$.
***Water class :

1 : Very clean water, utilized for :
- drinking and other consumption ; water treatment may be not necessary but disinfection required,
- conservation of freshwater ecology and natural growth of aquatic plants.

2 : Clean water utilized for :
- drinking and other consumption ; conventional water treatment and disinfection will be needed,
- conservation of aquatic life and suitable for fisheries development,
- recreation

3 : Fairly clean water, utilized for
- drinking and other consumption ; conventional water treatment and disinfection necessary,
- agricultural use as irrigation water.

4 : Moderately clean water, utilized for :

- drinking and other consumption ; special water treatment is necessary,
- industrial water supply,
- other activities.

5 : Water other than classes 1-4, utilized for water transportation.

§ Industrial wastewater quality standards (1)

(1) pH	Between 5.0 and 9.0
(2) Permanganate value [mg l^{-1}]	60
(3) Dissolved solids [mg l^{-1}]	
3. 1 Discharge into water-courses	2,000 or more but not exceeding 5,000, depending upon discharge point
3. 2 Discharge into sea or estuaries (salinity not higher than 2, 000 mg l^{-1})	5,000 higher than dissolved solids in sea or estuary waters
(4) Sulfide as H_2S [mg l^{-1}]	1.0
(5) Cyanide as HCN [mg l^{-1}]	0.2
(6) Heavy metals [mg l^{-1}]	
6.1 Zn	5.0
6.2 Cr	0.5
6.3 As	0.25
6.4 Cu	1.0
6.5 Hg	0.005
6.6 Cd	0.03
6.7 Ba	1.0
6.8 Se	0.02
6.9 Pb	0.2
6.10 Ni	0.2
6.11 Mn	5.0
(7) Tar	Nil
(8) Oil and grease [mg l^{-1}]	5.0(except for crude oil refinery and lubricant blending plant ; less than 15)
(9) Formaldehyde [mg l^{-1}]	1.0
(10) Phenols and cresols [mg l^{-1}]	1.0
(11) Free chlorine [mg l^{-1}]	1.0
(12) Insecticides and radioactive substances	Nil
(13) Suspended solids [mg l^{-1}]	30 or more depending on dilution ratio as shown below
Dilution ratio 8-150	Allowable suspended solids 30
151-300	80
301-500	150
(14) BOD, 5 day, 20°C [mg l^{-1}]	20 or more but not exceeding 60, depending upon discharging point, except for industries shown below
14.1 Fish canning	New process as in (14)
14.2 Tapioka starch	Old process 100
14.3 Noodle factory, using less than 500kg of rice per day	100
14.4 Tanneries	100
14.5 Pulp mills	100
14.6 Seafood processing	100
(15) Temperature [°C]	Less than 40
(16) Color and odor	Not objectionable when mixed in receiving water

§ Inland freshwater quality standards (1)

Characteristics [unit]	Percentile	Water class 1	2	3	4	5
Temperature [°C]	-	n	n′	n′	n′	n′
pH		6 8	6-8	6-8	6-8	6.8
DO [mg l^{-1}]	80>	n	6	4	2	-
BOD [mg l^{-1}]	80<	Less than 2	1.5	2.8	4.0	-
Coliform bacteria [MPN 100 ml^{-1}]						
Total coliforms	80	-	5,000	20,000		
Faecal coliforms	-	-	1,000	4,000	-	-
NO_3 as N [mg l^{-1}]	100		5.0			
NH_3 as N [〃]			0.5			
Phenols [〃]			0.005			
Cu [〃]			0.1			
Ni [〃]			0.1			
Mn [〃]			1.0			
Zn [〃]			1.0			
Radioactivity [curie]	100		None			
Toxic substances [mg l^{-1}]	100					
As			0.01			
Cd			0.005* (0.05**)			
Cr			0.05			
Cu			0.005			
Pb			0.05			
Hg			0.002			
Pesticides			0.05			

For water classes, symbols and foot notes, see p.10.

I3 EUTROPHICATION (1)

§ Nuisance caused by eutrophication: Unusual algal bloom; blooms of *Nostoc* sp. and *Euglena* sp. were observed in Thale Luang in the past.

§ Nitrogen and phosphorus loadings: Songkhla Basin Planning Study (1) shows forecasted nutrient loads to the lake for different planning scenarios. The natural growth scenario presents the estimates for BOD, N and P loadings [metric ton yr^{-1}] as follows.

Year	BOD	N	P
1984	26,267	20,494	5,526
1986	27,809	21,365	5,747

I4 ACIDIFICATION (Q)

§ Extent of damage: None.

J. WASTEWATER TREATMENT(Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (c) Limited pollution with some wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS: Nonpoint sources 90%, point sources 10%.

J3 SANITARY FACILITIES AND SEWERAGE

- § Percentage of municipal population provided with adequate sanitary facilities (on-site treatment systems): 100%.
- § Percentage of rural population provided with adequate sanitary facilities: 0%.
- § Municipal wastewater treatment systems: Septic tank and cesspool.
- § Industrial wastewater treatment systems: Biological treatment required by law for organic pollutants in all industrial plants.

K. IMPROVEMENT WORKS IN THE LAKE

K3 OTHERS (Q)

Construction of new fishing ports with wastewater treatment facilities; plans for sewerage and sewage treatment systems.

L. DEVELOPMENT PLANS

Deep sea-port under construction; Koh Yor Bridge completed; salinity barrier under study (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (Q)

§ Names of the laws (the year of legislation)

(1) Factory Act (1969)
(2) National Environmental Quality Act (1975)
(3) Public Health Act

§ Responsible authorities

(1) Ministry of Industry
(2) National Environment Board
(3) Ministry of Health; local authorities and municipalities.

§ Main items of control

(1) Industrial effluent standards
(2) Establishment of standards and environment impact assessment
(3) Sanitation, solid waste management, food sanitation and toxic substance control.

M2 INSTITUTIONAL MEASURES(Q)

None solely responsible for the lake; the following agencies take collective responsibilities.

(1) National Environment Board established in 1975; the monitoring of the lake environment has been kept since 1978 in collaboration with Songkhla University.
(2) Department of Industrial Works, Ministry of Industry; occasionally undertakes monitoring.

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES (Q)

(1) Prince of Songkhla University, Hat Yai.
(2) National Institute of Coastal Aquaculture, Songkhla
(3) Thailand Institute of Scientific and Technological Research, Bangkok.

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. Surin Setamanit, Institute of Environmental Research, Chulalongkorn University, Bangkok, Thailand.

(1) National Economic and Social Development Board/National Environment Board (1985) Songkhla Lake Basin Planning Study. Bangkok (with data citations from Meteorological Department, Applied Science and Technology Research Institute, Provincial Industry Offices, Songkhla and Patthalung Municipalities, Prince of Songkhla University, National Environment Board and LANDSAT).

(2) Information from the National Institute of Coastal Aquaculture.

(3) Thai University Research Association (1981) Social, Economic and Demographic Studies for Better Environmental Management of the Songkhla Lake Basin. 624pp. Office of the National Environment Board of Thailand, Bangkok.
(4) Dobias, R. J. (1982) The Shell Guide to the National Parks of Thailand. 37pp. The Shell Company of Thailand, Bangkok.
(5) Information from National Environment Board of Thailand.
(6) Ecological Research Division, Thailand Institute of Scientific and Technological Research (1981) Ecological Studies for Conservation of Shore Birds in Songkhla Lake. Vol. 1. 559pp. Office of the National Environment Board of Thailand, Bangkok.
(7) Information from Ecological Research Division, Thailand Institute of Scientific and Technological Research.
(8) Information from Mr. Narmg Na, Chiang Mai, based on Songkhla Lake Research Report, 1978-1979, Prince of Songkhla University.

LAKE RARA

A view from the lakeside hill

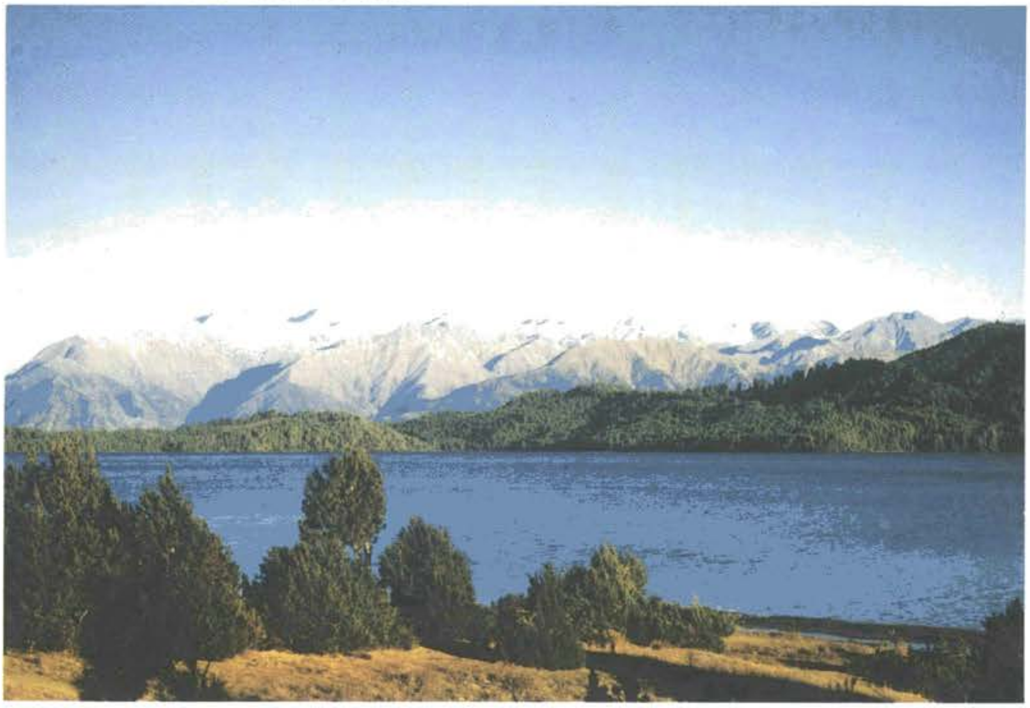


Photo: D. B. Swar

A. LOCATION

§ Karnali Zone, Mugu District, Nepal.
§ 29°24′N, 82°05′E ; 3,000 m above sea level.

B. DESCRIPTION

Lake Rara is situated in the western part of Nepal, at about 300 km northwest of Kathmandu, the capital of Nepal. It is a warm, oligotrophic lake with a monomictic type of water circulation. It is surrounded by hills and mountains from which more than 30 brooks flow into the lake. It has only one outlet, Khater Khola, on its western shore (khola = stream). Khater Khola forms a deep gorge at about 7 km downstream from the outlet and finally joins Karnali River, a tributary of the Ganga.

Lake Rara is somewhat oval in shape. It has relatively large maximum depth for its surface area. It has two basins. The main basin, occupying the western part of the lake, covers about 80 % of the total surface area. It is characterized by a steep margin and vast flat bottom. The area below 160 m accounts for about 27 % of the lake area. The eastern sub-basin has a gently sloping margin and a small bottom. Lake Rara is a part of 'Rara Lake National Park and Wildlife Conservation Area' (Q).

C. PHYSICAL DIMENSIONS (1, 2)

Surface area [km^2]	9.8
Volume [$10^9 m^3$]	0.98
Maximum depth [m]	167
Mean depth [m]	100
Length of shoreline [km]	14.3

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (2)

§ Bathymetric map (Fig. ASI-3-1).

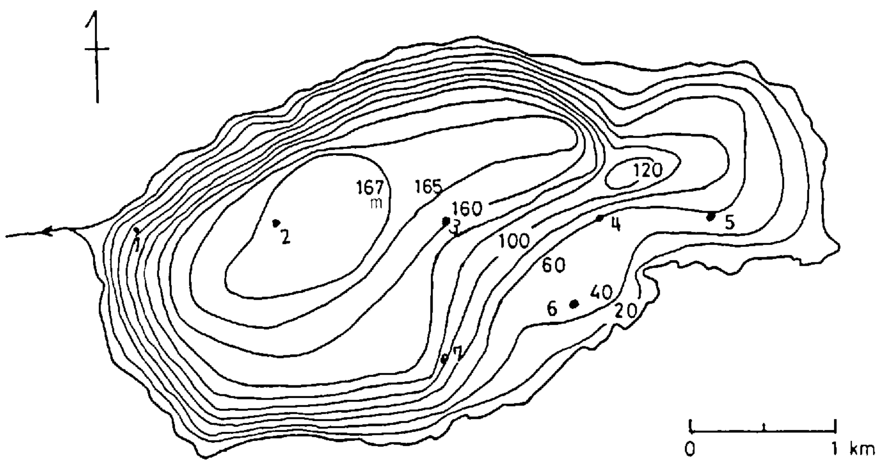
§ Outflowing rivers and channels (number and names) : 1 (Khater Khola).

D2 CLIMATIC (6)

§ Climatic data at Rara, 1983-1984

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	1.1	2.4	9.3	8.6	14.4	13.2	15.5	16.0	14.1	9.2	7.0	3.9	9.6
Precipitation [mm]	41	94	34	63	23	201	189	337	346	216	0	12	1,556

Fig. ASI-3-1 Bathymetric map (2).



§ Water temperature [°C] (2)

Station 2, May 20, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface (0)			–	–	12.1	–	–			–	–	–
8	–	–	–	–	11.9	–	–		–	–	–	–
16	–	–	–	–	11.3	–	–	–	–		–	–
32	–	–	–	–	9.2	–	–	–	–	–	–	–
60			–		8.3	–	–	–			–	–
120	–	–	–		8.3	–	–	–	–	–	–	–
160	–			–	8.3	–	–	–	–			–

§ Freezing period : None.

§ Mixing type : Monomictic.

E. LAKE WATER QUALITY (2)

E1 TRANSPARENCY [m]

Station 1-7, May 16, 1983

Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7
16.6	16.6	16.2	15.9	13.0	15.0

E2 pH

Station 2, May 20, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	8.48		–	–	–	–	–	
8		–	–	–	8.52	–		–	–	–	–	–
16	–	–	–	–	8.56	–	–		–	–	–	–
32	–	–	–	–	8.60	–	–	–	–		–	–
60	–	–	–	–	8.40	–	–	–	–	–	–	–
120	–	–	–	–	8.36		–	–	–	–	–	–
160	–	–	–	–	8.30		–	–	–	–	–	–

E4 DO [mg l⁻¹]

Station 2, May 20, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	7.50	–	–		–	–	–	–
8	–		–	–	7.59	–	–	–		–	–	–
16		–	–	–	7.93	–	–			–	–	–
32	–	–		–	8.06	–	–	–	–	–	–	–
60	–	–	–	–	6.91	–		–	–	–	–	–
120	–	–	–	–	6.58	–	–	–			–	–
160		–	–	–	6.52	–	–	–			–	–
167	–	–		–	4.84	–	–	–	–	–	–	

E6 CHLOROPHYLL CONCENTRATION [μg l⁻¹]

Station 2, May 20, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	0.061	–		–	–	–	–	–
8	–	–	–	–	0.125	–			–	–	–	–
16	–	–	–	–	0.160	–	–		–	–	–	–
32	–	–	–	–	0.381	–	–				–	–
60	–		–	–	0.465	–	–	–	–	–	–	–
160	–	–	–	–	0.036	–	–	–		–	–	–

E7 NITROGEN CONCENTRATION

§ Total-N [mg l⁻¹], Station 2, May 20, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8	–		–	–	0.030	–	–	–	–	–		–
16	–	–		–	0.027	–	–	–	–	–	–	
32	–		–	–	0.027	–	–	–	–		–	–
60		–	–	–	0.024	–	–	–	–		–	–
120		–	–	–	0.018	–	–	–			–	–
160	–	–	–	–	0.021	–	–		–	–	–	–

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l⁻¹], Station 1-7, May 1983

Depth [m]	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Stn. 6	Stn. 7
0	0.010	0.007	0.007	0.003	0.003	0.003	0.010

F. BIOLOGICAL FEATURES

F1 FLORA

§ Phytoplankton : *Ceratium hirundinella, Dinobryon* cf. *borgei*.

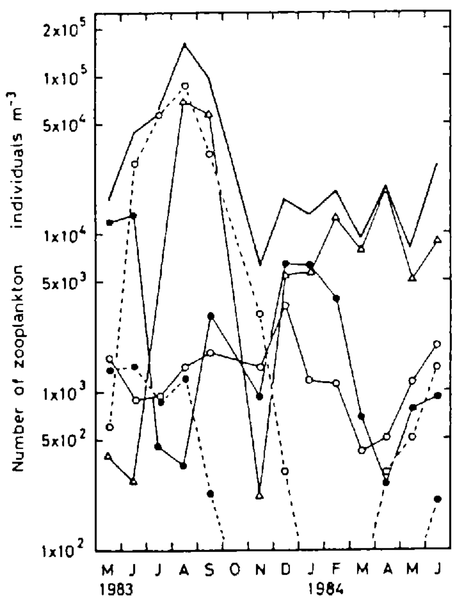
F2 FAUNA

§ Zooplankton : Rotifera (*Conochiloides coenobasis, Keratella quadrata, K. cochlearis, Lecane* spp., *Filinia opoliensis*) ; Cladocera (*Daphnia longispina, Holopedium* spp.) ; Copepoda (*Stenodiaptomus stewartiensis, Cyclops hutchinsoni*).

§ Fish : *Schizothorax raraensis, S. macrophthalmus, S. nepalensis, Schizothoraichthys esocinus* (4, 5).

§ Supplementary notes on the biota

Fig. ASI-3-2 Annual change in the individual number of total zooplankton (——), *Dinobryon cylindricum* cf. *borgei* (——△——), *Ceratium hirundinella* (·····○·····), *Conochiloides coenobasis* (—·-●), *Filinia opoliensis* (·····●···) and Copepods including nauplii (○——) (2).



F3 PRIMARY PRODUCTION RATE [mg O_2 l^{-1} day^{-1}]

Station 2, May 24, 1983

Community respiration	0.018 0.058
Gross production	0.020–0.045

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (6)

§ Main types of woody vegetation : *Abies spectabilis* forest, *Pinus excelsa* forest, *Quercus semicarpifolia* forest, *Picea smithiana* forest, *Betula utilis* forest.

§ Main types of herbaceous vegetation : Alpine grassland, moist herbosa.

§ Types of other important vegetation : Water plant vegetation.

G3 POPULATION IN THE CATCHMENT AREA

No residents (Q).

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Sightseeing and tourism (number of visitors in 1984 : ca. 5,000) (Q).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes : The sedimentation rate averaged 0.42-0.80g dry weight m^{-2} day^{-1} in May and 0.75-1.00g dry weight m^{-2} day^{-1} in September, 1983, and tended to decrease with depth.

I2 TOXIC CONTAMINATION

§ Present status : None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Not any nuisance.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (a) Pristine lake environments (Q).

N. SOURCES OF DATA

(Q) Questionnaire filled by Mr. Deep B. Swar, Fisheries Development Centre, Pokhara, based on the data from the following sources.

(1) Ferro, W. (1978/1979) Some limnological and biological data from Rara, a deep Himalayan lake in Nepal. J. Nepal Res. Centre, 2/3 : 241-261.

(2) Okino, T. & Satoh, Y. (1986) Morphology, physics, chemistry and biology of Lake Rara in west Nepal. Hydrobiologia, 140 : 125-261.

(3) Swar, D. B. (1979) Report on a single species of Cladocera from Rara Lake, Nepal. J. Inst. Sc., 2 : 185-190.

(4) Terashima, A. (1984) Three new species of cyprinid genus *Schizothorax* from Lake Rara, northwestern Nepal. Jap. J. Ichthyol., 31 (2) : 122-135.

(5) Shrestha, J. (1978) Fish from Rara. J. Inst. Sc., 1 : 157-158.

(6) Tabata, H. (personal communication).

LAKE PHEWA

Fish culture in the coastal area

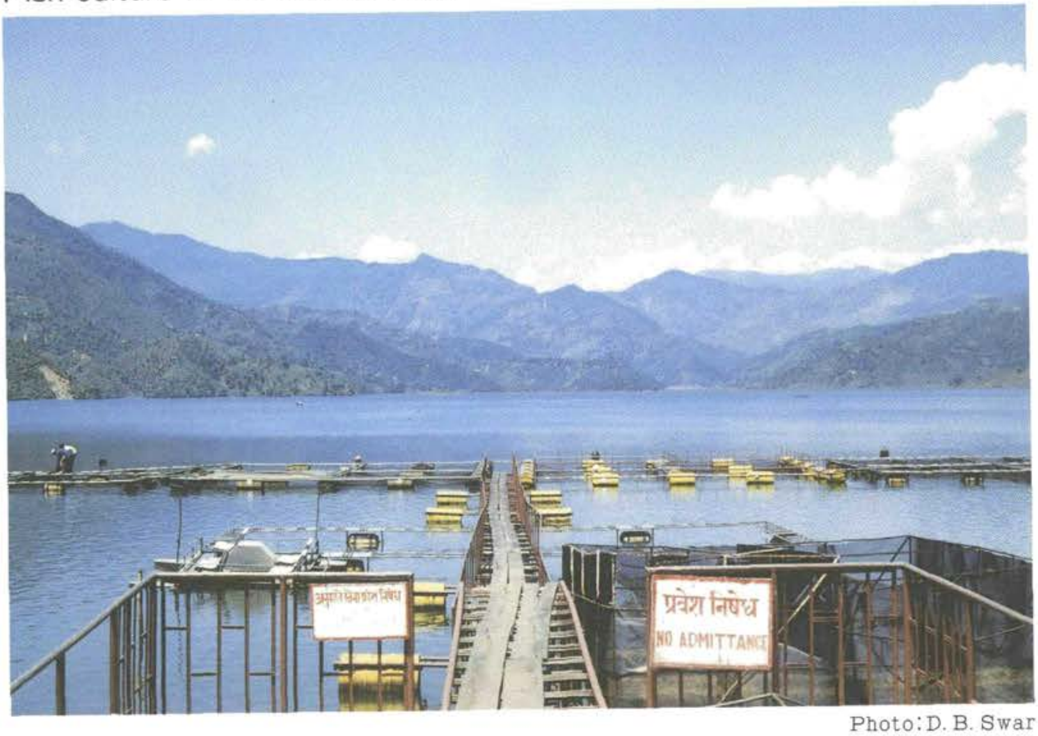


Photo: D. B. Swar

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A. LOCATION

§ Gandaki Zone, Kaski District, Pokhara, Nepal.
§ 28°10′N, 83°55′E ; 742 m above sea level.

B. DESCRIPTION

Lake Phewa is one of the largest lakes of Nepal. It is situated in Pokhara Valley in the western part of the country. The main inflows into this lake are two perennial spring-fed streams, Harpan Khola (khola=stream) and Seti Khola. In addition, several temporary streams drain into the lake during the rainy season. This lake has a single outflow which joins Phusre Khola. The lake belongs to a warm monomictic type with thermal stratification. The lake water has very low electrical conductivity.

Lake Phewa is very young in geological terms as tree trunks are still standing in water down to 6 m depth. There are two versions about the formation of this lake. According to Hagen (1969), there was a "Paleo-Pokhara Lake" filling whole Pokhara basin and the existing lakes are the remains of the former huge lake. But Gurung (1970) and several other workers agree with the view that this lake was formed by damming of tributaries by sediments of Seti River.

Lake Phewa is one of the main sources of recreation, natural beauty, drinking water, hydroelectricity, fisheries and irrigation in Pokhara Valley (1, 2, 3).

C. PHYSICAL DIMENSIONS (4, 5)

Surface area [km^2]	5.0
Volume [$10^6 m^3$]	39
Maximum depth [m]	21
Mean depth [m]	8.6
Normal range of annual water level fluctuation (regulated) [m]	1
Length of shoreline [km]	18
Catchment area [km^2]	110

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (6, 7, 8)

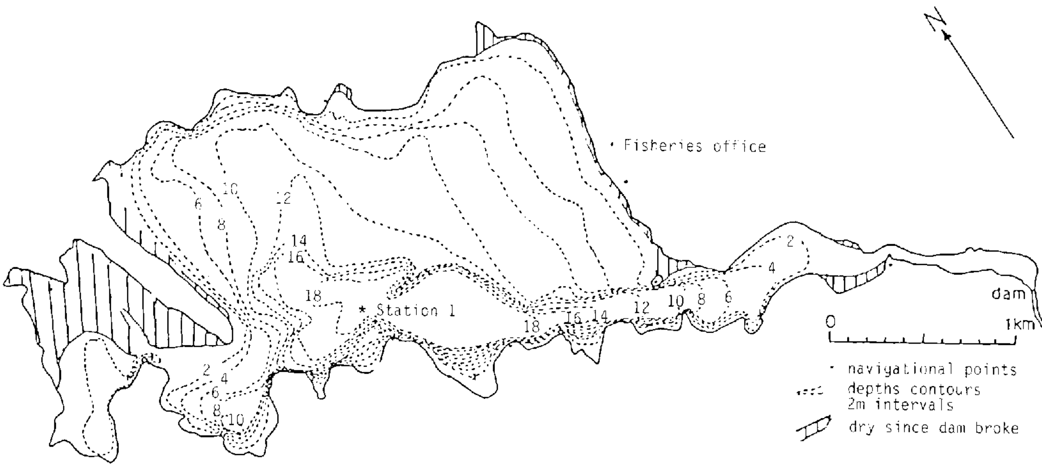
§ Bathymetric map (Fig. ASI-4-1) (4).
§ Main islands (name and area): Baraki Temple (5×10^4 m^2).
§ Outflowing rivers and channels (number and names): 1 (Patale Chhango).

D2 CLIMATIC

§ Climatic data at Pokhara, 1977-1978

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	12.6	15.7	20.5	20.8	21.6	23.9	26.1	25.3	24.7	20.6	18.4	13.8	20.3
Precipitation [mm]	23	11	65	278	321	460	718	1,118	332	332	101	54	3,814

Fig. ASI-4-1 Bathymetric map (4).



§ Water temperature [°C]
Station 1, 1977-1978

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	16	17	20	23	–	27	28	27	27	22	20	18
4	16	16	19	22	–	26	25	25	25	22	20	18
8	16	16	17	18	–	20	22	23	23	22	20	18
10	16	–	17	17	–	19	20	22	22	22	20	18
12	16	16	17	17	–	19	20	21	22	22	20	18
14	16	16	16	17		19	19	20	21	21	20	18
16	16	16	16	17	–	19	19	20	21	21	20	18
18	16	16	16	17	–	18	19	20	21	21	20	18

§ Freezing period: None.
§ Mixing type: Monomictic.
§ Notes on water mixing and thermocline formation: A stable temperature stratification exsits from the end of February until October. The pattern is of a classical monomictic type with one turnover in winter.

E. LAKE WATER QUALITY (6, 7, 8, 9, 10, 11)

E1 TRANSPARENCY [m], 1977-1978

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4	3	1.7	2	1.6	1.7	1.9	1.3	2.6	2	2.4	1.8

E2 pH, Sep. 10, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	–	–	–	8.3	–	–	–
1	–	–	–	–	–	–	–	–	8.3	–	–	–
2.5	–	–	–	–	–	–	–	–	8.0			
5	–	–	–	–	–	–	–	–	6.9	–	–	–
10	–	–	–	–	–	–	–	–	6.4	–	–	–
15	–	–	–	–	–	–	–	–	6.9	–	–	–
20	–	–	–	–			–	–	6.9	–	–	–

E4 DO [mg l⁻¹], 1977 1978

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	9	10	10	9	–	9	8	8	8	8	8	8
4	9	9	9	9	–	6	6	6	7	8	8	8
8	9	9	5	0	–	0	1	2	0	5	2	8
10	9	9	3	0		0	0	0	0	4	1	8
12	9	9	2	0	–	0	0	0	0	4	1	8
14	9	9	2	0	–	0	0	0	0	1	0	8
16	9	9	2	0		0	0	0	0	0	0	8
18	9	9	2	0	–	0	0	0	0	0	0	8

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$], Sep. 10, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	–	–	–	4.8		–	–
1	–	–	–	–	–	–	–	–	5.6	–	–	–
2.5	–	–	–	–	–	–	–	–	6.5	–	–	–
5	–	–	–	–	–	–	–	–	15.3	–	–	–
10	–	–	–	–	–	–	–	–	1.3	–	–	–
15	–	–	–	–	–	–	–	–	1.1	–	–	–
20	–	–	–	–	–	–	–	–	1.1	–	–	–

E7 NITROGEN CONCENTRATION

§ Total-N* [mg l⁻¹], Sep. 10, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	–	–	–	0.117	–	–	–
2.5	–	–	–	–	–	–	–	–	0.197	–	–	–
5	–	–	–	–	–	–	–	–	0.163	–	–	–
10	–	–	–	–	–	–	–	–	0.326	–	–	–
15	–	–	–	–	–	–	–	–	1.010	–	–	–
20	–	–	–	–	–	–	–	–	1.202	–	–	–

* Total-N is estimated from PON and DTN concentrations.

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l⁻¹], Sep. 10, 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	–	–	–	0.011	–	–	–
2.5	–	–	–	–	–	–	–	–	0.012	–	–	–
5					–	–	–	–	0.011	–	–	–
10	–	–	–	–	–	–	–	–	0.011	–	–	–
15	–	–	–	–	–	–	–	–	0.018	–	–	–
20	–	–	–	–	–	–	–	–	0.026	–	–	–

F. BIOLOGICAL FEATURES

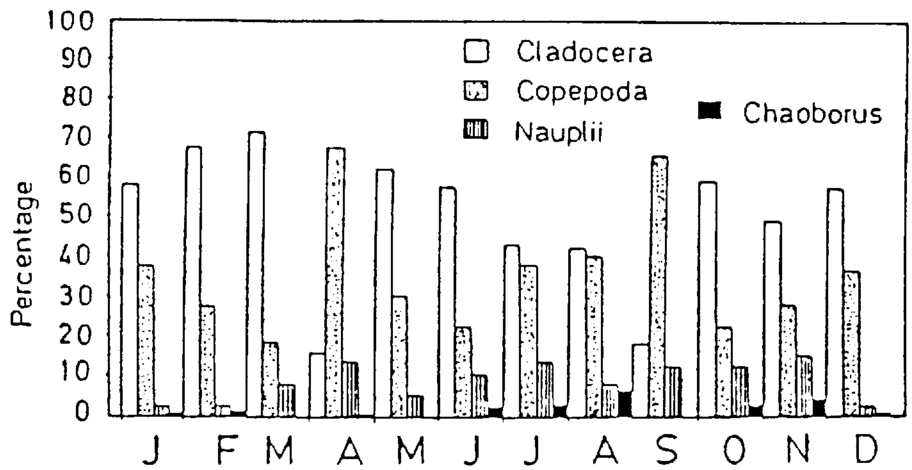
F1 FLORA

§ Phytoplankton : *Merismopedia elegans*, *Microcystis* spp., *Synura petersenii*, *Dinobryon divergens*, *Mallomonas* spp., *Navicula rhyncocepala*, *Navicula* spp., *Cyclotella* spp., *Tabellaria fenestrata*, *Diatomella* spp., *Stephanodiscus carconensis*, *Nitzchia acicularis*, *Melosira granulata*, *M. italica*, *M.* spp., *Synedra acus*, *Surirella robusta*, *Rhoicosphenia curvata*, *Botryococcus braunii*, *Centritractus belonophorus*, *Ceratium hirundinella*, *Gymnodinium* spp., *Peridinium* spp., *Cryptomonas compressa*, *C.* spp., *Gonyostumum semsn*, *G.* spp., *Staurastrum pseudopelagicum*, *S. dimazum*, *S. dorsidentiferum*, *S. curvatum*, *S.* spp., *Arthrodesmus triangularis*, *A. ralfsii*, *Arthrodesmus* spp., *Euastropsis richteri*, *Cosmarium contractum*, *C. reniforme*, *Cosmarium* spp., *Spondirosium* spp., *Closterium* spp., *Oocystis lacustris*, *O.* spp., *Nephrocytium* spp., *Glaeotaenium loitelsbergerianum*, *Tetraedron hastatum*, *Crucigenia tetrapedia*, *Galenkinia radiata*, *Carteria cordiformis*, *Chlamydomonas moewusii*, *Dictyospherium ehrenbergianum*, *D. pulchellum*, *Gonotozygon pilosum* (7, 9).

F2 FAUNA

§ Zooplankton : Rotifera (*Collotheca* sp., *Conochilus unicornis*, *Hexarthra mira*, *Keratella cochlearis*, *K. tropica*, *Brachionus patulus*, *Tricocera cylindrica*, *T. similis*) ; Cladocera (*Diaphanosoma excisum*, *Daphnia longispina*, *D. lumholtzi*, *Ceriodaphnia reticulata*, *C. cornuta*, *Simocephalus vetulus elisabethae*, *Bosmina longirostris*, *Eubosmina coregoni*, *Moina micrura*) ; Copepoda (*Neodiaptomus strigilipes*, *Phyllodiaptomus blanci*, *Mesocyclops leuckarti*, *Thermocyclops crassus*, *Tropocyclops confinis*, *Chaoborus* sp.) (12, 13, 14, 15, 16, 17).

ASI-4-2 Seasonal abundance of Crustacean zooplankton in Lake Phewa, Jan.–Dec., 1977. Numbers represent the animals/m² and histograms represent the percentages of different groups (15).



Months	*Diaphanosoma excisum*	*Daphnia longispina*	*Daphnia lumholtzi*	*Ceriodaphnia cornuta*	*Bosmina longirostris*	*Moina micrura*	Calanoida	Cyclopodia	Nauplii	*Chaoborus* spp.
Jan	116,900	1,200	5,600	5,800	200	–	77,800	6,600	6,000	1,200
Feb	54,200	1,100	84,700	4,100	300	–	56,700	2,700	6,000	2,400
Mar	15,400	2,700	157,200	33,900	6,200		48,800	8,400	25,200	–
Apr	4,500	–	2,200	2,100	-	–	22,100	13,600	7,500	200
May	41,100	–	–	1,200	500		12,100	9,200	5,100	0
Jun	4,900			3,500		12,200	8,400	1,500	3,900	1,200
Jul	2,400	–	400	1,500		7,200	6,300	3,900	3,900	900
Aug	5,100	–	800	–	400	3,600	5,500	3,900	2,100	1,600
Sep	51,300	–	2,300	35,400	85,500	10,600	23,100	608,600	130,300	1,700
Oct	1,400	1,100	58,800	1,200	400	–	14,000	21,000	4,100	2,900
Nov	3,800	300	800	15,000	700		3,000	9,000	6,600	2,100
Dec	26,500	200	19,100	1,000			25,600	4,500	2,700	1,000

§ Fish : *Barilius barna*, *B. bendelensis*, *Cirrhinus rewa**, *Labeo gonius**, *L. rohita**, *Puntius sarana**, *P. sophora*, *Tor tor**, *T. putitora**, *Acrossochielus hexagonolepsis**, *Anguilla bengalensis*, *Xenentodon cancilla*, *Channa gachua*, *Mastacembelus armatus*, *Aristichthys nobilis**, *Hypophthalmichthys molitrix**, *Ctenopharygodon idellus**, *Cyprinus carpio** (*economically important) (18, 19).

F3 PRIMARY PRODUCTION RATE* [kg O_2 $m^{-2}yr^{-1}$], 1977-1978 (6)

	Annual total
Net production	0.35
Dark respiration	1.85
Gross production	2.2

* Estimated by a modified light/dark oxygen method.

F5 FISHERY PRODUCTS

§ Annual fish catch in 1985 : 40 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1984)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	30	27
Herbaceous vegetation	10	9
Swamp	2	2
Others	8	8
Agricultural land		
Crop field	20	18
Pasture land	20	18
Residential area	20	18
Total	110	100

§ Main types of woody vegetation : Subtropical deciduous broadleaf forest.
§ Main kinds of crops : Rice, maize, wheat, fruit trees.
§ Levels of fertilizer application on crop fields : Light.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1984)

	Gross product per year [US $]
Fisheries	75,000

G3 POPULATION IN THE CATCHMENT AREA (1984)

		Population	Population density [km $^{-2}$]	Main cities
Urban	ca.	10,000	–	Pokhara
Rural	ca.	5,000	–	
Total	ca.	15,000	136	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Sightseeing and tourism (number of visitors in 1984 : 50,000), recreation (swimming, sport fishing, yachting), fisheries and source of water.

H2 THE LAKE AS WATER RESOURCE (1984)

	Use rate
Domestic water	10 m^3 day^{-1}
Irrigation	10 m^3 sec^{-1}
Power plant	10 m^3 sec^{-1}

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Serious.
§ Supplementary notes : The lake is receiving heavy silt loads every year during the rainy season due to the deforestration on the northern belt of the watershed area.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : None.

I4 ACIDIFICATION

§ Extent of damage : None.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Fisheries Development Centre, Baidam, Phewa Tal, Pokhara, Nepal

N. SOURCES OF DATA

(Q) Questionnaire filled by Mr. Deep B. Swar, Fisheries Development Centre, Pokhara, Nepal, based on the data obtained from the following sources.

(1) Hagen, T. (1969) Report on the geological survey of Nepal. Vol. 1. Preliminary reconnaissance. Denkschr. d. Schweiz. Naturf. Ges., 86 : 1-185.

(2) Gurung, H., (1970) Geomorphology of Pokhara Valley. Himalayan Review, 2/3 : 37-49.

(3) Yamanaka, H., Yoshida, M. & Arita, K. (1982) Terrace landform and quaternary deposit around Pokhara Valley, central Nepal. Journal of Nepal Geological Society, 2 : 113-142.

(4) Ferro, W. & Swar, D. B. (1978) Bathymetric maps from three lakes of the Pokhara Valley (Nepal). J. Inst. Sc. Tribhuvan University, Kathmandu, Nepal, 1 : 177-188.

(5) Swar, D. B. (1980) Present status of limnological studies and research in Nepal. "Proceedings of the First Workshop on the Promotion of Limnology in the Developing Countries" (ed. Mori, S. & Ikusima, I.), pp. 43-47. XXI SIL Congress, Kyoto.

(6) Ferro, W. (1981/1982) Limnology of the Pokhara Valley lakes (Himalayan Region, Nepal) and its implication for fishery and fish culture. Journal of Nepal Research Centre, Kathmandu, Nepal, 5/6 : 27-52.

(7) Hickel, B. (1973) Limnological investigations in lakes of the Pokhara Valley, Nepal. Int. Revue ges. Hydrobiol., 58 : 659-672.

(8) Swar, D. B. & Fernando, C. H. (1980) Some studies on the ecology of limnetic crustacean zooplankton in Lakes Begnas and Rupa, Pokhara Valley, Nepal. Hydrobiologia, 70 : 235-245.

(9) Nakanishi, M. (1986) Limnological study in Phewa, Begnas and Rupa Lakes. "Studies on Distribution, Adaptation and Evolution of Microorganisma in Nepal Himalaya (Second Report)" (ed. Ishida, Y.), pp. 1-13. Kyoto Univ., Kyoto.

(10) Nakanishi, M., Terashima, A., Watanabe, M. & Misra, P. (1984) Preliminary report on limnological survey in lakes of Pokhara Valley (Nepal) in November-December, 1982. "Studies on Distribution, Adaptation and Evolution of Microorganisms in Nepal Himalaya (Preliminary Report)" (ed. Kadota, H.), pp. 31-41. Kyoto Univ., Kyoto.

(11) Kato, K. & Hayashi, H. (1982) Limnological presurvey of Lake Phewa, Nepal. J. Fac. Sc. Sinshu Univ., 15 : 27-29.

(12) Swar, D. B. & Fernando, C. H. (1979a) Seasonality and fecundity of *Daphnia lumholtzi* Sars in Lake Phewa, Nepal. Hydrobiologia, 64 : 261-268.

(13) Swar, D. B. & Fernando, C. H. (1979b) Cladocera from Pokhara Valley, Nepal with notes on distribution. Hydrobiologia, 66 : 113-128.

(14) Swar, D. B. (1979). Some studies on freshwater crustacean zooplankton (natural fish food) from Nepal. M. Sc. thesis, University of Waterloo, Ontario, Canada, 152pp.

(15) Swar, D. B. (1981) Seasonal abundance of limnetic crustacean zooplankton in Lake Phewa, Pokhara Valley, Nepal. Verh. Int. Ver. Limnol., 21 : 535-538.

(16) Dumont, H. J. & van de Velde, I. (1977) Report on the collection of Cladocera and Copepoda from Nepal. Hydrobiologia, 53 : 1 : 55-65.

(17) Deams, G. & Dumont, H. J (1974) Rotifers from Nepal, with description of a new species of *Scaridium* and a discussion of Nepalese representative of the genus *Hexarthra*. Biol. Jb. Dodonaea, 42 : 61-81.

(18) Ferro, W. (1980) Data on the fishery in Pokhara Valley (Nepal) and their implications for the fishery management. J. Inst. Sc. Tribhuvan University, Kathmandu, Nepal, 3 : 221-236.

(19) Ferro, W. & Badagami, P. R. (1980) On the biology of the commercially important species of fish of the Pokhara Valley (Nepal). J. Inst. Sc., 3 : 237-250.

CHŪZENJI-KO (LAKE CHŪZENJI)

A northward view over the whole lake

Photo: A. Kurata

A. LOCATION

§ Tochigi Prefecture, Japan.
§ 36°44′N, 139°29′E ; 1,269 m above sea level.

B. DESCRIPTION

Lake Chûzenji is located close to Nikkô, one of the most familiar sightseeing places in Japan, about 120 km north of Tôkyô. The lake is a natural dammed lake produced by the eruption of the volcano Mt. Nantai, now rising on the northeastern side of the lake. Its forest-covered drainage basin is designated as a national park. The area is blessed with abundant natural beauty, such as the Kegon Falls and the Hakuun Falls, formed by the underground flow of the lake water, as well as fine stands of white birch and rich flora. The famous Tôshôgû Shrine is also near the lake. Thus about four million tourists visit the area annually both from interior and abroad.

The trophic level of the lake is oligotrophic and a few kinds of trout can be caught. The transparency is generally around 9m, but is becoming lower as compared with the values in the 1930's.

In these several years, *Uroglena americana* often blooms during June, and causes a foul smell of tap water from the lake. To reduce the nutrient loading on the lake, municipal wastewater treatment systems have been provided in the area of Lake Chûzenji and water quality improvement countermeasures are also being promoted in Yu-no-ko, a small lake in the upstream of its drainage basin. The Tochigi Prefectural Government enacted in May 1986 the Lake Water Quality Management Plan and the Water Quality Protection Countermeasure Ordinance for Lakes Chûzenji and Yu-no-ko (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	11.5
Volume [10^{9}m^3]	1.16
Maximum depth [m]	163
Mean depth [m]	94.6
Normal range of annual water level fluctuation (regulated) [m]	2
Length of shoreline [km]	24
Residence time [yr]	6.1
Catchment area [km^2]	121

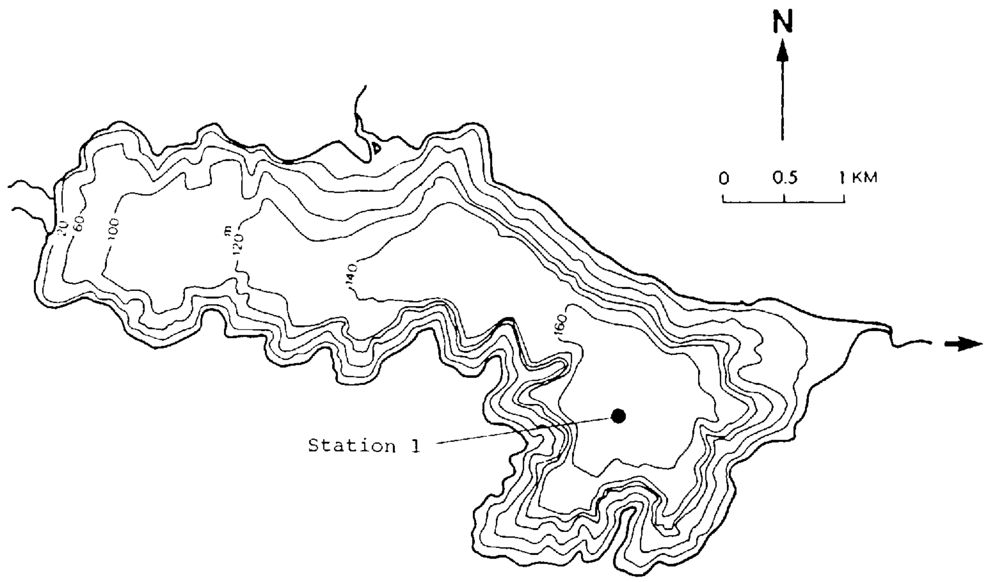
D. PHYSIOGRPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Bathymetric map (Fig. ASI-5-1).

§ Outflowing rivers and channels (number and names) : 1 (Daiya R.).

Fig. ASI-5-1 Bathymetric map (8).



D2 CLIMATIC

§ Climatic data at Chûgûshi, Nikkô, 1983-1985

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-5.6	-5.4	-2.5	5.1	9.8	12.7	17.5	19.1	14.4	8.3	3.2	-2.4	6.2
Precip itation [mm]	22	106	93	169	116	244	320	386	209	129	81	28	1,901

§ Number of hours of bright sunshine (Chûgûshi, Nikkô, 1983-1985) : 2,058 hr yr^{-1}.

§ Water temperature [°C]

Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–		–	4.0	8.0	15.6	18.5	22.2	22.0	15.3	8.6	–

§ Freezing period : None.

§ Mixing type : Monomictic.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], 1985 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Station 1			–	9.4	9.7	6.2	5.3	13.5	11.5	11.0	10.2	–

E2 pH, 1985 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	7.2	7.8	8.2	8.5	7.8	8.3	7.9	7.7	–

E3 SS [mg l⁻¹], 1985 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	1	<1	<1	<1	<1	<1	<1	<1	–

E4 DO [mg l⁻¹], 1985 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	11	11	9.6	9.2	8.0	8.3	9.0	10	–

E5 COD [mg l⁻¹], 1985 (2)
Determined by $KMnO_4$ method.

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–		–	0.7	0.6	0.7	1.0	1.0	0.8	1.3	1.2	–

E6 CHLOROPHYLL CONCENTRATION [μg l⁻¹], 1985 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	–

E7 NITROGEN CONCENTRATION
§ Total-N [mg l⁻¹], 1985 (2)

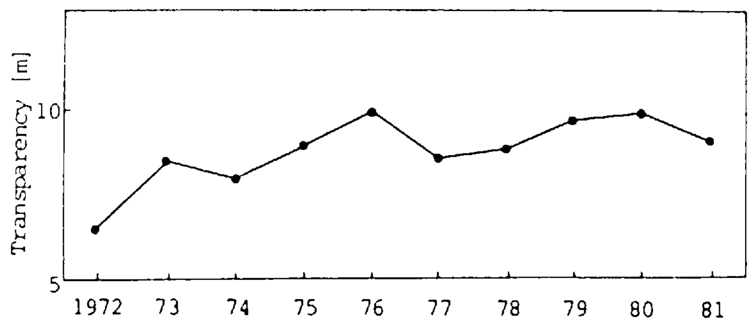
Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	0.21	0.19	0.14	0.19	0.12	0.16	0.12	0.10	

E8 PHOSPHORUS CONCENTRATION
§ Total-P [mg l⁻¹], 1985 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	0.004	0.003	0.003	0.003	<0.003	<0.003	0.004	0.005	–

E9 PAST TRENDS

Fig. ASI-5-2 Trend of transparency at the lake center (7).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Submerged macrophytes: *Elodea nuttallii*, *Potamogeton crispus* (3).

§ Phytoplankton: *Melosira italica*, *Uroglena americana*, *Ceratium hirundinella*, *Quadrigula chodatii*, *Fragilaria crotonensis* (2).

F2 FAUNA

§ Zooplankton: Nauplius, *Acanthodiaptomus pacificus*, *Daphnia longispina* (2).

§ Benthos: *Stictochironomus* spp., *Prodiamesa* sp., *Chironomus nipponensis* (3).

§ Fish: *Oncorhynchus nerka*, *Salmo gairdneri* (Q).

F3 PRIMARY PRODUCTION RATE* [mg O_2 l^{-1} hr^{-1}] (5)

Station 1, 1985

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net production	–	–	–	0.0154	0.0500	0.0192	-0.0242	0.0175	0.0067	-0.0375	-0.0120	–
Dark respiration	–	–	–	-0.0076	0.0233	0.0267	0.0275	-0.0104	0.0108	0.0708	0.0104	
Gross production		–	–	0.0076	0.0733	0.0458	0.0033	0.0070	0.0175	0.0333	-0.0016	–

* Tank method at 8,000 lux.

F5 FISHERY PRODUCTS

§ Annual fish catch in 1984: 25 [metric tons] (4).

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1986)

	Area [km²]	[%]
Natural landscape	119.7	99.1
Agricultural land	0.35	0.3
Residential area	0.33	0.3
Others	0.35	0.3
Total	120.7	100.0

§ Main types of woody vegetation (main species): Deciduous broadleaf forest (*Fagus crenata*, *Quercus mongolica* var. *grosseserrata*, *Ulmus japonica*); evergreen conifer forest (*Tsuga diversifolia*, *Thujopsis dolabrata*, *Abies homolepis*); deciduous conifer plantation (*Larix kaempferi*) (6).

§ Main types of herbaceous vegetation: Dwarf bamboo community and high moor (6).

§ Main kinds of crop plants: Vegetables (radish, lettuce, etc.).

§ Levels of fertilizer application on crop fields: Moderate.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

	Gross product per year (US$)	No. of persons engaged	No. of establishments	Main products or major industries
Primary industry				
Crop production Animal husbandry	N.A.	32	N.A.	Radish, lettuce
Fisheries	69×10^3	88	N.A.	*Oncorhynchus nerka, Salmo gairdneri*
Others	N.A.	N.A.	N.A.	

§ Number of domestic animals in the catchment area : Cattle 20.

G3 POPULATION IN THE CATCHMENT AREA (1987)

	Population	Population density [km^{-2}]
Urban	0	0
Rural	1,366	11.3
Total	1,366	11.3

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Tourism (number of visitors in 1984 : 4,000,000), recreation (sport-fishing, yachting), fisheries and source of water.

H2 THE LAKE AS WATER RESOURCE (1982)

	Use rate [m^3 sec^{-1}]
Domestic water	0.027
Power plant	1.32
Others	0.86

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : None.

I2 TOXIC CONTAMINATION

§ Present status : No information.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Algal bloom (*Uroglena*) and foul smell of tap water.

§ Nitrogen and phosphorus loadings to the lake (1982) [kg yr^{-1}] (4).

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	–	8,653	2,457	65,923	77,033
T-P	–	805	584	5,898	7,287

§ Supplementary notes : Since the progress of the lake's eutrophication was indicated by a foul odour of tap water caused by phytoplankton since 1981 and the sporadic appearance of organic foams on the lake surface since 1984, the Tochigi Prefectural Government has promoted countermeasures against the the degradation of water quality according to the Water Quatity

Protection Countermeasure Ordinance for Lakes Chûzenji and Yu-no-ko.

J. WASTEWATER TREATMENT (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage*
Natural	87.1
Settlements	8.8
Municipal	4.1
Total	100%

* COD basis.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)
- (1) For national laws see "Biwa-ko".
- (2) Tochigi Prefectural Pollution Control Ordinance (1972)

§ Responsible authorities
- (2) Tochigi Prefectural Government

§ Main items of control
- (2) pH, BOD, COD, SS, T-N, T-P

M2 INSTITUTIONAL MEASURES
- (1) Tochigi Prefectural Institute for Pollution Control, Utsunomiya

N. SOURCES OF DATA

*Printed in Japanese.
(Q) Questionnaire filled by Prefectural Government of Tochigi.
(1) Utsunomiya Regional Weather Office (1983, 1984, 1985) Annual Report of Weather, Tochigi Prefecture. Utsusomiya.*
(2) Department of Public Health and Environment, Tochigi Prefecture (1986) Annual Table of Water Quality, Tochigi Prefecture. Utsunomiya.*
(3) Tochigi Prefectural Government (1984) Report of Water Quality Protection Countermeasures of Chûzenji-ko and Yu-no-ko. Utsunomiya.*
(4) Tochigi Prefectural Government (1986) Lake Water Quality Management Plan, Tochigi Prefecture. Utsunomiya.*
(5) Tochigi Prefectural Institute for Pollution Control (1985) Annual Report of Tochigi Prefectural Institute for Pollution Control, No. 9. Utsunomiya.*
(6) Environment Agency (1981) The 2nd National Survey on the Natural Environment (Vegetation), Actual Vegetation Map, Tochigi Prefecture. Japan Wildlife Research Center, Tôkyô.*
(7) Department of Public Health and Environment, Tochigi Prefecture (1983) Report of Water Quality Survey of Chûzenji-ko and Yu-no-ko. 127pp. Utsunomiya.*
(8) Japan Map Center (ed.) (1982) Collection of Maps on Japanese Lakes (Technical Data of National Geographical Institute, D•1-No. 221). National Geographical Institute, Tsukuba.*

NAGASE-DAMU-KO (NAGASE RESERVOIR)

A view of the dam site

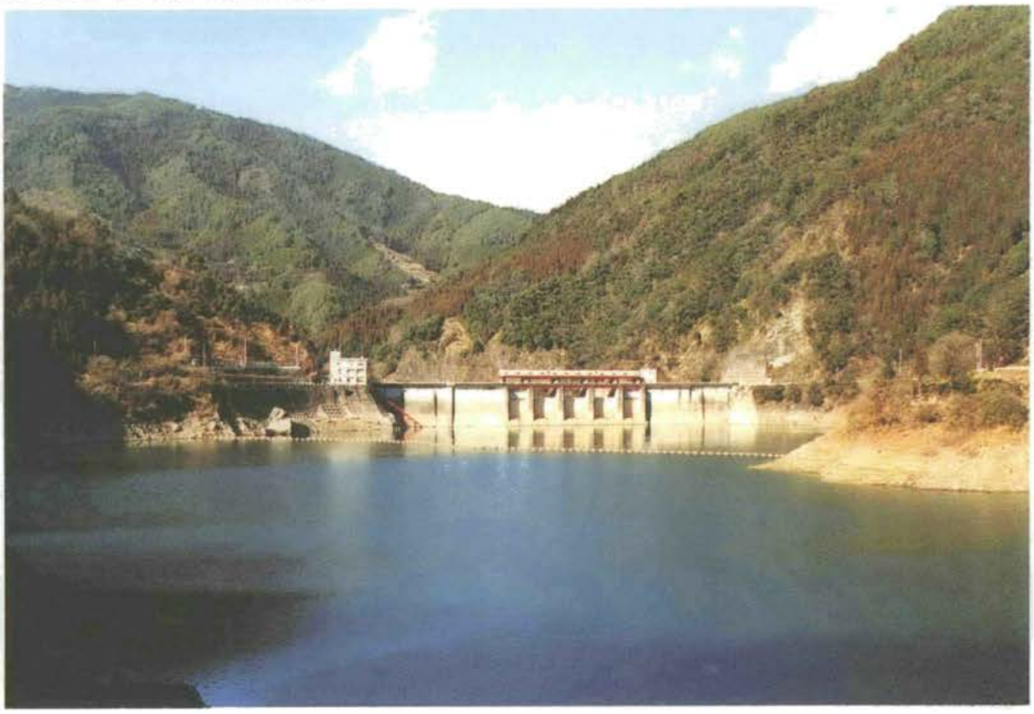
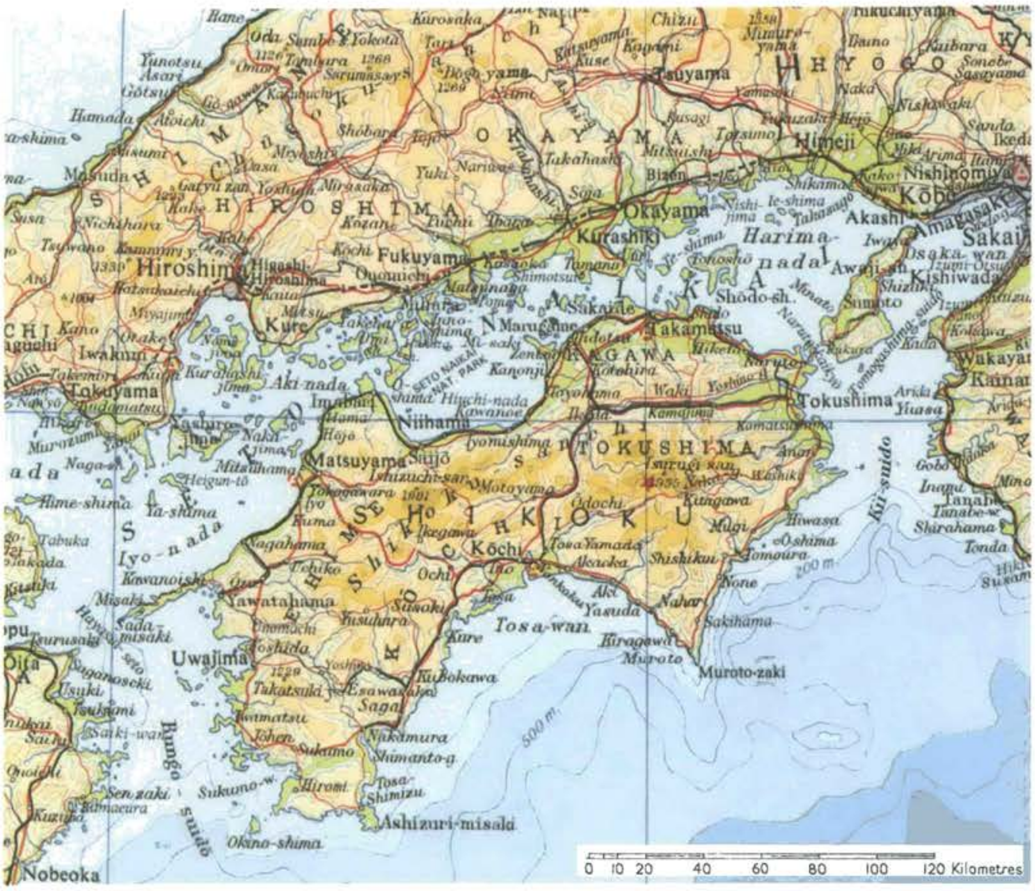


Photo: T. Nishijima



A. LOCATION

§ Kôchi Prefecture, Japan.
§ 33°42′N, 133°52′E ; 196 m above sea level.

B. DESCRIPTION

Nagase-damu-ko is a multiple-purpose reservoir located in the upper reaches of Monobe River, which is 71 km long and flows through the granary area of Kôchi Prefecture on Shikoku Island. The river's watershed, 508 km^2 wide, is one of the areas in Japan where frequent visits of typhoon bring the heaviest rainfall. However, the rainfall is so variable that paddy fields in the watershed often suffered from severe drought, while flood disasters were also frequent.

The Japanese Ministry of Construction initiated in 1949 a comprehensive development project for the river system including the construction of this reservoir. The Nagase Dam was completed in 1957 with the total cost of 3,939 billion yen, and now supplies irrigation water at an average rate of 30 m^3 sec^{-1} together with the hydroelectric power of about 111 $\times$ 10^6 KWH. The Prefectural Government of Kôchi is now responsible for the management of this reservoir.

The catchment area of the reservoir (295 km^2) is largely covered by dense forest, containing only a small village situated near the dam site. The water has remained oligotrophic, the annual mean of total phosphorus concentration being 0.006-0.008 mg l^{-1}, though the bloom of flagellate algae, *Peridinium* spp., has occurred in May-September annually in recent years. The density of algal population usually ranges from 10^3 to 10^4 cells per litre. Otherwise the lake water quality has been free from the effects of siltation, acid rain and chemical pollution and suitable for drinking (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	2.1
Volume [$10^6 m^3$]	58.8
Maximum depth [m]	67.0
Mean depth [m]	28.2
Normal range of annual water level fluctuation (regulated) [m]	26
Residence time [yr]	0.056
Catchment area [km^2]	295.2

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. ASI-6-1 and 2).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Monobe R.).

D2 CLIMATIC (Q)

§ Climatic data at Station A, 1983-1985

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2.5	3.5	7.6	14.9	19.6	22.5	27.7	27.7	24.2	17.4	11.0	5.3	15.3
Precipitation [mm]	54	89	211	276	259	413	249	208	290	150	46	55	2,300

§ Number of hours of bright sunshine : 140 hr $month^{-1}$ (summer).

Fig. ASI-6-1 Sketch map of the reservoir (1).

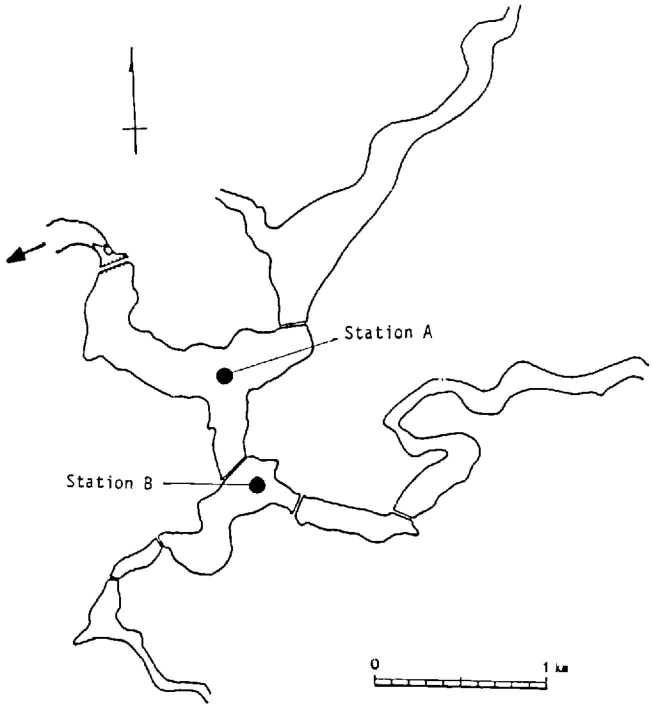
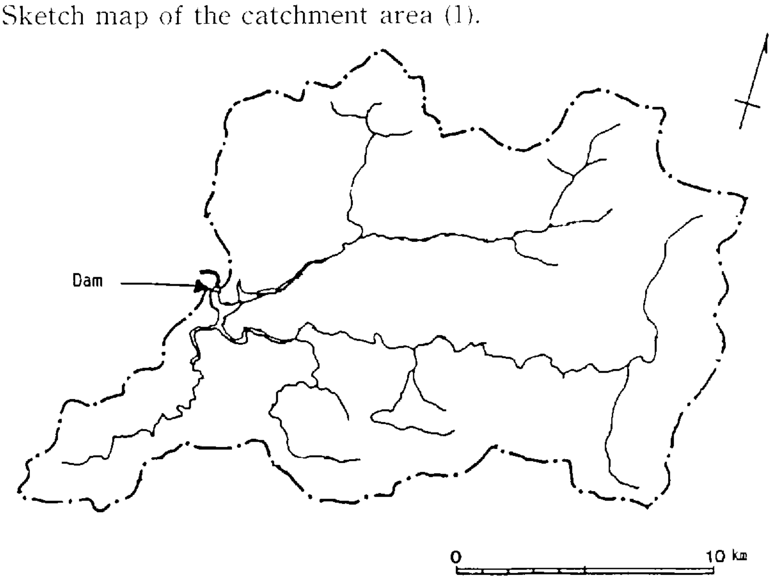


Fig. ASI-6-2 Sketch map of the catchment area (1).



§ Water temperature [°C] (Q)
Station A, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface (0 m)	6.4	7.4	10.4	14.9	18.8	19.6	23.1	25.5	25.0	18.5	13.8	9.0
10	6.3	7.0	8.7	11.6	14.8	14.2	16.2	18.9	19.5	16.1	13.5	9.0
20	6.2	6.3	7.0	9.6	7.5	6.4	13.4	15.0	7.9	15.5	8.9	7.5
30	5.8	5.8	6.1	6.7	5.5	5.4	6.3	6.7	6.5	9.1	6.8	7.0
40	—	—	6.0	6.0	5.5	5.3	6.1	6.3	6.5	6.7	6.8	7.0

§ Freezing period : None.

§ Notes on water mixing and thermocline formation : Usually the thermocline is formed from May to November, but not in 1982 owing to heavy floods.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (Q)

Station A, 1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.0	0.4	3.0	2.0	2.0	1.7	2.8	1.8	4.5	1.8	3.8	4.0

E2 pH (Q)

Station B, 1982-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	7.6	8.1	7.9	8.5	8.9	9.2	8.0	9.3	9.3	8.5	8.0	8.2
10	7.0	8.0	7.8	7.7	7.8	8.1	8.0	8.9	8.4	7.9	8.0	8.0
20	6.9	8.1	7.8	7.2	8.2	8.0	7.8	8.2	8.2	7.9	8.0	8.2
30	6.9	8.0	7.7			8.0	7.7	8.1	7.9	8.1	8.0	8.1
40	—	—	7.6	—	—	8.2	7.9	—	7.3	—	—	—

E3 SS [mg l^{-1}] (Q)

Station B, 1985-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	2	—	< 1	—	3	—	4	—	3	—	2
10	—	—	—	< 1	—	2	—	5	—	5	—	—
20	—	—	—	< 1	—	3	—	5	—	6	—	—
30	—	—	—	—	—	2	—	3	—	3	—	—
40	—	—	—	—	—	—	—	—	—	7	—	—
45	—	—		< 1		—	—			—	—	—

E4 DO [mg l^{-1}] (Q)

Station B, 1982-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	12.2	11.7	9.8	—	—	9.8	11.6	10.2	8.0	10.1
10	—	—	11.7	10.9	9.6	—	—	8.3	9.0	9.2	8.0	—
20	—	—	11.2	11.1	6.6	—	—	7.0	9.7	9.1	8.3	—
30	—	—	10.0			—	—	5.0	8.1	8.8	8.6	10.3
40	—	—	10.2	—	—	—	—	—	8.2	—	—	—

E5 COD [mg l⁻¹] (Q)

Determined by $KMnO_4$ method.

Station B, 1985-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	1.0	–	1.4	–	1.3	–	3.4	–	1.5	–	0.6
10	–	–	–	0.8	–	1.1	–	1.5	–	1.1	–	–
20	–		–	0.8	–	0.5	–	0.8	–	0.7	–	–
30	–	–	–	–	–	0.6		1.1	–	0.7	–	–
40	–	–	–	–	–		–	–	–	0.7	–	–
46	–	–		0.6	–	–	–	–	–		–	–

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$] (Q)

Station B, 1982-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	2.4	3.0	6.1	7.7	6.5	4.1	37.6	4.3	9.3	5.9	4.2	2.2
10	1.4	1.7	0.6	2.3	6.5	2.1	0.9	1.6	3.6	6.3	1.4	1.8
20	1.5	1.5	0.8	2.1	0.4	1.0	0.3	1.2	2.3	1.6	1.8	0.2
30	1.8	1.6	0.7	–	–	0.2	0.2	1.7	3.2	2.2	2.3	0.4
40	–	–	0.9	–	–	0.5	0.1	–	0.4	–	–	–

E7 NITROGEN CONCENTRATION (Q)

§ Total-N [mg l^{-1}]

Station B, 1982-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.20	0.18	0.52	0.34	1.41	0.45	1.15	0.16	0.18	0.33	0.23	0.28
10	0.32	0.16	0.29	0.23	0.40	0.29	0.39	0.22	0.20	0.26	0.24	0.30
20	0.22	0.15	0.35	0.36	0.72	0.31	0.38	0.29	0.31	0.30	0.21	0.35
30	0.23	0.25	0.23	–	–	0.51	0.37	0.29	0.36	0.26	0.21	0.29
40	–	–	0.29	–	–	0.34	0.35	–	0.96	–	–	–

E8 PHOSPHORUS CONCENTRATION (Q)

§ Total-P [mg l⁻¹]

Station B, 1982-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.006	0.012	0.027	0.020	0.011	0.023	0.183	0.010	0.011	0.011	0.008	0.014
10	0.021	0.011	0.015	0.014	0.010	0.006	0.018	0.015	0.006	0.009	0.011	0.019
20	0.007	0.074	0.028	0.026	0.006	0.010	0.016	0.015	0.031	0.010	0.019	0.019
30	0.007	0.106	0.018	–	–	0.011	0.007	–	0.028	0.013	0.020	0.019
40	–	–	0.038	–	–	0.008	0.007	–	0.325	–	–	–

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

Station A

§ Emerged macrophytes : None.

§ Floating macrophytes : None.

§ Submerged macrophytes : None.

§ Phytoplankton : Spring (Mar.-May) (*Peridinium penardii, Synedra* sp.) ; summer (Jun.-Aug.) (*P. cunnigtonii, P. africanum, Pandrina monum*) ; autumn (Sep.-Nov.) (*Cyclotella* sp., *P. africanum*) ; winter (Dec.-Feb.) (*P. penardii*).

F2 FAUNA

§ Fish : *Cyprinus carpio, Carassius* spp., *Zacco temmincki.*

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Since 1962, the red tide of *Peridinium* spp. has occurred annually from May to September.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1979) (1)

	Area [km^2]	[%]
Natural landscape Woody vegetation	291	98.6
Agricultural land	4	1.4
Total	295	100.0

§ Levels of fertilizer application on crop fields : Light.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1981) (Q)

§ Number of domestic animals in the catchment area : Cattle 60.

G3 POPULATION IN THE CATCHMENT AREA (1981) (Q)

	Population	Population density [km^{-2}]	Main cities
Rural	5000	16.9	None
Total	5000		

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Generation of electricity and source of irrigation water.

H2 THE LAKE AS WATER RESOURCE

	Use rate
Irrigation	N. A.
Power plant	30 m^3 sec^{-1} (106.4×10^6 KWH)

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : None.

I2 TOXIC CONTAMINATION (Q)

§ Present status : None.

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication : Unusual algal bloom (*Peridinium*).

§ Nitrogen and phosphorus loadings to the lake [kg day^{-1}] (1981)

	Industrial	Domestic	Agricultural	Natural	Total
T-N	–	18	73.6	188.7	280.3
T-P	–	6.1	0.8	14.2	21.1

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

L. DEVELOPMENT PLANS (Q)

None.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) See "Biwa-ko" concerning national laws.

§ Responsible authorities

(1) National Government and Kôchi Prefectural Government

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Department of Agriculture, Kôchi University, Nangoku-shi

(2) Kôchi Prefectural Environmental Pollution Prevention Center, Kôchi

N. SOURCES OF DATA

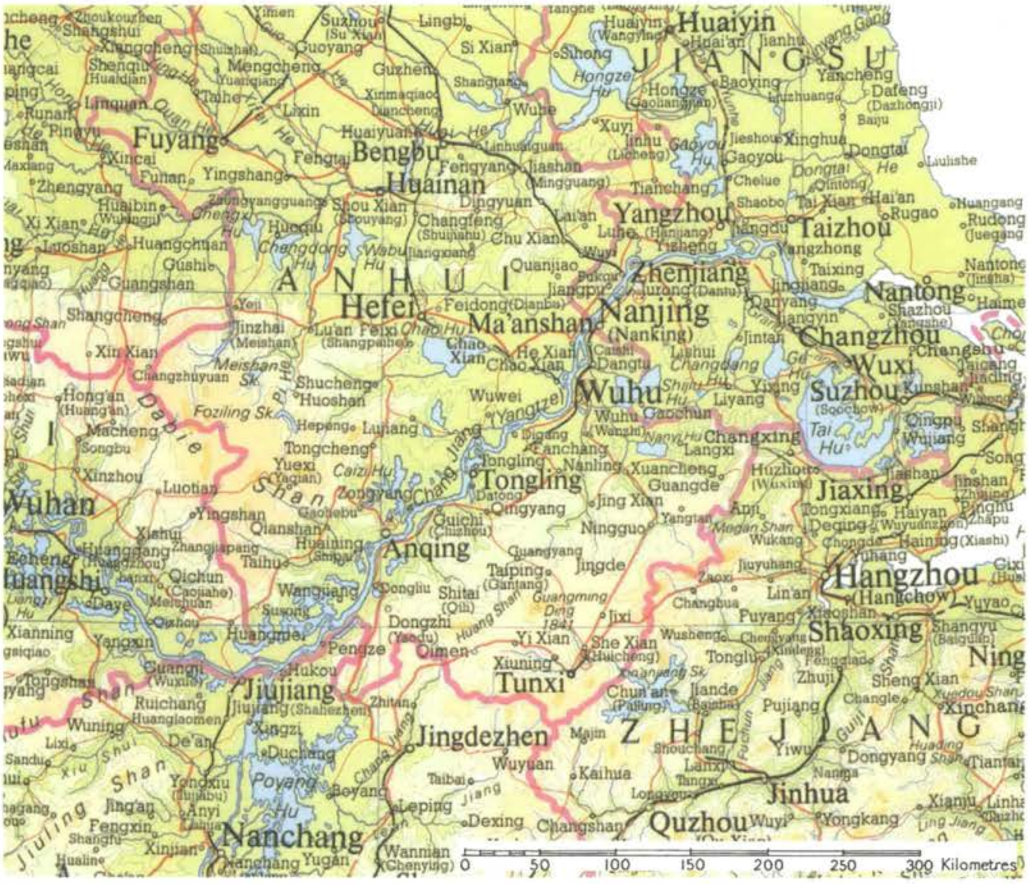
(Q) Questionnaire filled by the Prefectural Government of Kôchi.

(1) Hata, S. (ed.) (1984) Report on the mechanism of occurrence of algal bloom by *Peridinium* spp. in Nagase-damu-ko (in Japanese).

CHAO-HU

A lakeside view

Photo: Chinese Research Academy of Environmental Sciences



A. LOCATION

§ Anhui Province, P. R. China.
§ 30°25′-31°43′N, 117°17′-117°52′E.

B. DESCRIPTION

Lake Chao is located 15 km southeast from Hefei City, the capital of Anhui Province. It is one of the five largest freshwater lakes in China, and is the largest lake in the Province. The life of the lake is about 10 thousand years.

The lake is famous for its beautiful landscape and historic sites, and is extensively used as water sources for drinking and irrigation and for fishery and transportation. About 5 million people live around the lake. In 1962, a dam was built at the only outflowing river. Control of water level has brought about some merits for irrigation and transportation, but at the same time it resulted in some demerits. The most evident effect was the reduction of fish production.

Owing to the rapid development of industry, fast increase of population and establishment of water conservancy facilities, the lake has suffered from eutrophication and silting in recent years (Q).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	756.2
Volume [$10^9 m^3$]	1.7
Mean depth [m]	7.5 7.8
Water level	Regulated
Length of shoreline [km]	185
Catchment area [km^2]	10,430

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Main islands (name and area): Laoshan Island (0.86 km^2).
§ Outflowing rivers and channels (number and names): 1 (Yuxi R.).

D2 CLIMATIC

§ Climatic data, 1980-1984

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2-3	–	–	–			28-30		–	–	–	–	15-16
Precipitation [mm]	(121)			(308)			(429)			(231)			1,100

§ Water temperature [°C], 1982-1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	5.2	–	–	24.4	–	–	32.1	–	–	19.1	–

§ Freezing period: None.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m], 1982-1984

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	0.133	–	–	0.153			0.18	–	–	0.179	–

E2 pH, 1982-1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	7.57	–	–	7.81			8.09	–	–	8.18	–

E4 DO [mg l^{-1}], 1982-1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	12.12	–	–	7.93	–	–	6.09	–	–	10.13	–

E5 COD [mg l^{-1}], 1982-1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	3.75	–	–	4.38	–	–	4.36	–	–	–	–

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}], 1982-1984

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	3.75	–	–	4.38	–	–	4.36	–		–	–

E7 NITROGEN CONCENTRATION [mg l^{-1}]

§ Total-N, 1982-1984.

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	2.37	–	–	1.70	–	–	0.91		–	1.58	–

E8 PHOSPHORUS CONCENTRATION [mg l^{-1}]

§ Total-P, 1982-1984.

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	0.155	–	–	0.144	–	–	0.097	–	–	0.144	–

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Phytoplankton: Winter-spring (*Microcystis aeruginosa M. flos-aquae Anabaena spiroides. Aphanizomenon flos-aquae*); Summer fall (*Cyclotella comta, Melosira islandica, Eudorina elegans*).

F5 FISHERY PRODUCTS

§ Annual fish catch in 1980: 3,000 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1984)

	Area [km^2]	[%]
Natural landscape	1,836	17.6
Woody vegetation	706	6.8
Herbaceous vegetation	1,130	10.8
Agricultural land	6,480	62.1
Crop field	6,480	62.1
Others	2,115	20.3
Total	10,430	100

§ Main kinds of crops: Rice, wheat.

§ Levels of fertilizer application on crop fields: Heavy.

G3 POPULATION IN THE CATCHMENT AREA

	Population	Population density [km^{-2}]	Main cities
Urban	970×10^3		Hefei
Rural	4.36×10^6		
Total	5.33×10^6	583	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, navigation and transportation, sightseeing and tourism, fisheries.

H2 THE LAKE AS WATER RESOURCE: No information.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage: Serious.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources

Name of contaminants	Range of concentrations [ppm] in				Main Sources
	Water	Bottom mud	Fish	Other organisms	
		(1982)			
Hg	–	0.132	–	–	Weathering of rock
As	–	11.21	–	–	Industrial sewage
Cu	–	19.04		–	〃
Zn	–	76.65	–		〃
Pb	–	34.51	–	–	〃

I3 EUTROPHICATION

§ Nitrogen and phosphorus loadings to the lake [t yr^{-1}] (1982)

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	N. A.	3,540.5	N. A.	275.88	N. A.
T-P	N. A.	177	N. A.	15.05	N. A.

I4 ACIDIFICATION

§ Extent of damage : No information.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (e) Severe pollution with no wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGES : No treatment system.

K. IMPROVEMENT WORKS IN THE LAKE

K3 OTHERS (Q)

The following measures are being planned.

1) For soil erosion control, the whole catchment will be divided into several subregions which are to be managed by different technological, biological and agricultural schemes.
2) The total pollutant loads to the lake will be controlled.
3) Necessary rules and regulations for environmental protection will be strengthened.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED : No information.

M2 INSTITUTIONAL MEASURES : No information.

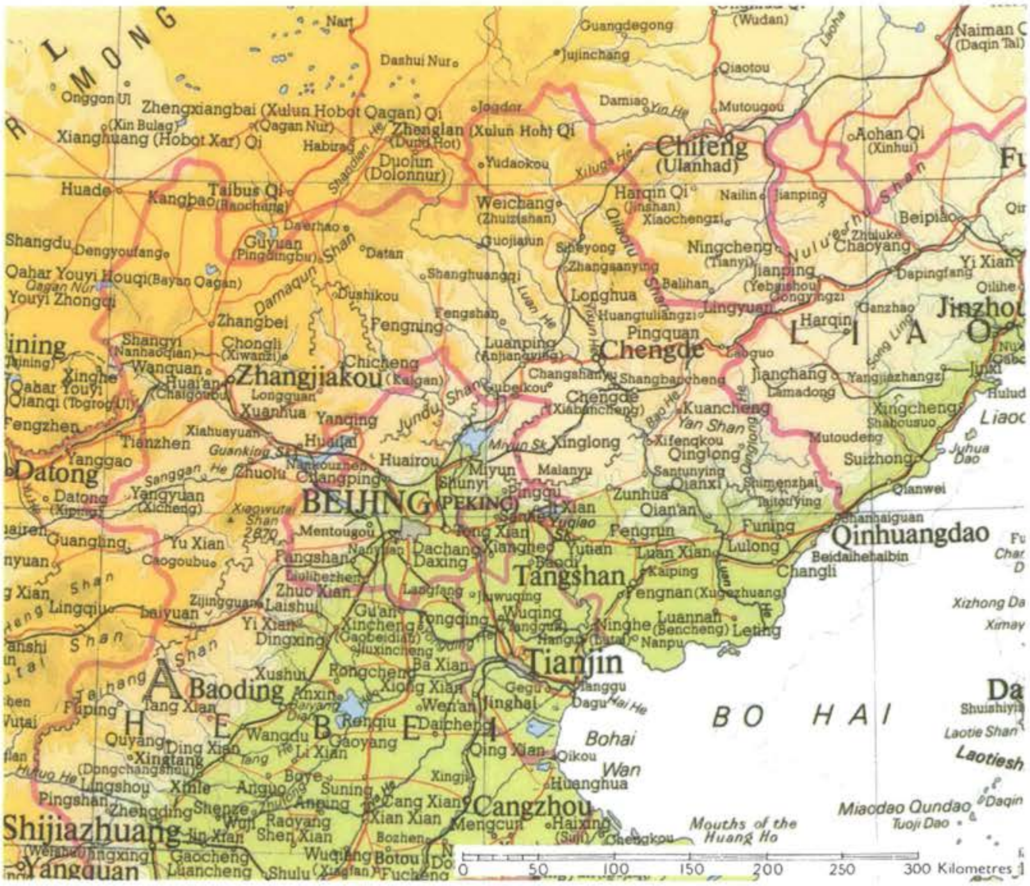
N. SOURCES OF DATA

(Q) Questionnaire filled by Prof. Liu Hongliang, Chinese Research Academy of Environmental Sciences, Beijing.

MIYUN RESERVOIR

An overview of the lake

Photo: Chinese Research Academy of Environmental Sciences.



A. LOCATION

§ Miyun County, Beijing, P.R. China.
§ 40°13'-40°48'N, 116°40'-117°30'E ; 75 m above sea level.

B. DESCRIPTION

Miyun Reservoir, located 100 km northeast of Beijing City, is a mountain valley reservoir. It was built in September, 1960, and is the largest reservoir in Beijing area. Two main rivers, Chaohe and Baihe, flow into Miyun Reservoir. The catchment is about 15,788 km², consists of mountains and piedmonts and lacks large industrial enterprises. Sediments and nutrients from agricultural, pastoral and forestry lands that enter the reservoir with overland flow make the main pollution sources.

The initial purpose of building Miyun Reservoir was flood control, irrigation and fishery, but it has become more and more important as a main drinking water storage for Beijing area. The water quality is therefore of great importance.

Recently, the nutrient concentration and the number of phytoplankton in the Reservoir are constantly rising to arrest the attention of Beijing municipality. A project for keeping the water clean is being put into effect (Q).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km²]	188
Volume [10^8 m³]	4.375
Maximum depth [m]	43.5
Catchment area [km²]	15,788

D. PHYSIOGRAPHIC FEATURES (Q)

D1 GEOGRAPHICAL

§ Outflowing rivers and channels (number and names) : 2 (Chaobaihe R. and a canal).

D2 CLIMATIC

§ Climatic data at Miyun Station, 1980-1983

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation [mm]	1	5	7	27	28	95	124	162	43	19	6	3	520

§ Number of hours of bright sunshine (Miyun Station, 1980-1983) : 2,861.8 hr yr^{-1}.
§ Solar radiation (Miyun Station, 1980-1983) : 15.5 MJ cm^{-2} day^{-1}.
§ Water temperature [°C]
Lake center, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface (0.5)	—	—	—	10.0	19.5	22.8	26.0	26.5	21.1	18.2	9.4	—
1.5	—	—	—	—	19.0	—	26.0		—	18.2	—	—
3.0	—		—	—	17.5	—	26.0	—	—	18.1	—	—
5.0	—	—	—	—	17.0	—	26.0	—	—	18.0		—
9.5	—	—	—	—	15.9	—	26.0	—	—	17.9	—	—
Bottom (16)	—	—	-	—	—	—	—	-	—	16.6	—	—

§ Freezing period : From Dec. to Mar.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Lake center, 1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	—	—	—	1.25	-	1.72	—	—	2.58		—

E2 pH

Lake center, 1985-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
0.5	—	—	—	8.2	8.2	8.3	8.2	8.5	8.3	8.2	8.2
1.5	—	—	—	—	8.34	—	—	—	—	—	—
3.0	—		—	—	8.1		—	—	—	—	—
5.0	—	—	—		7.65	—	—	—		—	—
7.5		—	—	—	7.33		—	—	—	—	-
10.0	—	—	-	—	7.15	—	7.9	—		—	—
15.0	—	—	—	—	-	—	8.0	—	—	—	

E3 SS [mg l^{-1}], 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	4.5	—		—	—	—	—	—
1.5	—	—	—		—	—	—	—		—	—	—
3.0		—	—	—	—		2.8	—	—	—	—	—
5.0	—	—	—	—	—	—	4.0	—	—	—	—	—
7.5	—	—	—	—	—	—	—		—	—	—	—
10.0	—	—	—	—		—	2.0	—	—	—	—	—

E4 DO [mg l^{-1}], 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	10.8	—	7.7	—	—	—	—	—
1.5	—	—	—	—	10.5	—	7.1		—	—	—	—
3.0	—	—	—	—	10.9	—	6.9	—	—	—	—	—
5.0	—	—	—	—	10.7		7.0	—	—	—	—	—
7.5	—	—		—	8.6	—	6.3	—	—	—	—	
10.0	—	—	—	—	9.3	—	6.2	—		—	—	—
15.0	—	—	—	—	—		6.5	—	—	—	—	—

E5 COD [mg l^{-1}], 1985

Determined by $KMnO_4$ method.

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	1.88	2.51	2.63	2.82	2.82	3.10	2.58	2.85	—

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$], 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	2.77	—	4.14	—	—	—	—	—
1.5	—	—	—	—	2.82	—	5.41		—	—	—	—
3.0	—	—	—	—	3.10	—	6.00	—		—	—	—
5.0	—	—		—	3.33	—	5.71	—		—	—	—
7.5		—	—	—	3.20	—	5.36	—	—	—		—
10.0	—	—	—		2.92	—	4.65	—		—	—	—
15.0	—	—	—	—	—		5.09	—	—	—	—	—

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}], 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	0.11	—	0.06	—	—	0.05	—	—
3.0	—	—	—	—	—	—	0.06	—	—	0.07	—	—
16.0		—	—	—	—		0.16	—	—	0.05		—

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	–	0.025	–	0.022	–	–	–	–	–
1.5	–	–	–	–	0.013	–	0.028	–	–	–	–	–
3.0		–	–	–	0.011	–	0.027	–	–		–	–
5.0	–	–	–	–	0.025	–	0.030	–	–	–	–	–
7.5	–	–	–	–	0.008	–	0.028	–	–	–	–	
10.0	–	–	–		0.012	–	0.029	–	–	–	–	–
15.0	–	–	–	–	–	–	0.038	–	–		–	–

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Phytoplankton : Spring (*Cyclotella, Bimuclearia*) : summer and autumn (*Cyclotella, Scenedesmus*).

F2 FAUNA

§ Zooplankton : *Conochilus, Keratella cochlearis, Polyarthra trigla.*

§ Benthos : Oligochaeta.

§ Fish : *Hypophthalmichthys molitris, Aristichthys nobilis.*

F5 FISHERY PRODUCTS

§ Annual fish catch in 1980 : 1,360.5 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1984)

	Area [ha]	[%]
Natural landscape	129086.2	85.3
Woody vegetation	41953.5	27.7
Herbaceous vegetation	87132.7	57.6
Agricultural land	11421.6	7.5
Crop field	11421.6	7.5
Residential area	8201.2	5.4
Others	2636.1	1.7
Total	151345.1	100.0

§ Main kinds of crops : Maize, wheat.

§ Levels of fertilizer application on crop fields : Light.

§ Trends of change in land use in recent years : It is planned to increase forest area.

G2 POPULATION IN THE CATCHMENT AREA

	Population	Population density [km $^{-2}$]	Main cities
Urban	None	–	None
Rural	130,000	8.2	
Total	130,000	8.2	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION
Sources of water, fisheries.

H2 THE LAKE AS WATER RESOURCE : No information.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION
§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION
§ Present status : None.

I3 EUTROPHICATION
Though nitrogen, phosphorus and COD contents of the lake water are low, the population densities of plankton and benthic invertebrates have increased as compared with those in 1981, indicating a trend toward eutrophication. To counter this trend, the establishment of industrial factories in the catchment area as well as swimming and other surface recreations in the lake is prohibited.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J2 SANITARY FACILITIES AND SEWERAGE : No treatment system.

K. IMPROVEMENT WORKS IN THE LAKE

No information (Q).

L. DEVELOPMENT PLANS (Q)

Since Miyun Reservoir will be one of the most important water sources for Beijing City, fishery may be allowed with certain limitation as long as it causes no harm to water quality. Water recreations are all forbidden. In the catchment area, water and soil conservation practices are encouraged.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M2 INSTITUTIONAL MEASURES
(1) Miyun Environmental Monitoring Station, Miyun County (mission : monitoring and control of water quality and restoration of the environment)
(2) Miyun Reservoir Management Division, Miyun County (mission : monitoring of water quantity and control of water uses)

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES
(1) Chinese Research Academy of Environmental Sciences, Beijing
(2) Beijing Environmental Monitoring Station

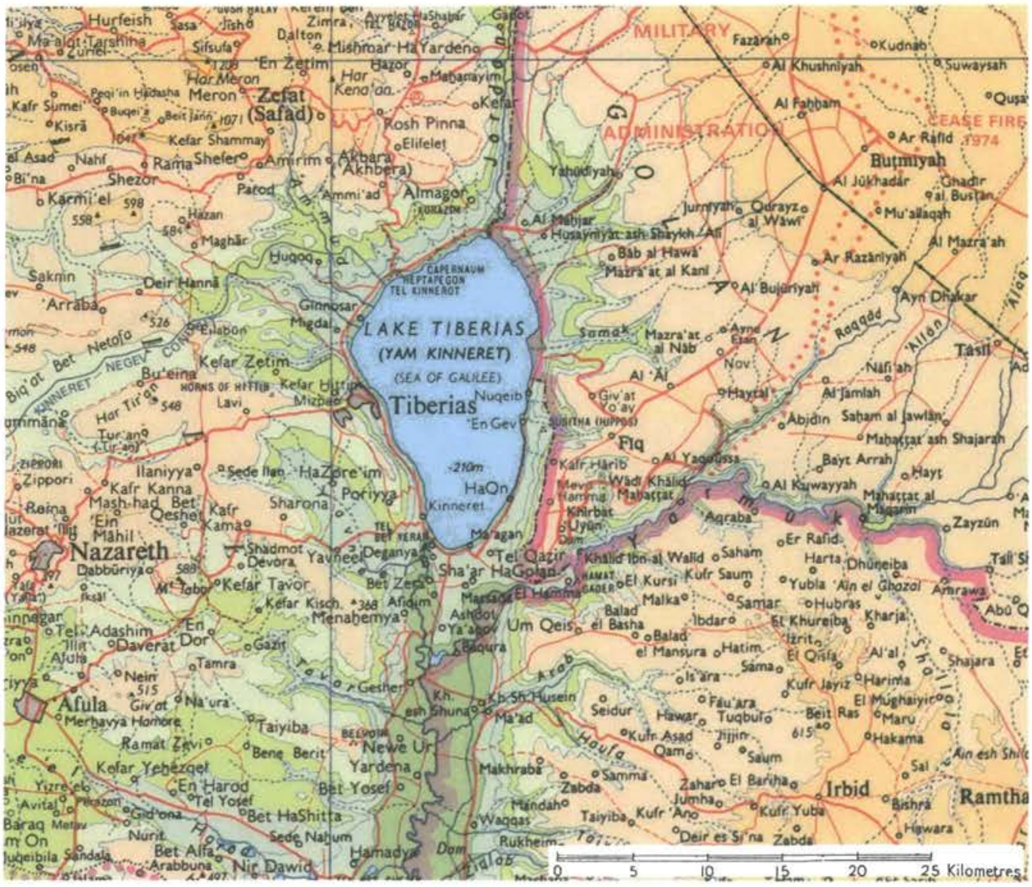
N. SOURCES OF DATA

(Q) Questionnaire filled by Prof. Liu Hongliang, Chinese Research Academy of Environmental Sciences, Beijing.

LAKE KINNERET (SEA OF GALILEE)

A view from the lakeside hill

Photo: T. Berman



A. LOCATION

§ Israel.
§ 32°50′N, 35°35′E ; 209 m below sea level.

B. DESCRIPTION

Lake Kinneret (The Biblical Sea of Galilee) is a warm, monomictic lake, located at the northern end of the Afro-Syrian Rift Valley in Northern Israel with a surface area of 170 km^2, a maximum depth of 40 m and a mean depth of 24 m. The climate is hot in summer, with winter rains from November through April. There is extensive agriculture in the catchment area especially in the Hula Valley (cotton, alfalfa, agricultural ponds) and around the lake shores (bananas, dates, cotton). Lake Kinneret serves as the major reservoir for Israel's National Water Carrier System and supplies approximately one third of the country's annual water requirements. It is also an important tourist and vacation area, famous for antiquities and historical sites especially those associated with the New Testament accounts of Jesus and his disciples. As in Biblical Times, there is a significant commercial fishery on the lake with annual yields of 1,500-2,000tons.

Over the past twenty years, extensive limnological studies have been carried out on this lake, mainly at the Kinneret Limnological Laboratory which has recently set up an International Centre for Warm Freshwater Research (Q1).

C. PHYSICAL DIMENSIONS (Q 1)

Surface area [km^2]	170
Volume [10^9 m^3]	4
Maximum depth [m]	43
Mean depth [m]	25.6
Length of shoreline [km]	53
Residence time [yr]	4.8
Catchment area [km^2]	2,730

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-9-1).

§ Outflowing rivers and channels (number and names) : 1 (Jordan R.) (Q1).

D2 CLIMATIC

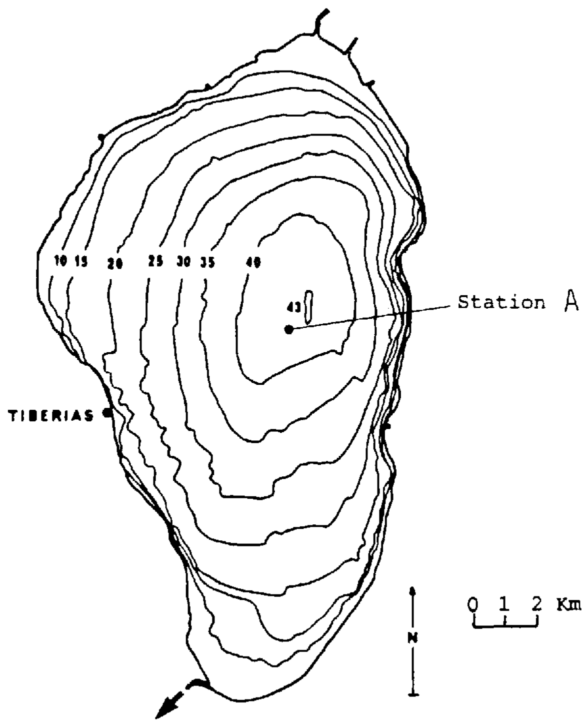
§ Climatic data at Deganya, 1945-1970 (Q1, 2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	12	13	15	18	22	24	28	29	28	20	18	14	20
Precipitation [mm]	96	74	58	23	6	0	0	0	1	14	47	89	408

§ Snowfall : None.

§ Average solar radiation : 1.7-24.3 MJ m^{-2} day^{-1}.

Fig. ASI-9-1 Bathymetric map (1).

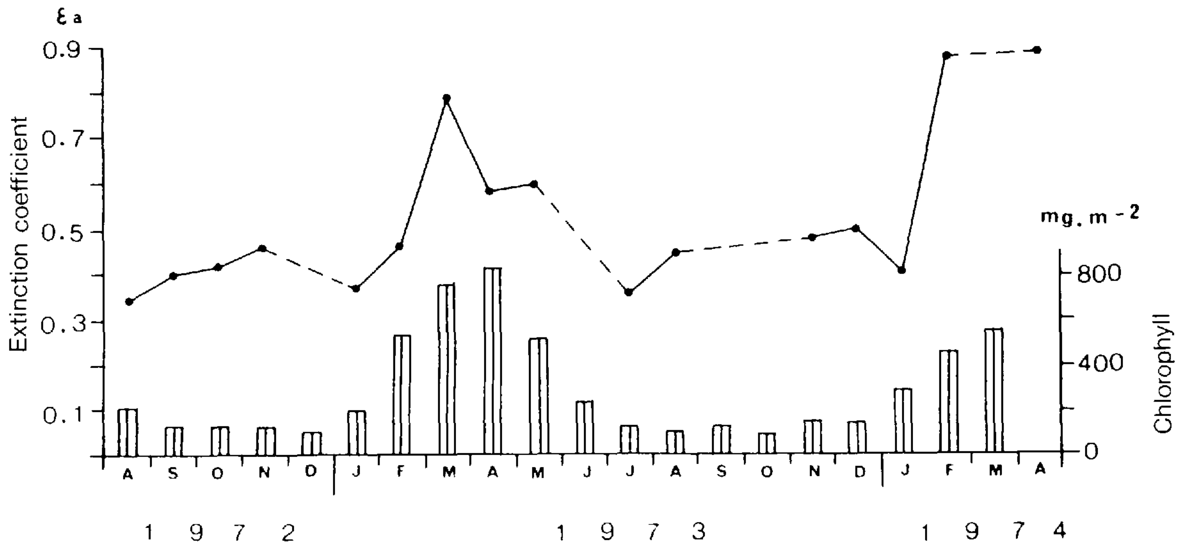


§ Water temperature [°C] (Q3)
Station A, 1969 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface (0)	15.7	14.7	16.0	19.4	23.2	26.7	27.9	28.6	28.4	26.3	22.3	18.0
5	15.7	14.7	15.4	18.7	22.6	25.9	27.4	28.3	28.2	26.2	22.3	18.0
10	15.7	14.7	15.0	17.7	21.5	24.7	27.1	28.1	28.1	26.2	22.3	18.0
15	15.7	14.6	14.7	16.7	19.2	21.5	24.6	26.5	27.3	26.0	22.3	18.0
20	15.7	14.6	14.5	15.9	17.4	17.4	17.7	18.6	20.3	21.8	20.8	17.6
25	15.6	14.5	14.4	15.4	16.4	16.1	16.1	16.3	16.8	17.1	17.7	17.5
30	15.4	14.5	14.3	15.0	15.7	15.4	15.4	15.8	16.1	16.1	15.9	16.2
35	15.4	14.5	14.3	14.8	15.4	15.1	15.2	15.5	15.9	15.9	15.6	15.8
40	15.4	14.5	14.3	14.2	15.3	15.0	15.1	15.5	15.9	15.8	15.5	15.5

§ Freezing period : None.
§ Mixing type : Monomictic.
§ Notes on water mixing and thermocline formation : Strong stratification from May until mid-end November. Hypolimnion strongly observed.

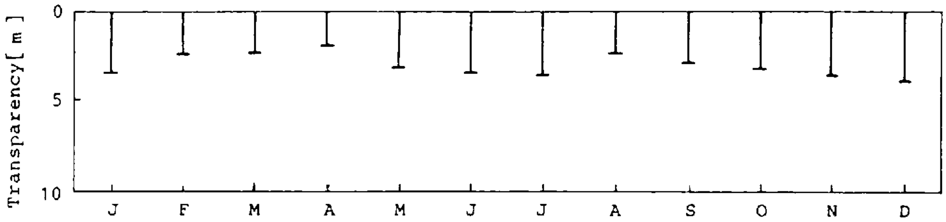
Fig. ASI-9-2 Average monthly light extinction coefficient [m^{-1}] measured with a Whiteney photometer without filters in relation to chlorophyll standing crop (Q1).



E. LAKE WATER QUALITY

E1 TRANSPARENCY

Fig. ASI-9-3 Seasonal change in transparency, Station A (3).



E2 pH, 1969-1986 (Q1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 – 12	8.0	8.3	8.6	8.7	8.8	8.9	8.7	8.6	8.6	8.5	8.3	8.0
12 – 22	8.0	8.1	8.1	7.9	7.9	8.0	8.0	7.9	7.9	7.9	7.9	8.0
22 – 32	7.9	8.1	8.0	7.7	7.7	7.6	7.6	7.5	7.5	7.5	7.7	7.7
32 – 40	7.8	8.0	7.9	7.7	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.5

E3 SS [mg l^{-1}], 1967 1982 (Q1)

620-669 (0-16 m), 650-702 (16-40 m), 674 (mixed).

E4 DO [mg l^{-1}], 1969-1986 (Q3)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 – 12	7.3	9.1	10.9	11.9	10.1	8.1	7.6	7.6	7.7	7.4	6.9	6.4
12 – 22	7.2	8.3	7.5	5.2	2.0	1.5	1.9	1.7	1.7	2.3	3.4	6.0
22 – 32	6.0	7.9	6.4	3.1	0.7	0.1	0	0	0	0	1.2	2.3
32 – 40	5.3	6.8	5.5	2.2	0.3	0	0	0	0	0	0	1.1

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$], 1986 (Q1)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	6.4	6.0	22.0	37.0	2.3	4.0	3.6	4.0	2.2	4.8	3.6	5.2
1	6.4	14.4	48.0	45.0	3.4	8.6	5.6	5.0	2.6	5.2	4.6	4.4
2	6.8	17.6	20.0	52.0	–	5.6	4.8	4.6	2.6	4.8	3.6	5.2
3	6.0	11.2	14.0	96.0	14.4	6.0	7.2	5.2	1.5	5.6	4.8	5.2
5	6.4	6.4	9.6	29.0	16.8	9.0	7.2	5.4	3.0	5.6	4.6	5.2
7	6.6	7.2	9.6	27.5	9.4	7.2	2.4	6.4	3.6	5.2	3.4	7.2
10	5.0	3.2	8.8	28.5	10.7	7.4	2.0	6.2	3.5	4.0	4.0	6.0
15 or T*	7.2	2.4	12.0	3.8	7.4	3.4	4.0	4.1	3.3	4.8	1.6	5.0

*Thermocline.

E7 NITROGEN CONCENTRATION (Q1)

§ Total-N [mg l^{-1}], 1969-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 12	0.811	0.862	0.948	0.869	0.836	0.739	0.636	0.609	0.576	0.563	0.630	0.787
12−22	0.803	0.873	0.874	0.812	0.702	0.665	0.689	0.674	0.711	0.729	0.832	0.847
22−32	0.877	0.841	0.896	0.833	0.750	0.744	0.837	0.931	1.005	1.075	1.086	1.210
32−40	1.139	0.935	0.562	0.768	0.724	0.842	0.966	1.060	1.344	1.533	1.803	1.735

E8 PHOSPHORUS CONCENTRATION (Q1)

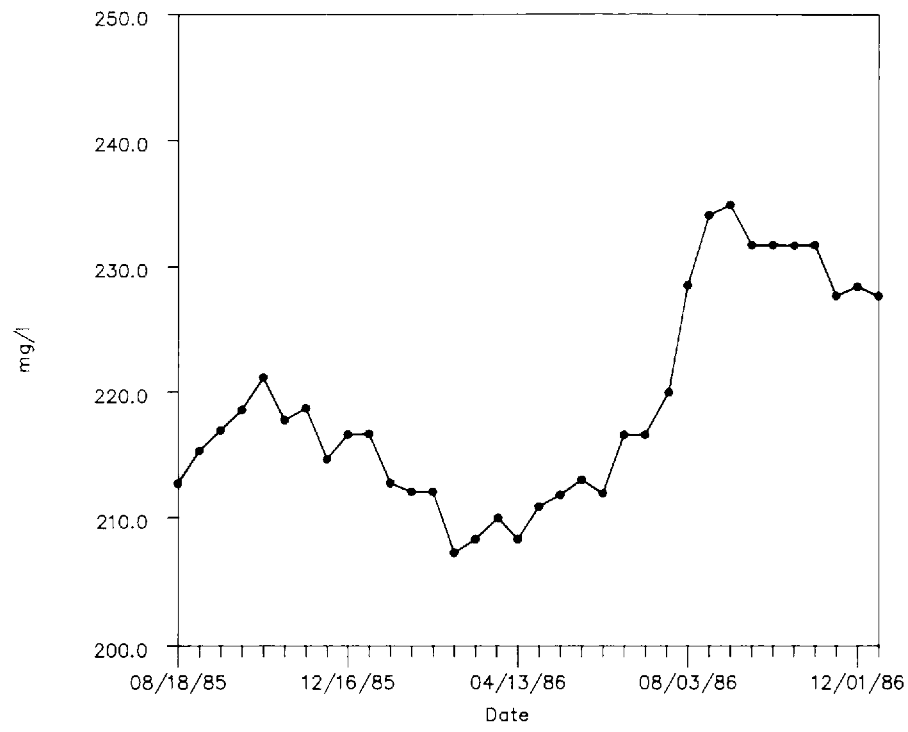
§ Total-P [mg l^{-1}], 1969-1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 −12	0.017	0.024	0.028	0.028	0.026	0.016	0.016	0.015	0.014	0.014	0.016	0.016
12−22	0.016	0.019	0.016	0.017	0.018	0.016	0.015	0.015	0.013	0.014	0.016	0.016
22−32	0.020	0.019	0.017	0.016	0.017	0.017	0.021	0.021	0.023	0.022	0.020	0.024
32 40	0.033	0.029	0.023	0.019	0.023	0.024	0.024	0.031	0.044	0.057	0.071	0.060

E9 CHLORINE ION CONCENTRATION (Q1)

Chlorine ion concentration in Lake Kinneret declined from 400 mg l^{-1} to 210-240 mg l^{-1} since 1967. This is mainly because there is a salt water diversion canal which removes ca. 70,000 tons of chlorides annually from the lake into the southern Jordan.

Fig. ASI-9-4 Annual change of chlorides concentration at station A, 1985-1986 (Q3).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites australis*, *Arundo donax*, *Juncus actus* (Q1, 4).

§ Submerged macrophytes : *Myriophyllum spicatum*, *Najas marina* (Q1).

§ Phytoplankton : *Peridinium cinctum*, *Coelastrum* spp., *Closterium aciculare* var. *subpronum*, *Cyclotella* spp., *Microcystis* spp., *Oocystis* spp., *Cosmarium* (3).

F2 FAUNA

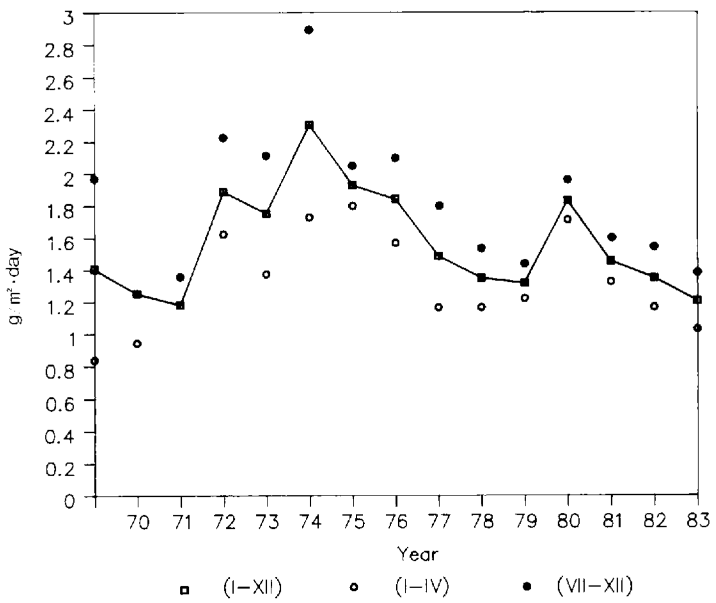
§ Zooplankton : *Mesocyclops leuckarti*, *Cyclops agilis*, *Diaphanosoma brachyurum*, *Asplanchna brightwelli*, *A. priodonta*, *Ceriodaphnia reticulata* (3).

§ Benthos : *Nannopus palustris*, *N. palustris tiberiadis*, *Pseudobradya barroisi*, *Nitocra incerta*, *Typhlocaris galilea*, *Unio semirgatus*, *Melanopsis praemorsum*, *Theodoxus jordani* (5).

§ Fish : *Mirogrex terraesanctae*, *Mugil cephalus*, *Sarotherodon galilaeus*, *S. aureus*, *Barbus longiceps* (3).

F3 PRIMARY PRODUCTION (Q1)

Fig. ASI-9-5 Past trend of primary productivity, annual and seasonal averages.



F4 BIOMASS

Fig. ASI-9-6 Past trend of phytoplankton biomass, in terms of annual and seasonal averages of chlorophyll standing crop (Q3).

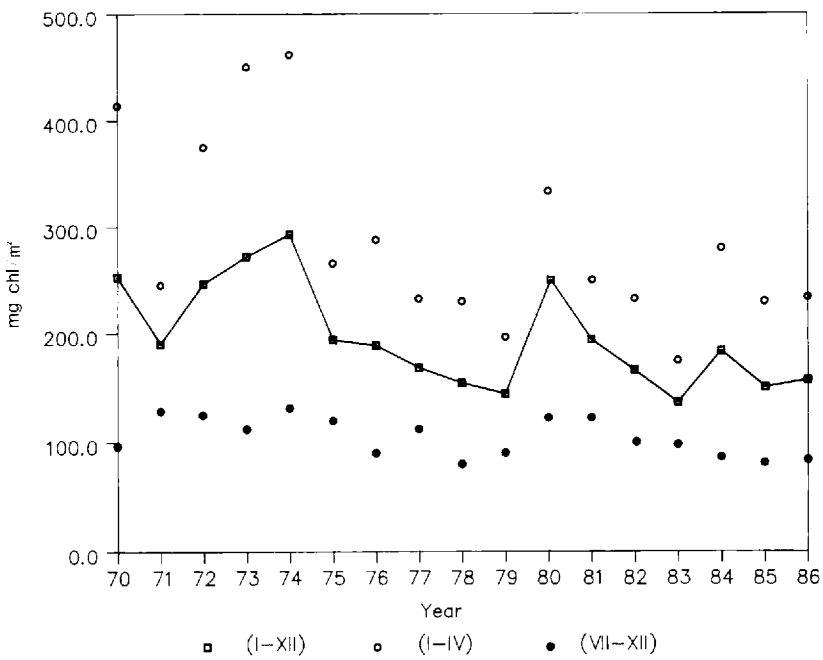
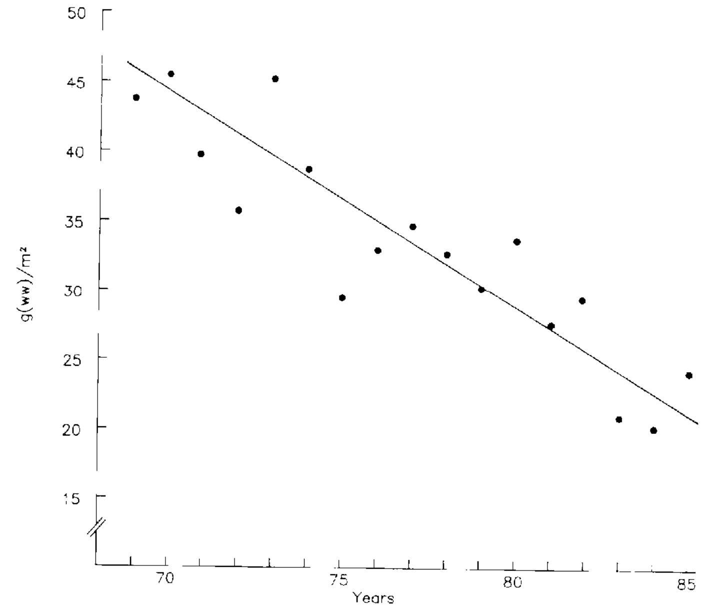


Fig. ASI-9-7 Annual averages of zooplankton biomass (wet weight) (Q).



F5 FISHERY PRODUCT (Q1)

§ Annual fish catch in 1968–1980 : 1,800 [metric tons].

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (Q1)

During the years 1973 1978, there was a period of lowered *Peridinium* biomass and some increases of nannoplankton (mostly Chlorophyta). Also there has been some tendency to an increase in Cyanobacteria in the fall. These changes may be related to the lower lake level at the end of a dry summer-autumn season (till November).

Since the construction of the salt water diversion canal (1967) and the heavy flooding in winter 1968/1969, there has been a distinct trend to lower salinity in the lake from 380 mg l^{-1} to 215 mg l^{-1}. Comparing the period 1969 73 with 1974–82, there was a trend to higher levels of organic nitrogen and total phosphorus, a decrease in the proportion of large algae (mainly *Peridinium*) to nannoplankton, and a decrease in the overall amount and individual size of zooplankton. This appears to have been accompanied by an increase in the number of fishes (mainly Kinneret sardines) which feed on zooplankton.

With the completion of hydrological projects in the watershed aimed at optimizing recycling and agricultural use of water, there should be a dramatic improvement in the quality of water reaching the lake via the Jordan River. Also new fish stocking practices have been advocated which should lead to a better balance of commercially valuable fish (eg. St. Peter's fish, *Sarotherodon galilaeus*) to the less desirable "sardine" (*Mirogrex terraesanctae*). The research team at the Kinneret Limnological Laboratory is presently formulating a five year plan to assess the impact of changes brought about by the new management policies.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1982) (Q2)

	Area [km²]	[%]
Natural landscape		
Woody vegetation	100	3.7
Herbaceous vegetation	1,460	53.4
Others	70	2.6
Agricultural land		
Crop field	1,050	38.5
Residential area	50	1.8
Total	2,730	100.0

§ Main types of woody vegetation : Low trees (*Quercus, Pistacia, Prunus, Ruta*) : water trees (*Salix*).

§ Main types of herbaceous vegetation : Low and high grassland with scattered low bushes ; high water bushes (*Nerium, Vitex, Myrtus*).

§ Main kinds of crops : Irrigated field crops (cotton, vegetables, forage grass, wheat, citrus, avocado, apple and pear) (184 km^2), and non-irrigated field crops (150 km^2).

§ Levels of fertilizer application on crop fields : Heavy.

§ Trends of change in land use in recent years : Decrease in area of fish ponds by about 50 % in northern catchment area. Increase in reservoirs for water storage and recycling. Completion of new pipeline from Dam River for irrigation of W. Hula Valley. All these measures should decrease pollution pressures on Lake Kinneret.

G2 INDUSTRIES IN THE CATCHMEN AREA AND THE LAKE (Q2)

§ Number of persons engaged (1981) : Agriculture 5,000 ; fisheries 300.

§ Main agricultural products : Cotton, vegetables and fruits.

§ Main industrial products : Optics, electronics, metallurgy, textile and plastics.

§ Tertiary industry : Tourism and recreation facilities.

G3 POPULATION IN THE CATCHMENT AREA (1983) (Q2)

	Population	Population density [km^{-2}]	Main cities (population)
Total	255,000	93.4	Tiberias (24,000), Kiryat Shemona, Zefat.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q2)

Fisheries, navigation, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1981) (Q2)

	Use rate [m^3 sec^{-1}]
Domestic and industrial	6.3
Irrigation	9.5

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q3)

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION (Q3)

§ Present status : Detected but not serious.

§ Supplementary notes

In order to assess the potential input of toxic chemicals into Lake Kinneret, routine analyses of the Kinneret ecosystem have been carried out over the past 6 years. Such compounds (usually agricultural chemicals such as pesticides) were extracted and analysed subsequently by gas chromatography. In general, lake water contained little if any pesticide residues, therefore further studies were carried out on samples from the Upper Galilee, close to the sites of application of these chemicals. Initial studies showed that pollution of the waterways entering the lake was mainly due to accidental spraying and/or the washing of spray containers. These sources of pollution have now been largely reduced due, partially, to increased awareness of this problem through our monitoring programme.

Accidental (and deliberate) poisonings of fish continue to be one of the major problems in this field, although suspected cases have also dropped over in recent years. In general, Kinneret St. Peter's fish (*Sarotherodon galileum*) has been largely effected by these chemicals (usually the pesticides Endosulphan or Lindane).

The combined use of more and more sophisticated agricultural chemicals (and various combinations of them) has caused increasing concern in our laboratory. Our programme will therefore become of increasing importance in the near future.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Occasional problems in National Carrier System because of the increase of nanoplanktonic algae (e.g. *Cyclotella*) ; e. g. disturbed filtration in cleaning bed, foul smell of tap water and difficulties in use of water for irrigation.

§ Nitrogen and phosphorus loadings to the lake (1985) (Q1)

Annual (Oct.-Sep.) River Jordan yield and nutrient input [tons] from the northern Lake Kinneret watershed, 1968-1984

Year	Jordan yield [10^6 m^3]	Total N	Organic N	Ammonia	Nitrate	Dissolved P	Total P
1968/69	1,096	3,480	632	54	2,738	27	186
1969/70	574	1,257	356	31	748	9	71
1970/71	650	1,837	573	35	1,205	4	195
1971/72	491	1,171	411	41	708	7	75
1972/73	270	700	237	26	426	7	58
1973/74	480	2,118	447	61	1,580	12	105
1974/75	387	1,138	575	32	524	9	121
1975/76	478	1,293	683	43	659	12	176
1976/77	557	1,528	667	59	799	14	126
1977/78	575	1,512	639	63	806	17	239
1978/79	276	676	265	45	365	9	61
1979/80	569	2,240	683	94	1,464	22	164
1980/81	633	3,148	478	119	2,280	29	175
1981/82	380	911	258	27	626	15	83
1982/83	558	2,375	362	106	1,906	27	122
1983/84	463	1,024	243	97	684	14	114
Average (S.D.)	527 (189)	1,651 (829)	486 (183)	58 (30)	1,098 (713)	15 (8)	129 (54)

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment. There is a concerted effort to minimize pollutant loads. A major contributor to this is the work of the Kinneret Authority which is responsible for monitoring and regulating development in the region (Q3).

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS (Q3)

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	90
Point sources	0
Rural settlements	10
Total	100

J3 SANITARY FACILITIES AND SEWERAGES (Q3)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment system) or public sewerage : 100.

§ Percentage of rural population with adequate sanitary facilities : 90.

§ Municipal wastewater treatment systems

Number of tertiary treatment systems : 1.

Number of secondary treatment systems : 5, oxidation ponds.

Number of primary treatment systems : 5.

K. IMPROVEMENT WORKS IN THE LAKE (Q1, Q2)

K1 RESTORATION

Construction of reservoirs for sewage storage, sewage treatment plants, agricultural management, and lake management (fisheries, water level, recreation, etc.).

K2 DIVERSION

Sewage diversion and salty water diversion systems. A salt water diversion (removing high salinity water from sources to the north-west of the lake) was built in the mid 1960's. This also comes treated sewage and diverts it into the South Jordan ; a similar sewage diversion was recently built on the southeast shore.

K3 OTHERS

Development of public beachs, research of lake and watershed as basis for management recommendations. Much effort has been placed in improving the quality of water entering the lake from the Northern Jordan River. Agro-technical methods in the cultivated land of the watershed are aimed at lowering sediment and nutrient inputs.

L. DEVELOPMENT PLANS (Q3)

(1) Possible construction of large pump-storage facility for generation of peak hour electricity.

(2) Depending on political developments-changes in pumping regimen and addition of winter floods from Yormuk River shoring of water sources with Jordan.

(3) Continued management strategy of low autumn and early winter lake levels to maximize reservoir.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (Q2)

§ Names of the laws (the year of legislation)

(1) Water Law (1959)

§ Responsible authorities

(1) Water Commissioner, Agricultural Ministry, Kinneret Authority and Local Municipalities

§ Main items of control

(1) Water quality (management of watershed and lake)

M2 INSTITUTIONAL MEASURES (Q3)

(1) Kinneret Authority (established in 1972 by the Water Commissioner).

(2) The Yogal Alon Kinneret Limnological Laboratory of the Israel Oceanographic and Limnological Research Ltd. (Ministry of Energy and Infrastructure, established in 1968)

(3) Mekorot Water Company (Watershed Monitoring Team, since 1964)

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES (Q3)

(1) The Yogal Alon Kinneret Limnological Laboratory of the Israel Oceanographic and Limnological Research Ltd*

*This laboratory is mandated by law to be the centre for Kinneret research. The laboratory coordinates lake studies carried out by scientists at many other institutions.

§ Supplementary notes

In 1987, International Centre for Warm Freshwater Research will be established at the Kinneret Laboratory.

N. SOURSES OF DATA

(Q1) Questionnaire filled by Dr. T. Berman, Kinneret Limnological Laboratory, Israel.

(Q2) Questionnaire filled by Dr. M. Gophen, Kinneret Limnological Laboratory, Israel.

(Q3) Questionnaire filled by Dr. D. Wynne, Kinneret Limnological Laboratory, Israel.

(1) Serruya, C., Edelstein, M., Pollingher, U. & Serruya, S. (1974) Lake Kinneret sediments; nutrient composition of the pore water and mud water exchanges. Limnol. Oceanogr., 19(3): 489-508.

(2) Stanhill, G. & Neuman, J. (1978) The general meteorological background. "Lake Kinneret" (ed. Serruya, C.), pp. 49-58. Dr. W. Junk Publishers, The Hague-Boston-London.

(3) Berman, T. (ed.) (1973) Lake Kinneret Data Record. Israel National Council for Research and Development.

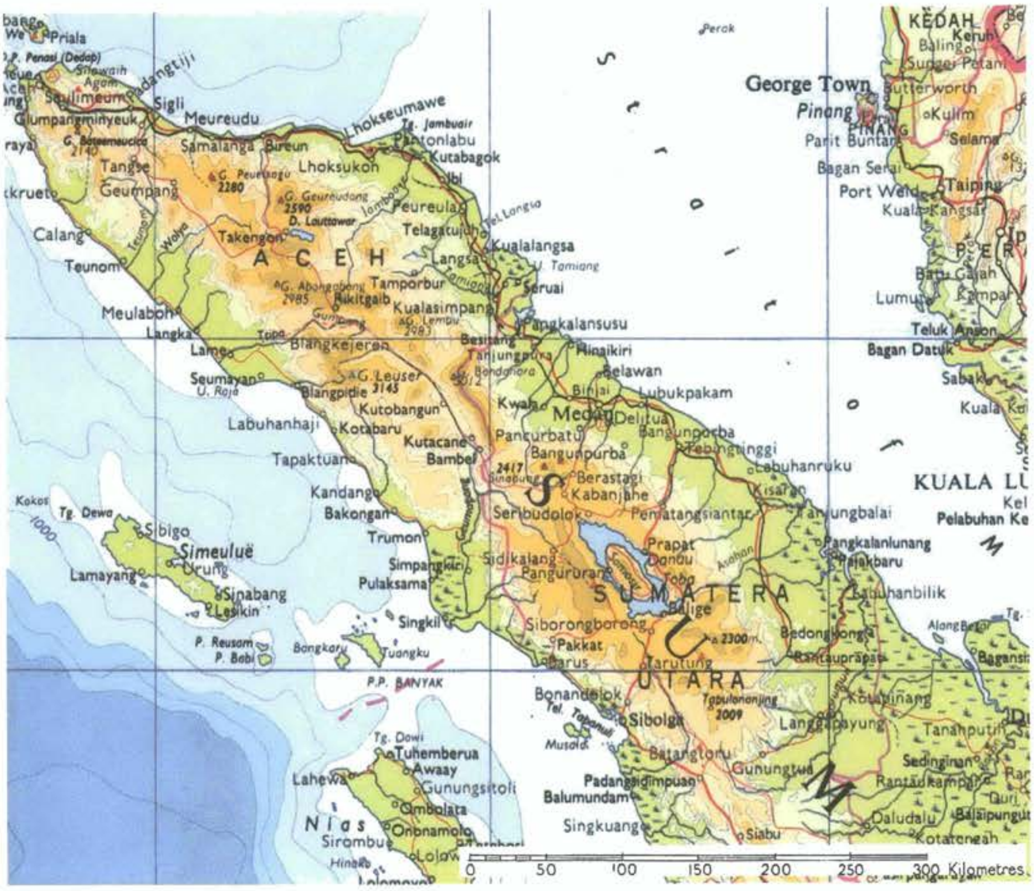
(4) Serruya, C. (1978) General background. "Lake Kinneret" (ed. Serruya, C.), pp. 123-146. Dr. W. Junk Publishers, The Hague-Boston-London.

(5) Serruya, C. & Pollingher, U. (1983) Lakes of the Warm Belt. 569 pp. Cambridge University Press, London.

DANAU TOBA (LAKE TOBA)

A bird-eye view of the lake

Photo: H. Haerumen Js



A. LOCATION

§ North Sumatera Province, Indonesia.
§ 2°21′32″-2°56′28″N, 98°26′35″-99°15′40″E ; 905 m above sea level.

B. DESCRIPTION

Lake Toba lies in the northern part of Barisan Mountain Range, which is volcanic and traverses Sumatera Island from northwest to southeast as its backbone.

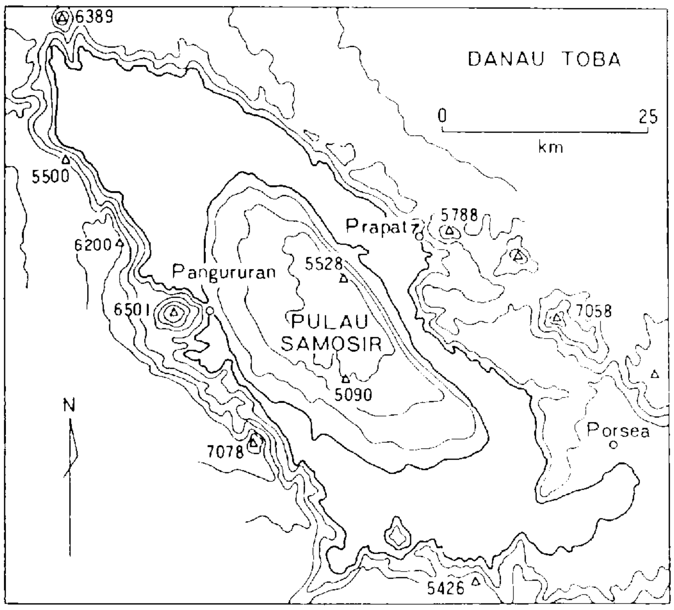
The lake trough is surrounded by precipitous cliffs 400 1,200 m high. Based on the topographic feature and the wide distribution of volcanic ejecta around the lake, some geologists and volcanologists have considered it to be a giant caldera or cauldron.

The water surface of L. Toba is 905 m above sea level and about 1,100 km^2 wide. The total area of the lake, including the areas of Samosir and Paradapur Islands, amounts to 1,780 km^2. The mountains around the lake are called Batak Highlands. The only draining river from L. Toba, the Asahan, flows southeastwards dissecting the gentle slopes of the pyroclastic plateau.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	1,100
Volume [10^9m^3]	1,258
Maximum depth [m]	529
Normal range of annual water level fluctuation (unregulated) [m]	1.5
Catchment area [km^2]	3,440

Fig. ASI-10-1 Sketch map (altitude in ft.) (14).



D. PHYSIOGRAPHIC FEATURES (Q)

D1 GEOGRAPHICAL

§ Sketch map of the lake (Fig. ASI-10-1).

§ Main islands (name and area): Samosir (640 km^2), Paradapur (7 km^2).

§ Outflowing rivers and channels (number and names): 1 (Asahan R.).

D2 CLIMATIC

§ Climatic data at Parparean, 1961-1980.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp [°C]	19.3	19.0	18.9	19.3	19.4	19.1	19.0	18.8	19.0	19.4	19.4	19.1	19.1
Precipitation [mm]	100	105	115	132	124	102	83	110	148	174	182	178	1,732

§ Solar radiation (Parparean, 1961-1980): 15.7 MJ m^{-2} day^{-1}.

§ Water temperature [°C]

Station	Surface
Haranggaul	27
Tigaras	27
Tomok	26
Simanindo	27
Pangururan	27
Nainggolan	27
Prapat	27
Porsea	26

§ Freezing period: None.

§ Notes on water mixing and thermocline formation: Mizuno observed an extremely homogeneous vertical distribution of water temperature from the surface down to 300 m depth on January 23, 1976 (13).

E. LAKE WATER QUALITY (Q)

E2 pH, 1979

Station	Surface
Lotung	8.4
Situmeang	7.9
Bukit	8.4
Tongging I	7.0
Tongging II	7.9
Onan Runggu	7.6
Prapat	8.2

E4 DO [mg l^{-1}], 1979

Station	Surface
Lotung	6.7
Situmeang	6.8
Bukit	9.3
Tongging I	6.3
Tongging II	7.0
Onan Runggu	7.0
Prapat	8.0

E5 COD [mg l^{-1}], 1979

Determined by $KMnO_4$ method.

Station	Surface	Station	Surface
Haranggaol	2.30	Hasinggahan	1.30
Prapat	2.80	Tomok	1.53
Mogang	2.24	Sabulan	1.72
Onan Runggu	2.15	Muara	1.36
Porsea	2.06	Balige	1.24

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], 1979

Station	Surface
Haranggaol	0.31
Hasinggahan	0.32
Tomok	0.66

E9 CHLORINE ION CONCENTRATION [mg l^{-1}], 1979

Station	Surface	Station	Surface
Haranggaol	8.6	Hasinggahan	11.8
Prapat	8.3	Tomok	11.0
Mogang	10.1	Sabulan	9.2
Onan Runggu	10.4	Muara	9.6
Porsea	10.3	Balige	9.5

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes : *Nelumbo nucifera*, *Nymphaea* sp.

§ Floating macrophytes : *Eichhornia crassipes*, *Lemna minor*, *Azolla pinnata*, *Spirodella polyrhiza*.

§ Submerged macrophytes : *Potamogeton malaianus*, *P. polygonifolius*, *Myriophyllum spicatum*, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Chara* sp.

§ Phytoplankton : *Amphora*, *Cocconema*, *Asterionella*, *Synedra*, *Gomphonema*, *Orthosira*, *Navicula*, *Mastogloia*, *Pleurosigma*, *Nitzschia*, *Genicularia*, *Botryococcus*, *Synechococcus*, *Anabaena*, *Oscillatoria*.

F2 FAUNA

§ Zooplankton : *Cyclops*, Cladocera.

§ Benthos : *Macrobrachium sintangensis*, *Brotia costula*, *Thiara scabra*, *Melanoides tuberculata*, *Melanoides granifera*, *Anentome helena*, *Lymnaea brevispira*, *L. rubiginosa*, *Physastra sumatrana*, *Corbicula tobae*.

§ Fish : *Tilapia mossambica*, *Aplocheilus pachax*, *Lebistes reticulatus*, *Osphronemus goramy*, *Trichogaster trichopterus*, *Channa striata*, *C. gachua*, *Clarias batrachus*, *C. nieuhofi*, *C.* sp., *Nemachilus fasciatus*, *Cyprinus carpio*, *Puntius javanicus*, *P. binotatus*, *Osteochilus nasselti*, *Lissochilus* sp., *Labeobarbus sora*, *Rasbora* sp.

F4 BIOMASS [g (wet wt.) m^{-2}]

§ Biomass of submerged macrophytes

Station	*Potamogeton* sp.	*Myriophyllum spicatum*	Others	Total
Lotung	2,470	130	<25	2,600
Onan Runggu	2,800	150	0	2,950
Parbaloan Urat	1,833	310	520	2,663
Tongging	1,947	157	<25	2,104
Lumban Sitorus	150	1,640	0	1,750

F5 FISHERY PRODUCTS

§ Annual fish catch in 1978 : 2,820 [metric tons].

F5 PAST TRENDS

§ Annual fish catch

Year	Production [metric ton yr^{-1}]			
	Tilapia mossambica	*Cyprinus carpio*	Others	Total
1967	1,039	207.8	831.2	2,078
1976	–	–		2,211
1977	–	–	–	2,569
1978	2,175.1	4.6	640.2	2,820

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE

Increasing : *Tilapia mossambica*. Decreasing : *Cyprinus carpio*.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1981)

	Area [ha]	[%]
Agricultural land	51,208	21.8
Plantation	2,088	0.9
Grass (alang-alang)	95,500	40.6
Scrub	5,924	2.5
Natural forest	15,966	6.8
Reforestation	38,870	16.6
Regreening	22,828	9.7
Others	2,356	1.1
Total	234,750	100

§ Main types of woody vegetation : Tropical high mountain forest ; *Pinus merkusii* forest ; *Macadamia hildebrandii* forest.

§ Main types of herbaceous vegetation : *Imperata cylindrica* with *Rhodomyrtus tomentosa*, *Melastoma* sp. and *Gleichenia linearis*.

§ Main kinds of crops : Rice, sweet potato, maize, vegetables.

§ Levels of fertilizer application on crop fields : Moderate.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE : No information.

G3 POPULATION IN THE CATCHMENT AREA (1980)

District	Area [km^2]	Population	Family	Population density [km^{-2}]
Tapanuli Utara	2,420.5	309,111	66,744	128
Tanah Karo	63.0	3,901	731	62
Dairi	45.0	9,011	1,810	200
Total	2,528.5	322,023	69,285	127

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, navigation and transportation (amount of cargo in 1978 : 1,922 metric tons), sightseeing and tourism (number of visitors in 1978 : 44,625), recreation (yachting), fisheries.

H2 THE LAKE AS WATER RESOURCE : No information.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION : No information.

I3 EUTROPHICATION : No information.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Measurable pollution without wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGES

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment system) or public sewerage : None.

§ Percentage of rural population with adequate sanitary facilities : None.

§ Municipal wastewater treatment systems : None.

§ Industrial wastewater treatment systems : None.

K. IMPROVEMENT WORKS IN THE LAKE

None.

L. DEVELOPMENT PLANS (Q)

(1) Integrated management on Toba Lake catchment area.

(2) Hydroelectric power plant under construction.

M. LEGISLATEVE AND INSTITUTIONAL MEASURES FOR UPGRANDING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Act of the Republic of Indonesia No 4 concerning Basic Provisions for the Management of the Living Environment (1982)

(2) State Regulation of the Republic of Indonesia No. 29 on Environmental Impact Assesment (1986)

§ Responsible authorities

(1) & (2) The State Minister for Population and Environment, Ministry of Home Affairs, Ministry of Public Works, Ministry of Forestry and Local (Provincial) Governments

M2 INSTITUTIONAL MEASURES

(1) The State Minister for Population and Environment responsible for coordinating environmental managements

(2) Ministry of Public Works responsible for lake utilization
(3) Ministry of Home affairs responsible for regional development
(4) Ministry of Forestry responsible for forest management and soil conservation

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES
(1) Centre of Environmental Studies (University).
(2) Institute of Hydraulic Engineering Agency of Resources and Development.

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. Herman Haerumen Js, Ministry of State for Population and Environment, Indonesia, based on the following literature (1)-(12).

(1) Abdullah Angaedi (1980) Studi Perencanaan Perbaikan Keadaan Danau Toba, Sumatera Utara, PT. Indah Karya & Ministry of Public Works.

(2) Asahan Development Authority (1984) Laporan Penyelesaian Pelaksanaan Pembangunan Proyek Asahan.

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(4) Hehanussa P. E. (1982) Tefra Toba. National Geology & Mining Institute, National Institute of Sciences.

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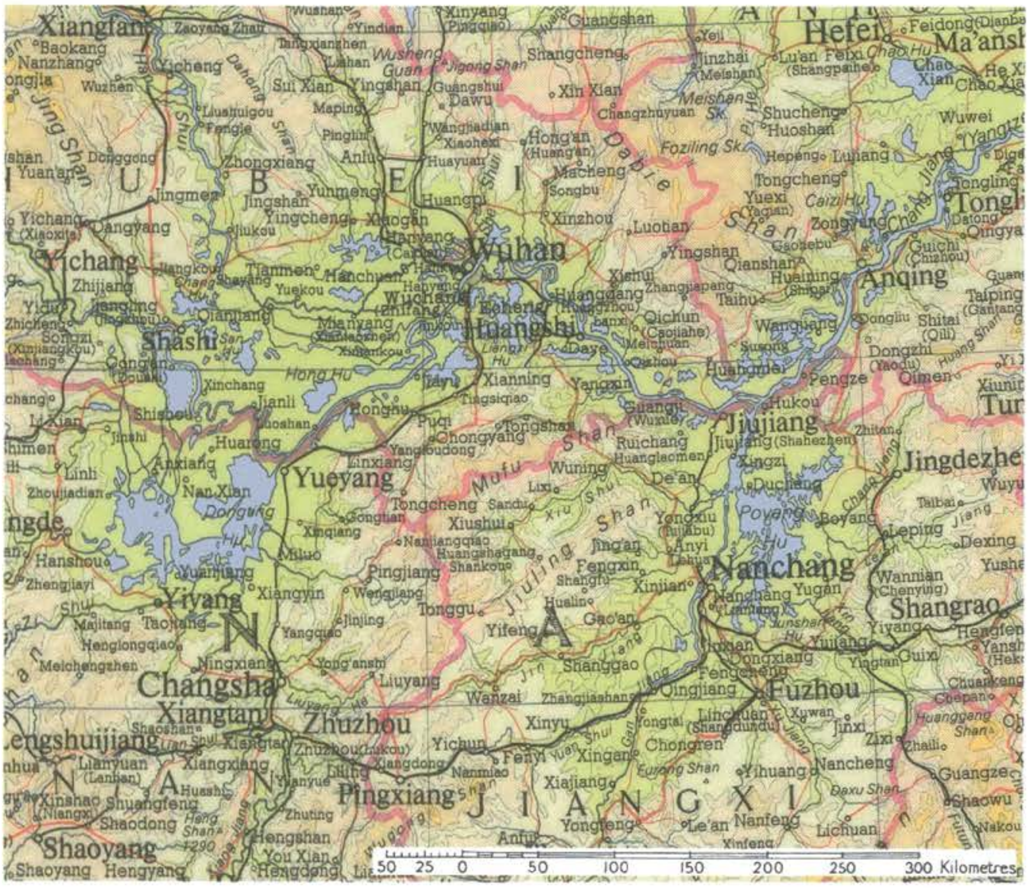
DONGTING-HU

On the Yueyang Bay, East Lake

Photo: T. Kira



A. LOCATION

§ Hunan Province, People's Republic of China.
§ 28°30′-30°20′N, 111°40′-113°10′E ; 33.5 m above sea level.

B. DESCRIPTION

Lake Dongting, in northeastern Hunan, is the second largest freshwater lake of China, with an extensive catchment area including the whole of Hunan and parts of the neighboring provinces, Hubei, Sichuan and Guizhou. It serves as a great retarding basin for the Chang Jiang (Yangtse River), from which flood water pours into the lake in July-September. The inflow from the Chang Jiang amounts to more than a half of the total water influx to L. Dongting, and carries with it a tremendous sediment load of 140×10^6 m^3yr^{-1} on average.

One hundred and fifty years ago, the lake was much bigger (6,200 km^2) than it is now (2,740 km^2), but the rapid progress of sedimentation and land reclamation works have since reduced its size, resulting in the formation of three more or less separate basins, West, South and East Dongting. In the summer flooding season, however, the three lakes unite into a single water body of about 3,900 km^2 surface area. The water from the Chang Jiang flows mainly into the West and East Lake through three channels, and is drained from the northeastern corner of East Lake at Yueyang directly into the Chang Jiang again. The annual range of water level fluctuation in normal years ranges between 6.5 m (W. Lake) and 17.8 m (E. Lake).

The greatest environmental problem for L. Dongting is the rapid sedimentation (at a rate of ca. 5 cm yr^{-1} on a whole lake average) that causes trouble for surface transportation by boats, diminishes the lake's capacity for water storage and flood control, and affects fishery production through changes in the aquatic ecosystem. The Provincial Ordinance for Environmental Protection formulated in 1981, therefore, allows for no further reclamation work in or around the lake.

The heavy application of pesticides to rice fields as well as industrial development in recent years has caused local contamination of rivers and small attached lakes with BHC, heavy metals and organic wastes, but the main lake as a whole maintains fairly good water quality, with a mesotrophic nutrient level.

C. PHYSICAL DIMENSIONS

Surface area [km^2]*	2,740
Volume [10^9m^3]	17.8
Maximum depth [m]	30.8
Mean depth [m]	6.7
Nomal range of annual water level fluctuation (unregulated) [m]	6.5-17.8
Catchment area [km^2]	259,430

* At the low water level.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. ASI-11-1).

§ Main islands : None.

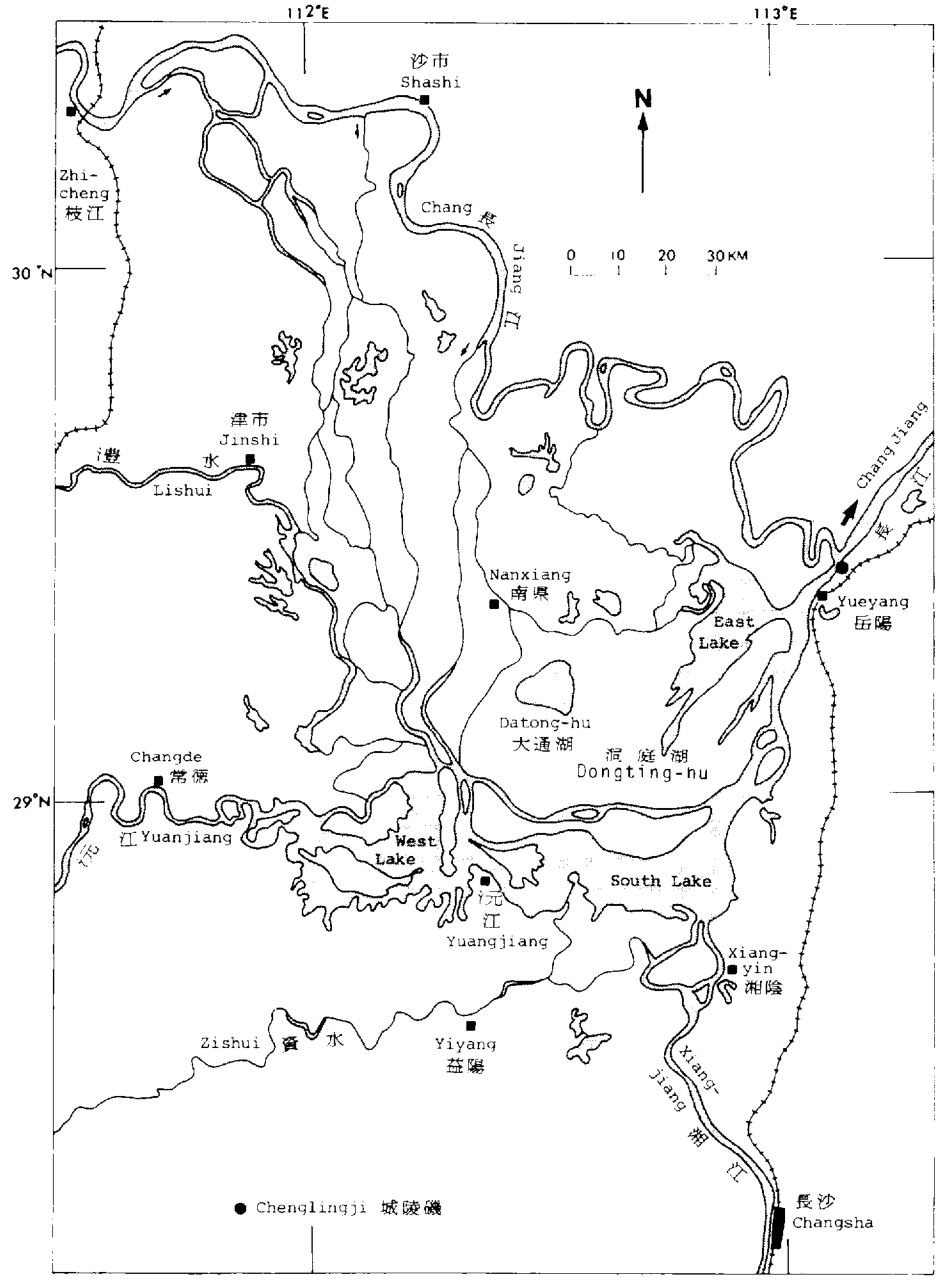
§ Outflowing rivers and channels : Directly connected with the Chang Jiang (Yangtse R.) at Chenglingji in Yueyang.

D2 CLIMATIC

§ Climatic data at Yuanjiang, 1980-1982

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	4.5	5.7	10.3	16.2	22.3	25.0	28.8	27.2	22.5	18.0	18.2	7.3	16.7
Precipitation [mm]	77	78	176	149	162	170	123	177	48	91	116	11	1,369

Fig. ASI-11-1 Sketch map of Dongting Lake area.



§ Water temperature [°C]
Chenglingji, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	11	4	9.8	13.1	21.2	23.8	26.8	28.4	25.3	23.3	18.3	17.9

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]
Chenglingji, 1982

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.24	0.25	0.12	–	0.16	0.11	0.21	0.20	0.24	0.22	0.26	0.26

E2 pH
Chenglingji, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	7.9	7.9	8.0	7.9	8.0	7.8	7.8	7.9	7.9	8.1	8.0	8.0

E4 DO [mg l^{-1}]
Chenglingji, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	–	7.7	–	–	7.9	–	–	8.4	–

E5 COD [mg l^{-1}]
Chenglingji, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	1.3	1.4	1.7	1.7	1.4	1.6	1.3	1.5	1.0	0.9	1.2	1.1

E7 NITROGEN CONCENTRATION [mg l^{-1}]
0.5m depth, Chenglingji, 1983

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NH_4-N	–	–	–	–	0.12	–	–	0.38	–	–	0.3	–
NO_3-N	–	–	–	–	0.30	–	–	0.35	–	–	0.43	–

E8 PHOSPHORUS CONCENTRATION
§ Total-P [mg l^{-1}]*
Chenglingji, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	.001	.004	.000	.005	.003	.001	.000	.000	.002	.000	.005	.000

* Converted from the original P_2O_5 values.

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites communis, Polygonum hydropiper,* etc.
§ Floating macrophytes : *Lemna minor, Pistia stratiotes,* etc.
§ Submerged macrophytes : *Vallisneria spiralis, Potamogeton crispus,* etc.
§ Phytoplankton : *Chroococcus* sp., *Ceratium* sp., etc.

F2 FAUNA

§ Fish : *Coilia ectenes, Mylophoryngodon piceus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Cyprinus carpio, Aristichthys nobilis, Megalobrama* spp., *Sinipera* spp., *Anguilla japonica,* etc. (total number of fish species 114).

F4 BIOMASS

§ Phytoplankton : 48–164 [cell no ml^{-1}].
§ Zooplankton : 1.9–5.7 [cell no ml^{-1}].
§ Aquatic macrophytes : 66 [g m^{-2}].
§ Benthos : 78 [g m^{-2}].

F5 FISHERY PRODUCTS

§ Annual fish catch in 1981 : ca. 70,000 [metric tons].

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE

Gradual decrease of economically important fish species and migratory fishes, and the increase of sedentary fishes.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE DONGTING-HU AREA*

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	7,990	25.9
Herbaceous vegetation	2,120	6.9
Swamp	4,938	16.0
Agricultural land	8,900	28.8
Settlement area	4,559	13.2
Others	2,837	9.2
Total	31,344	100.0

* The lowland area around Lake Dongting, encircled by the 33.5 m contour (equivalent to the altitude of the lake surface). The whole area would turn into a single big lake, if the embankment did not exist. Only the districts belonging to the lake's catchment are enumerated here.

§ Main types of woody vegetation : Tree groves around villages (*Pterocarya stenoptera, Salix babylonica, Cedrela sinensis, Populus canadensis,* etc.) ; pine (*Pinus massoniana*) forest and plantations of pine and some other trees on low hills.
§ Main kinds of crops : Rice, cotton, ramie, jute, rapeseed, tobacco, sugar-cane, tea, citrus, mulberry, etc.

G2 INDUSTRIES IN THE DONGTING-HU AREA AND THE LAKE (1982)

	Gross product during the year [10^4yuan]	No. of persons engaged	No. of establishments	Main products and main kinds of industry
Primary industry	32.2	4,725,000	N.A.	
Agriculture	23	N.A.	N.A.	1)
Fisheries	0.6	N.A.		
Others	8.6	N.A.		
Secondary industry	25	640,000	2,280	
Manufacturing	N.A.	N.A.	N.A.	2)
Mining	N.A.	N.A.	N.A.	3)
Tertiary industry	N.A.	N.A.	N.A.	

1) Rice, cotton, rapeseed oil, jute, ramie, etc.
2) Machinery, electricity, chemicals, metal smelting, etc.
3) Lead, zinc, antimony, tangsten and other metals, coal, etc.

G3 POPULATION IN THE DONGTING-HU AREA (1982)

Population	Population density [km^{-2}]	Main cities (population)
11,754,000	381.0	Changsha (ca. 800,000), Yueyang.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, fisheries, navigation (passengers 2-3 millions per year ; cargo 15-19 million tons per year), tourism and recreation (swimming).

H2 THE LAKE AS WATER RESOURCE

Used as the sources of tap water in some cities and industrial water.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Not apparent.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

Number of secondary treatment systems : 1 (activated sludge, 60,000 m^3 day^{-1}).

K. IMPROVEMENT WORKS IN THE LAKE

K3 OTHERS

3.4 million tons of bottom sediments are annually dredged in the four main inflowing rivers and part of the lake. The improvement of the course of a river has reduced the influx of mud into the lake by $2{,}840 \times 10^4$ t yr^{-1}. About 147 million trees have been planted for erosion control during the last 30 years.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Environment Protection Law (1979, tentative)

(2) Ordinance for Environment Protection of Hunan Province (1981, tentative)

§ Responsible authorities

(1) Bureau of Environment Protection, Ministry of Urban & Rural Construction and Environment Protection, National Government

(2) Managing Office for Environment Protection, Committee for Basic Construction and Environment Protection, Provincial Government of Hunan

§ Main items of control

(1) DO, pH, SS, COD, BOD, NH_4-N, NO_3-N, Hg, Cd, Pb, radioactive U, chlorinated hydrocarbons, etc.

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Research Institute for Environmental Science of Hunan Province, Changsha

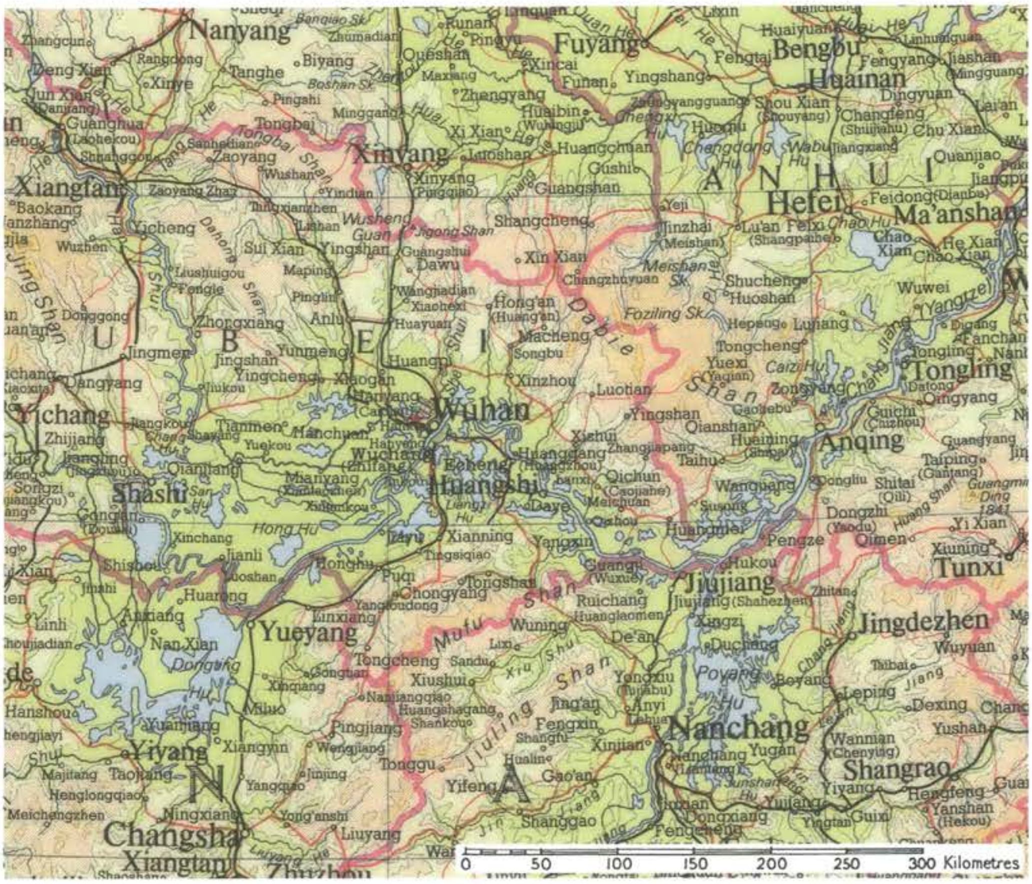
N. SOURCES OF DATA

All the data are based on the questionnaire filled by the Managing Office for Environment Protection, Provincial Government of Hunan. Some other informations were also supplied from the Research Institute for Environmental Science of Hunan Province.

DONG-HU

A view from the survey boat on the lake

Photo: T. Kira



A. LOCATION

§ Wuhan City, Hubei Province, People's Republic of China.
§ 30°33′N, 114°23′E ; 20.5 m above sea level.

B. DESCRIPTION

Dong (east)-hu (lake) is a small lake in the Wuchang Ward of Wuhan City, the capital of Hubei Province. It obtained its name from being located at the eastern end of this big city. Dong-hu is a natural dammed lake formed in the early Holocene as a so-called "lateral lake" attached to the right bank of the Chang Jiang which flows through Wuhan, and is only five kilometers away from the river.

The lake area, especially the northwestern coast, is a park and recreation area for the citizens of Wuhan, with museums, a botanic garden, observation towers, restaurants, sanatoria, beautiful groves of exotic swamp cypress, swimming sites and sightseeing boats. The Wuhan Institute of Hydrobiology established by the Academia Sinica in 1954 is located on the westernmost shore of the lake. Its research activity made Dong-hu one of the most familiar lakes of China to world limnologists.

It is also intensively utilized for fish production. Many small bays are separated from the main lake by causeways for artificial stocking of fish. Introduction of such planktophagous fishes as the silver carp and the bighead carp, increased the fish production by more than four times in a seven-year period. The increasing density of fish as well as the inflow of waste water from the city and industrial factories, however, has caused a rapid change in the lake's biota. Accelerated eutrophication is producing noxious effects which now hinder the utilization of lake water and recreational activity. A plan for establishing a waste water treatment plant for domestic sewage and the diversion of treated water to Chang Jiang, is now being carried out by the Municipality of Wuhan (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	27.9
Volume [$10^6 m^3$]	62
Maximum depth [m]	4.75
Mean depth [m]	2.2
Normal range of annual water level fluctuation (regulated) [m]	0.5
Length of shoreline [km]	9.2
Residence time [yr]	0.44
Catchment area [km^2]	97

D. PHYSIOGRAPHIC FEATURES (5)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-12-1).

§ Main islands : None.

§ Outflowing rivers and channels (number and names) : 1 (Qingshan Canal).

D2 CLIMATIC

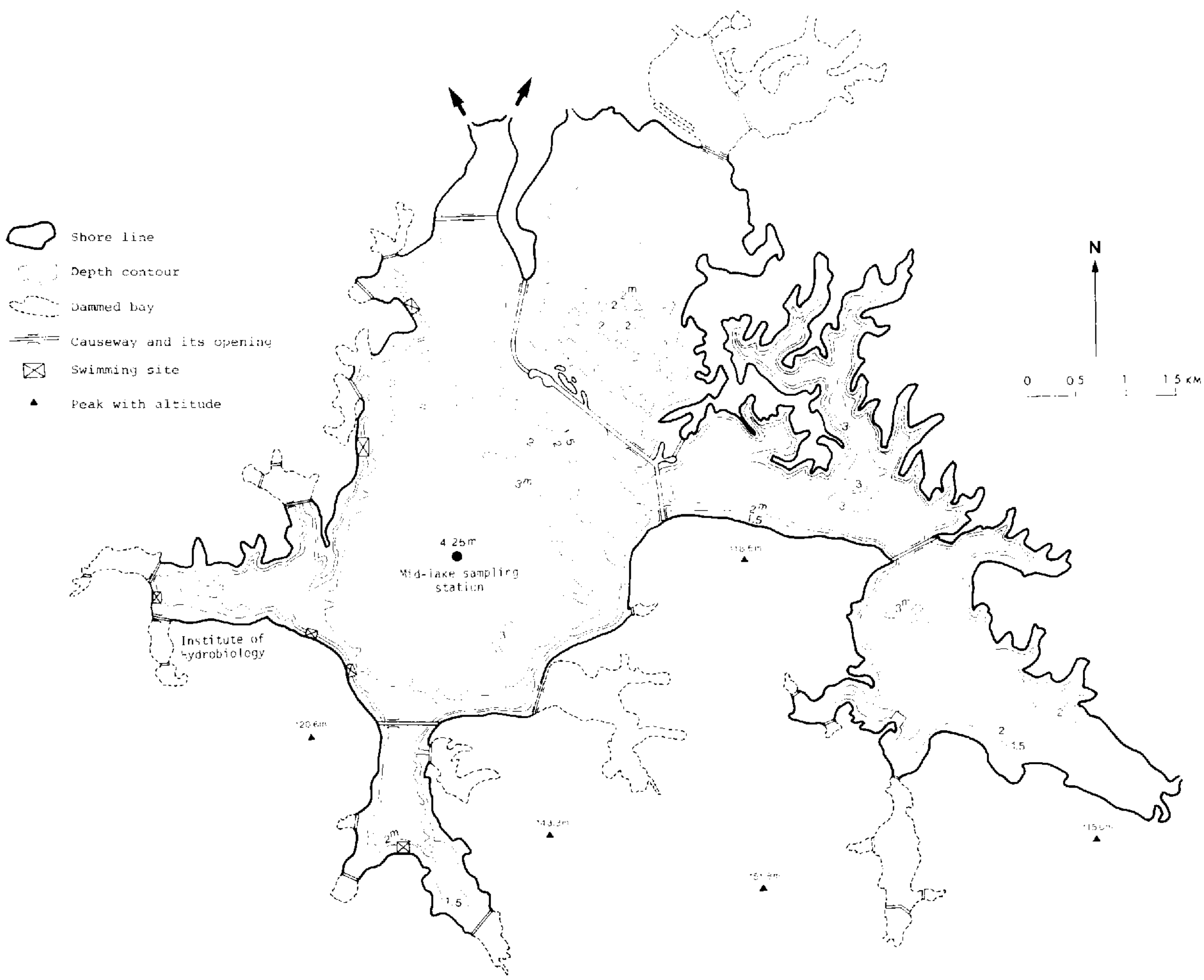
§ Climatic data at Wuhan, 1961-1970 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2.9	4.8	9.9	15.8	21.6	25.5	28.8	28.5	23.2	17.4	11.0	5.1	16.2
Preciptation [mm]	30	51	90	148	132	175	181	152	9	53	64	35	1,450

§ Number of hours of bright sunshine (Wuhan, 1982) : 1,624 hr yr^{-1} (2).

§ Solar radiation (Wuhan, 1982) : 12.53 MJ $m^{-2}day^{-1}$ (2).

Fig. ASI-12-1 Bathymetric map (Q).



§ Water temperature [°C] (Q)
Mid-lake sampling station, 1982

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	6.1	5.3	10.6	16.6	23.4	25.9	29.1	29.2	24.8	21.5	14.7	6.5

§ Freezing period : In January or February, if ever happens.
§ Mixing type : Polymictic (Q).
§ Notes on water mixing and thermocline formation : Strong mixing ; practically no thermocline formation.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Mid-lake sampling station, 1983 1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.87	2.12	3.17	2.43	1.97	1.63	1.07	0.62	0.55	0.62	0.98	2.25

E2 pH

Mid-lake sampling station, 1983-1985

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	7.97	8.30	8.21	8.30	8.48	8.78	1.07	0.62	0.55	0.62	0.98	2.25
3.5	8.12	8.34	8.21	8.38	8.55	8.69	9.29	8.97	8.69	8.66	8.36	8.13

E3 TDS [mg l^{-1}]

Mid-lake sampling station, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	166.3	137.3	196.5	258.0	236.3	200.5	195.5	142.2	129.0	121.2	152.5	150.0
3.5	152.2	184.8	183.8	222.5	261.5	189.7	133.0	136.8	121.5	119.0	144.2	138.8

E4 DO [mg l^{-1}]

Mid-lake sampling station, 1983-1985

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	10.94	11.78	9.17	7.25	8.39	9.00	7.91	7.92	6.62	8.05	8.00	10.29
3.5	11.23	10.85	9.59	8.07	7.51	8.46	7.00	7.22	5.98	* 7.06	7.75	10.19

* Mean for 1983 & 1985.

E5 COD [O_2 mg l^{-1}]

Determined by $KMnO_4$ method
Mid-lake sampling station, 1983-1985

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	5.89	5.21	4.58	4.57	3.22	2.58	4.57	6.38	4.68	4.91	4.73	3.02
3.5	5.81	5.15	4.03	4.72	3.04	2.96	4.22	* 5.65	5.32	4.87	4.88	3.02

* Mean for 1983 & 1985.

E6 CHLOROPHYLL CONCENTRATION [mg m^{-3}]

Mid-lake sampling station, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	6.12	1.45	3.27	6.85	3.21	12.58	28.41	35.40	38.19	45.18	10.25	0.70
3.5	3.06	1.00	1.36	5.59	4.60	12.02	28.41	38.66	43.78	40.52	13.97	0.70

E7 NITROGEN CONCENTRATION

§ NO_3-N [mg l^{-1}]

Mid-lake sampling station, 1983-1985

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.241	0.263	0.323	0.489	0.175	0.138	0.024	0.013	0.007	0.021	0.060	0.156
3.5	0.253	0.262	0.359	0.455	0.242	0.173	0.024	0.020	0.007	0.020	0.066	0.124

§ NH_4-N [mg l^{-1}]

Mid-lake sampling station, 1983-1985

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.32	0.24	0.32	0.35	0.47	0.18	0.09	0.50	0.10	0.06	0.67	0.35
3.5	0.32	0.25	0.35	0.29	0.57	0.17	0.19	0.29	0.09	0.03	0.39	0.32

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l^{-1}]

Mid-lake sampling station, 1983-1985

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.010	0.007	0.010	0.016	0.004	0.006	0.004	0.023	0.030	0.002	0.014	0.021
3.5	0.011	0.008	0.015	0.021	0.008	0.007	0.001	0.037	0.037	0.003	0.009	0.012

§ Total-P [mg l^{-1}]

Mid-lake sampling station, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.108	0.058	0.040	0.013	0.015	0.016	0.032	0.040	0.027	0.034	0.015	0.027
3.5	0.094	0.020	0.022	0.016	0.017	0.014	0.036	0.020	0.048	0.040	0.058	0.029

E9 PAST TRENDS

Fig. ASI-12-2 Trend of transparency at 0.5 m depth, Mid-lake sampling station.

Fig. ASI-12-3 Trend of pH in the depth 0.5 m, Mid-lake sampling station.

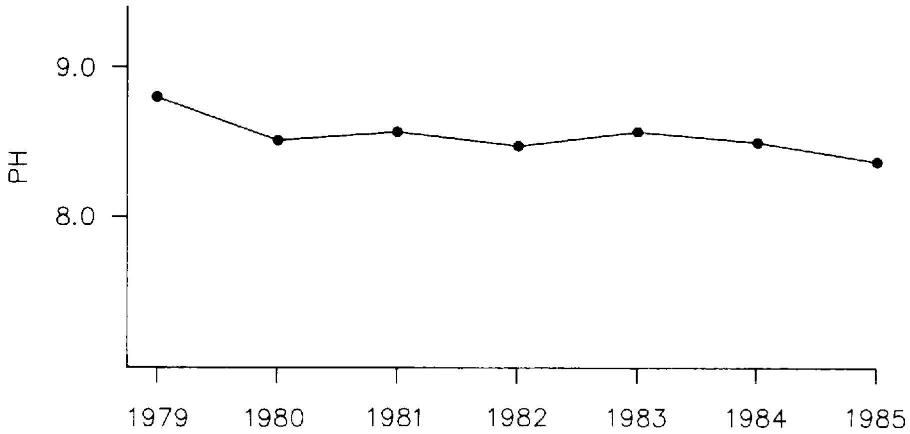


Fig. ASI-12-4 Trend of NO_3-N of the depth 0.5 m, Mid-lake sampling station.

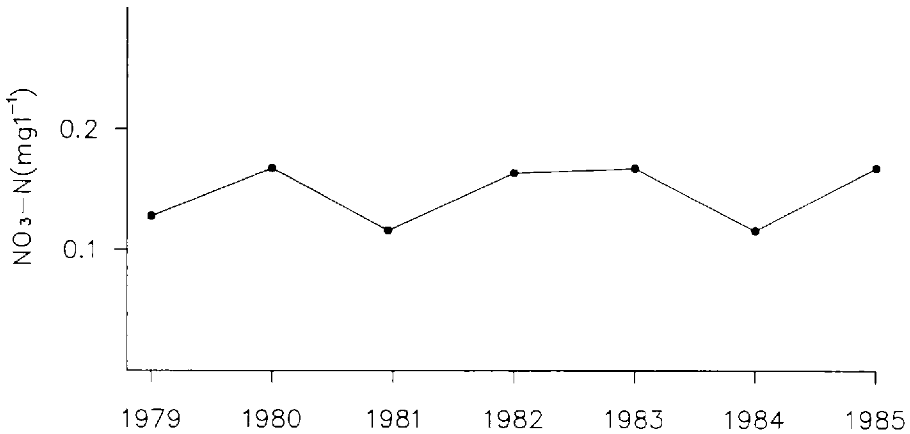


Fig. ASI-12-5 Trend of NH_4-N in the depth 0.5 m, Mid-lake sampling station.

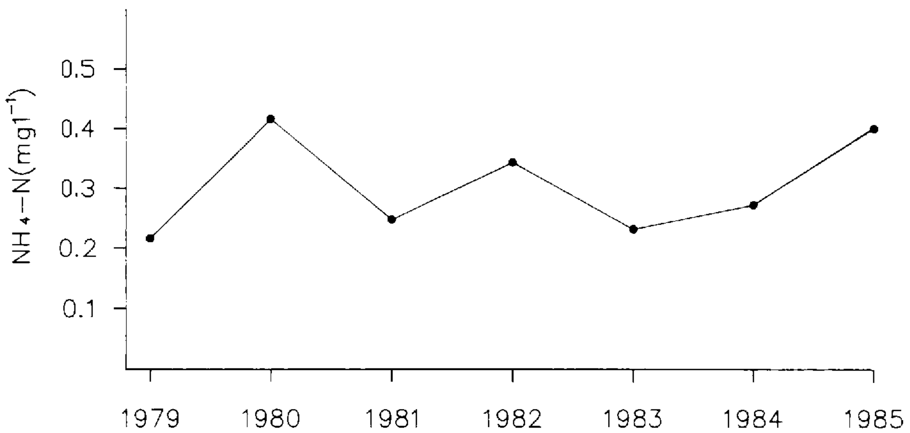
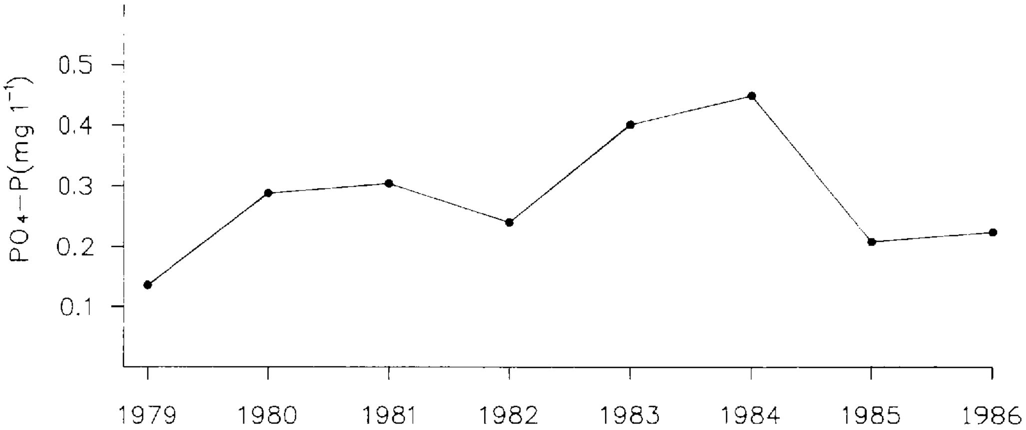


Fig. ASI-12-6 Trend of PO_4-P at 0.5 m depth, Mid-lake sampling station.



F. BIOLOGICAL FEATURES

Mid-lake sampling station for plankton, whole lake for macrophytes and benthos, during 1972-1978, except for submerged macrophytes (recorded in 1964) (Q).

F1 FLORA (4, 5)

§ Emerged macrophytes : *Phragmites communis, Echinochloa crus-galli, Leersia japonica, Typha angustifolia Nelumbo nucifera.*

§ Floating macrophytes : *Trapa natans, Nymphaea tetragona, Eichhornia crassipes, Limnanthemum indicum, Lemna minor.*

§ Submerged macrophytes : *Najas major, Myriophyllum spicatum, Ceratophyllum demersum, Potomogeton maakianus, Hydrilla verticillata.*

§ Phytoplankton : *Microcystis, Merismopedia, Anabaena, Cyclotella, Melosira, Cryptomonas, Chroomonas, Scenedesmus, Schroederia, Chlamydomonas, Crucigenia, Oscillatoria, Aphanizomenon.*

F2 FAUNA (4, 5)

§ Zooplankton : *Askenasia, Cyclidium, Didinium, Halteria, Tintinnidium, Tintinnopsis, Strombidium, Vorticella, Diurella, Polyarthra, Trichocerca, Asplanchna, Brachionus, Conochilus, Filinia, Pompholyx, Synchaeta, Pedalia, Daphnia, Cyclops, Mesocyclops, Mediaptomus, Neutrodiaptomus.*

§ Benthos : *Alocinma longicornis, Bellamya aeruginosa, Parafossarulus striatula, Anodonta woodiana, Limnodrillus hoffmeisteri, Brachiura sowerbyi,* Chironomidae (*Pelopia, Procladius, Einfeldia*).

§ Fish : *Hyophthalmichthys molitrix, Aristichthys nobilis, Cyprinus carpio, Carassius auratus, Megalobramma amblycephala, Ctenopharyngodon idellus.*

§ Supplement note : See F7.

F3 PRIMARY PRODUCTION RATE

§ Phytoplankton production rate [mg O_2 $m^{-2}day^{-1}$]
Mid-lake sampling station, 1981

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
Net prod.	1.51	0.37	0.20	5.32	3.99	4.63	6.88	9.49	5.56	1.91	1.50	0.26	3.49
Dark resp.	1.05	0.57	1.14	3.54	2.99	2.55	2.79	4.09	7.67	0.82	1.99	1.93	2.61
Gross prod.	2.56	0.94	1.34	8.86	6.98	7.18	9.67	13.58	13.23	2.73	3.49	2.19	6.08

F4 BIOMASS

§ Biomass of zooplankton at Mid-lake sampling station in 1980 : 3.54 mg l^{-1} (wet weight, average value) (3).

F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in a managed area of 1,700 ha in 1978 : 801.5 [metric tons].

§ Fishery products other than fish : Shrimp and shellfish are of no fishery significance here. Stocking of the mitten crab (*Eriocheir sinensis*) was successful, but abandoned because of the damage to fish nettings and the difficulty of harvesting.

F6 PAST TREND

§ Trend of primary production rate (Mid-lake sampling station)

Year	Maximum daily gross production rate [mg O_2 day^{-1}]
1963	4.7
1964	6.3
1973	5.6
1974	5.8
1977	7.4
1983	8.8

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (5)

Remarkable decrease in the biomass of submerged macrophytes, which had been widespread and grown luxuriantly in the lake up to 1967, took place in 1967-1975 owing to the increased stocking of grass carp (*Ctenopharyngodon idellus*) fingerlings. This was especially the case with *Potamogeton maackinus* that had once been the dominant species but is now absent from the lake.

The depletion of macrophytes proved favorable for the growth of phytoplankton, but adversely affected the populations of certain gastropods, aquatic insects and fish which laid eggs on aquatic vegetation.

Blooms of blue-green algae have developed rapidly and altered the species composition and population density of phytoplankton. The dominance of Phyrrophyta and Bacillariophyta was replaced by that of Cyanophyta and Chlorophyta. This was associated with the rise of primary production rate of phytoplankton.

The population density and biomass of zooplankton, particularly Protozoa and Rotifera, have increased steadily.

Intensive stocking of planktophagous silver carp (*Hypopthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) has increased the annual fish yield of the Lake 4.4 times in a seven-year period. Stocked silver carp and bighead carp account for more than 90 % of fish yield, but the diversity of fish fauna seems to have been much reduced.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1981) (Q)

	Area	
	[km^2]	[%]
Agricultural land	34.2	35.3
Orchard and hilly area	36.0	37.0
Residential and industrial areas	26.8	27.6
Total	97.0	100.0

§ Main Types of woody vegetation : No natural woody vegetation ; rows and groves of trees, mainly *Taxodium distichum*, are planted around the lake.
§ Main kinds of crops : Rice, wheat, tea and cotton.
§ Level of fertilizer application on crop fields : Moderate.
§ Trends of change in land use in recent years : Land for growing vegetables and rice has been increasingly turned into land for house-building (Q).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (Q)

Beside agriculture, fishery (aquaculture) is also an important primary industry. There are several sanatoria and hospitals and about one hundred factories (including a big steel plant) around the lake.

G3 POPULATION IN THE CATCHMENT AREA (1981) (Q)

	Population	Population density [km^{-2}]	Main cities (population)
Total	More than 200,000	>2,062	Wuhan* (3,900,000)

* Not all the city area is included in the catchment area.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, navigation and transportation, tourism, recreation (swimming, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE (Q)

§ Domestic and industrial (1981) : $300\text{-}350\times10^3$ m^3day^{-1}.

Over one million m^3 day^{-1} of cooling water used by a steel plant is recycled in the lake.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : Not serious.
§ Supplementary notes : Rate of sedimentation is low, but larger in the northern part of the lake than in the southern part.

I2 TOXIC CONTAMINATION : No information (Q).

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication

Unusual algal bloom : *Microcystis flos-aquae, M. aeruginosa, Anabaena spiroides, Aphanizomenon flos-aquae, Oscillatoria limosa*, etc.
Disturbed filtration in cleaning beds.
Foul smell of tap water.
Harms to fishery products ; summer-kill of tilapias in net-cages occasionally occurs in sultry weather.

§ Nitrogen and phosphorus loadings to the lake [$t\ yr^{-1}$] (1979-1980) (7)

	Total dissolved nitrogen (N)	Total dissolved phosphate (PO_4^{3-})
	536.3 $t\ yr^{-1}$ or 19.22 $g\ m^{-2}yr^{-1}$	87.8 $t\ yr^{-1}$ or 3.15 $g\ m^{-2}yr^{-1}$
Industrial+Domestic	59.2 %	74.7 %
Surface runoff	34.0 %	24.2 %
Atmospheric	6.8 %	1.1 %

Supplementary notes : The increasing urbanization and the rapid development of industry, agriculture and animal husbandry in the drainage basin pour hundreds of semi-treated effluent. The lake at its present stage can be regarded as an eutrophic lake on the way to a hyper-eutrophic stage (4). The construction of the sewerage system leading to a wastewater treatment plant has been under way since 1985.

I4 ACIDIFICATION (Q)

§ Extent of damage : None. Acid rain has been detected, but so far no damage is reported for forestry, crop and architecture. The lake ecosystem is practically unaffected because of its high buffering capacity.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA (Q) : (d) Measurable pollution with limited wastewater treatment.

K. IMPROVEMENT WORKS IN THE LAKE

A plan for establishing the waste water treatment plant for domestic sewage is now being carried out by the Municipality of Wuhan. The treated water will be discharged into the Chang Jiang (Q).

L. DEVELOPMENT PLANS

No information (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (Q)

§ Names of the laws (the year of legislation)

(1) Bulletin for Strengthening the Work of Protection and Management of Scenic Spots, promulgated by the State Council of the Peoples Republic of China (1981).

§ Responsible authorities

(1) Provincial Bureau of Urban Construction, Hubei Province.

§ Main items of control

(1) Sources of serious pollution must be properly treated, or else removed away. Effluents from sanatoria, restaurants, etc. should conform to the standards of permissible drain.

M2 INSTITUTIONAL MEASURES (Q)

(1) Bureau of Environmental Protection, Provincial Government of Hubei, Luojiashan, Wuhan.

(2) Administrative Board of the Dong-Hu Scenery Area, affiliated to the Municipal Government of Wuhan, Wuchang, Wuhan.

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES (Q)

(1) Provincial Institute of Environmental Protection of Hubei, established in the early 1970s, Luojiashan, Wuhan.

(2) Institute of Hydrobiology, Academia Sinica, moved from Shanghai to Wuhan in 1954, Luojiashan, Wuhan.

N. SOURCES OF DATA

* In Chinese, with English summary.

(Q) Questionnaire filled by Dr. Liu Jiang-Kang, Institute of Hydrobiology, Academia Sinica, Wuhan.

(1) Tokyo Astronomical Observatory(ed.) (1987) Chronological Scientific Tables (in Japanese). 916pp. Maruzen, Tokyo.

(2) Provincial Hydrographic Station of Hubei, according to the questionnaire.

(3) Huang, X., Chen, X., Wu, Z. & Hu, C. (1984) Studies on the changes in abundance and biomass of zooplankton in Lake Dong Hu, Wuhan. Acta Hydrobiologica Sinica, 8(3) : 345-358.*

(4) Jao, C. and Zhang, Z. (1980) Ecological changes of phytoplankton in Lake Dong Hu, Wuhan, during 1956-1975 and the eutrophication problem. Ibid., 7(1) : 1-17.*

(5) Liu, J.K. (1984) Lakes of the middle and lower basins of the Chang Jiang (China). In "Ecosystems of the World", vol. 23, Lakes and Reservoirs (ed. by Frieda Taub), pp. 331-355. Elsevier, Amsterdam.

(6) Liu, J.K. (1984) Pollution studies on three Chinese lakes. Proceedings of Shiga Conference '84 on Conservation and Management of World Lake Environment, pp. 73-80. Shiga Prefectural Government, Otsu.

(7) Zhang, S., Liu, Q. & Huang, Y. (1984) The main sources of nitrogen and phosphorus in Lake Dong Hu, Wuhan. Oceanologia et Limnologia Sinica, 15(3) : 203-213.*

LAGUNA DE BAY (LAKE BAY)

Water-hyachinth (*Eichhornia crassipes*) and fishing boats

Photo: K. Ôya

A. LOCATION

§ Rizal and Laguna Provinces, Luzon, Philippines.
§ 14°02′-14°05′N, 121°0′ 121°05′E ; 1.8 m above sea level.

B. DESCRIPTION

Laguna de Bay (Lake Bay) is often erroneously called the "Laguna Lake". It is the largest lake in the Philippines. On the lake, there are an island, Talim, and two peninsulas jutting out a long way from the north coast. The lake is considered to have once been a branch of Manila Bay but later became separated from the bay by volcanic deposits and the upheaval of land. Water flows out from the northwestern end of the lake to Manila Bay. Since, the difference of water level between the lake and the sea is so small, the adverse tides occur frequently during the dry season from January to April.

Vast paddy fields, sugar cane fields and coconut plantations spread over the alluvial plain around the lake. Cash products like vegetables, fruits and poultry are also raised for consumption in neighboring big cities as Manila and Quezon City. The Laguna Lake Development Authority established in 1970 is mainly responsible for promoting development and conservation works in the lake and its drainage basin (Q1).

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	ca. 900
Volume [10^9m^3]	ca. 3.2
Maximum depth [m]	7.3
Mean depth [m]	2.8
Water level	Regulated
Length of shoreline [km]	ca. 220
Catchment area [km^2]	ca. 3,820

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (1)

§ Sketch map (Fig. ASI-13-1).
§ Outflowing rivers and channels (number and names) : 1 (Rasig R.).

D2 CLIMATIC (2)

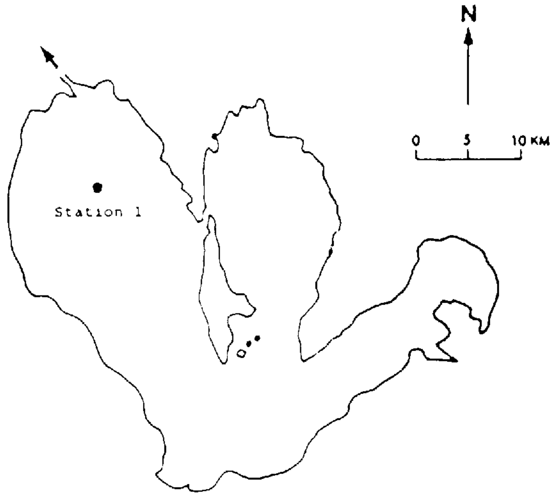
§ Climatic data at Manila

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C][1]	25.0	25.5	26.8	28.3	28.6	27.9	27.1	27.0	26.9	26.7	25.9	25.2	26.7
Precipitation [mm][2]	23	11	17	32	128	253	414	437	353	195	138	68	2,069

*1 61-year average. *2 30-year average.

§ Number of hours of bright sunshine (Manila, 1931-1960) : 2,103 hr yr^{-1}.
§ Solar radiation (Manila, 1986) : 22.5 MJ m^{-2} day^{-1}.

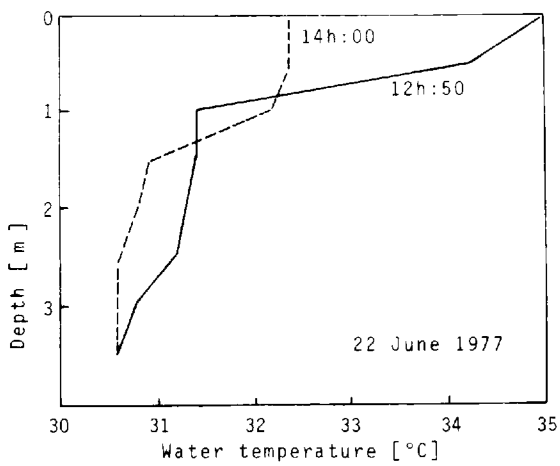
Fig. ASI-13-1 Sketch map of the lake (1).



§ Water temperature [°C] (3)
Station 1, 1976

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	24.6	24.6	26.5	28.2	30.3	28.6	30.6	29.2	30.0	30.2	28.4	25.6
2.0	24.4	25.0	26.3	28.1	29.6	28.3	30.2	28.9	29.0	29.8	28.3	25.4

Fig. ASI-13-2 Vertical distribution of water temperature (1).



§ Freezing period : None.
§ Mixing type : Polymictic.
§ Nots on water mixing and thermocline formation : As a shallow lake, it is normaly well-mixed and the thermocline formation is not seasonal but diurnal.

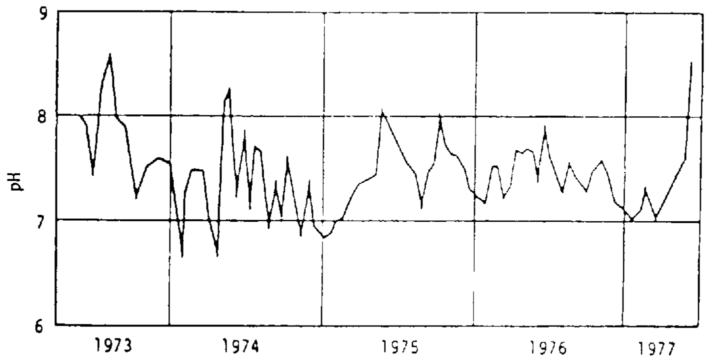
E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (1)
Station 1, 1976

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	0.2	0.1	0.2	0.6	0.3	–	0.6	0.7	0.5	0.5	0.3

E2 pH

Fig. ASI-13-3 pH (average for whole lake, 1973 1977) (1).



E4 DO [mg l^{-1}]

Fig. ASI-13-4 DO at 0.5m depth (average for whole lake) (1).

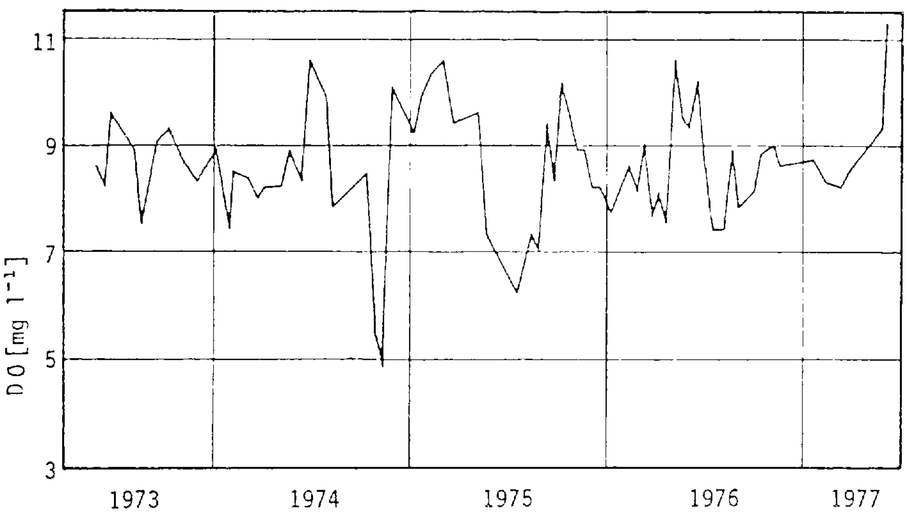
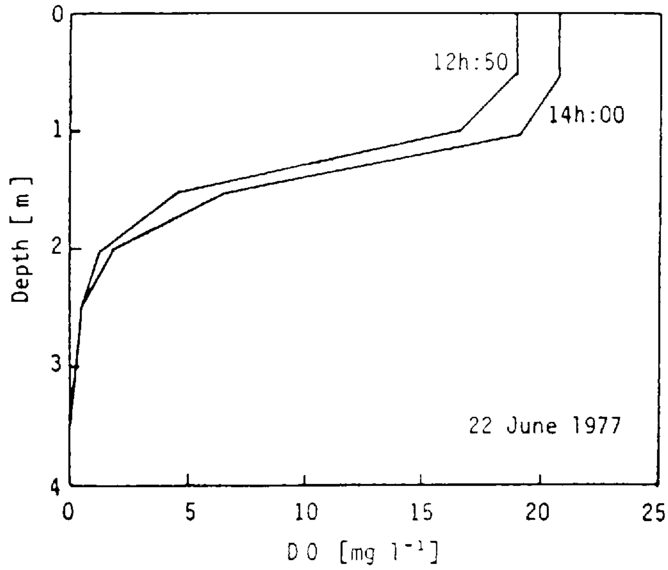


Fig. ASI-13-5 Vertical distribution of DO (1).



E5 COD [mg l^{-1}] (Q2)

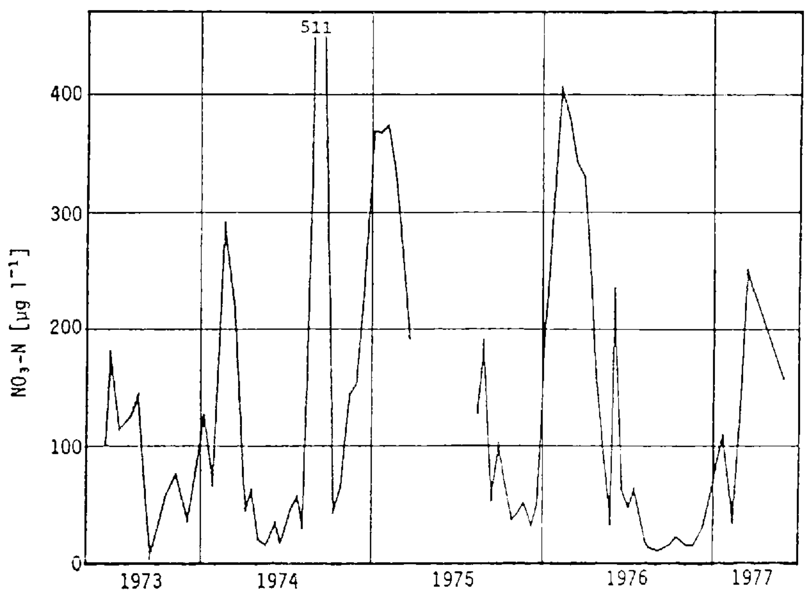
Determined by K_2CrO_4 method ; whole lake average, 1986.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.90	–	32.72	14.25	16.72	22.01	14.31	12.38	7.57	10.12	5.27	–

E7 NITROGEN CONCENTRATION

§ NO_3-N

Fig. ASI-13-6 NO_3-N (average for whole lake, 1973-1977) (1).



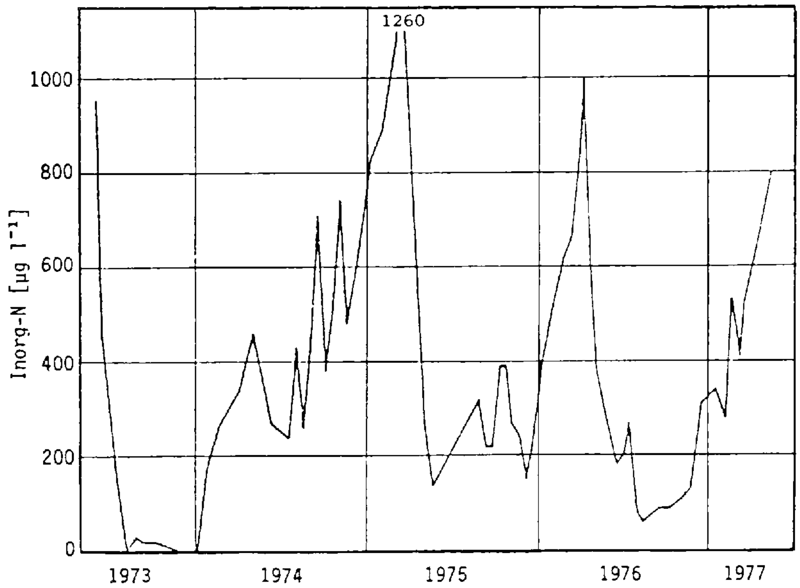
§ Total-N [mg l^{-1}], 1984 (Q2)

Jap	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	1.25	0.96	0.746	1.34	0.72	0.94	0.80	0.499	0.78	–

E8 PHOSPHORUS CONCENTRATION

§ Inorg-P [$\mu g\ l^{-1}$]

Fig. ASI-13-7 Inorg-P (average for whole lake, 1973-1977) (1).



E9 CHLORINE ION CONCENTRATION [mg l^{-1}], 1984 (Q2)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
—	—	50.76	44.27	75.40	164.66	88.07	85.86	82.77	11.91	76.71	—

F. BIOLOGICAL FEATURES (1)

F1 FLORA

§ Floating macrophytes : *Eichhornia crassipes.*

§ Submerged macrophytes : *Vallisneria gigantea, Najas graminea, Hydrilla verticillata.*

§ Phytoplankton : *Microcystis, Anabaena, Oscillatoria, Closterium, Scenedesmus, Melosira, Stephanodiscus.*

F2 FAUNA

§ Zooplankton : *Cyclops, Diaptomus, Lernaea cyprinacea, Bosmina, Diaphanosoma, Moina, Keratella, Brachionus, Filinia.*

§ Benthos : *Branchiura, Limnodrilus, Tubifex.*

§ Fish : *Therapon plumbeus, Glossogobius giurus, Chanos chanos, Megalops cyprinoides, Anabas testudeneus, Hemiramphus* sp., *Mugil* sp.

F3 PRIMARY PRODUCTION RATE

May-Sep., 1977 : 4.4-12.0 gC m^{-2} day^{-1}.

F4 BIOMASS

Fig. ASI-13-8 Phytoplankton biomass (average for whole lake, 1973-1977) (1).

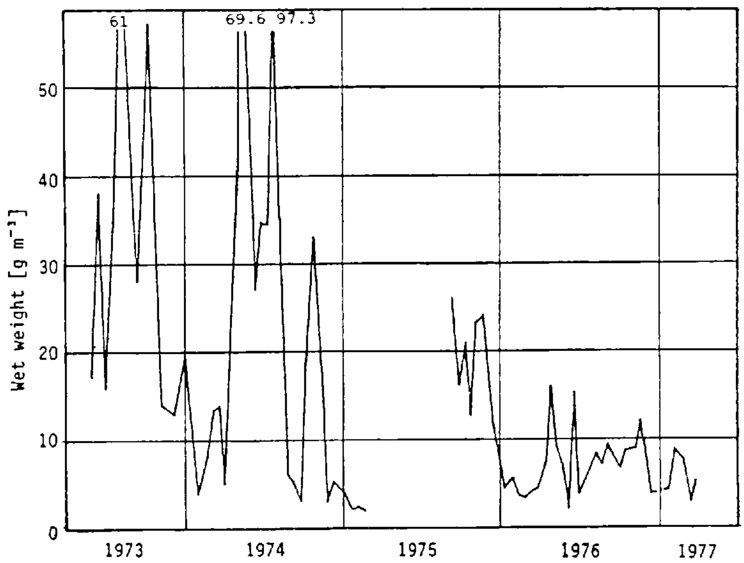


Fig. ASI-13-9 Population density of total zooplankton (average for whole lake, 1973 -1977) (1).

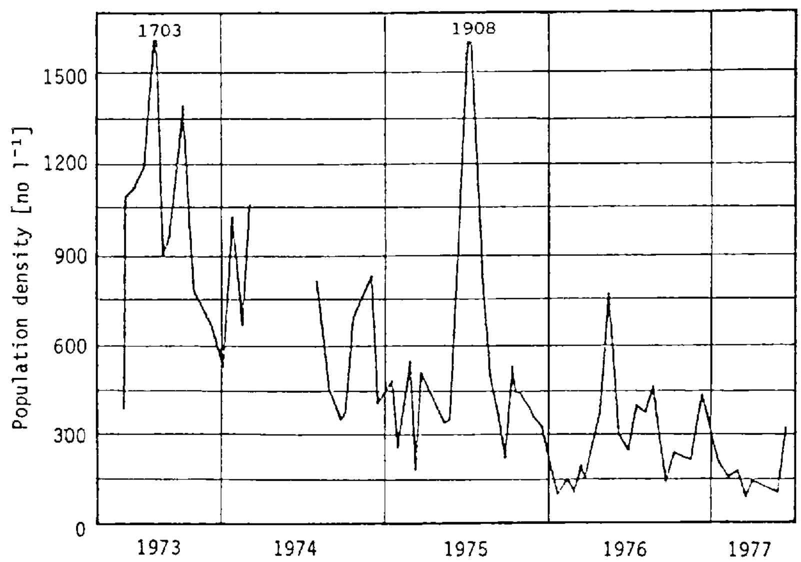
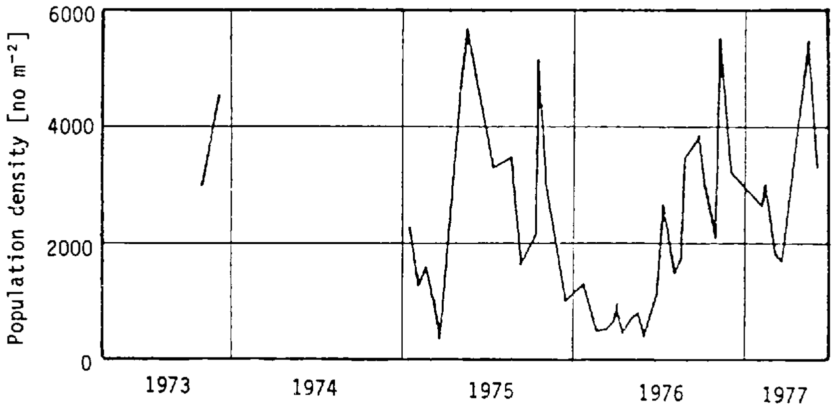


Fig. ASI-13-10 Population density of total benthos (average for whole lake, 1973-1977) (1).



F5 FISHERY PRODUCTS

§ Annual fish catch : 120,000 [metric tons] (Q1).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE (Q2)

Notable increase of *Tilapia* spp. Significant increase of pathogenic microorganisms along shoreline.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (Q1, Q2)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	908.6	23.8
Herbaceous vegetation	617.0	16.2
Swamp	25.3	0.7
Others	12.9	0.3
Agricultural land	1,984.6	52.0
Residential area	248.3	6.5
Total	3,796.7	99.4

§ Main kinds of crops : Rice, maize, sugarcane, other diversified crops and coconuts.
§ Levels of fertilizer application on crop fields : Moderate.
§ Trends of change in land use in recent years : Extensive urbanization especially on western side.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1975) (1, 4)

	Number of persons engaged	Main products
Primary industry		
Agriculture	109,065	Rice, maize, vegetable, fruits
Fisheries	32,828	Milkfish, white goby, therapon
Forestry	2,943	
Secondary industry		
Manufacturing	376,457	Textile, garment
Mining	5,612	
Tertiary industry	951,487	

G3 POPULATION IN THE CATCHMENT AREA (1980) (Q1)

Total population	Population density [km^{-2}]	Main cities (population)
2,381,300	712.7	San Pablo (99,000), Calamba, Los Baños

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q1)

Source of water, navigation and transportation, sightseeing and tourism, recreation (swimming and sport-fishing) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1977) (Q1)

	Use rate [m^3 sec^{-1}]
Industrial water	8.91
Power plant	46.30

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION : No information (Q2).

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual bloom of *Microcystis*.

§ Nitrogen and phoshorus loadings to the lake [t yr^{-1}], 1976 (5).

Sources	Industrial	Domestic	Agricultural	Livestock	Others	Total
T-N	190	1,400	772	1,132	448	3,942
T-P	40	197	172	453	80	942

§ Supplementary notes : Algal blooms in the 70's not as serious in the 80's, perhaps due to intensive aquaculture which harvests N and P from the lake (Q2).

I4 ACIDIFICATION

§ Extent of damage : Not serious (Q2).

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Severe pollution with no wastewater treatment plants in the immediate vicinity of the lake (Q2).

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF NUTRIENT LOADS (Q2)

	Percentage
Non-point sources	
Agricultural, natural and dispersed settlements	60
Point sources	
Municipal	25
Industrial	15
Total	100%

J3 SANITARY FACILITIES AND SEWERAGE (Q2)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : None.

§ Percentage of rural population with adequate sanitary facilities : None.

§ Municipal wastewater treatment systems

Number of tertiary treatment systems : None.

Number of secondary treatment systems : None.

Primary treatment systems : Individual septic tanks among upper and middle class households ; none for lower class housholds.

§ Number of industrial wastewater treatment systems : 40 140 (activated sludge, biogas works, sedimentation ponds, oxidation ponds).

K. IMPROVEMENT WORKS IN THE LAKE

Occasional cleaning of tributaries polluted by settlements.

L. DEVELOPMENT PLANS

Napindan Hydraulic Control Structure in operation since 1985 by MPWH. Manggahan Floodway 80% completed. MPWH Lake Zoning and Management Plan, ongoing implementation by LLDA.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

(1) National Pollution Control Decree, P. D. 984 (1976) ; National Pollution Control Commission

M2 INSTITUTIONAL MEASURES

(1) Laguna Lake Development Authority (1966, as amended by P. D. 813 in 1975), Univ. of Life Complex, Pasig, Metro Manila

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Institute of Chemistry, University of the Philippines at Los Baños (UPLB)
(2) Institute of Biological Sciences Limnological Research Station, UPLB
(3) SEAFDEC, Binangonan Station

N. SOURCES OF DATA

(Q1) Questionnaire filled by Dr. Teodoro B. Baquilat, Laguna Lake Development Authority, Manila.

(Q2) Questionnaire filled by Dr. Marlito Lanzona Cardinas, Institute of Chemistry, University of the Philippines at Los Baños.

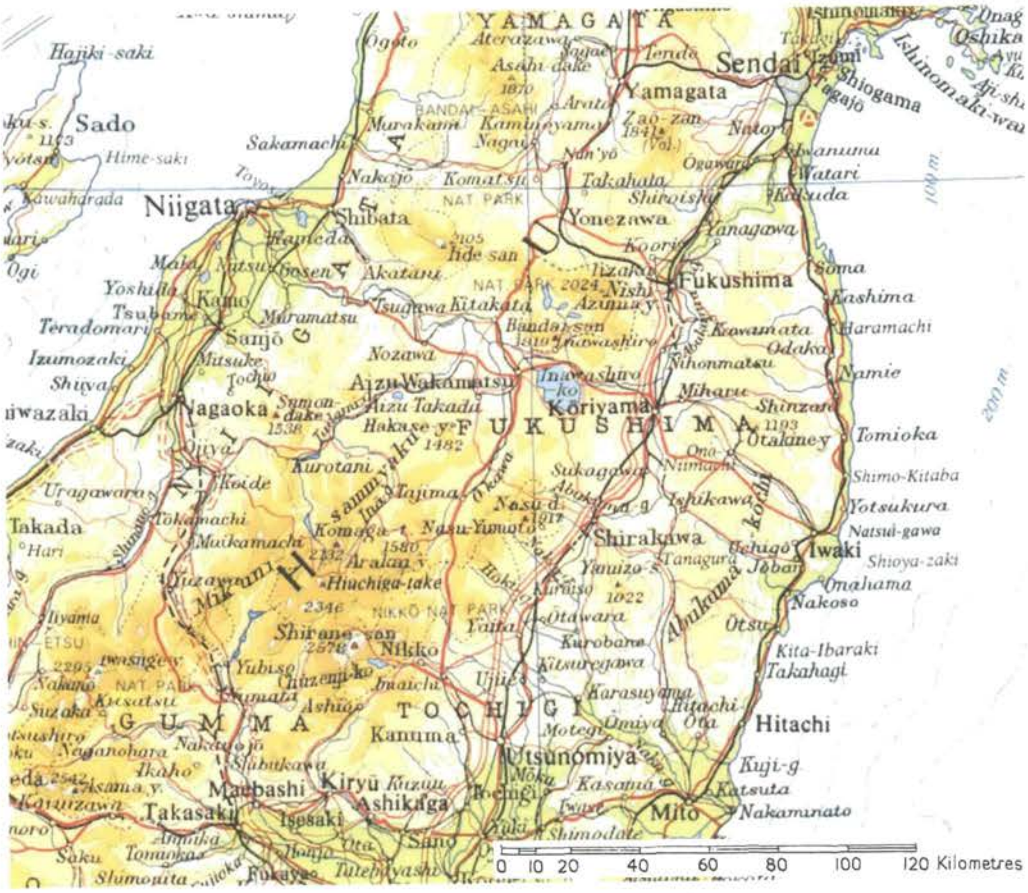
(1) World Health Organization & Laguna Lake Development Authority(1978) Final Report,

Comprehensive Water Quality Management Program Laguna de Bay, Vol. 1 (Summary Report). 231 pp. Laguna Lake Development Authority, Manila.
(2) Müller, M. J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306 pp. Dr. W. Junk Publishers, the Hague.
(3) World Health Organization & Laguna Lake Development Authority(1978) Final Report, Comprehensive Water Quality Management Program Laguna de Bay, Vol. 7(Limnology of Laguna de Bay), Appendix 2. 370 pp. Laguna Lake Development Authority, Manila.
(4) National Census and Statistics Office(1975) Integrated Census of the Population and its Economic Activities. Manila.
(5) Fernandez, A. L. (1981) Fundamental Study on Multiobjective Water Resources Planning. 238 pp. In partial fulfillment of the requirements for Master's degree in engineering, Osaka University, Osaka.
(6) Annual Report, College of Engineering and Agro-industrial Technology, Vol. 24(1982) Department of Agrometeorology, University of the Philippines at Los Baños, College Laguna.
(7) Annual Report, College of Arts and Sciences, Vol. 28(1986) Institute of Chemistry, Department of Analytical and Environmental Chemistry, University of the Philippines at Los Baños, College, Laguna.

INAWASHIRO-KO (LAKE INAWASHIRO)

A bird-eye view of the whole lake from the south

Photo: Fukushima Prefectural Government



A. LOCATION

§ Fukushima Prefecture, Japan.
§ 37°28′N, 140°06′E ; 514 m above sea level.

B. DESCRIPTION

Lake Inawashiro was formed some 30,000 years ago in a tectonic depression due to the eruption of Mt. Bandai and other volcanoes which dammed rivers by mud flows and topographic changes. It is considered that the original water level of the lake has since been lowered considerably owing to the erosion by the outflowing river, R. Nippashi.

The lake water has been used from ancient times for irrigating rice paddies in the Aizu Basin. An irrigation channel was completed in the 17th century during the Edo period. In 1882, another channel from the lake to the Kôriyama Basin was completed to give rise to about 300 km^2 of newly reclaimed rice fields. One additional channel was constructed in 1915, parallel with the old, to supply the city of Kôriyama with water for drinking and industrial use. Since the lake surface is higher than the land surface of the two basins by about 300 m, many hydroelectric power plants have been made along the outflowing river and channels, the electricity being supplied to the Tôkyo area.

The lake water is slightly acidic, with a pH value of approximately 5.0, owing to the inflow of acidic water containing sulfuric acid, derived from hot springs and sulfur mines in the drainage basin. Transparency was recorded to be 20 m or more in the early 1930's, but recent measurements revealed its diminishing trend. However, the decrease of transparency is not likely to be caused by the increase in photosynthetic production, since the concentration of chlorophyll-a has maintained a low level around 1 mg m^{-3} (1).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	104.8
Volume [10^9m^3]	3.86
Maximum depth [m]	94.6
Mean depth [m]	37
Normal range of annual water level fluctuation (regulated) [m]	1.06
Length of shoreline [km]	55.3
Residence time [yr]	3.8
Catchment area [km^2]	711

D. PHYSIOGRAPHIC FEATURES(Q)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-14-1).
§ Main islands (name and area): Okina jima (0.07 km^2).
§ Outflowing rivers and channels (number and names): 3 (Nippashi R., Asaka Canal and New Asaka Canal).

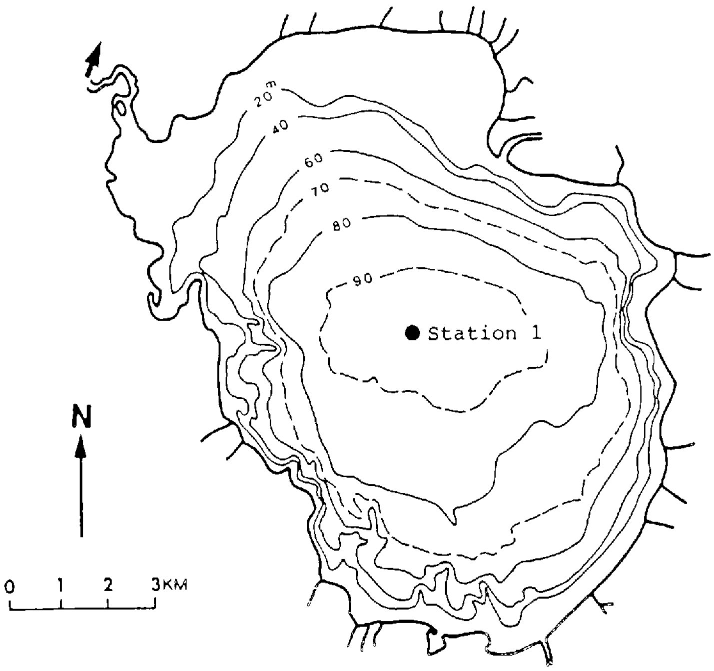
D2 CLIMATIC

§ Climatic data at Inawashiro, 1979-1983

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	−2.4	−2.4	0.8	7.3	13.0	17.3	19.9	21.4	16.9	11.2	5.5	0.5	9.1
Precipitation [mm]	73	77	77	102	106	106	254	150	109	110	97	81	1,404

§ Number of hours of bright sunshine (Inawashiro, 1979-1983): 1974.9 hr yr^{-1}.

Fig. ASI-14-1 Bathymetric map (2).



§ Water temperature [°C]
Station 1, 1985

Depth [m]	May	Jun	Jul	Aug	Sep	Oct	Nov
Surface (0.5)	11.7	12.7	16.7	27.6	24.8	17.6	11.5
10	7.1	12.4	17.0	21.2	24.1	17.4	11.4
20	6.9	11.9	11.5	12.1	13.6	13.7	11.3
50	5.2	6.8	6.9	6.5	6.8	6.5	6.7

§ Freezing period: Not freezing.
§ Mixing type: Monomictic.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Station 1, 1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	7.0	7.8	5.3	10.0	10.5	8.0	8.0	–

E2 pH, Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5		–	–	–	4.9	4.9	4.8	4.8	4.7	4.9	5.0	
10	–	–	–	–	5.0	4.9	4.8	4.8	4.7	4.9	5.0	–
20	–	–	–	–	5.0	4.9	4.9	4.9	4.8	5.0	5.1	–
50	–		–	–	5.0	5.0	5.0	4.9	4.8	5.0	5.2	

E3 SS [mg l^{-1}], Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–		–	<1	<1	<1	<1	<1	<1	1	–
10	–	–	–	–	<1	<1	<1	<1	<1	<1	1	–
20	–	–	–	–	<1	<1	1	<1	<1	<1	1	–
50	–	–	–	–	<1	<1	<1	<1	<1	<1	<1	–

E4 DO [mg l^{-1}], Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	–	10	10	9.5	8.7	8.5	10	9.8	–
10	–	–	–	–	11	10	9.9	9.2	8.8	10	9.9	–
20	–	–	–	–	11	11	11	11	11	11	9.9	–
50	–	–	–	–	11	11	11	11	11	11	11	–

E5 COD [mg l^{-1}], Station 1, 1985

Determined by $KMnO_4$ method

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	–	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	–
10			–	–	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	–
20	–	–	–	–	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	–
50	–	–	–	–	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	–

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}], Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	–	<1	<1	<1	3.0	2.0	1.0	–	–

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}], Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—			0.26	0.31	0.38	0.29	0.26	0.27	—	—
10		—	—	—	0.28	0.30	0.35	0.31	0.23	0.26	—	—
20	—	—	—	—	0.26	0.28	0.41	0.33	0.24	0.27	—	—
50	—	—	—	—	0.25	0.27	0.38	0.28	0.30	0.33	—	—

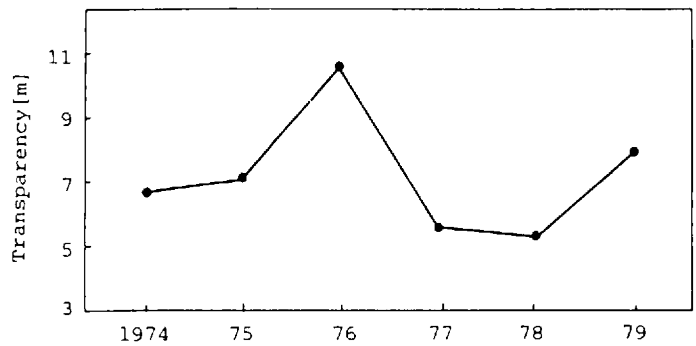
E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	—	—	—	—	—	—	<0.003	<0.003	0.005	<0.003	—	—
10	—	—	—		—	—	<0.003	<0.003	0.005	<0.003	—	—
20	—	—	—	—	—	—	<0.003	<0.003	0.005	<0.003		—
50	—	—	—	—	—	—	<0.003	<0.003	0.005	<0.003	—	—

E9 PAST TRENDS

Fig. ASI-14-2 Trend of transparency at the lake center (3).



F. BIOLOGICAL FEATURES

F1 FLORA (Q)

§ Emerged macrophytes : *Phragmites communis, Zizania latifolia, Scirpus lacustris, S. mucronatus.*
§ Floating macrophytes : *Nuphar japonicum, Nymphoides peltata, Trapa incisa, Brasenia schreberi.*
§ Submerged macrophytes : *Potamogeton perfoliatus, Hydrilla verticillata, Myriophyllum verticillatum.*
§ Phytoplankton : *Surirella robusta, Synedra ulna, Hormidium subtile.*

F2 FAUNA

§ Zooplankton : *Bosmina longirostris, Ploesoma truncatus, Lecane* sp., *Cyclops* sp. (4).
§ Benthos : *Chironomus plumosus, Ch. bathophilus, Limnodrilus* sp. (4).
§ Fish : *Carassius gibelio, Leuciscus hakonensis, Salvelinus leucomaenis* (5).

F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in 1985 : 56 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA

	Area [km²]	[%]
Natural landscape		
Woody vegetation	620.0	87.2
Agricultural land		
Crop field	69.8	9.8
Others	21.0	3.0
Total	710.8	100.0

§ Main types of woody vegetation : Deciduous broadleaf forest (*Fagus crenata*, *Quercus mongolica* var. *grosseserrata*, *Q. serrata*) ; subalpine conifer forest (*Abies mariesii*, *Tsuga diversifolia*) ; pine forest (*Pinus densiflora*) ; conifer plantation (*Cryptomeria japonica*, *Pinus densiflora*, *Larix kaempferi*) (6).

§ Main types of herbaceous vegetation : Glassland and dwarf bamboo community (6).

§ Main kinds of crops : Rice and vegetables (Q).

§ Levels of fertilizer application on crop fields : Moderate.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1983) (Q)

§ Numbers of domestic animals in the catchment area : Cattle 2,829 and swine 565.

G3 POPULATION IN THE CATCHMENT AREA (1983) (Q)

Total population	Population density [km⁻²]
30,332	42.7

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (number of visitors in 1983 : 2.285×10^6), recreation (swimming, sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1983) (Q)

	Use rate [m³ day⁻¹]
Domestic water	112,896
Irrigation	1,471,997
Industrial water	
Power plant	5,832,000

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : None.

I2 TOXIC CONTAMINATION (Q)

§ Present status : No information.

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication : Not any nuisance.

§ Phosphorus loadings to the lake [kg day^{-1}], 1983

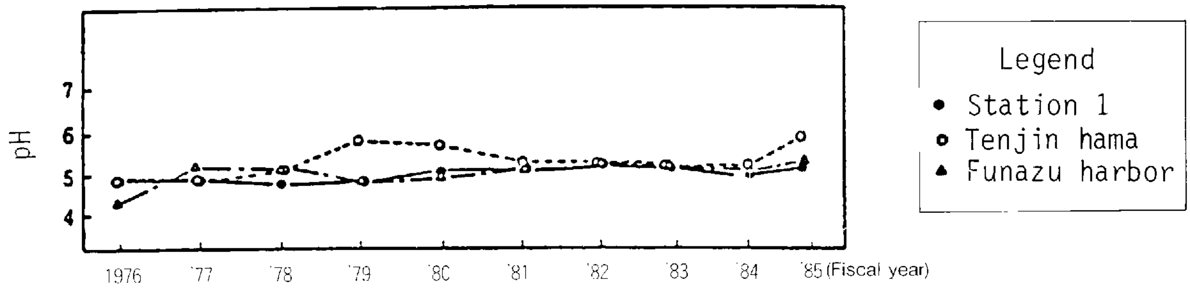
Sources	Industrial	Domestic	Agricultural and natural	Total
T-P	0.441	1.714	3.735	5.89

I4 ACIDIFICATION (Q)

§ Extent of damage : None.

§ Past trends

Fig. ASI-13-3 Past trend of pH (Q).



J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	Percentage
Non-point sources (agricultural, natural and dispersed settlements)	92.5
Point sources	
Industrial	7.5
Total	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment system) or public sewerage : 9.3 %.

N. SOURCES OF DATA

(Q) Questionnaire filled by the Prefectural Government of Fukushima.

(1) Horie, S. (1953) A study of the lacustrine terraces of Lake Inawashiro. Geogr. Rev. Jap., 26 : 550-562 (in Japanese).

(2) Japan Map Center (ed.) (1982) Collection of Maps on Japanese Lakes (Technical Data of National Geographical Institute, D•1-No. 221). National Geographical Institute, Tsukuba (in Japanese).

(3) Fukushima Prefectural Government (1979) Report of Lake Survey. 208pp. Fukushima (in Japanese).

(4) Research Group of Fukushima University (1980) Study on Nature of Lake Inawashiro, No. 1. Fukushima (in Japanese).

(5) Inlandwater Fisheries Experiment Station of Fukushima Prefectural Government (1979)

Research Report from Inlandwater Fisheries Experiment Station of Fukushima Prefectural Government, 3 (in Japanese).
(6) Environment Agency (1981) The 2nd National Survey on the Natural Environment (Vegetation), Actual Vegetation Map, Fukushima. Japan Wildlife Research Center, Tokyo (in Japanese).

TASEK BERA (SWAMP LAKE TASEK BERA)

On an open water near Pos Iskander

Photo: T. Kira

A. LOCATION

§ Pahang State, Peninsular Malaysia.
§ 3°05′N, 102°38′E ; >30 m above sea level.

B. DESCRIPTION

Tasek Bera is an alluvial blackwater swamp lake located in the southern part of Malay Peninsula at uppermost reach of the southern branch of River Pahang. It occupies an area of about 25 km × 35 km on the forest-covered peneplain that stretches over the low east-west watershed of the peninsula. A narrow channel drains its water northward to River Pahang and eventually eastward into South China Sea.

The lake is a complex dendritic system consisting of extensive swamp forests that account for nearly two-thirds of its area, littoral swamps overgrown by *Pandanus* shrub or sedges (mostly *Lepironia*), network of flowing channels and scattered small open waters. The open water area constitutes less than 1.5 % of the whole system. The water is poor in calcium and magnesium contents, and is acidic and brown-colored due to dissolved humic substances. The decomposition of plant detritus is thus remarkably inhibited resulting in the accumulation of peat several meters thick on the lake bottom. The vigorous growth of insectivorous *Utricularia* in open waters and the occurrence of the other insectivores, *Nepenthes* spp., along the lake shore suggest oligotrophic nature of the habitats. However, the nitrogen and phosphorus contents of lake water and the biological productivity are not very low.

The catchment area has been inhabited for centuries by a Malayan aboriginal tribe, Semalai. Their subsistence depended on the shifting cultivation of upland rice and cassava, fishery in the lake and gathering forest and swamp products. The slash-and-burn agriculture has turned an extensive area of original vegetation of mixed rain forest into low secondary forest in the northern half of the catchment. In recent years, they were given a chance to go beyond their traditional subsistence economy by growing rubber trees and wetland rice, which may gradually affect the lake environment.

An integrated ecosystem research on Tasek Bera was carried out during 1970–1974 at Pos (Fort) Iskander, within the framework of the International Biological Program by the Joint Malaysian-Japanese Team of 19 scientists. The program contributed much to the knowledge of the swamp ecosystem of this type, which once widely occurred throughout the lowlands of equatorial Southeast Asia but has almost disappeared. As its valuable relics that escaped exploitation, it is desirable to preserve the peculiar biota and natural physiognomy of Tasek Bera as a nature reserve (Editor).

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	61.5
Maximum depth [m]	7
Mean depth [m]	2 2.5
Normal range of annual water level fluctuation (unregulated) [m]	1 5
Catchment area [km^2]	ca. 550

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. ASI-15-1).

§ Outflowing rivers and channels (number and names): 1 (Sungai (River) Bera).

D2 CLIMATIC (1, 2)

§ Climatic data at Pos Iskander, 1971 (temperature; average of several readings during daytime on a few days per month); 1970-1972 (precipitation).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	24.6	26.2	27.1	26.4	27.5	27.4	27.4	25.8	25.3	28.3	24.0	23.9	26.2
Precipitation [mm]	—	—	—	—	—	—	—	—	—	—	—	—	2,522

§ Seasonal distribution of rainfall (1970) (Fig. ASI-15-2).

§ Solar radiation (Pos Iskander, Jun. 1972-Mar. 1973): 13.6: MJ $m^{-2}day^{-1}$ (1).

Fig. ASI-15-1 Map of the lake and catchment area (1).

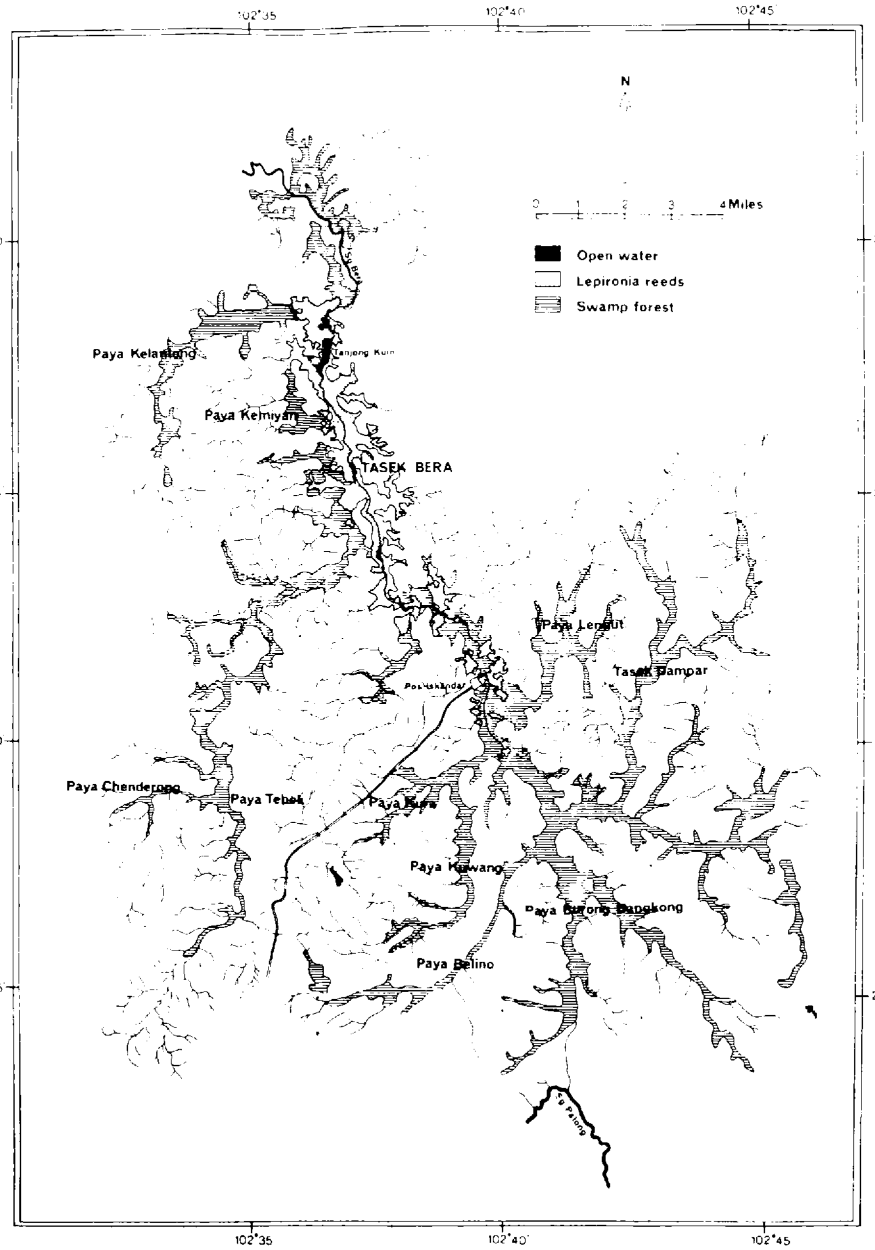
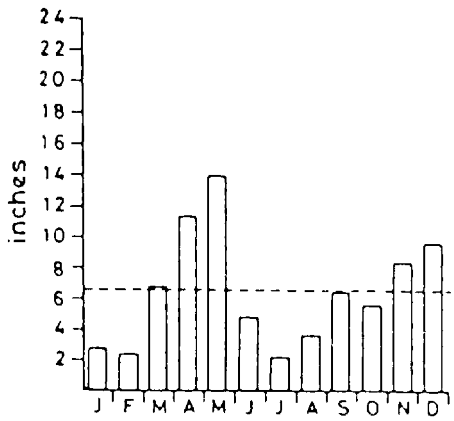


Fig. ASI-15-2 Seasonal distribution of rainfall at Dunlop Estate (Bahau, Negeri Sembilan Province, ca. 20km to the southwest of Pos Iskander) in 1970 (1).



§ Water temperature [°C] (2)

Pos Iskander (open water), 1971

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface (0)	23.9	24.5	25.5	26.7	25.9	25.9	26.6	26.6	25.7	26.3	25.8	24.1
1	23.8	24.4	25.3	26.0	25.7	25.7	25.8	25.5	25.2	26.3	25.1	24.1
2	23.7	24.4	25.3	25.9	25.7	25.6	25.6	25.3	25.5	26.2	25.0	24.1
3	23.7	24.3	25.2	—	—		—	—	—	—	25.0	24.1
4.5 (bottom)	23.6	—		—	—	—	—	—		—	—	—

§ Freezing period : None.

§ Mixing type : Polymictic.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Pos Iskander (open water), 1971 (2)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.2	1.5	1.6	1.7	2.0	1.9	2.1	1.8	2.7	2.5	2.2	2.1

E2 pH, Pos Iskander (open water), 1971 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	4.8	4.9	4.7	5.0	4.9	5.0	5.1	5.0	4.7	4.8	4.8	4.8
1	—	4.9	4.7	5.0	4.8	5.0	5.1	5.1	4.8	4.9	4.9	4.8
2		4.9	4.7	5.0	4.8	5.0	5.1	5.0	4.8	4.9	4.8	4.8
3	—	4.9	4.8	—	—	—	—			—	4.8	4.8

E4 DO [mg l^{-1}], Pos Iskander (open water), 1971 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.36	1.46	1.41	1.31	1.49	2.21	2.58	2.96	2.29	2.70	2.61	1.80
1	1.10	1.50	1.52	1.31	1.83	2.04	2.41	2.68	2.48	2.02	2.23	1.75
2	1.08	1.45	1.64	1.22	1.88	1.81	2.16	2.41	2.26	2.11	2.07	1.62
3	1.03	0.93	1.46	—	—	—			—	—	2.41	1.78
4.5	0.95	—	—	—	—	—		—	—	—	—	—

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$], Sep.- Oct., 1973

Average and range for open and forest-covered waters: 1.32 (0.70-1.94).

E7 NITROGEN CONCENTRATION

Pos Iskander (open water), 1970 1972 [$mg\ l^{-1}$] (1)

Average (range)	Total-N : 1.12 (0.50-2.38)
〃	NO_3-N : 0.11 (0.02-0.29)
〃	NO_2-N : 0.008(0.000-0.059)
〃	NH_4-N : 0.33 (0.00-0.77)
〃	Organic N : 0.58 (0.06-1.53)

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [$g\ l^{-1}$], Pos Iskander (open water), 1970-1972 (1)

Average (range): 0.021 (0.00-0.065). Nearly depleted in summer and fall. The ratio of reactive to unreactive phosphorus: 1/21 on an average.

F. BIOLOGICAL FEATURES (1)

F1 FLORA

§ Emerged macrophytes: *Pandanus helicopus, Lepironia articulata, Eleocharis ochrostachys.*

§ Floating macrophytes: *Nymphoides indica.*

§ Submerged macrophytes: *Utricularia flexuosa, Cryptocoryne griffithii.*

§ Epiphytic algae: Diatoms (*Frustulia rhomboides* var. *saxonica, Eunotia naegelii*); green algae (*Bulbochaete praereticulata, Closterium* spp., *Xanthidium* spp., *Staurastrum* spp., *Desmidium* spp.); blue-green algae (*Stigonema panniforme, Hapalosiphon stuhlmanni*).

§ Phytoplankton: Diatoms (*Tabellaria fenestrata, Eunotia gracilis, E. lunaris, E. robusta, Frustulia rhomboides, Pinnularia major*); desmids (*Cosmarium moniliforme, Closterium dianae, C. gracile, C. libellula, Hyalotheca dissiliens, H. undulata, Micrasterias foliacea*).

F2 FAUNA

§ Zooplankton: Cladocera (*Alona affinis, A. guttata, Chydorus* spp., *Macrothrix spinosa*); Rotifera (*Euchlanis dilatata, Colurella colurus, Keratella cochlearis*); Protozoa (*Euglypha brachiata, Difflugia* spp., *Arcella* spp., *Centropyxis aculeata*).

§ Benthos: (In *Utricularia* community) chironomids, Cladocera, Ostracoda, Ephemeroptera, *Macrobrachium trompi, Caridina thambipillai*; (Bottom) larvae of Diptera (chironomids), Ephemeroptera, Trichoptera and Odonata; Custacea (Decapoda), Oligochaeta, Nematoda.

§ Fish (relatively abundant near Pos Iskander): *Notopterus notopterus, Oxygaster oxygastroides, Rasbora dorsicellata, Cyclocheilichthys apogon, Puntius tetrazona, P. fasciatus, Kryptopterus bicirrhis, Pristolepis fasciatus, Nandus nebulosus, Betta pugnax, Labiobarbus faestiva, Tor clouremis, Botia hymenophysa, Kryptopterus limpok.*

§ Supplementary notes on the biota: The great abundance and diversity of desmids, which includes several taxa endemic to Tasek Bera, is a striking feature of the algal flora of the lake. Ninety-five species of fish have so far been recorded from Tasek Bera. Almost all the species seem to be indigenous to Peninsular Malaysia.

F3 PRIMARY PRODUCTION RATE (1)

§ Phytoplankton production, Pos Iskander, 1973

	Open water (still)	Flowing channel
Net production [mgC $l^{-1}day^{-1}$]	0.02-0.07	0.01
Dark respiration [mgO_2 $l^{-1}day^{-1}$]	0.08-0.75	0.12-0.64
Gross production [mgC $l^{-1}day^{-1}$]	0.07-0.25	0.19

§ Submerged macrophyte production [g (dry wt.) $m^{-2}day^{-1}$]
Net production rate : *Utricularia flexuosa* 12 ; *Cryptocoryne griffithii* 5.

§ Emerged macrophyte production (*Lepironia articulata*) [g (dry wt.) $m^{-2}day^{-1}$]
Net production rate 2.24 ; dark respiration rate 2.65 ; gross production rate 4.89.

F4 BIOMASS (1)

Average biomass	Open water	*Utricularia* mat	*Lepironia* zone	Swamp forest
Phytoplankton [cell no. l^{-1}]	198	440	–	124
Utricularia flexuosa [g (wet wt.) m^{-2}]		105	–	–
Cryptocoryne griffithii [g (dry wt.) m^{-2}]	0.9	–	–	19.9
Lepironia articulata [〃]	–	–	477	–
Shrimp (*Macrobrachium* & *Caridina*) [g (dry wt.) m^{-2}]	–	1.5	–	–

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE WHOLE CATCHMENT AREA (1970's) (1)

	Area [km^2]	[%]
Natural landscape		
Upland forest vegetation	ca. 550	90
Swamp	61	10
Open water	0.75	0.1
Others	–	
Total	614	100

§ Main types of upland forest : Lowland rain forest (mixed *Shorea-Dipterocarpus* forest), secondary forest (produced by shifting cultivation and logging).

§ Main types of swamp vegetation : Tall swamp forest (*Eugenia, Elaeocarpus, Alstonia,* etc.), *Pandanus helicopus* thicket, reed (*Lepironia articulata*) swamp.

§ Main kinds of crops and cropping systems : Shifting cultivation (upland rice, cassava, etc.), rubber plantation.

§ Levels of fertilizer application on crop fields : None.

§ Trends of change in land use : Beside the traditional shifting cultivation by native inhabitants, rubber plantation and wet paddy cultivation were recently introduced on a small scale. The watershed forests have been cut for commercial timber since 1975, mostly from near the swamp.

G3 POPULATION IN THE CATCHMENT AREA (1970's) (1)

	Population*	Population density [km^{-2}]	Main cities
Urban	—	—	None
Rural	ca. 700	—	
Total	ca. 700	1.3	

* The population consists of aborigines (Semalai) living on shifting cultivation, collecting natural products and fishery. A small number of domestic animals (goats and poultry) are also raised.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION
Fisheries and navigation.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION
§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION
§ Present status : No information.

I4 ACIDIFICATION
§ Extent of damage : No information.

J. WASTEWATER TREATMENT

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (a) Pristine lake environments.

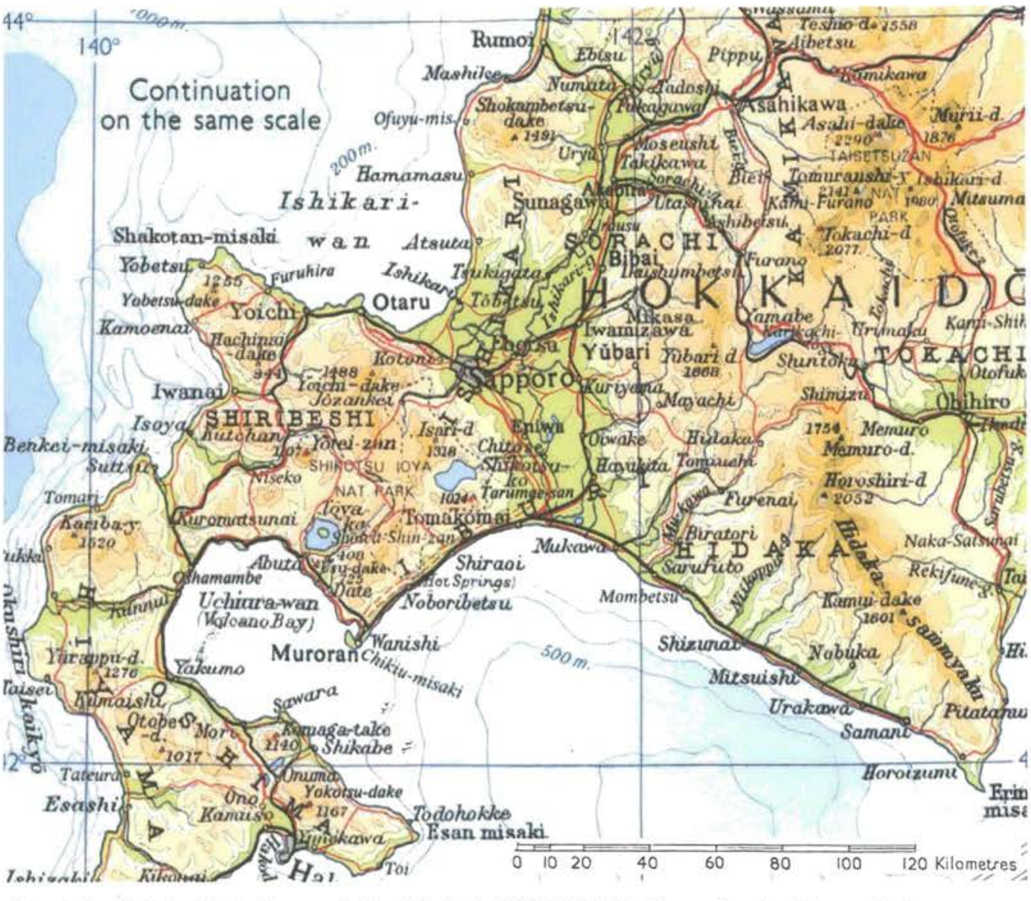
N. SOURCES OF DATA

(1) Furtado, J. I. & Mori, S. (ed.) (1982) Tasek Bera — the Ecology of a Freshwater Swamp. Dr. W. Junk Publishers, The Hague-Boston-London.
(2) The Malaysian IBP (PF) Subcommittee (1972) Data on Malaysian-Japanese IBP (PF) Research at Tasek Bera, Malaysia. No. 1. Kuala Lumpur (Mimeograph).

SHIKOTSU-KO (LAKE SHIKOTSU)

Looking southward across the lake

Photo: Hokkaidō Prefectural Government



A. LOCATION

§ Hokkaidô, Japan.
§ 42°45′N, 141°17′E ; 248.0 m above sea level.

B. DESCRIPTION

Lake Shikotsu is a typical crater lake situated in the western part of the island of Hokkaidô. The lake was created approximately 32,000 years ago, originally in a circular shape with a diameter of 12 km. Its present shape was achieved by the activity of surrounding volcanoes such as Mt. Eniwa, Mt. Fuppushi and Mt. Tarumai. The lake has a mean water depth of 266 m and the water volume (21 km^3) is so large for its surface area that it rarely freezes in winter, despite an average temperature of −5°C. Thus L. Shikotsu and neighboring L. Tôya represent the northern boundary of distribution of non-freezing lakes in Japan.

The lake is typically oligotrophic. A transparency value of 25 m was recorded in 1926. From 1927 to 1929, a large amounts of nitrogen and phosphorus were introduced into the lake to help the breeding of kokanee salmon (*Oncorhynchus nerka*) transplanted from L. Akan. Between 1973 and 1979, however, the maximum and average transparency still amounted to 38.5 m and 20 m, respectively, indicating that the water quality has been fairly stable during the past 50 years.

In the Winter Olympic Games of 1972, a downhill race was held on Mt. Eniwa and the road system from the city of Sapporo was well improved. With the subsequent completion of lakeside roads, people now enjoy recreation, camping and field sports in the magnificent natural environs of Shikotsu-Tôya National Park.

C. PHYSICAL DIMENSIONS (Q)

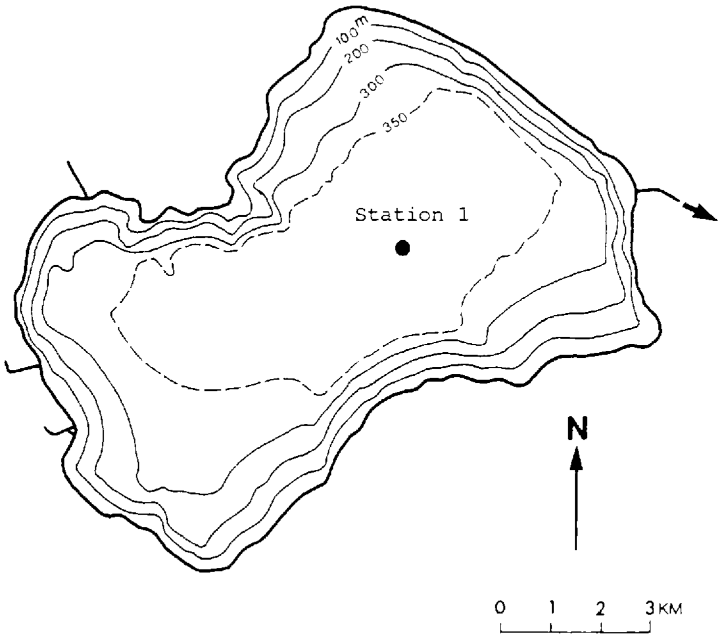
Surface area [km^2]	78.8
Volume [10^9 m^3]	20.95
Maximum depth [m]	360.1
Mean depth [m]	266.0
Length of shore line [km]	40.3
Residence time [yr]	51.2
Catchment area [km^2]	223

D. PHYSIOGRPHIC FEATURES

D1 GEOGAPHICAL (Q)

§ Bathymetric map (Fig. ASI-16-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Chitose R.).

Fig. ASI-16-1 Bathymetric map (1).



D2 CLIMATIC

§ Climatic Data at Tomakomai (alt. 6 m), 1973-1982 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-5.0	-5.3	-1.7	3.8	9.7	14.2	18.6	19.6	15.6	9.8	2.7	2.3	6.6
Precipitation [mm]	98	76	144	128	103	145	131	299	215	260	145	92	1,767

§ Number of hours of bright sunshine (Tomakomai, 1973-1982) : 1,982 hr yr^{-1}.
§ Water temperature [°C] (Q)
Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	5.5	12.0	–	20.1	–	12.4	7.7	5.8
20	–	–	–	–	5.0	9.3	–	10.0	–	12.4	7.8	5.1

§ Freezing period : Not freezing.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], Station 1, 1981-1983 (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	15.5	17.8	–	21.3	–	12.8	19.8	21.3

E2 pH, Station 1, 1981-1983 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	7.5	7.6	–	7.6	–	7.6	7.4	7.3
20	–	–	–	–	7.5	7.5		7.6	–	7.6	7.3	7.3

E3 SS [mg l^{-1}], Station 1, 1981-1983 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	1	1	–	1	–	< 1	< 1	< 1
20	–	–	–	–	1	< 1	–	1	–	< 1	< 1	< 1

E4 DO [mg l^{-1}], Station 1, 1981-1983 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	12	11	–	8.6	–	9.8	10	12
20	–	–	–	–	11	11		11	–	10	10	11

E5 COD [mg l^{-1}], Station 1, 1981-1983 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	0.5	0.6	–	0.6		0.9	0.6	0.6
20	–	–	–	–	0.5	0.7	–	0.7	–	0.9	0.6	0.7

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}], Station 1, 1981-1983 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	<0.05	<0.05	–	<0.05	–	<0.05	<0.05	<0.05

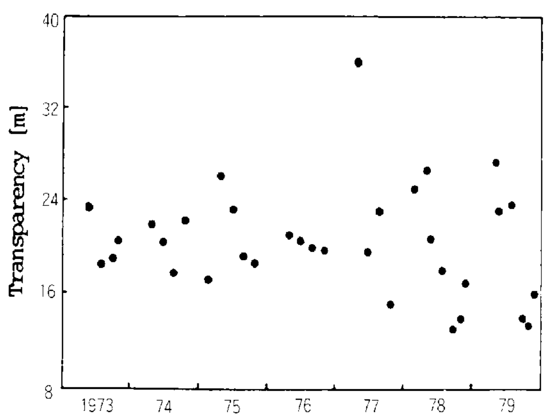
E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], Station 1, 1981-1983 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	<0.005	<0.005	–	<0.005	–	<0.005	<0.005	<0.005

E9 PAST TRENDS

Fig. ASI-16-2 Trend of transparency (3).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Phytoplankton : *Cyclotella* spp., *Sphaerocystis schroeteri.*

F2 FAUNA

§ Zooplankton : *Acanthodiaptomus pacificus, Daphnia longispina.*
§ Benthos : Ephemeridae spp., Chironomidae spp., Phryganeidae spp.
§ Fish : *Salvelinus leucomaenis, Oncorhynchus nerka, Cottus nozawae.*

F5 FISHERY PRODUCTS

§ Annual fish catch in 1983 : 36, 575 individuals yr^{-1}.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (Q)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	221.1	99.3
Others	1.6	0.7
Total	222.7	100.0

§ Main types of woody vegetation : Deciduous broadleaf forest (*Betula ermanii, Quercus mongolica* var. *grosseserrata, Acer mono, Tilia japonica*) ; evergreen conifer forest (*Picea jezoensis, Abies sachalinensis*) ; mixed evergreen conifer/deciduous broadleaf forest ; scrub (*Quercus mongolica* var. *undulatifolia*) ; evergreen conifer plantation (*Picea jezoensis, Abies sachalinensis*) (4).
§ Levels of fertilizer application on crop fields : No information.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1981) (Q)

	Gross product [yen]	No. of establishments	Main products and main kinds of industry
Primary industry			
Fisheries	N.A.	N.A.	Kokanee salmon, rainbow trout
Secondary industry			
Mining	3.4×10^6	N.A.	Gold, silver
Tertiary industry	N.A.	44	Hotels, souvenir shops

G3 POPULATION IN THE CATCHMENT AREA (1982) (Q)

	Population	Population density [km^{-2}]	Main cities
Total	340	1.53	None

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Sightseeing and tourism, recreation (sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE (Q)

The lake is not used as water source.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION : No information.

I2 TOXIC CONTAMINATION : No information.

I3 EUTROPHICATION : No information.

I4 ACIDIFICATION : No information.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGES

§ Municipal wastewater treatment systems

Number of secondary treatment systems : 1.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

For national laws see "Biwa-ko".

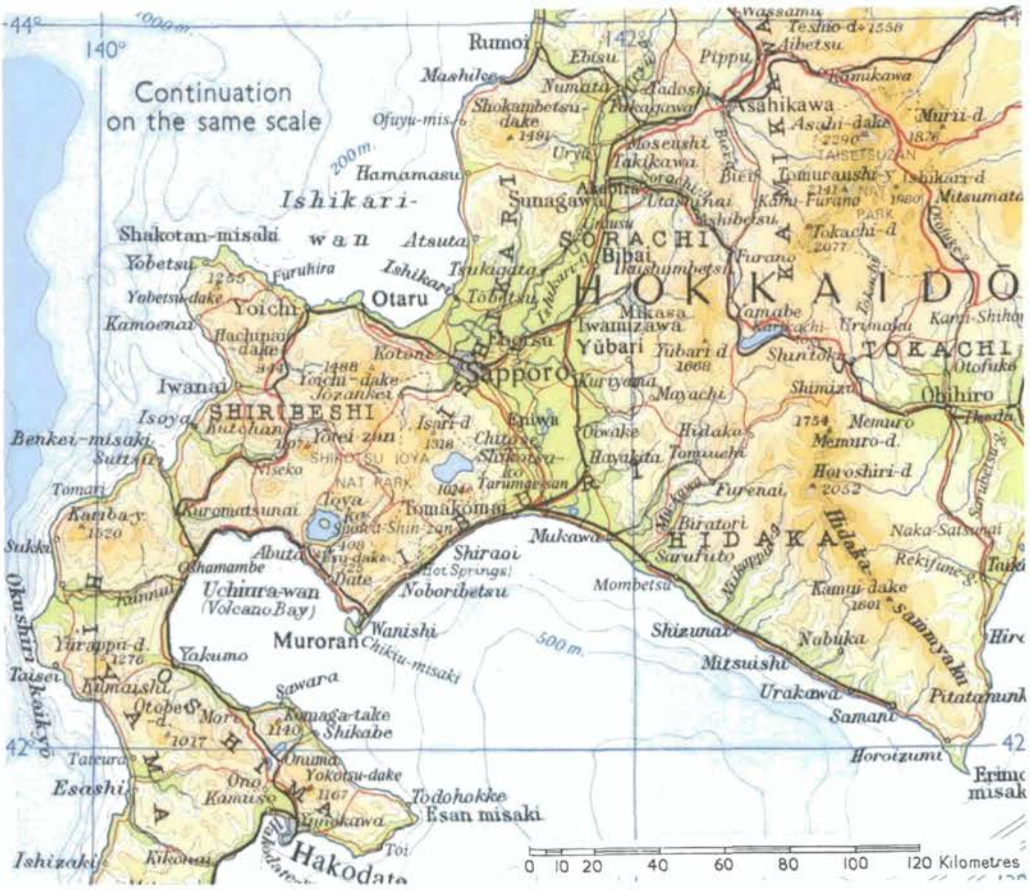
N. SOURCES OF DATA

*Printed in Japanese. The title are tentatively translated into English.
(Q) Questionnaire filled by the Prefectural Govenment of Hokkaidô.
(1) Japan Map Center (ed.) (1982) Collection of Maps on Japanese Lakes (Technical Data of National Geographical Institute, D•1-No. 221). National Geographical Institute, Tsukuba.*
(2) Uchida, E., Asakura, T. & Kawamura, T. (ed.) (1983). Meteorological Data of Japan. 1060pp. Tôyô-keizaishinpô-sha, Tôkyô.*
(3) Imada, K., Ito, T., Yoshizumi, Y., Awakura, T. & Yonekawa, T. (1980) Fluctuations of transparency, COD and several dissolved ions in Lake Shikotsu (1973 1979). Sci. Rep. Hokkaido Fish Hatchery, 35 : 21 24.*
(4) Environment Agency (1981) The 2nd National Survey on the Natural Environment (Vegetation), Actual Vegetation Map. Japan Wildlife Research Center, Tôkyô.*

TÔYA-KO (LAKE TÔYA)

Western part of the lake with Usu Volcanos

Photo: A. Kurata



A. LOCATION

§ Hokkaidô, Japan.
§ 42°36′N, 140°51′E ; 84 m above sea level.

B. DESCRIPTION

Lake Tôya is a caldera lake in the western part of Shikotsu-Tôya National Park in southern Hokkaidô. There are Tôya Hot Springs and Usu Volcano Group on the southern shore. The lake is more or less circular in shape and has a group of islands at its center. The bottom is covered by pyroclastic sediments.

There are some 30 inflowing streams, but their discharge rates are very small except that of R. Horobetsu. R. Sôbetsu is the sole outflowing river. Since 1937, however, R. Oru became a new outlet through the diversion of the lake water for hydroelectric power generation and flood control.

The lake water became acidic since 1937 owing to the inflow of mining wastewater until pH 5 is reached around 1970, but the acidity has recently been improved to pH 6.8-7.0 after the neutralizing treatment in 1972.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	70.4
Volume [10^9m^3]	8.19
Maximum depth [m]	179
Mean depth [m]	116
Water level	Regulated
Length of shoreline [km]	36
Catchment area [km^2]	173

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

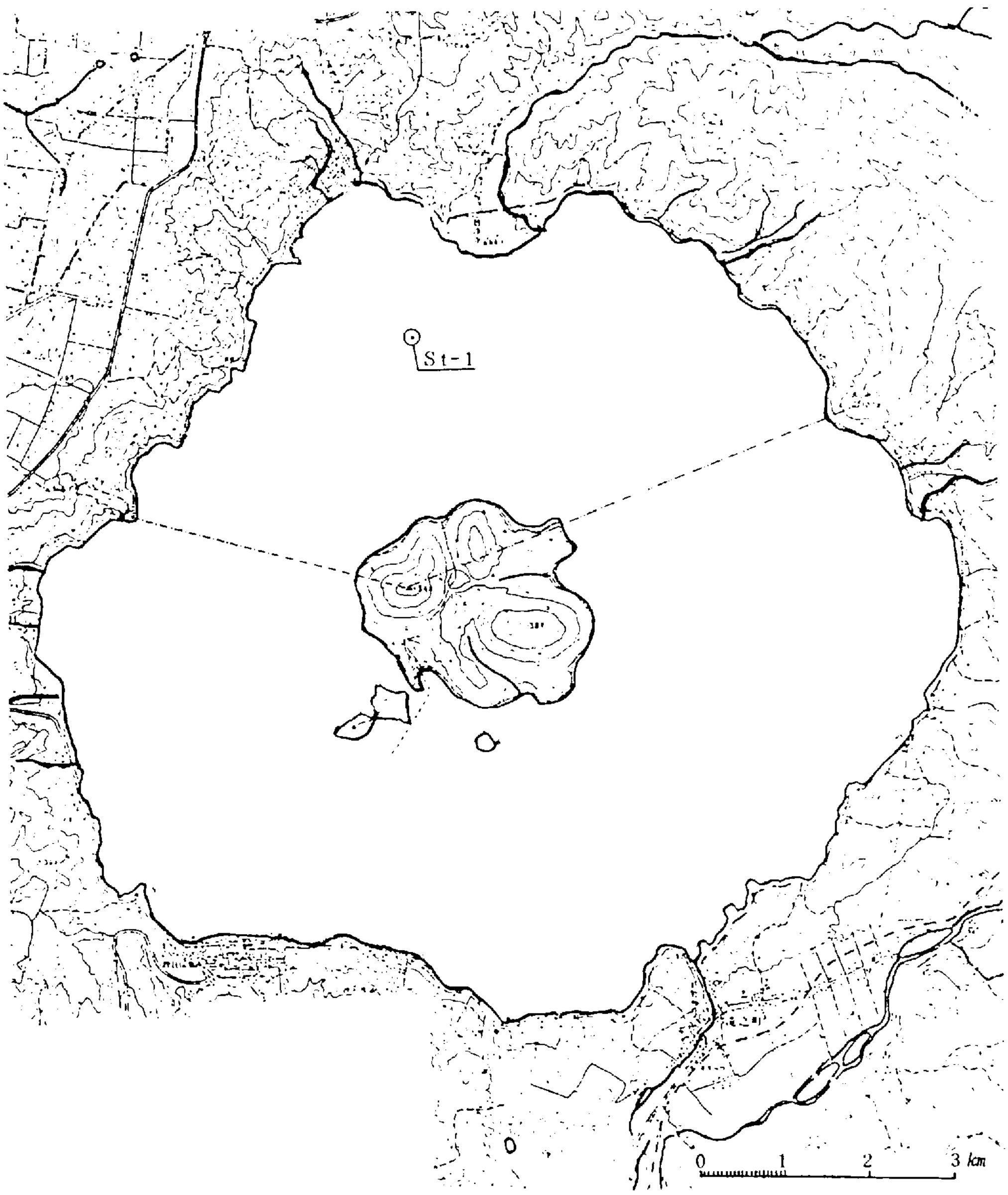
§ Sketch map (Fig. ASI-17-1).
§ Main islands : Naka-jima, Kannon-jima.
§ Outflowing rivers and channels (number and names) : 2 (Sôbetsu R., Water Intake).

D2 CLIMATIC (Q)

§ Climatic data at Ôtaki, 1982-1983

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [C]	−6.9	−8.5	−3.2	4.1	9.6	11.8	16.5	19.6	13.8	6.7	1.7	4.9	5.8
Precipitation [mm]	113	69	71	177	79	128	58	162	149	219	124	94	1,443

Fig. ASI-17-1 Sketch map of the lake (Q).



§ Water temperature [°C]
Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–		–	4.7	7.8	14.4	22.4	–	20.8	15.2	–	–
5	–	–	-	4.2	7.3	11.8	19.7	–	20.5	14.7	–	–

§ Freezing period : Not freezing.
§ Mixing type : Dimictic.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m], Station 1, 1981-1983

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	10	11	13	20	–	13	8	·	–

E2 pH, Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	6.5	6.5	6.6	6.6	–	6.8	6.4	–	–
5		–	–	6.4	6.6	6.7	6.6		6.7	6.5	–	–

E3 SS [mg l⁻¹], Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	<1.0	1.0	1.0	1.0	–	1.0	3.0	–	–
5	–		–	1.0	<1.0	1.0	<1.0	–	1.0	2.0	–	–

E4 DO [mg l⁻¹], Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	12	11	10	8.4	-	9.3	9.8	–	–
5	–	–	–	12	11	11	9.8	–	9.3	9.8	–	–

E5 COD [mg l⁻¹], Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	<0.5	<0.5	<0.5	0.7		0.7	1.1	–	–
5	–	·	–	<0.5	0.6	0.7	0.7	–	0.9	1.0	–	–

E7 NITROGEN CONCENTRATION

§ Total-N [mg l⁻¹], Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	0.32	0.29	0.33	0.30	·	0.37	0.28	–	–

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	<0.005	<0.005	<0.005	<0.005	–	<0.005	<0.005	–	–

F. BIOLOGICAL FEATURES

F2 FAUNA

§ Fish: *Salmo nerka, Salmo mykiss, Zacco platypus, Cyprinus carpio, Carassius gibelio langsdorfi, Leuciscus (Tribolodon) ezoe, Hypomesus olidus.*

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1983) (Q)

	Area [km²]	[%]
Woody vegetation	333.4	92.1
Agricultural land	19.9	5.5
Residential area	2.8	0.8
Others	5.8	1.6
Total	361.9	100.0

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRANDING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

For national laws see "Biwa-ko".

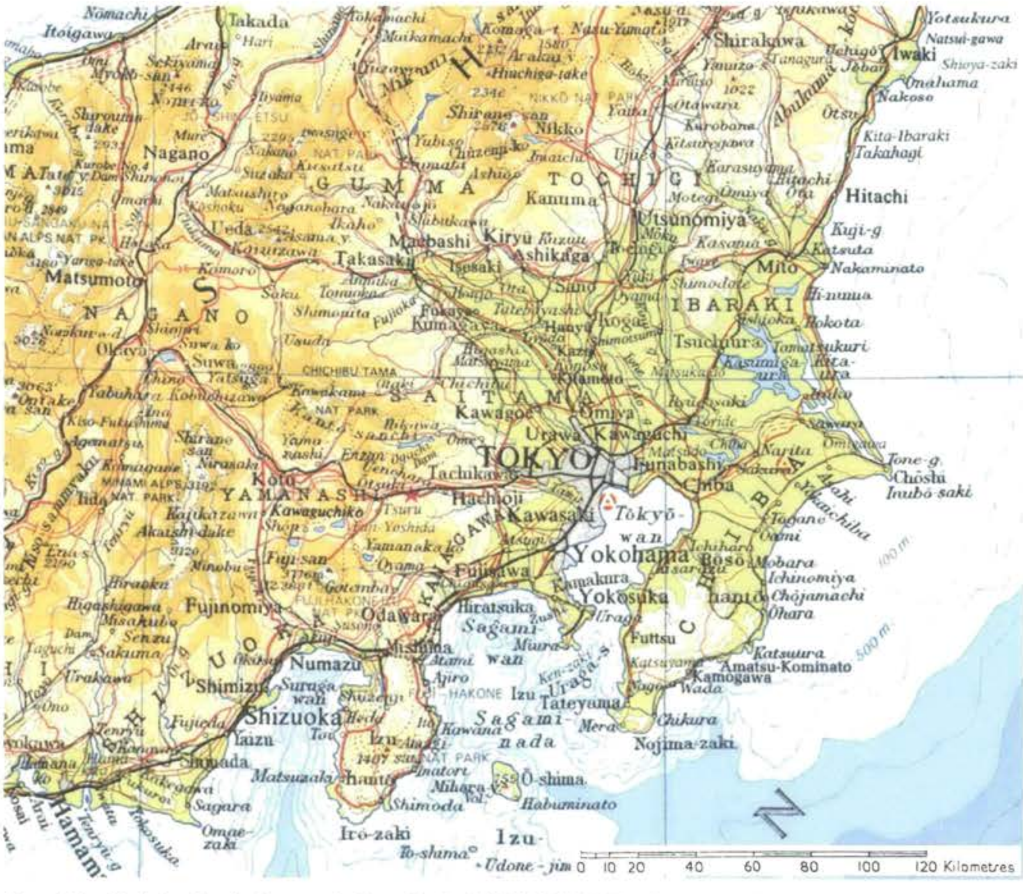
N. SOURCES OF DATA

(Q) Questionnaire filled by the Prefectural Government of Hokkaidô.

SAGAMI-KO (SAGAMI RESERVOIR)

A lake view from the eastern shore

Photo: A. Kurata



A. LOCATION

§ Kanagawa Prefecture, Japan.
§ 35°36′N, 139°11′E ; 167 m above sea level.

B. DESCRIPTION

This is a man-made lake, completed in 1947 by damming up the Sagami River in its middle course. The river comes from Yamanaka-ko, one of the Five Lakes of Fuji, and flows into Sagami Bay on the Pacific side of the island of Honshû. The drainage basin of the lake is therefore large for its size, having more than 300 times the surface area of the lake itself. With an effective storage of some 48 million tons, water for city and industrial use in such big cities of Kanagawa Prefecture as Yokohama and Kawasaki, for irrigating upland fields on the Sagamihara Plateau, and for hydroelectric power generation can all be provided by the lake.

Excess water is discharged through the dam gate in time of flood, but otherwise it passes through a duct 24 m under the water surface, mainly to a hydroelectric power station. During the warm season from late spring to early fall, as is often the case with many other reservoirs used for hydroelectricity, two thermoclines are observed at depths corresponding, respectively, to the bottom of normal metalimnion and the level of subsurface outlet. The inflowing river water forms a continuous density current leading to the subsurface discharge between these two thermoclines. Most of the inflowing nutrients may therefore not be available for biological production during this period.

In spite of such hydrographical constraints, the large amount of nutrient loading from the wide drainage basin has furthered the progress of eutrophication in Sagami-ko since its construction. Spring blooms of diatoms lead to clogging trouble in the filtration bed, while the growth of certain blue-green algae often gives an unpleasant smell to tap water. To suppress the bloom of *Microcystis*, which has appeared every summer since 1967, a device for vertical water mixing and aeration is being tested, together with other measures (1).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	3.26
Volume [10^6m^3]	63.2
Maximum depth [m]	32
Mean depth [m]	19
Normal range of annual water level fluctuation (regulated) [m]	5 10 (1981 1985)
Length of shoreline [km]	34.4
Residence time [yr]	0.05
Catchment area [km^2]	1,064

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-18-1).

§ Outflowing rivers and channels (number and names): 1 (Sagami R.).

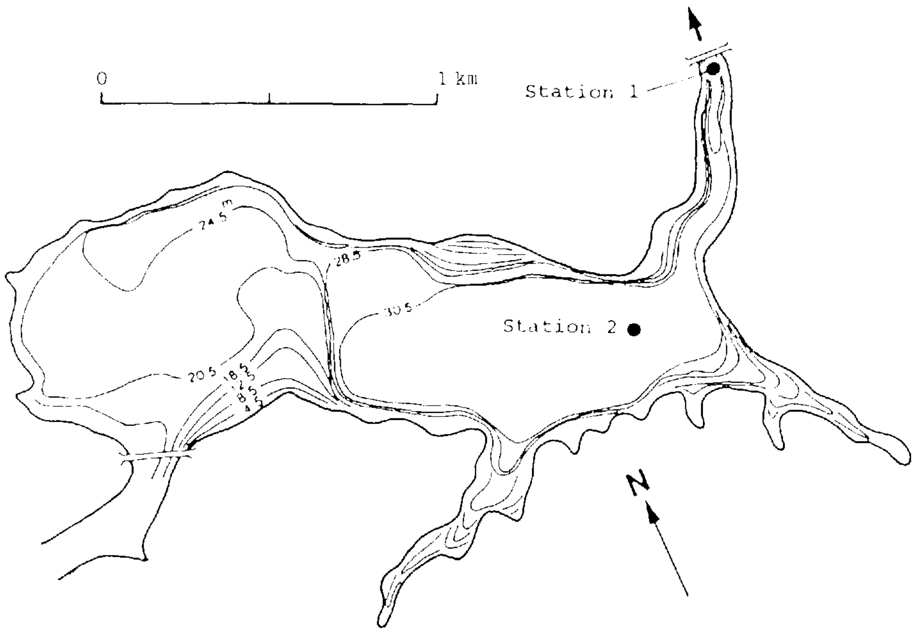
D2 CLIMATIC

§ Climatic data at Tsukui (temp.) and Sagami-ko (precipitation), 1983-1985 (Qk, 3).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	0.6	0.9	5.1	12.6	19.9	19.6	24.0	26.5	22.0	15.4	8.9	1.8	12.9
Precipitation [mm]	32	116	104	144	87	274	138	228	132	100	63	23	1,441

§ Number of hours of bright sunshine (Ebina, 1983-1985): 2,235.7 hr yr^{-1} (Qk, 3).

Fig. ASI-18-1 Bathymetric map (2).



§ Water temperature [°C]

Station 1, Apr. 1983-Mar. 1986 (Qk)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	6.1	6.6	8.7	12.8	18.1	19.8	24.1	25.1	20.7	16.7	12.0	8.7
Bottom	5.9	6.2	7.0	9.2	11.1	12.8	14.4	14.7	15.6	15.1	11.3	8.5

§ Freezing period: None.

§ Mixing type: Monomictic.

§ Thermocline formation: Jun.-Oct.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], Station 1, Apr. 1983-Mar. 1986 (Qk)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.1	1.7	1.6	1.8	1.2	1.8	1.6	1.5	1.3	1.9	2.6	2.7

E2 pH, Station 1, Apr. 1983-Mar. 1986 (Qk)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	7.6	7.3	7.5	8.0	9.0	8.4	9.7	8.7	8.9	8.1	7.6	7.6

E3 SS [mg l^{-1}], Station 1, Apr. 1983-Mar. 1986 (Qk)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	2	2	4	4	7	8	3	5	6	3	3	2
Bottom	3	3	5	7	8	6	4	15	11	10	4	3

E4 DO [mg l^{-1}], Station 1, Apr. 1983-Mar. 1986 (Qk)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	9.7	9.8	9.6	10.8	12.9	12.1	13.7	11.1	13.3	9.9	9.7	9.5
Bottom	9.6	9.4	7.7	9.4	3.2	2.8	4.0	3.1	2.2	7.1	9.3	9.5

E5 COD [mg l^{-1}], Station 1, Apr. 1983-Mar. 1986 (Qk)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	2.1	1.9	2.4	2.7	3.6	4.2	4.4	3.2	5.4	2.4	1.9	1.6
Bottom	2.1	1.8	2.2	2.0	1.9	2.3	1.6	2.2	2.4	2.1	1.7	1.4

E6 CHLOROPHYLL CONCENTRATION [mg m^{-3}], Station 1, Apr. 1983-Mar. 1986 (Qk)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	2.2	1.8	3.0	10	33	37	29	15	58	9.7	9.9	1.3

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}], Station 1, Apr. 1983-Mar. 1986 (Qk).

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1.5	1.4	1.5	1.3	1.3	1.3	1.1	1.3	1.4	1.2	1.4	1.4
Bottom	1.5	1.6	1.5	1.3	1.4	1.4	1.3	1.3	1.4	1.5	1.3	1.4

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], Station 1, Apr. 1983-Mar. 1986 (Qk).

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	0.110	0.120	0.110	0.085	0.076	0.081	0.067	0.056	0.077	0.065	0.096	0.100
Bottom	0.110	0.120	0.097	0.071	0.065	0.068	0.078	0.072	0.078	0.078	0.093	0.110

E9 PAST TRENDS

Fig. ASI-18-2 Trend of transparency and pH (annual mean, Station 2) (Qk).

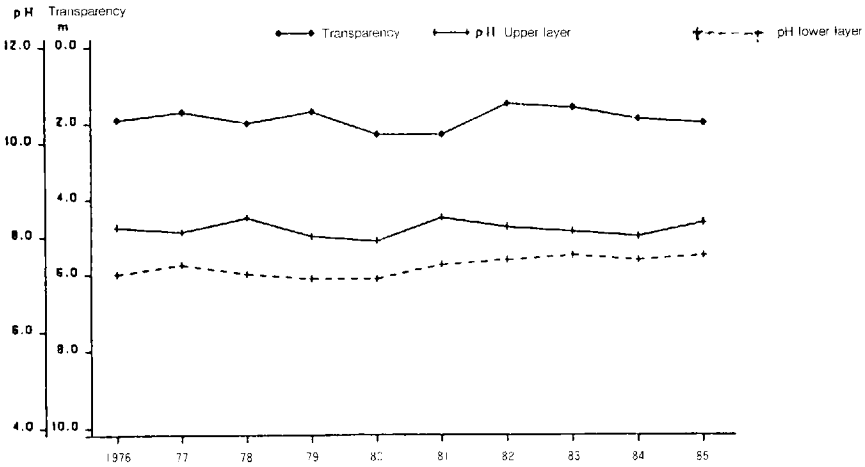


Fig. ASI-18-3 Trend of COD and BOD (annual mean, Station 2) (Qk).

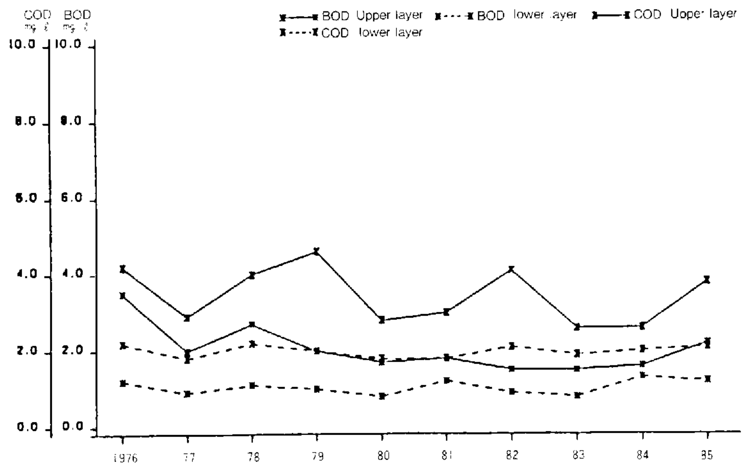
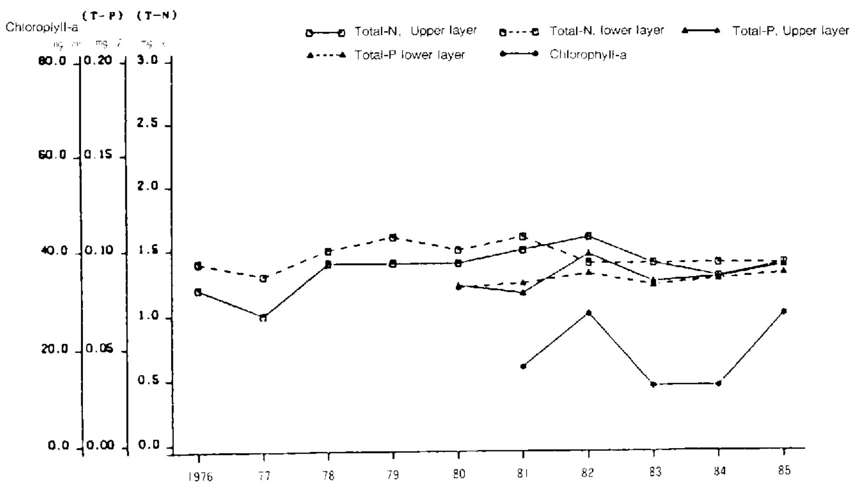


Fig. ASI-18-4 Trend of chlorophyll-a, Total-P and Total-N (annual mean, Station 2) (Qk).



F. BIOLOGICAL FEATURES (Qk)

F1 FLORA

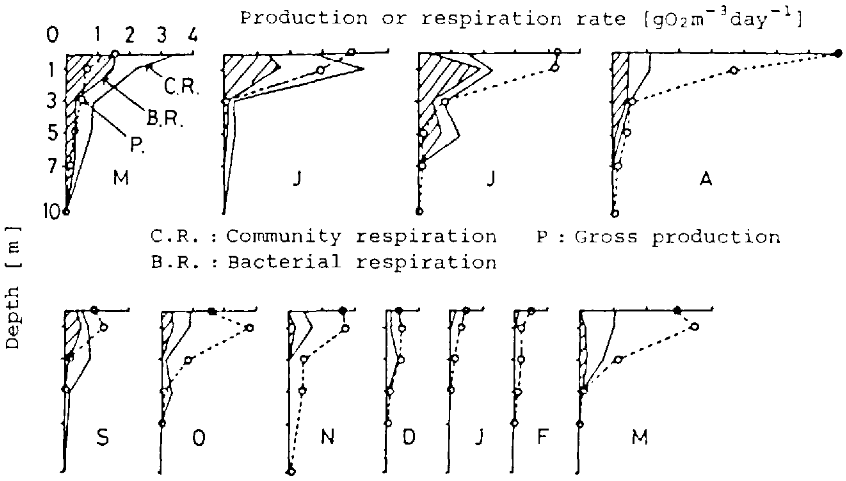
§ Emerged macrophytes : None.
§ Floating macrophytes : None.
§ Submerged macrophytes : None.
§ Phytoplankton : *Microcystis aeruginosa, Stephanodiscus hantzschii, Fragilaria crotonensis, Synedra acus, Cyclotella* spp.

F2 FAUNA

§ Zooplankton : *Kellicotia longispina, Daphnia longispina, Synchaeta* spp., *Ploesoma* sp.
§ Benthos : Tubificids, Chironomids (*Tanypus* sp., *Chironomus, Sergentia*).
§ Fish : *Hypomesus lidus, Carassius cuvieri, Zacco platypus, Leuciscus hakonensis.*

F3 PRIMARY PRODUCTION RATE

Fig. ASI-18-5 Primary production rate (May, 1978-Mar., 1979) (6).



F5 FISHERY PRODUCTS

§ Annual fish catch : None.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

No remarkable change.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1983) (Qk, Qy)

	Area [km^2]	[%]
Natural landscape	931	87.5
Agricultural land	49	4.6
Residential area Others	84	7.9
Total	1,064	100.0

§ Main types of woody vegetation : Deciduous broadleaf forest (*Quercus serrata, Q. acutissima, Q. mongolica* var. *grosseserrata, Castanea crenata*) ; pine forest (*Pinus densiflora*) ; conifer plantation (*Pinus densiflora, Cryptomeria japonica, Chamaecyparis obtusa, Larix kaempferi*) (7, 8).
§ Main types of herbaceous vegetation : Grasslands and weeds (7, 8).
§ Main kinds of crops : Rice and vegetables (7, 8).
§ Levels of fertilizer application on crop fields : Moderate.

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (1980) (9, 10, 11)

	Gross product per year [yen] (160yen = US$1.00)	No. of persons engaged	No. of establishments
Primary industry			
Crop production	N.A.	5,039	N.A.
Animal husbandry	N.A.	N.A.	N.A.
Fisheries	N.A.	N.A.	N.A.
Others	N.A.	449	N.A.
Secondary industry	1.558×10^6	30,547	6,590
Tertiary industry	N.A.	46,602	9,303

§ Numbers of domestic animals in the catchment area (1983) : Cattle 1,600, swine 4,300, poultry 276,000 (Qk, Qy).

G3 POPULATION IN THE CATCHMENT AREA (1985) (Qk, 12, 13)

	Population	Population density [km^{-2}]	Main cities (population)
Urban	122,900	–	Fujiyoshida (54,800)
Rural	77,400	–	Ohtsuri (34,900)
Total	200,300	188.3	Tsuru (33,200)

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (number of visitors in 1985 : 1,880,000), recreation (sport-fishing, boating), and others (canoe race).

H2 THE LAKE AS WATER RESOURCE (1985) (Qk)

	Use rate [m^3sec^{-1}]
Domestic water	10.34
Irrigation	4.16
Industrial water	2.15
Power plant	85 (31,000 kw hr^{-1})

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : None.

§ Supplementary note : Up to December 1985, the total amount of sediments was about 13,400,000 m^3 (21 percent of total pondage). The sedimentation rate is estimated to be about 350 m^3 km^{-2} yr^{-1}.

I2 TOXIC CONTAMINATION

§ Present status : None.

§ Main contaminants, their concentrations and sources

Station 1, 1985 (Qk)

Name of contaminant	Range of concentration [ppm]
	Water
Cd	<0.002
CN, Organic P, PCB, Alkyl-Hg	ND
Pb	<0.02
Cr (III)	<0.05
As	<0.02
Total Hg	<0.005
CNP	<0.00001

§ Environmental quality standards for contaminations in the lake

Cd : <0.01 mg l^{-1}, CN : ND (<0.1 mg l^{-1}), Organic P : ND (<0.1 mg l^{-1}), Pb : <0.1 mg l^{-1}, Cr (IV) : <0.05 mg l^{-1}, As : <0.05 mg l^{-1}, Total Hg : <0.005 mg l^{-1}, Alkyl Hg : ND (<0.0005 mg l^{-1}), PCB : ND (<0.0005 mg l^{-1}).

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Mycrocystis aeruginosa*), disturbed filtration in cleaning beds, foul smell of tap water.

§ Supplementary notes : To suppress the bloom of *Microcystis*, a device for intermittent aeration and vertical water mixing is being tested.

Records of *Microcystis* bloom in Lake Sagami.

Year	Blooming period	Max. cell no. [ml^{-1}]*	Note
1967	Aug-Sep	2,200	First observation
1968	Aug	380,000	
1969	Aug-Sep	1,500	
1970	Aug	380	
1971	May-Aug	13,000	
1972	Jun-Aug	3,100	
1973	Jul-Oct	590,000	Water supply rate was reduced due to clogging of sand filters
1974	Jul-Oct	1,000,000	
1975	Jun-Oct	180,000	A floating fence was built to prevent algal dispersion
1976	Jun-Jul	1,200,000	
1977	Jul-Aug	2,000,000	
1978	Jul-Sep	130,000	
1979	Jul-Oct	2,500,000	

* Surface water. (Compiled from the data of Kawasaki Municipal Waterworks Bureau)

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE (Qk, Qy)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage (1985) : 19 %.

§ Percentage of rural population with adequate sanitary facilities (1985) : 13 %.

§ Municipal wastewater treatment systems

Number of secondary treatment systems : 1 (activated sludge).

Number of other types : 3 (anaerobic treatment).

§ Number of industrial wastewater treatment systems (1984) : 170 (activated sludge).

K. IMPROVEMENT WORKS IN THE LAKE

K2 AERATION

Intermittent aeration system.

K3 OTHERS

Dredging at the upper stream of the reservoir.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRANDING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) For national laws see "Biwa-ko".

(2) Kanagawa Prefectural Pollution Control Ordinance (1978)

(3) Yamanashi Prefectural Pollution Control Ordinance (1975)

§ Responsible authorities

(2) Kanagawa Prefectural Government

(3) Yamanashi Prefectural Government

§ Main items of control

(2) Permit system for construction of industrial premises, control of fluegas and wastewater

(3) Permit system for construction of industrial premises, control of smoke and soot, and wastewater

M2 INSTITUTIONAL MEASURES

(1) Water Quality Preservation Section, Department of Environment, Kanagawa Prefectural Government, Yokohama

(2) Public Nuisances Control Center of Kanagawa Prefecture, Yokohama

(3) Preservation of Environment Section, Department of Livelihood, Yamanashi Prefectural Government, Kôfu

N. SOURCES OF DATA

* All printed in Japanese.

(Qk) Questionnaire filled by Kanagawa Prefectural Government.

(Qy) Questionnaire filled by Yamanashi Prefectural Government.

(1) Mori, K. (1970) On the depth of inflowing layer of river water in the Sagami Reservoir. Jap. J. Limnol., 31 : 111-128.

(2) Ishibashi, T. (1978) A research on sediment and its contents in Lake Sagami. J. Waterworks, 3.

(3) Yokohama Local Meterological Observatory (1986) Monthly Report of Meteorology in Kanagawa Prefecture (1983-1985).

(4) Shiraishi, H. & Fukushima, S. (1949) Report of the Studies on Sagami-ko (a Man-made Lake), I. Freshwater Fisheries Research Laboratory, Fisheries Agency.

(5) Shiraishi, H., Tokunaga, H., Furuta, Y. & Kitamori, R. (1953) Limnological Studies on Sagami-ko, a Man-made Lake (1949-1950). Freshwater Fisheries Research Laboratory, Fisheries Agency.

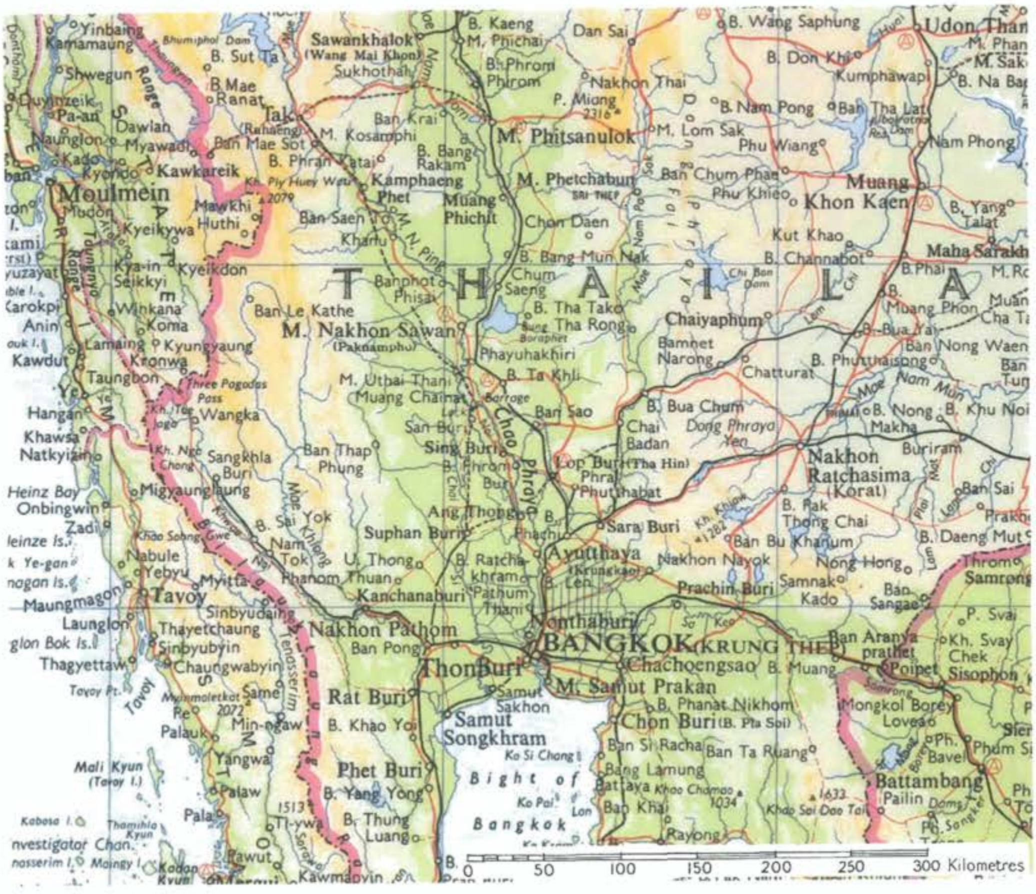
(6) Maeda, S. (1982) The bacterial mineralization of organic matter in Lake Sagami. Jap. J.

Limnol., 43 : 88-95.
(7) Miyawaki, A., Suzuki, K., Okuda, S., Fujiwara, K., Minowa, R., Harada, H., Sasaki, Y., Nakamura, Y., Ohyama, H., Hotta, K., Kimura, M., Ogawa, Y. & Yamada, M. (1977) Vegetationskarte der Präfektur Yamanashi. Yamanashi Prefectural Government, Kôfu.
(8) Environment Agency (1982) The 2nd National Survey on the Natural Environment (Vegetation), Actual Vegetation Map, Kanagawa Prefecture. Japan Wildlife Research Center, Tokyo.
(9) Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry (1985) Census of Manufactures for 1983, Report by Cities, Towns and Villages.
(10) Statistics Bureau, Prime Minister's Office (1982) Population Census of Japan for 1980, Vol. 3, Part 2 ; 14, Kanagawa Prefecture ; 19,Yamanashi Prefecture.
(11) Statistics Bureau, Prime Minister's Office (1982) Establishment Census of Japan for 1981, Vol. 2, Results for Prefectures (Cities, Wards, Towns, Villages).
(12) Statistics Bureau, Prime Minister's Office (1986) Population Census of Japan for 1985, Vol. 2, Part 2 ; 19, Yamanashi Prefecture.
(13) Statistics Bureau, Prime Minister's Office (1986) Population Census of Japan for 1985, Vol. 2, Part 2 ; 14, Kanagawa Prefecture.

BUNG BORAPHET (BORAPED RESERVOIR)

Fishing boats on the lake

Photo: T. Kira



A. LOCATION

§ Nakhon Sawan Province, Thailand.
§ 15°50′N, 100°10′E ; 23.8 m above sea level.

B. DESCRIPTION

Bung (= big pond) Boraped is a half man-made reservoir originating from a natural retarding basin situated close to the city of Nakhon Sawan, where the two rivers, Mae Nam Nan and Mae Nam Ping, unite into Mae Nam Chao Phraya (sometimes erroneously called the Menam River). The lake area had been a vast retarding basin known as the Boraped Swamp, which formed a big lake of 600 km² in seasons of high water level while turning into a grass-covered plain with scattered ponds and swampy depressions during the dry season. A dam was built at the head of the main outflowing channel (Klong Boraped) by the Fishery Department of Thailand in 1926–30 mainly for increasing fish production. Part of the swamp thus turned into a lake which has since been known as Bung Boraped. The present lake area is about 106 km² at the spill level, but it varies extensively owing to the water level fluctuation, amounting to as much as 300 km² in time of floods.

The majority of some 30,000 people living around the lake gain their livelihood from both farming and fishing. Since the lake is the largest source of fishery products for central Thailand, the Nakhon Sawan Fishery Station was established at Klong Boraped for the study of fish biology and for stocking the lake with artificially grown fry. Bung Boraped and surrounding swampy areas form one of the non-hunting nature reserves established by the Royal Thai Forest Department. Two development projects have been drafted for tourism development, upgrading aquaculture and utilizing the lake as sources of irrigation and domestic water supply (Q, 1, 2, 3).

C. PHYSICAL DIMENSIONS

Surface area [km²]	106.4
Volume [10⁶m³]	276.4
Maximum depth [m]	5.8
Mean depth [m]	2
Normal range of annual water level fluctuation (Regulated) [m]	1–1.2
Length of shoreline [km]	Max. 62.5, min. 53
Catchment area [km²]	4,200

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

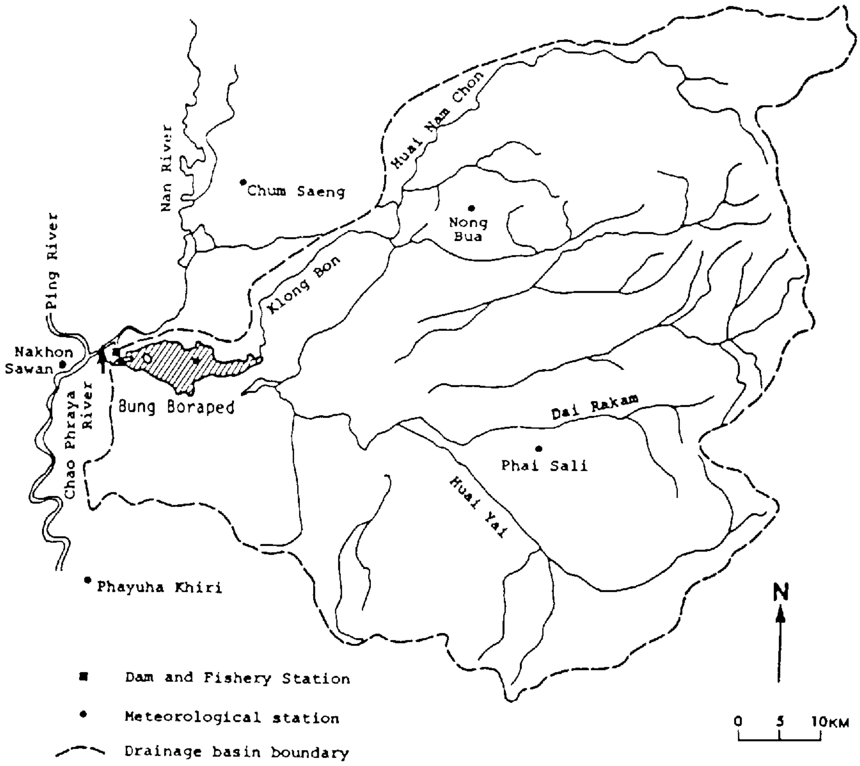
§ Sketch map (Fig. ASI-19-1).
§ Outflowing rivers and channels (number and names): 1 (Klong Boraped).

D2 CLIMATIC (Q)

§ Climatic data at Nakhon Sawan, 1951-1970

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	24.9	27.7	30.2	31.4	30.5	29.4	28.9	28.5	28.0	27.6	26.3	24.4	28.2
Precipitation [mm]	12	25	43	72	141	134	144	167	264	152	30	6	1,187

Fig. ASI-19-1 Sketch map of Bung Boraped and its drainage basin (1).



§ Water temperature [°C] (2)
Open water area, 1975

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	29.0	28.0	28.0	33.5	34.0	31.0	29.0	28.0	30.0	31.0	29.0	29.0

§ Freezing period: None.
§ Mixing type: Polymictic.
§ Thermocline formation: Not formed.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Open water area, 1975 (2)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.4	1.7	1.2	1.8	1.5	1.3	1.3	1.1	1.1	1.3	1.2	1.2

E2 pH, 1975 (2)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	7.6	7.4	7.4	7.0	7.4	7.0	7.2	7.3	6.7	6.6	7.0	6.9

E3 SS [mg l^{-1}]

SS of surface water, average of five sampling points, 1981 : 14.8 (Jul.), 2.0 (Aug.) (1).

E4 DO [mg l^{-1}], 1975 (2)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	8.0	8.0	8.0	6.0	8.0	7.0	9.0	8.0	3.0	8.0	8.0	7.0
Bottom	7.0	5.0	7.0	6.0	6.0	6.0	9.0	7.0	3.0	8.0	7.0	7.0

E5 COD [mg l^{-1}]

Determined by $KMnO_4$ method.

COD of surface water, average of five sampling points, 1981 : 40.5 (Jul.), 22.4 (Aug.) (1).

E6 CHLOROPHYLL CONCENTRATION : No information.

E7 NITROGEN CONCENTRATION [mg l^{-1}]

Surface water, average of five sampling points, 1981 (1).

§ NH_4-N : 0.50 (Jul.), 0.01 (Aug.).

§ Org-N : 1.5 (Jul.), 1.0 (Aug.).

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l^{-1}], 1975* (2)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	0.07	0.10	0.13	0.13	0.07	0.07	0.07	0.07	0.10	0.13	0.07	0.10

* Converted from the original determination of phosphate.

F. BIOLOGICAL FEATURES (Q, 2, 4, 5)

F1 FLORA

§ Emerged macrophytes : *Phragmites karka, Colocasia esculenta, Nelumbo nucifera, Coix aquatica, Isachne globosa, Leesia hexandra.*

§ Floating macrophytes : *Salvinia cucullata, Eichhornia crassipes, Pistia stratiotes, Nymphaea stellata.*

§ Submerged macrophytes : *Utricularia flexuosa, Potamogeton* sp., *Hydrilla verticillata, Najas graminea, Ceratophyllum demersum.*

§ Phytoplankton : *Sphaerozosma vertebratum, Oedogonium* sp., *Micrasterias foliacea, Synedra ulina, Volvox aureus.*

F2 FAUNA

§ Zooplankton : *Bosmina excisum, Bosminopsis deitersi, Heliodiaptomus kikuchii, Keratella valga* (5).

§ Benthos : Chironomids, Oligochaeta, Mollusca (*Ensidens ingallsianus, Unio thaiensis, Corbicula larnaudieri, C. petiti, Mekongia hainesiana*), Crustacea (including a big prawn, *Macrobrachium rosenbergii*) (5).

§ Fish : *Pristolepsis fasciatus, Notopterus notopterus, Osteochei hasselti, Hampala microlepidota, Ambasis siamensis, Cyclochcilichthys armatus, Mystus vittatus, Ophiocephalus striatus, Clupeoides hypselosoma, Labiobarbus liniatus* (5).

F3 PRIMARY PRODUCTION RATE : No information.

F4 BIOMASS [g m^{-3}] (Q)

	Wet weight	Dry weight
Phytoplankton	146.0×10^{3}	0.143
Zooplankton	245.3×10^{3}	0.104
Total Biomass		0.247

§ Population density (open water area, Sep.-Nov., 1981) (1).
Phytoplankton 4,847.5 [l^{-1}]; zooplankton 76.5 [l^{-1}]; benthos 248 [m^{-2}].

F5 FISHERY PRODUCTS

§ Annual fish catch in 1975: 723,048 [metric tons] (2).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN NAKHON SAWAN PROVINCE* (1980) (1)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	1,734	16.3
Swamp	104	1.0
Others (open water)	213	2.0
Agricultural land	7,258	68.3
Residencial area	1,314	12.4
Total	10,622	100.0

* Statistics for the drainage basin of Bung Boraped only, which accounts for 40 % of the area of the whole province, were not available.

§ Main types of woody vegetation: Secondary forests derived from the original semi-deciduous seasonal forest (4).

§ Main kinds of crops: Rice, sugarcane, sorghum, maize, cassava, soybean, tobacco, sesame and lotus.

§ Levels of fertilizer application on crop fields: Light.

§ Trends of change in land use in recent years: Increasing number of acreage is now being allocated to fish ponds and livestock raising. Area used as fish ponds amounts to 2.78 % of the catchment area (Q).

G2 INDUSTRIES IN NAKHON SAWAN PROVINCE AND THE LAKE (1)

	Number of persons engaged	Number of establishments	Main products and main kinds of industry
Primary industry			
Agriculture	521,800	N.A.	
Secondary industry			
Manufacturing	114,900	831**	Sugar, cement, matches
Mining	6,437*	N.A.	Marble, gypsum, iron, lime
Tertiary industry	22,700	N.A.	

* Including the number of persons engaged in commerce.
** Besides there are 401 rice mills.

G3 POPULATION IN NAKHON SAWAN PROVINCE (1980)

Population	Population density [km^{-2}]	Main cities (population)
979,200	92.19*	Nakhon Sawan (86,000)

* Population density for the subdistricts around Bung Boraped : 153.8 km^{-2}.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Sources of water, fisheries, navigation and tourism.

H2 THE LAKE AS WATER RESOURCE(Q)

Domestic : 300 m^3 day^{-1} (1980).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : Not serious.

§ Supplementary notes : Heavy rainfall in the later part of the year and resultant soil erosion cause high turbidity of water and reduction of plankton, benthos and fish populations.

I2 TOXIC CONTAMINATION : No information.

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication : Foul smell of tap water.

I4 ACIDIFICATION : No information.

J. WASTEWATER TREATMENT (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Limited pollution without wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS : No information.

J3 SANITARY FACILITIES AND SEWERAGE

§ Public sewerage system : Not present.

L. DEVELOPMENT PLANS

The policy of Department of Fisheries (DOF) in the rehabilitation and development of these swamps is directed toward optimizing fish production by controlling floods, ensuring domestic water supply and sanitary facilities, and allowing limited water use for agricultural purposes (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (Q)

§ Names of the laws (the year of legislation)

(1) Fisheries Act BE 2490
(2) Land Law
(3) Forestry Law
(4) Environmental Act

§ Responsible authorities

(1) Department of Fisheries
(2) Land Department
(3) The Royal Forestry Department
(4) National Environment Board

§ Main items of control

(1) Conservation of fishery resources and control of fishing gears
(2) Control of land use development
(3) Conservation of forestry and wildlife
(4) Control of environmental quality

M2 INSTITUTIONAL MEASURES (Q)

(1) Department of Fisheries

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES (Q)

(1) Nakhon Sawan Fishery Station, Department of Fisheries, Klong Boraped

N. SOURCES OF DATA

(Q) Questionnaire filled by the Office of the National Environment Board of Thailand, Bangkok.
(1) Asian Institute of Technology (1982) Rehabilitation and Development of Bung Boraped and Mong Han. Vol. 1. Bung Boraped. 196pp. Office of the National Economic and Social Development Board, Bangkok.
(2) Suraswadi, Plodprasop (1976) Newly covered grass as a habitat for fish in Bung Boraped, Thailand. Ph. D. Thesis, Department of Zoology, University of Manitoba, Canada.
(3) Dobias, R. J. (1982) The Shell Guide to the National Parks of Thailand. 137pp. The Shell Company of Thailand, Ltd., Bangkok.
(4) The editors' observation.
(5) Mizuno, T. & Mori, S. (1970) Preliminary hydrobiological survey of Southeast Asian inland waters. Biol. J. Linn. Soc., 22 : 77-117.
(6) Department of Fisheries (1985) Large Swamps Inland Fisheries Project (LSIFP). Bangkok.

AKAN-KO (LAKE AKAN)

Near the southeastern end of the lake

Photo: T. Kira

A. LOCATION

§ Hokkaidô, Japan.
§ 43°27′N, 144°06′E ; 420 m above sea level.

B. DESCRIPTION

Lake Akan in eastern Hokkaidô is a dammed lake formed approximately 6,000 years ago by volcanic activity in a caldera depression that dates back to the middle Pleistocene. Its complicated shoreline is characteristic of dammed lakes. The lake is famous as the only native habitat of "Marimo", or fine ball-like masses of the alga, *Aegagropila sauteri*, 2–15 cm in diameter. It is believed that the globular shape is formed by the aggregation of filamentous alga and the rotary motion due to water turbulence. Similar kinds of spherical algal mass are observed in a few other lakes of Japan, but they are more irregular in shape. L. Akan is also known as the original home of kokanee salmon (*Oncorhynchus nerka*).

Transparency in the early 1930's was 8–9 m throughout the year, but the lake has recently been eutrophicated to a considerable extent owing to the inflowing waste water from the hot-spring town on the coast in spite of its cool and deep water. The eutrophication exerted a profound influence on the benthic fauna, which had once consisted of Chironomidae, Tubificidae, *Chaoborus* and *Pisidium* in its deepest bottom. According to the result of a general limnological survey made in 1973, however, the dissolved oxygen concentration in bottom water was only around 5 % of saturation and no organisms were observed beyond a depth of 30 m (1, 2, 3).

C. PHYSICAL DIMENSIONS (Q. 4, 5)

Surface area [km^2]	13.0
Volume [$10^9 m^3$]	ca. 0.23
Maximum depth [m]	44.8
Mean depth [m]	17.8
Length of shoreline [km]	25.9
Catchment area [km^2]	148

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (ASI-21-1).

§ Outflowing rivers and channels (number and names): 1 (Akan R.).

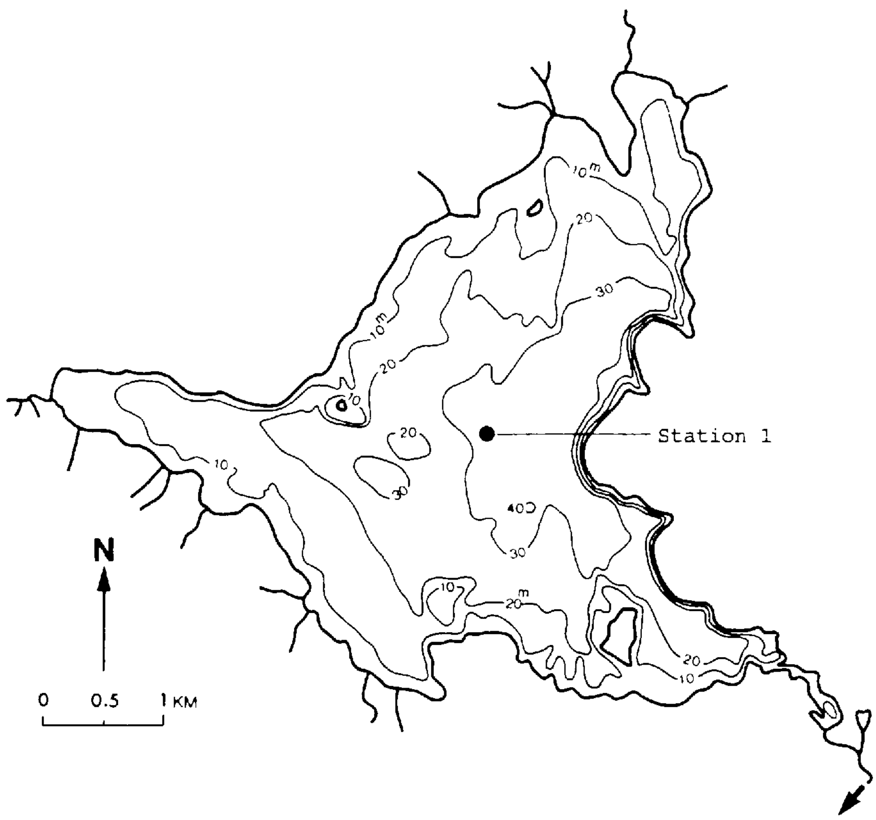
D2 CLIMATIC

§ Climatic data on the shore, 1982-1983

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-10.4	-12.2	-5.4	3.2	8.9	9.7	14.8	18.0	12.7	6.5	0.6	-6.1	3.4
Precipitation [mm]	57	11	73	82	70	100	69	166	106	138	95	47	1,014

§ Number of hours of bright sunshine (L. Akan, 1982-1983): 2,218 hr yr^{-1}.

Fig. ASI-21-I Bathymetric map (4).



§ Water temperature [°C] (Q)

Station 1, 1981-1983

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	—	—	—	—	8.4	12.6	18.5	19.3	18.1	12.9	—	—
5			—	—	8.8	12.5	17.3	18.7	17.9	12.7	—	—

§ Freezing period: From Dec. to Apr.

§ Mixing type: Dimictic.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m], Station 1, 1981-1983

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	3.4	4.4	3.5	3.8	3.1	2.4	–	–

E2 pH, Station 1, 1981-1983

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	7.7	7.9	8.3	8.2	8.0	7.7	–	–
5	–	–	–	–	7.8	7.9	8.2	8.2	8.1	7.7	–	–

E3 SS [mg l^{-1}], Station 1, 1981-1983

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	1	1	2	1	1	3	–	–
5	–	–	–	–	2	1	2	1	1	3		

E4 DO [mg l^{-1}], Station 1 1981-1983

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	9.9	8.8	9.3	8.1	9.1	8.2	–	–
5	–	–	–	–	9.4	8.7	9.0	7.9	8.3	8.1	–	–

E5 COD [mg l^{-1}], Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	2.1	2.3	3.0	2.8	2.9	3.0	–	–
5	–	–	–	–	2.4	2.3	3.0	2.7	3.4	3.1	–	–

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}], Station 1 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	0.14	0.13	0.14	0.17	0.15	0.38	–	–
5	–				0.12	0.18	0.15	0.31	0.15	0.44	–	–

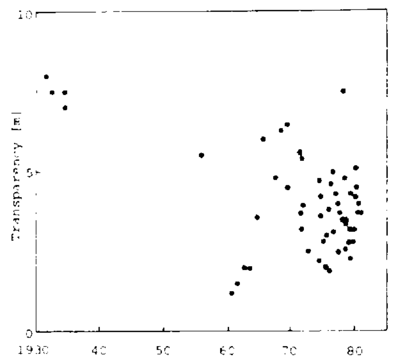
E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], Station 1, 1981-1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	0.036	0.024	0.025	0.035	0.054	0.049	–	–
5	–	–	–	–	0.041	0.029	0.015	0.032	0.035	0.052	–	–

E9 PAST TRENDS

Fig. ASI-21-2 Trend of transparency at the lake center (7).



F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes : *Phragmites communis*.
§ Floating macrophytes : *Nuphar* sp.
§ Submerged macrophytes : *Potamogeton crispus*, *Hydrilla verticillata*, *Myriophyllum verticillatum*, *Vallisneria gigantea*.
§ Phytoplankton : *Melosira italica*, *Asterionella formosa*, *Synedra* sp.

F2 FAUNA

§ Zooplankton : *Daphnia longiremis*, *Bosmina coregoni*, *Eurytemora affinis*.
§ Benthos : *Chironomus plumosus*, Tubificidae.
§ Fish : *Oncorhynchus nerka*, *Cyprinus carpio*, *Carassius* sp., *Hypomesus olidus*, *Leuciscus hakonensis*.

F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in 1979 : 139 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	147	99.3
Residential area	1	0.7
Total	148	100.0

§ Main types of woody vegetation : Deciduous broadleaf forest (*Betula ermanii*, *Quercus mongolica* var. *grosseserrata*, *Acer mono*, *Cercidiphyllum japonicum*) ; evergreen conifer forest (*Picea jezoensis*, *Abies sachalinensis*) (8).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (Q)

	No. of establishments	Main products and main kinds of industry
Primary industry		
Fisheries	——	Kokanee salmon, smelt and carp
Tertiary industry	Several facilities for tourists	

G3 POPULATION IN THE CATCHMENT AREA (1982) (Q)

	Population	Population density [km^{-2}]
Rural	2,100	
Total	2,100	14.4

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Tourism, recreation (sport-fishing, yachting) and fisheries.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

For national laws see "Biwa-ko".

N. SOURCES OF DATA

* Printed in Japanese. The titles are tentatively translated into English.

(Q) Questionnaire filled by the Prefectural Government of Hokkaidô.

(1) Imada, K., Ito, T., Yoshizumi, Y. & Yonekawa, T. (1981) Fluctuations of transparency, COD and several dissolved ions in Lake Akan (1973-1980). Sci. Rep. Hokkaido Fish Hatchery, 36 : 33-50.*

(2) Miyadi, D. (1932) Studies on the bottom fauna of Japanese Lakes VII. Lakes of Hokkaido. Jap. J. Zool., 4 : 223-252.

(3) Kitagawa, (1976) Studies on the benthos facies of four lakes (Kussharo, Akan, Toro, Shikaribetsu) in the eastern part of Hokkaido. Jap. J. Limnol., 37 : 37-41.*

(4) Japan Map Center, (ed.) (1982) Collection of Maps on Japanese Lakes (Technical Data of National Geographical Institute, D•1-No. 221). National Geographical Institute, Tsukuba.*

(5) Horie, M. (1956) Morphometry of Japanese lakes. Jap. J. Limnol., 18 : 1-28.

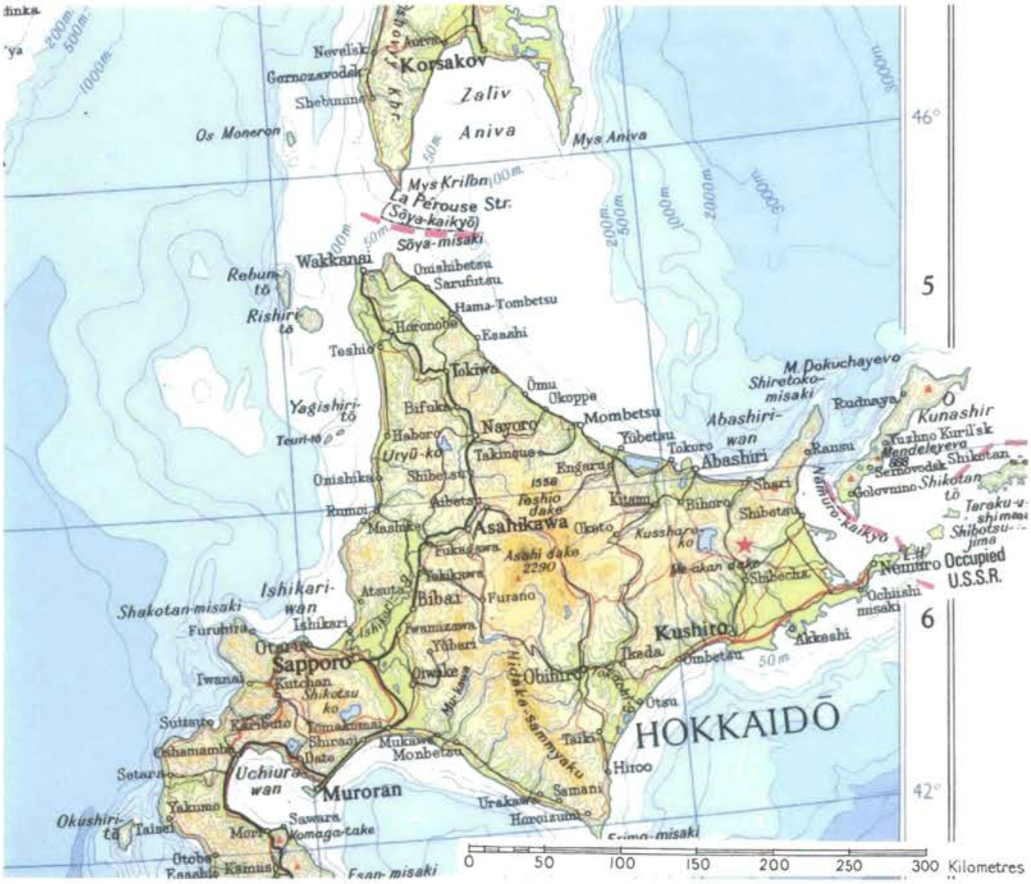
(6) Uchida, E., Asakura, T. & Kawamura, T., (ed.) (1983) Meteorological Data of Japan. 1060 pp. Tôyô-keizaishinpô-sha, Tôkyô.*

(7) Yoshizumi, Y., Ito, T., Imada, K., Awakura, T. & Okamoto, M. (1976) Water quality of Lake Akan and inflowing rivers (1972-1976). Sci. Rep. Hokkaido Fish Hatchery, 31 : 113-154.*

MASHŪ-KO (LAKE MASHŪ)

Overlooking the lake from the west

Photo: A. Kurata



A. LOCATION

§ Hokkaidô, Japan.
§ 43°35′N, 144°32′E ; 355 m above sea level.

B. DESCRIPTION

Lake Mashu is located in the eastern part of Akan National Park and is known as a misterious scenic spot. The "mystery" is attributed to the fact that the lake can be rarely seen in the summer tourist season due to frequent heavy fog. The Environment Agency prohibits entry to the lake-shore area and allows only viewing from observation towers.

It is a beautiful crater lake with its steep encircling wall in complete shape. There is a 300 meter high overhanging cliff in the western part of the crater wall. In the center of the lake there is an oval-shaped small island, Bentenjima (Kamuisshu in Ainu language), 70 m×50 m in size. The central portion of the island stands 25 m above the water surface. The maximum depth of the lake is 211.5 m and the lake bottom is almost flat and covered by pumice deposits.

There are two inflowing streams, but no observable outlet from the lake exists. It is believed that the lake water seeps out through porous bottom sediments, since the water level remains fairly constant. The lake is oligotrophic and the lake water appears indigo-blue. The transparency of 41.6 m measured in August 31, 1931 was said to be the highest in the world, surpassing that of Lake Baikal at that time (40.5 m). The transparency has, however, decreased substantially in recent years (Q).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	19.1
Volume [$10^9 m^3$]	2.7
Maximum depth [m]	211.5
Mean depth [m]	141.3
Length of shoreline [km]	19.8
Catchment area [km^2]	33

D. PHYSIOGRAPHIC FEATURES (Q)

D1 GEOGRAPHICAL

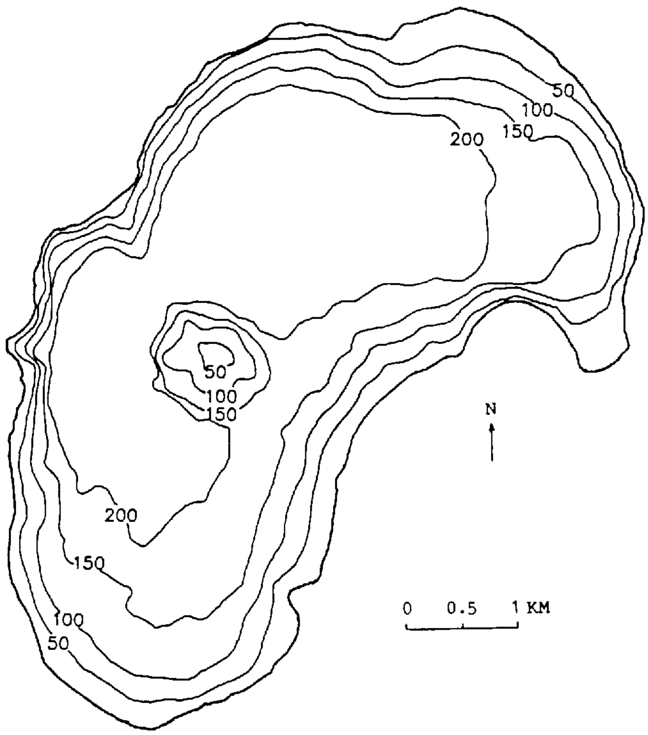
§ Bathymetric map (Fig. ASI-22-1).
§ Main islands (name and area): Bentenjima (70 m×50 m).
§ Outflowing rivers and channels: None.

D2 CLIMATIC

§ Climatic data at Teshikaga (alt. 250 m), 1982-1983

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-7.6	-9.1	-3.95	3.55	8.65	9.5	14.5	17.95	14	7.9	2.05	-4.05	4.45
Precipitation [mm]	41.5	13	52.5	74	63.5	101.5	96	200	92	87.5	86	31	938

Fig. ASI-22-1 Bathymetric map (1).



§ Water temperature [°C]
Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	5.5	–	19.1	16.0	12.7	–	–
30	–	–	–	–		4.2	–	7.1	8.0	10.5	–	–

§ Freezing period: Dec.-Apr.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Station 1, 1984-1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	–	–	25.4	–	23.3	22.0	23.3	–	–

E2 pH

Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	7.2	–	7.4	8.0	7.4	–	–
30	–	–	–	–	–	7.2	–	7.3	7.6	7.2	–	–

E3 SS [mg l^{-1}]

Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	<1		<1	<1	<1	–	–
30	–	–	–	–	–	<1		<1	<1	<1	–	–

E4 DO [mg l^{-1}]

Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	12.0		9.3	9.2	10.1	–	–
30	–	–	–	–	–	12.2	–	12.8	10.8	12.5	–	–

E5 COD [mg l^{-1}]

Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	<0.5	–	<0.5	<0.5	0.8	–	–
30	–	–	–	–	–	<0.5	–	<0.5	<0.5	0.8	–	–

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	0.26	–	0.35	0.32	0.22	–	–

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	<0.05	–	<0.05	<0.05	<0.05	–	–
30	–	–	–	–	–	<0.05	–	<0.05	<0.05	<0.05	–	–

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Station 1, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–	–	–	<0.003	–	0.003	<0.003	<0.003	–	–
30	–	–	–	–	–	<0.003	–	<0.003	<0.003	<0.003	–	–

F. BIOLOGICAL FEATURES

F1 FLORA
§ Phytoplankton : *Melosira* spp., *Synedra* sp.

F2 FAUNA
§ Zooplankton : *Daphnia longispina*, *Bosmina coregoni*.
§ Fish : *Salmo gairdneri*, *Oncorhynchus nerka*.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA
Natural landscape 100%.
§ Main types of woody vegetation : Evergreen conifer forest (*Picea jezoensis*, *Abies sachalinensis*) ; birch forest (*Betula ermanii*).

G2 POPULATION IN THE CATCHMENT AREA : None.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION : No direct uses ; sightseeing.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (a) Pristine lake environments.

M. INSTITUTIONAL MEASURES

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES
(1) Hokkaidô Research Institute for Environmental Pollution, Sapporo
(2) National Institute for Environmental Studies, Tsukuba

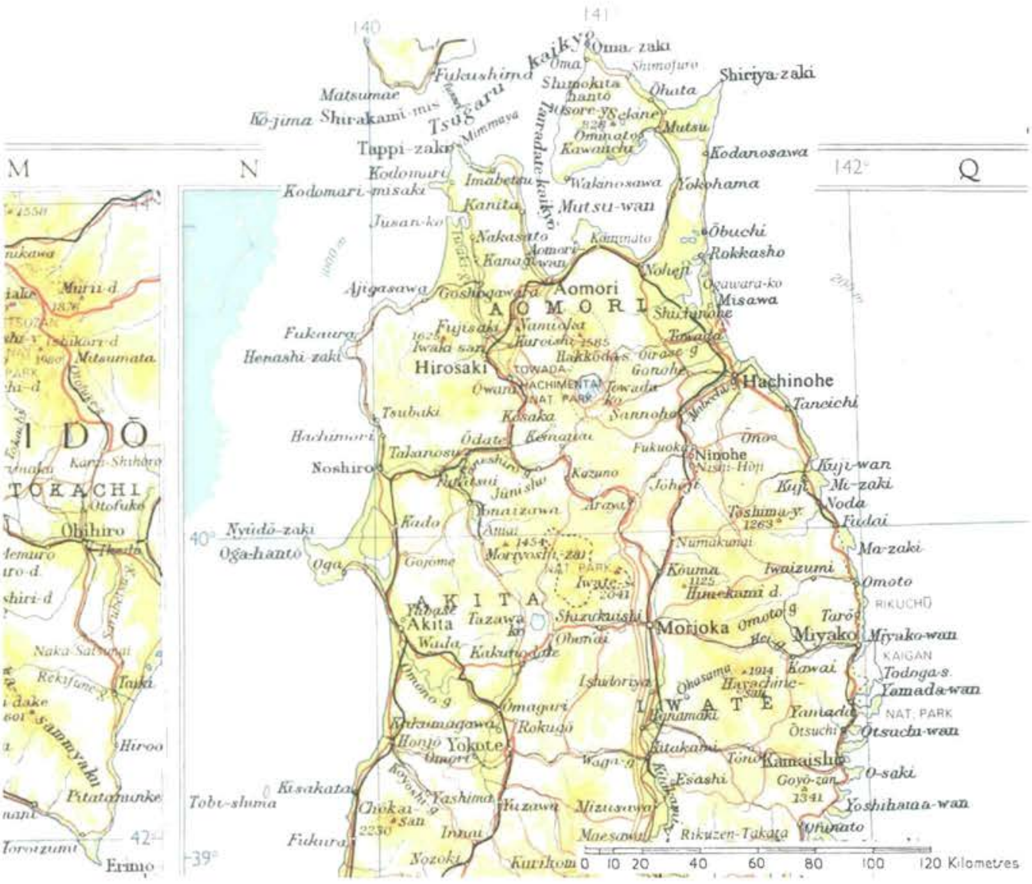
N. SOURCES OF DATA

* Printed in Japanese. The title is tentatively translated into English with the original title in romanized Japanese in parentheses.
(Q) Questionnaire filled by Hokkaidô Research Institute for Environmental Pollution.
(1) Geogr. Survey. Inst., Ministry of Construction (1986) 1 : 10,000 Map of Lake Mashu (1 : 10,000 Kosho zu, Mashu-ko).*

TOWADA-KO (LAKE TOWADA)

An aerial view of the whole lake

Photo: Aomori Prefectural Government



A. LOCATION

§ Akita and Aomori Prefectures, Japan.
§ 40°28′N, 140°53′E ; 401 m above sea level (1).

B. DESCRIPTION

Lake Towada is located in Towada-Hachimantai National Park, which occupies a mountainous area on the border between the two Prefectures, Aomori and Akita. It is known as a typical double caldera of volcanic origin, encircled by sommas about 800 m in altitude. The lake water drains from the northeastern part via Oirase River and eventually to the Pacific Ocean. A small town on the southern shore, Yasumiya, is the tourist center with Towada Science Museum, hotels and shops.

Though L. Towada remains oligotrophic, the local governments are trying to maintain and increase fish production by the artificial hatching and breeding of fry since the first success with sockeye salmon (*Oncorhynchus nerka*) in 1903. The salmon has recently been decreasing, while Japanese smelt (*Hypomesus nipponensis*) and common brackish gobby (*Acanthogobius flavimanus*) are increasing since 1984 (Q).

C. PHYSICAL DIMENSIONS (1, 2)

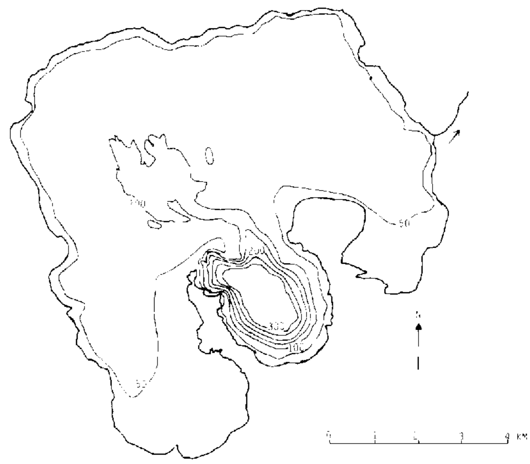
Surface area [km^2]	59
Volume [$10^9 m^3$]	4.2
Maximum depth [m]	334
Mean depth [m]	71.0
Normal range of annual water level fluctuation (regulated) [m]	1.7
Length of shoreline [km]	27.5
Residence time [yr]	8.5
Catchment area [km^2]	129

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Bathymetric map (Fig. ASI-23-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Oirase R.).

Fig. ASI-23-1 Bathymetric map [m] (Q).



D2 CLIMATIC

§ Climatic data at Yasumiya, 1977 1981 (9)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-4.6	4.7	-0.9	4.1	10.0	15.5	19.6	19.6	15.6	10.4	4.3	-0.2	7.4
Precipitation [mm]	81	81	127	126	120	169	176	264	152	152	137	140	1,725

§ Number of hours of bright sunshine : 1,690.7 hr yr^{-1} (9).
§ Water temperature [°C], 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	2.8	4.0	7.9	17.5	23.5	21.0	14.5	11.5	–
5	–	–	–	3.0	4.0	8.4	16.0	22.5	20.7	15.0	11.0	–

§ Freezing period : Dec.-Mar.
§ Mixing type : Dimictic.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Station A, 1985 (3, 10)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	8	11	11	12.5	16.5	11	14	14	–

E2 pH

Station A, 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5		–	–	7.8	7.8	7.7	7.9	8.1	8.1	8.0	7.9	–
5	–	–	–	7.8	7.8	7.7	8.0	8.2	8.1	8.0	7.9	–

E3 SS [mg l^{-1}]
Station A, 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	<1	<1	<1	<1	<1	<1	<1	<1	–
5	–	–	–	<1	<1	<1	<1	<1	<1	<1	<1	–

E4 DO [mg l^{-1}]
Station A, 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	13	12	12	9.2	7.9	8.7	9.0	10	–
5	–	–	–	13	13	12	9.7	8.2	8.7	9.2	10	–

E5 COD [mg l^{-1}]
Determined by $KMnO_4$ method.
Station A, 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–		<0.5	1.0	<0.5	0.9	0.8	<0.5	1.1	0.8	–
5	–	–	–	0.7	1.0	0.5	1.0	1.0	0.5	1.2	1.1	–

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]
Station A, 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	1.1	0.6	0.5	0.3	0.1	<0.5	0.4	0.5	–

E7 NITROGEN CONCENTRATION
§ Total-N [mg l^{-1}]
Station A, 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	<0.05	<0.05	<0.05	0.10	0.06	<0.05	0.05	<0.05	–

E8 PHOSPHORUS CONCENTRATION
§ Total-P [mg l^{-1}]
Station A, 1985 (3, 10)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	0.003	0.004	<0.003	0.005	0.004	<0.003	<0.003	<0.003	–

F. BIOLOGICAL FEATURES

F1 FLORA
§ Emerged macrophytes : *Phragmites communis* (10).

§ Submerged macrophytes : *Potamogeton maackianus*, *P. pectinatus*, *P. heterophyllus*, *P. compressus*, *Myriophyllum spicatum* (10).

§ Phytoplankton : Spring (*Fragilaria*, *Synedra*, *Mougeotia*, *Asterionella*) ; summer (*Fragilaria*, *Synedra*, *Mougeotia*) ; autumn (*Asterionella*) (4, 10).

F2 FAUNA

§ Zooplankton : *Keratella quadrata*, *Daphnia longispina*, *Acanthodiaptomas pacificus*, *Filinia quadrata*, *Polyarthra trigla* (4, 10).

§ Benthos : Tubificinae, chironomid larva, *Pisidium kawamurai* (in 1985, larvae of *Ephemera* and those of two species of Phyganoidea were also collected) (4).

§ Fish : *Oncorhynchus nerka*, *O. masou masou*, *Hypomesus nipponensis*, *Cyprinus carpio*, *Carassius*, *Gasterosteus aculeatus aculeatus*, *Chaenogobius urotaenia* (4, 10).

F4 BIOMASS

§ Plankton biomass (precipitated) [mg m^{-3}], summer average of 10 stations (4).

1981	1982	1983	1984	1985
5.64	1.81	2.10	1.26	0.56

F5 FISHERY PRODUCTS

§ Annual fish catch in 1985 : 88.2 [metric tons].

§ Fishery products other than fish : 450 [kg yr^{-1}] (1985).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

The amount of zooplankton was a bit smaller in 1985 than the average for past several years. *Hypomesus nipponensis*, *Gasterosteus aculeatus* and *Acanthogobius flavimanus* are increasing since 1984, while *Oncorhynchus nerka* tends to decrease (4).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (10)

Natural landscape nearly 100%.

§ Main types of woody vegetation : Deciduous broadleaf forest (*Fagus crenata* dominant, with *Pterocarya rhoifolia*, etc.).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1984) (5, 6)

	Gross product per year [10^3 yen] (250 yen≒US$ 1)	Number of persons engaged	Number of establishments	Main products and main kinds of industry
Primary industry				
Fisheries	45,859	N.A.	N.A.	
Teritary industry	N.A.	408	43	Hotel business

§ Number of domestic animals in the catchment area : Cattle 2.

G3 POPULATION IN THE CATCHMENT AREA

Number of permanent residents 263 ; population density 2.0 [km^{-2}].

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Tourism and recreation (swimming, yachting, sport-fishing) (number of visitors in 1985 : 1.59×10^6) and fisheries (8).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION (3)

§ Present status : None.

§ Main contaminants and their concentrations [ppm] in water, 1986.

Name of contaminant	T-Hg	Cd	Cr (VI)	CN	Pb	As	PCB	Pesticide (org-P)
Concentration	<0.0005	<0.005	<0.02	N.D.	<0.005	<0.02	N.D.	N.D.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : None.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of rural population with adequate sanitary facilities (on site treatment systems) : 100%.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) For national laws see "Biwa-ko".
(2) Akita Prefectural Pollution Control Ordinance (1972)
(3) Aomori Prefectural Pollution Control Ordinance (1972)

§ Responsible authorities

(2) Akita Prefectural Government
(3) Aomori Prefectural Government

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Center for Environmental Technics, Akita Prefecture, Akita (established in 1970)
(2) Inland Water Fishery Station, Akita Prefecture, Hachirôgata (established in 1957)
(3) Enuironmental Pollution Control Center of Aomori Prefecture

N. SOURCES OF DATA

(Q) Questionnaire filled by the Prefectural Goverments of Akita and Aomori.
(1) Tsuda, M. (ed.) (1975) Diagnosis of Japanese Lakes ; the Present Conditions of Eutrophication. Kyôritsu Shuppan, Tôkyô (in Japanese).
(2) Ministry of Construction (1978) Report of River Surveys. Tôkyô (in Japanese).
(3) Data supplied by Akita Prefectural Government.
(4) Lake Towada Hatchery Station : Report on Resource Conservation in Lake Towada (in Japanese).
(5) Data supplied by the town office of Kosaka-chô.
(6) Enterprise Statistics for 1986.
(7) Data supplied by the town office of Kosaka-chô.
(8) Data supplied by the Tourism Section, Akita Prefectural Government.
(9) Takahashi, K. (ed.) (1983) Meteorological Data of Japan. 157pp. Tôyô-keizaishinpô-sha, Tôkyô (in Japanese).
(10) Data supplied by Aomori Prefectural Government.

OGÔCHI-DAMU-KO (OKUTAMA RESERVOIR)

A bird-eye view of the reservoir

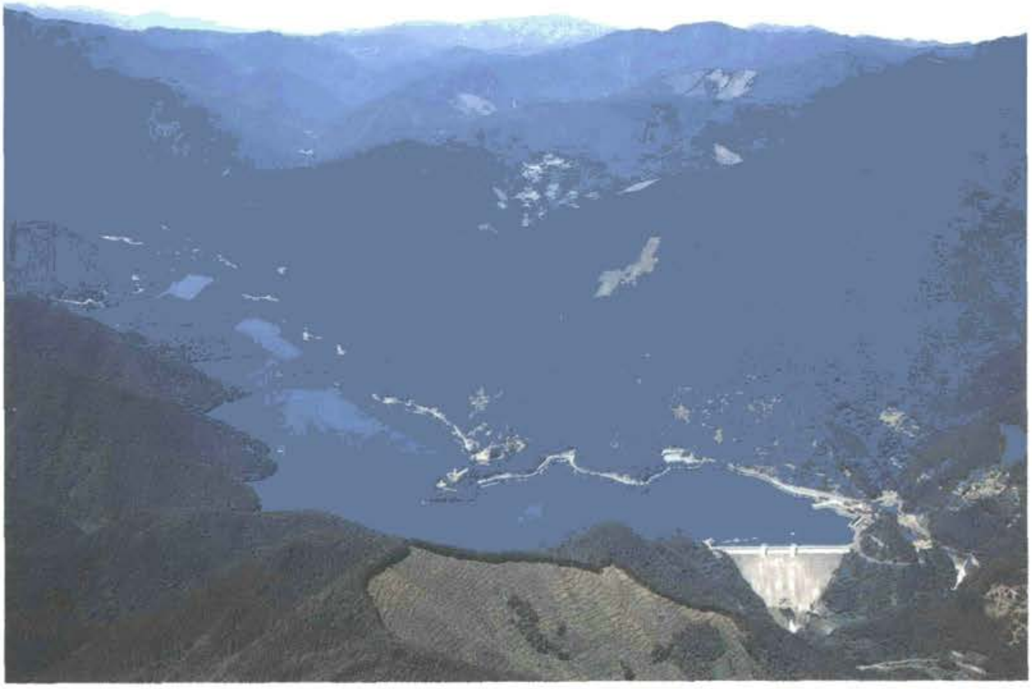


Photo: Tôkyô Metropolitan Government

A. LOCATION

§ Tôkyô Metropolis, Japan.
§ 35°46′N, 139°03′E ; 550 m above sea level.

B. DESCRIPTION (Q)

Ogôchi-damu-ko, or Okutama-ko, was formed by the construction of Ogôchi Dam in the upstream of Tama River to serve as a reservoir of drinking water for Tôkyô metropolitan area. It extends for 4 km in east-west direction, is 1.5 km wide (north-south), and has a water surface of 4.25 km^2. The lake is said to be the world's largest among the reservoirs used solely for city water supply. The construction work needed 19 years from November 1938 to November 1957.

Twenty percent of the lake's catchment area belongs to Tôkyô Metropolis and the rest to Yamanashi Prefecture. The catchment is mostly mountainous, ranging in altitude from 2,018 m on the top of Mt. Kumotori to about 550 m at the lake surface. Flat lands are limited only to the immediate vicinity of the lake. Mountain slopes are mostly covered by mixed beech-fir forests and evergreen conifer (*Cryptomeria*) plantations (Q).

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	4.25
Volume [$10^6 m^3$]	189.1
Maximum depth [m]	142.5
Mean depth [m]	44.4
Normal range of annual water level fluctuation (regulated) [m]	4
Length of shoreline [km]	45.4
Residence time [yr]	0.68
Catchment area [km^2]	259

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Bathymetric map (Fig. ASI 24 1).

§ Outflowing rivers and channels (number and names): 1 (Tama R).

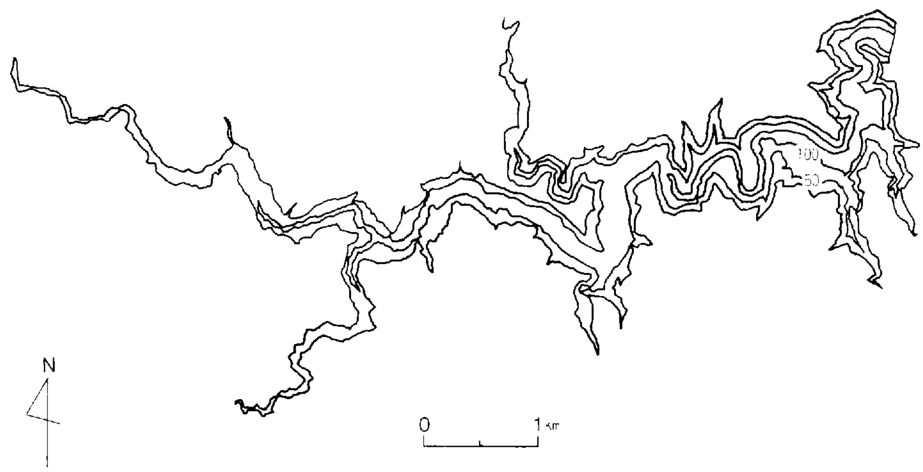
D2 CLIMATIC (Q)

§ Climatic data at the control office site, 1982-1984 (temp.), 1941 1984 (precip.).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	1.4	1.5	5.1	13.1	18.5	19.9	22.8	25.7	21.2	14.8	10.8	5.4	13.4
Precipitation [mm]	39	53	71	104	122	181	222	281	225	185	76	39	1,597

§ Solar radiation (1974-1980): 11.4 MJ m^{-2} day^{-1}.

Fig. ASI-24-1 Bathymetric map [m] (Q).



§ Water temperature [°C]

Near the dam, 1982 1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	8.8	7.2	7.0	10.2	16.9	20.4	22.6	24.9	22.2	17.8	14.7	12.0
Middle	8.5	6.9	6.2	6.2	6.4	6.5	6.6	8.2	11.0	12.1	12.2	11.4
Bottom	7.9	6.8	6.2	6.1	6.3	6.5	6.5	7.7	7.6	7.6	7.7	7.8

§ Freezing period: None.

§ Mixing type: Monomictic.

§ Notes on water mixing and thermocline formation: Thermocline is formed at about 73 m depth.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Near the dam, 1982-1984

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.4	2.7	3.6	3.9	5.1	6.7	8.0	3.7	4.5	3.2	1.7	1.5

E2 pH

Near the dam, 1982-1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	7.1	7.1	7.2	7.7	8.2	8.2	8.2	8.2	8.3	7.3	7.1	7.1
Middle	7.0	7.1	7.1	7.1	7.0	7.1	7.0	6.9	6.9	7.0	7.0	7.0
Bottom	6.8	7.0	7.0	6.9	6.8	6.7	6.6	6.6	6.6	6.6	6.6	6.6

E3 Turbidity

Near the dam, 1982-1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	7.2	4.3	2.8	2.1	1.3	0.8	0.7	7.4	2.2	10.3	25.6	9.7
Middle	9.9	5.8	3.9	2.7	2.0	1.7	1.2	65	97	76	15	13
Bottom	25	12	7.8	21	11	9.8	9.3	144	109	61	36	35

E4 DO [mg l^{-1}]

Near the dam, 1982-1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	9.3	10.1	10.8	11.3	9.9	9.1	8.7	8.5	8.8	8.2	8.1	8.7
Middle	9.2	9.9	10.3	10.2	10.0	9.7	9.2	8.1	7.9	8.2	8.1	8.3
Bottom	6.1	8.5	10.1	8.8	6.9	3.2	1.5	3.0	4.3	3.2	2.1	2.2

E5 COD [mg l^{-1}]

Determined by $KMnO_4$ method.

Near the dam, 1982-1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.4	1.2	1.2	1.4	1.6	1.5	1.5	2.1	2.2	1.9	1.9	1.5
Middle	1.4	1.2	1.2	1.1	1.1	1.1	1.2	4.0	1.0	3.3	1.6	1.6
Bottom	1.9	1.4	1.3	1.8	1.7	1.9	2.2	6.6	4.7	3.4	2.7	2.8

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Near the dam, 1982-1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	2.8	9.2	23.6	55.8	68.9	87.7	77.2	57.2	74.5	31.1	13.8	8.0

E7 NITROGEN CONCENTRATION

§ NO_3-N [mg l^{-1}]

Near the dam, 1982-1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.68	0.37	0.47	0.53	0.35	0.38	0.38	0.42	0.50	0.45	0.43	0.38
Middle	0.47	0.42	0.47	0.55	0.37	0.38	0.45	0.68	0.33	0.17	0.53	0.28
Bottom	0.95	0.45	0.45	0.57	0.38	0.48	0.58	0.70	0.32	0.47	0.63	0.72

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Near the dam, 1982-1984

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.008	0.007	0.005	0.005	0.003	0.000	0.002	0.006	0.028	0.020	0.018	0.011
Middle	0.009	0.006	0.005	0.004	0.003	0.001	0.001	0.020	0.055	0.038	0.012	0.013
Bottom	0.008	0.012	0.006	0.020	0.011	0.018	0.014	0.049	0.055	0.050	0.030	0.031

F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes : None.
§ Floating macrophytes : None.
§ Submerged macrophytes : None.
§ Phytoplankton : *Cyclotella*, *Kirchneriella*, *Cryptomonas*, *Rhizosolenia*, *Synedra*, *Asterionella*.

F2 FAUNA

§ Zooplankton : *Daphnia*, *Bosmina*.
§ Fish : **Oncorhynchus masou masou*, **Salmo gairdneri*, **Cyprinus carpio*, **Hypomesus nipponensis*, *Carassius*, *Zacco platypus*, *Tribolodon hakonensis*, *Micropterus salmonides* (*economically important).

F3 PRIMARY PRODUCTION RATE [g CO_2 m^{-2} day^{-1}]

Near the dam, Apr. 1984-Mar. 1985

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net production	0.41	0.54	3.22	(53.2)	(1.37)	(2.47)	(0.67)*	1.85	1.66	1.32	0.50	0.64
Dark respiration	0.22	0.24	2.00	–		–	1.66	0.59	0.67	0.97	0.35	0.38
Gross production	0.63	0.78	5.21			–	2.33	2.44	2.34	2.29	0.85	1.02

( ) Estimated from chlorophyll concentration. * Unusual value.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

Bloom of *Microcystis* was first observed in 1984. *Micropterus salmonides* has newly appeared in the lake.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1989)

	Area	[%]
Natural landscape		
Woody vegetation	245	94.6
Others	0.08	0.03
Agricultural land		
Crop field	4.5	1.7
Settlement area	0.41	0.0
Others	8.9	3.5
Total	259	100.0

§ Main types of woody vegetation: Evergreen conifer plantation (*Cryptomeria japonica*); mixed forest (*Fagus crenata*, *Abies homolepis*).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1984)

	No. of establishments	Main products or main kinds of industry
Secondary industry	5	Concrete mixing
Tertiary industry	85	Hotel services

§ Numbers of domestic animals in the catchment area: small numbers of sheep, goat, rabbit, poultry, etc.

G3 POPULATION IN THE CATCHMENT AREA

	Population	Population density [km^{-2}]
Rural	3,258	—
Total	3,258	12.4

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (ca. 770×10^3 visitors in 1983) and recreation (sport-fishing).

H2 THE LAKE AS WATER RESOURCE (1986)

	Use rate
Domestic water	672,210 m^3 day^{-1}
Irrigation	—
Industrial water	—
Power plant	662,934 m^3 day^{-1}

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : None.

I2 TOXIC CONTAMINATION

§ Present status ; None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Peridinium*, *Microcystis* and *Uroglena*).

§ Nitrogen and phosphorus loadings to the lake [kg day^{-1}] (1984)

Sources	Industrial	Domestic	Agricultural and fish culture	Natural	Total
T-N	0	17.59	9.52	188.7	215.81
T-P	0	1.92	3.58	7.23	12.73

§ Supplementary notes : Bloom of *Microcystis* first appeared in 1984. Sewage treatment plants for two villages in Yamanashi Prefecture are now under construction.

I4 ACIDFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS : Non-point sources 100%.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of rural population with adequate sanitary facilities (on site treatment systems) or public sewerage : 8.9%.

§ Number of industrial wastewater treatment systems : 5 (primary treatment : precipitation).

L. DEVELOPMENT PLANS (Q)

Facilities for camping and sport-fishing and a barbecue restaurant are offered. Further plans for utilizing the lake area for recreation and nature observation are being developed by Tokyo Metropolitan Government.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) For national laws see "Biwa-ko".
(2) Pollution Control Ordinance, Tôkyô Metropolis
(3) Pollution Control Ordinance, Yamanashi Prefecture

§ Responsible authorities

(2) Tôkyô Metropolitan Government
(3) Yamanashi Prefectural Government

M2 INSTITUTIONAL MEASURES

(2) Bureau of Environmental Protection, Tôkyô Metropolitan Government
Bureau of Water Works, Tôkyô Metropolitan Government
(3) Yamanashi Prefectural Government

N. SOURCES OF DATA

(Q) Questionnaire filled by Tôkyô Metropolitan Government, based on the following data sources.

Annual Report on the Management of Ogôchi Rservoir for 1982, 1983 and 1984 (in Japanese).

Report of survey for Determining Environmental Standards for Okutama-ko (1985) Bureau of Environmental Protection, Tôkyô Metropolitan Government, Tôkyô (in Japanese).

Report of Survey for Reducing Pollution Loads to Okutama-ko (1986). Bureau of Environmental Protection, Tôkyô Metropolitan Government, Tôkyô (in Japanese).

KAWAGUCHI-KO (LAKE KAWAGUCHI)

Mt. Fuji and the lake

Photo : A. Kurata

A. LOCATION

§ Yamanashi Prefecture, Japan.
§ 35°31'N, 138°45'E ; 832 m above sea level.

B. DESCRIPTION

Lake Kawaguchi is one of the five lakes surrounding Mt. Fuji. These lakes were formed as a result of barrage formation by volcanic debris and solidified magma spewed out of Mt. Fuji and the off-spring volcanic outlets nearby. The lake is the oldest of the five and it is at least 50-60 thousand years old. There are scores of underwater springs at the lake bottom. There is no discernible surface flow into or out of the lake. Major flows of water appear to take place underground. In 1912 a sluiceway was constructed to discharge a maximum flow of 7.79 m^3/sec (named Usobuki River). Artificial regulation of flow has been made possible by flow augmentation from Lake Sai, one of the remaining four lakes, for supplementing water for power generation. The number of visitors to the five-lake area exceeds ten million annually. Lake Kawaguchi, directly linked to Tokyo Metropolitan urban districts through a major artery highway and closest to the terminal of the Fuji Subaru scenic route, is a center of tourist attraction in this area.

The transparency of the lake was 4-7 m some 60 years ago, but the 1972 measurement indicated only 3-4 m. A regional sewerage project was initiated in 1974 and the provision of service to portion of the area has begun in 1986 (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	5.96 (1)
Volume [10^9 m^3]	55.5 (1)
Maximum depth [m]	16.1 (1)
Mean depth [m]	9.3 (1)
Normal range of annual water level fluctuation (regulated) [m]	2-3 (2)
Length of shoreline [km]	20.9 (3)
Residence time [yr]	0.31 (4)
Catchment area [km^2]	120.4 (5)

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Bathymetric map (Fig. ASI-25-1).
§ Main islands : Uno-shima.
§ Outflowing rivers and channels (number and names) : 1 (Usobuki R.).

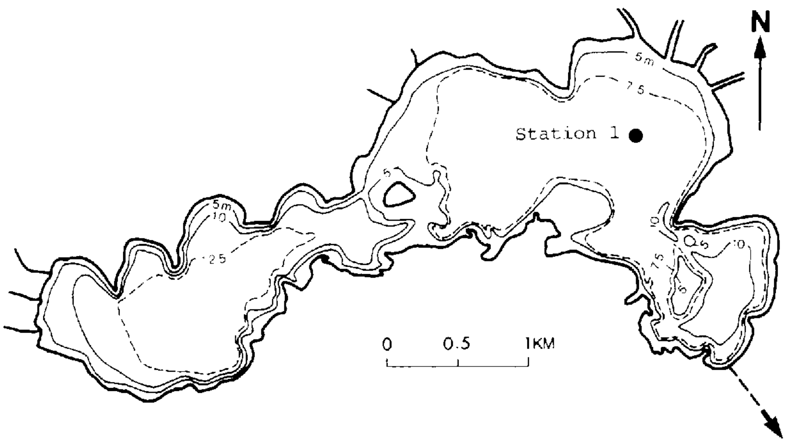
D2 CLIMATIC (6)

§ Climatic data at Kawaguchi-ko, 1951-1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-1.2	-0.4	2.9	8.8	13.3	16.9	20.9	21.6	17.7	11.7	6.8	1.7	10.6
Precipitation [mm]	53	62	87	115	129	182	171	205	209	165	79	51	1,506

§ Number of hours of bright sunshine : 2,039.5 hr yr^{-1}.
§ Average depth of maximum snow accumulation (1951-1980) : 0.33 m.

Fig. ASI-25-1 Bathymetric map (Q).



§ Water temperature [°C] (Q)
Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	4.0	4.6	6.5	14.4	17.9	20.6	23.9	24.6	20.7	15.7	11.9	7.5

§ Freezing period : From January to March (Q).
§ Mixing type : Dimictic (Q).

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Station 1, 1981-1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.6	3.7	3.5	2.9	3.3	3.0	2.8	2.4	2.8	2.2	2.6	3.0

E2 pH

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	7.6	7.5	7.6	7.9	8.1	8.5	8.7	8.3	7.9	7.6	7.7	7.6

E3 SS [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	1.6	2.1	1.7	2.2	2.0	1.8	2.0	4.2	1.9	3.3	2.7	2.3

E4 DO [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	11.5	11.1	11.1	10.2	9.6	9.7	9.1	8.2	8.1	8.2	9.2	10.0

E5 COD [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	3.1	2.9	2.8	2.9	3.6	3.5	3.4	3.8	3.1	2.9	2.9	2.9

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	–	–	–	–	6.6	–	7.4	7.1	–	–	8.2	–

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	0.57	0.46	0.38	0.37	0.44	0.34	0.34	0.52	0.44	0.50	0.49	0.45

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.3	0.012	0.010	0.011	0.09	0.011	0.017	0.012	0.018	0.017	0.013	0.013	0.012

E10 PAST TRENDS

Fig. ASI-25-2 Past trend of transparency at Station 1.

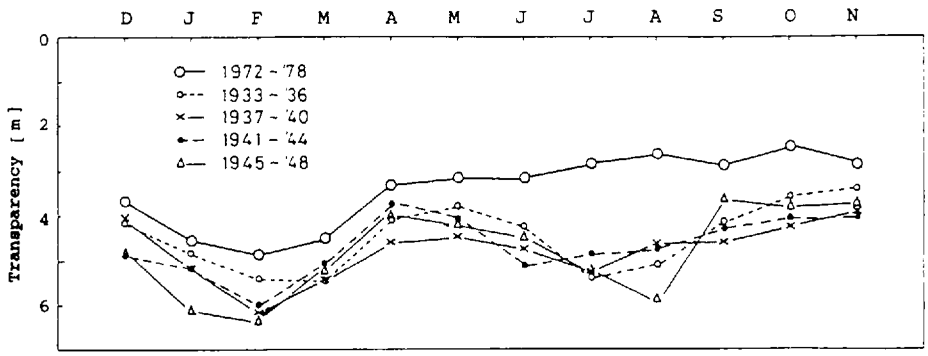
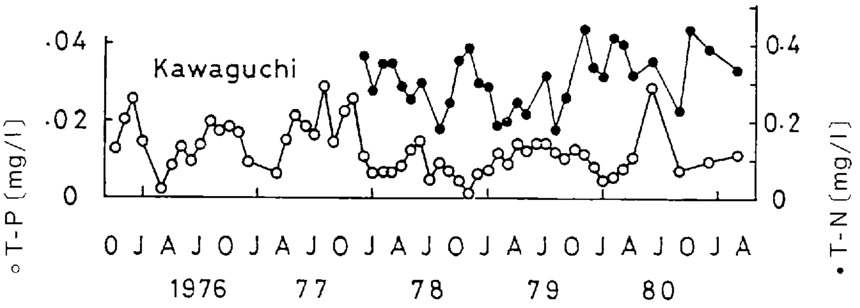


Fig. ASI-25-3 Past trends of total nitrogen and total phosphorus.



F. BIOLOGICAL FEATURES

F1 FLORA

§ Phytoplankton : *Anabaena solitaria f. planctonica, Melosira crenulata, M. granulata, Fragilaria erotonensis, Synedra ulna, Mougeotia* sp. (7).

F2 Fauna

§ Zooplankton : *Ploesoma hudsoni, P. truncatum, Bosminopsis deitersi, Bosmina longirostris* (8).

§ Benthos : *Chironomus fujitertius, Glyptotendipes tokunagai, Pentapedilum sordens, Tanytarsus oyamai* (3, 9).

§ Fish : **Hypomessus olidus*, **Cyprinus carpio*, **Carassius langsdorfi, Anguilla japonica, Zacco platypus, Tribolodon hakonensis hakonensis* (*economically important) (10).

F3 PRIMARY PRODUCTION RATE [g O_2 $m^{-2}day^{-1}$] (Q)

Station 1, 1981

	Jul
Net production	3.23
Dark respiration	0.98
Gross production	4.21

F5 FISHERY PRODUCTS (10)

§ Annual fish catch in 1982 : 24 [metric tons].

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE (Q)

Population of Japanese smelt (*Hypomessus olidus*) decreased in 1985 and 1986.
Large-mouth bass (*Micropterus salmoides*) increased in recent years.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1984) (Q)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	96.2	79.9
Herbaceous vegetation	1.1	0.9
Agricultural land	6.8	5.6
Settlement area	8.5	7.1
Others	7.8	6.5
Total	120.4	100

§ Main types of woody vegetation: Evergreen conifer forest (*Abies homolepis, A. veitchii, Tsuga diversifolia, Pinus densiflora*); deciduous broadleaf forest (*Quercus* spp., *Castanea crenata, Betula ermanii*); evergreen and deciduous conifer plantation (*Larix kaempferi, Pinus densiflora, Abies homolepis*) (11).

§ Types of important herbaceous vegetation: Grassland and weeds (11).

§ Main kinds of crops: Vegetables, maize (12).

§ Levels of fertilizer application on crop fields: Moderate (Q).

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (1980) (Q)

	Gross production per year [10^6 yen]	No. of persons engaged	No. of establishments
Primary industry	10		
Crop production Animal husbandry		1,130	
Fisheries		12	
Others		53	
Secondary industry	400	2,710	353
Tertiary industry	202	6,096	1,481

§ Numbers of domestic animals in the catchment area: Cattle 320, swine 221, poultry 33,400.

G3 POPULATION IN THE CATCHMENT AREA (1985) (Q)

	Population	Population density [km^{-2}]
Rural	20,654	
Total	20,654	171.5

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (number of visitors in 1983: 5,140,000), recreation (sport-fishing) and fisheries.

H2 THE LAKE AS WATER RESOURCE

	Use rate [m^3sec^{-1}]
Irrigation	2.53

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : None.

I2 TOXIC CONTAMINATION

§ Present status : None.

I3 EUTROPHICATION

§ Nitrogen and phosphorus loadings [t yr^{-1}] 1975

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	2.1	50.7	24.2	48.3	125.3
T-P	0.1	10.5	4.3	1.3	16.2

§ Supplementary notes

The annual means of measurements for a period between 1982-1985 were 2.6 3.4 m for transparency, 4.08-9.92 $\mu g\ l^{-1}$ for chlorophyll a, 0.35-0.56 mg l^{-1} for total nitrogen, and 0.011-0.016 mg l^{-1} for total phosphorus, indicating a trend from mesotrophic to eutrophic state. The Lake Kawaguchi Water Quality Protection Committee was formed by the municipalities concerned and it has been undertaking collaborative water quality management activities, including the promotion of the use of grey-water solid separation units. A local sewerage project has also been undertaken in Yamanashi Prefecture for part of the northern slope of Mt. Fuji.

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	[%]
Forests	8.8
Agricultural fields	19.7
Households	42.7
Tourists	16.9
Livestock	12.5
Total	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of rural population with adequate sanitary facilities (on site treatment systems) : 39 %.

§ Number of industrial wastewater treatment systems : 40 (biological treatment).

K. IMPROVEMENT WORKS IN THE LAKE (Q)

K1 RESTORATION

Sewerage discharge has been diverted from the catchment area.

L. DEVELOPMENT PLANS (Q)

A sight-seeing highway (Subaru Line) was constructed in 1961-1964 by Yamanashi Prefectural Government (cost: ¥1,700,000,000).

M. LEGISLATIVE AND INSTITUTINAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws
- (1) Yamanashi Prefecture Anti-Pollution Ordinance
- (2) Lake Kawaguchi Grey Water Regulation Ordinance

§ Responsible authorities
- (1) Yamanashi Prefecture
- (2) Kawaguchi-ko Town

§ Main items of control
- (1) Establishment of locally pertinent effluent standards
- (2) Promotion of the use of household grey-water solid separation units

M2 INSTITUTIONAL MEASURES

(1) Monitoring and regulatory measures; Environmental Protection Section, Livelihood Division, Yamanashi Prefectural Government.

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Yamanashi Prefectural Institute of Publilc Health and Anti-pollution

N. SOURCES OF DATA

* Printed in Japanese. The titles are tentatively translated into English with the original titles in romanized Japanese in parentheses.

(Q) Questionnaire filled by Economic Welfare Bureau, Environmental Protection Section, Yamanashi Prefectural Government.

(1) Shimizu, G. (1980) Annual Report of the Yamanashi Institute for Public Health and Anti-pollution (Yamanashi-ken Eisei Kôgai Kenkyû-sho Nenpô), 24 : 30-32.*

(2) Kasai et al. (1976) Journal of Water and Waste (Yôsui to Haisui), 18 : 25.*

(3) Geographical Survey Institute, (1975) Lake shoreline Statistics (Kogansen Shûkei-hyô) Digital National Land Information (Kokudo Sûchi Jôhô).

(4) Yamanashi Prefectural Government (1984) Survey on Limnological Aspects of the Lakes (Koshô no Shogen ni kansuru Chôsa), Kofu.*

(5) Land Bureau, National Land Agency (1982) Water Usage Map of Yamanashi-Shizuoka Regional Watersystems (Yamanashi-Shizuoka Chiiki Shuyô Suikei Risui Genkyô Zu), Kofu.*

(6) Kôfu Regional Meteorological Station (1982) Tables of Climatic Data in Yamanashi Prefecture (Yamanashi-ken Kishô Heinenchi Hyô), Kofu.*

(7) Yamanashi, T., Oshima, K. & Watanabe, M. (1982) Memoirs of the National Science Museum (Kokuritsu Kagaku Hakubutsu-kan Senpô), 15 : 91-97.*

(8) Yoshida, Suginome & Tanaka. (1974) Bulletin of Freshwater Fisheries Research Laboratory (Tansui-ku Suisan Kenkyû-sho Kenkyû Hôkoku), 24(1) : 1-9.*

(9) Sasa, M. (1985) Research Report from the National Institute for Environmental Studies, Japan, 83 : 106-160.

(10) Fish Hatchery Center of Yamanashi Prefecture.

(11) Yamanashi Prefectural Government (1977) Vegetation Map of Yamanashi Prefecture (Yamanashi-ken Shokusei-zu), Kôfu.*

(12) Yamanashi Prefectural Government (1986) Yamanashi Prefecturel Annual Statistics (Yamanashi-ken Tokei Nenkan), Kofu.*

TAI-HU

An evening view on the lake near Wuxi

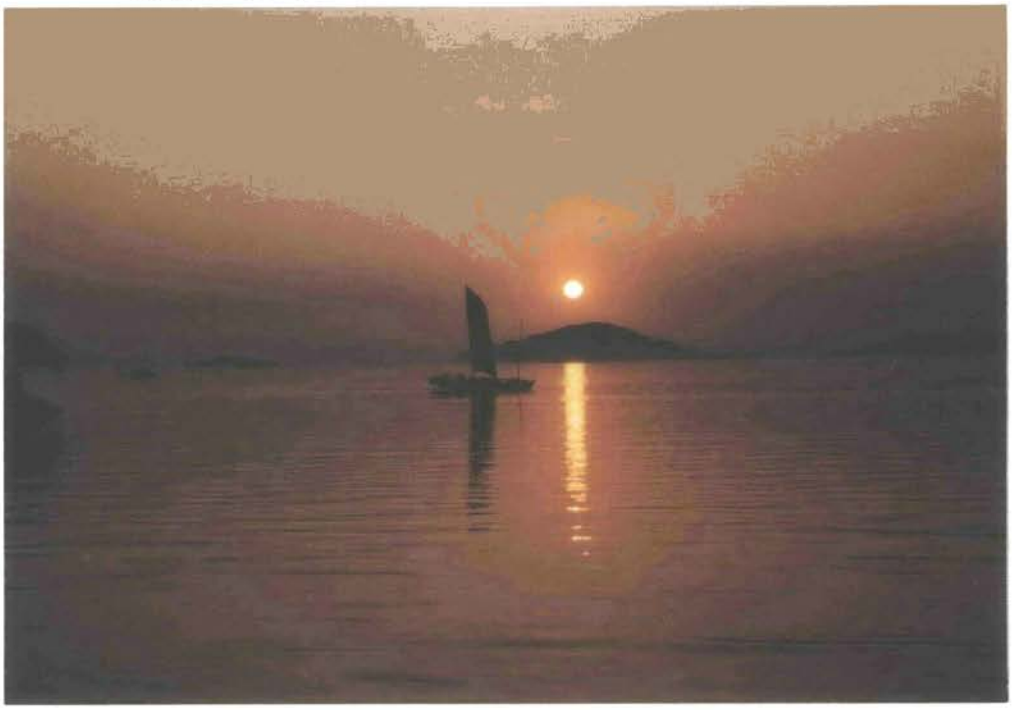
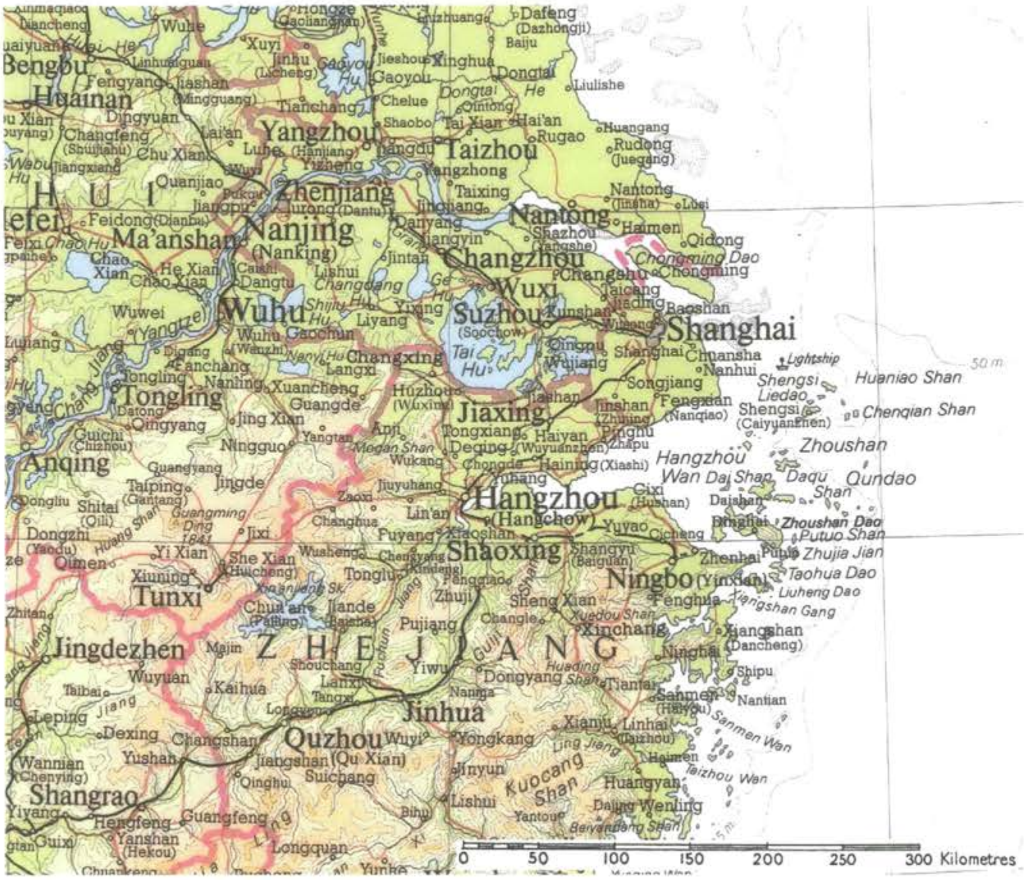


Photo: M. Akiyama



A. LOCATION

§ Jiangsu Province, People's Republic of China.
§ 30°56′-31°34′N, 119°54′ 120°36′E ; 3.1 m above sea level.

B. DESCRIPTION

Tai(great)-hu(lake) is the third largest freshwater lake of China, below in size Lakes Poyang and Dongting, situated about 100 km from the east coast of the Chang Jiang delta in central China. The whole lake is under the administration of Jiangsu Province, though its southern coast belongs to the neighboring province, Zhejang. It is located in the densely populated fertile plain of the delta known for its complicated network of small lakes, ponds, streams and man-made canals, including the Grand Canal built in the 7th century to connect Beijing with Hangzhou in Zhejang.

The inflowing water comes mainly from mountains to the west and southwest of the lake, while the draining rivers start mostly from the east coast of the lake. Several rivers and channels connect the lake with Chiang Jiang, but the water flux is controlled by dams to maintain the lake water level within a range of fluctuation of 2-3 meters.

The lake is famous for its abundant production of fishes and crabs, and the aquaculture farms on the coast that apply skillful techniques. In addition to supporting heavy boat traffic, Tai-hu provides some of the best known water-side scenery in China for domestic and foreign sightseeing visitors.

Tai-hu and its effluent rivers are important sources of water for the inhabitants and rapidly increasing industrial factories in Shanghai, Wuxi, Suzhou and other neighboring cities, so that the pollution of the lake is a serious social concern. The pollutants originate mainly from home sewage of the vast number of inhabitants, agricultural pesticides applied over fields in the drainage basin, and the industrial sewage of more than 700 factories and mines. The Film Studio, Tanshan Ore Dressing Plant, Westhill Mines and the Wuxi No. 3 Instrument and Metal Plant discharge 2,750 tons per day of waste water directly into the lake. Phenol, mercury, chromium etc. are widely detected over the lake, but at fairly low concentrations. The lake water is also highly eutrophic, with frequent blooms of blue-green algae even in late autumn (1, 2).

C. PHYSICAL DIMENSIONS (1, 2)

Surface area [km^2]	2,427.8
Volume [$10^9 m^3$]	4.3
Maximum depth [m]	2.6
Mean depth [m]	1.9
Residence time [yr]	Less than 0.79

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-26-1).

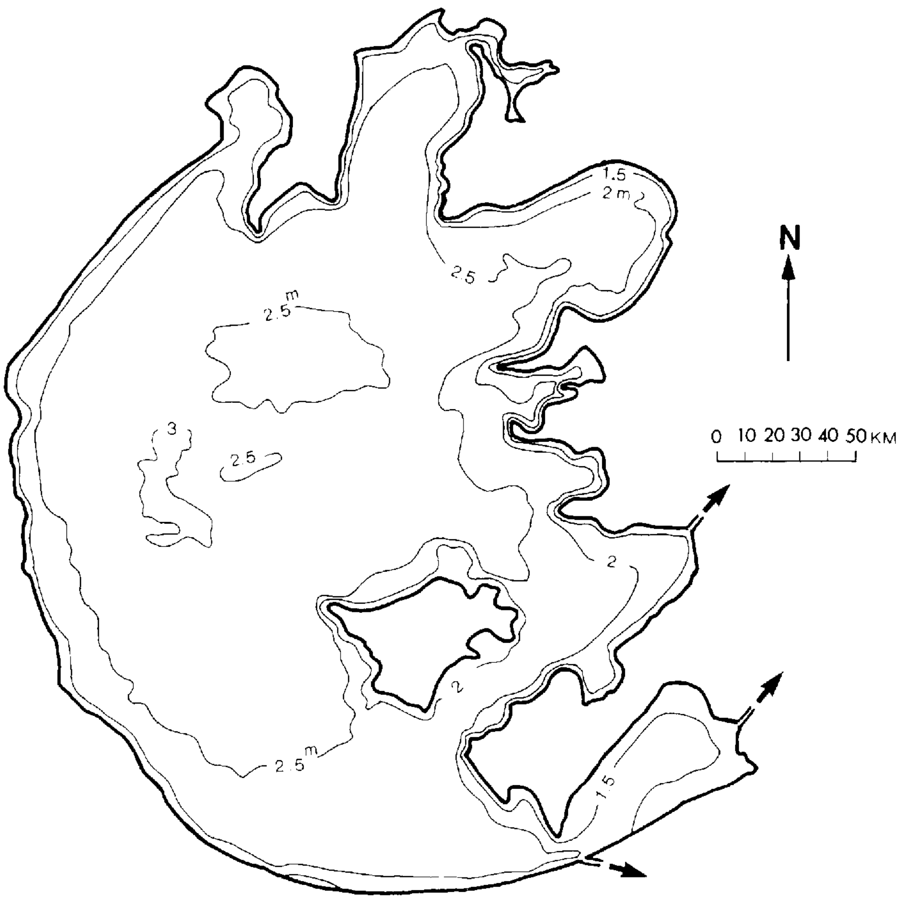
§ Outflowing rivers and channels (number and names): Dapu R., Wusong R., etc.

D2 CLIMATIC

§ Climatic data at Suzhou, 1956-1958 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2.9	3.7	8.1	15.1	18.7	24.7	29.9	27.3	22.8	16.7	11.3	6.3	(15.6) 16.2
Precipitation [mm]	38	61	51	91	99	156	152	104	93	42	48	40	974

Fig. ASI-26-1 Bathymetric map (1).



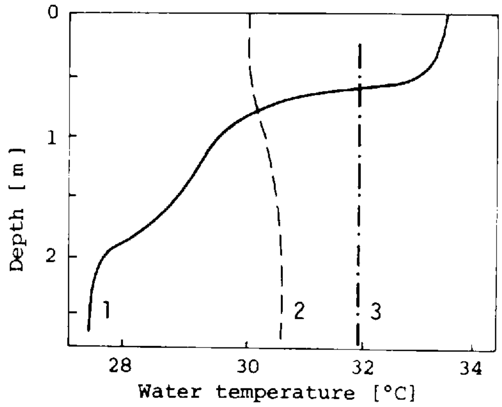
§ Water temperature [°C] (1)
Dapu, 1959

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	2.5	5.8	11.0	15.1	20.0	24.8	29.9	30.2	24.2	19.5	12.4	7.2

§ Freezing period: None.

§ Notes on water mixing and thermocline formation: Not formed; surface water temperature may rise very high on calm summer days with strong sunshine.

Fig. ASI-26-2 Vertical distribution of water temperature [°C] on summer days (near Sanshan Island) (1). 1 : 21 : 00 on 10 July 1960. 2 : 17 : 00 on 9 July 1960. 3 : 11 : 30 on 2 July 1960.



E. LAKE WATER QUALITY

E1 Transparency : 0.15-1.00 m (July-August) (1).

E2 pH of surface water : 8.0 (annual mean) (2).

E3 SS (suspended mud) : 50 mg l^{-1} (1).

E4 DO : 9.56 mg l^{-1} (annual mean) (2).

E5 COD : 1.04-5.21 mg l^{-1} (2).

E7 NITROGEN CONCENTRATION

§ NH_4-N : 0.108 mg l^{-1} (annual mean) (2).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites communis, Zizania latifolia, Alternanthera philoxeroides* (4).

§ Floating macrophytes : *Eichhornia crassipes, Trapa incisa* var. *quadricaudata, Euryale ferox* (4).

§ Submerged macrophytes : *Vallisneria spiralis, Potamogeton malaianus, Hydrilla verticillata* (4).

§ Phytoplankton : *Microcystis flos-aquae, M. aeruginosa, Anabaena flos-aquae, Aphanizomenon flos-aquae, Melosira* spp. (3).

F2 FAUNA (3)

§ Zooplankton : *Difflugia* spp., *Tintinnopsis* spp., *Polyarthra* sp., *Brachionus* spp., *Keratella* spp., *Bosmia fatalis, B. longirostris, Ceriodaphnia cornuta, Diaphanosoma sarsi, D. brachyurum.*

§ Benthos : *Corbicula fluminea, Stenothyra glabra, Viviparus guadratus.*

§ Fish : (economically important species) : *Coilia brachygnathus, Protosalanx hyalocranius, Neosalanx tankahkeii taihuensis, Mylopharyngodon piceus, Ctenopharyngodon idellus, Hypophthalmicthys molitrix, Aristichthys nobilis, Cyprinus carpio, Carassius auratus auratus, Megalobrama* spp., *Parabramis pekinensis, Erythroculter* spp., *Hemibarbus maculatus, Eleotris fusca, Sinipera* spp., *Ophiocephalus argus, Anguilla japonica,* etc.

F5 FISHERY PRODUCTS

§ Annual fish catch in 1979 : 13,696 [metric tons]. (Converted from the local weight unit [jin] at a rate of 1 jin=0.5 kg) (1).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE TAI-HU PLAIN* (5).

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	Very limited	N. A.
Herbaceous vegetation	〃	〃
Swamp	N. A.	〃
Agricultural land		
Crop field	14,400	39.6
Residential area	N. A.	N. A.
Total	36,355	100.0

*Data for the drainage basin proper were not available. "Tai-hu Plain" includes, in addition to plain part of the drainage basin, the area drained by the effluent rivers of Tai-hu as far east as Shanghai.

§ Types of important forest (main species of trees): Pine forest (*Pinus massoniana*); bamboo forest (*Phyllostachys pubescens*); mixed evergreen-deciduous scrub (6).

§ Types of important herbaceous vegetation: Swampy grassland of reeds and other emerged water plants on the lake shore and along water courses (5).

§ Main kinds of crops: Rice (single or double cropping), wheat, rapeseed, tea, mulberry, fruit trees (peach, orange, loquat, myrica, plum, Japanese apricot (*Prunus mume*), jujube) (1, 5).

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE

§ Agricultural production [t yr^{-1}]: Grain (11.5 million), cotton (125,000), rapeseed (290,000), fruits (60,000), pig (10 million heads), silkworm cocoon (50,000) (5).

§ Fisheries production: 13,696 t yr^{-1} (fish, crab, shrimp) (1).

§ Number of industrial factories: About 700 (Film studio, ore dressing plant, instrument and metal plant, traditional handicraft (embroidery, silk, etc.)) (2).

§ Tertiary industry: Hotels, sanatoriums, etc. (2).

G3 POPULATION IN THE TAI-HU PLAIN (1983)

	Population	Population density [km^{-2}]	Main cities (population).
Total	ca. 30,000,000	ca. (877)	Shanghai (5,900,000)*, Wuxi (810,000)*, Suzhou (600,000)*

*Approximate number for urban areas only.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Fisheries, navigation and tourism.

N. SOURCES OF DATA

* Printed in Chinese; tentatively translated into English.

(1) Nanjing Institute of Geography, Academia, Sinica (1982) Lakes of Jiangsu Province. 220 pp. Jiangsu Science and Technology Publisher, Nanjing.*

(2) Liu, Hongliang (1982) The pollution state of four big freshwater lakes in China. Mimeographed manuscript.

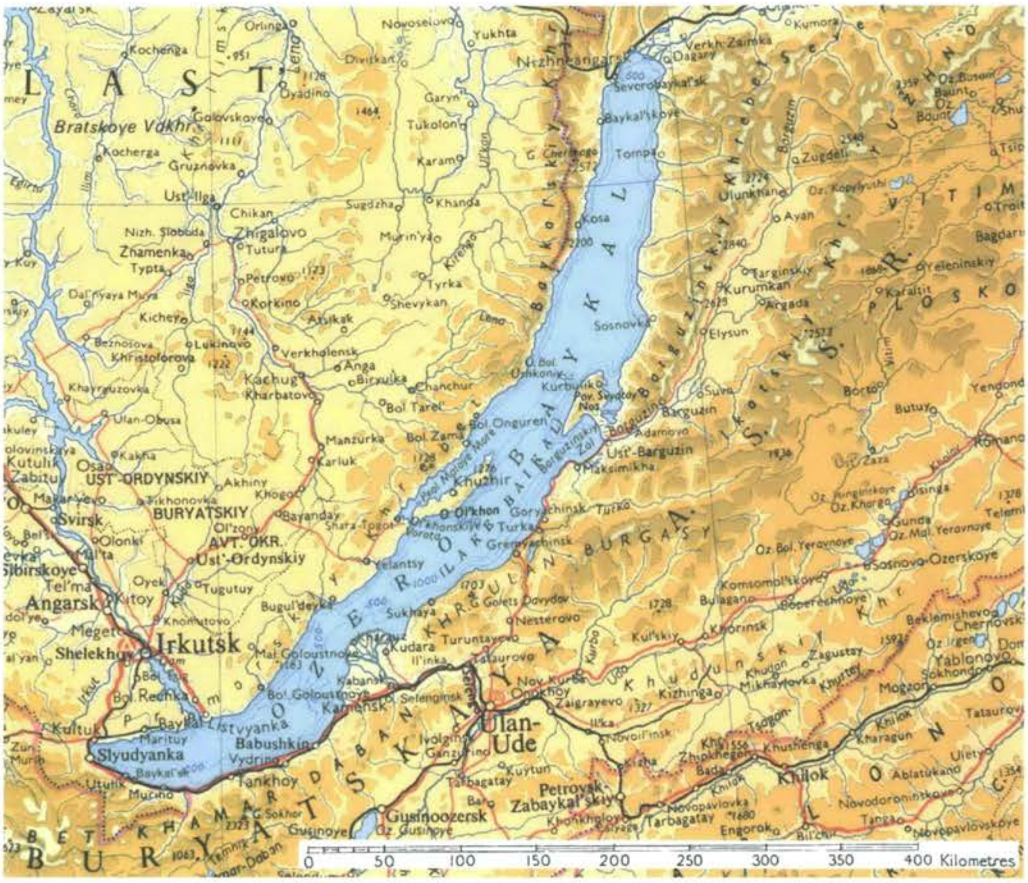
(3) Personal communication from the staff of the Nanjing Institute of Geography, Academia Sinica, Nanjing, China.

(4) Dai, Quanyu (1983) Monitoring of heavy metals in macrophytes and assessment of lacustrine environmental quality of Taihu Lake. Acta Scientiae Circumstantiae, 3 (3) : 213-221 (in Chinese with English summary).
(5) She, Z., Chen, Y. & Tanag, Z. (1983) Land use on the Lake Taihu Plain. Land Resources of the People's Republic of China ; Resource Systems Theory and Methodology (ed. Ruddle, K. & Wu, C.), pp. 31-36. The United Nations University, Tokyo.
(6) Botanical Institute, Academia, Sinica (1979) Vegetation Map of the People's Republic of China. Map Publisher, Beijing.*

OZERO BAYKAL (LAKE BAIKAL)

A coastal view from the cruising vessel

Photo: A. Kurata



A. LOCATION

§ Buryat A. S. S. R. and Irkutsk, U. S. S. R.
§ 51°29′-55°46′N, 103°40′-109°55′E ; 456 m above sea level.

B. DESCRIPTION

Lake Baikal is the deepest lake in the world. The bottom of the lake lies 1,285 m below sea level, and is the deepest continental rift on the earth. Its water volume is approximately equal to the total volume of the Great Lakes of North America, or to about 20% of the total freshwater on the earth. It is also known as one of the most ancient in geological history, and there are few lakes in the world to compete with this lake in biotic diversity. As many as 852 species and 233 varieties of algae and 1,550 species and varieties of animals have been known to inhabit L. Baikal. The world-famous Baikal seal, the only mammal living on the lake, is found throughout the whole area of the lake to this day.

The lake is completely surrounded by mountains, and there are 22 small islands over the lake. The lake water is fed by some 300 inflowing rivers, and is drained through the single outlet, the Angara River. The climate of the drainage basin is extremely continental with long, very cold and dry winters and short cool summers. The climax vegetation under the climate is the coniferous forest largely dominated by larch. The nutritional level of the lake water is typically oligotrophic as indicated by the highest transparency in the world, though an industrial pulp complex built in the early 1960's near the lake's southern end is said to have caused considerable pollution.

C. PHYSICAL DIMENSIONS (1, 2)

Surface area [km^2]	31,500
Volume [$10^{12}m^3$]	23
Maximum depth [m]	1,741
Mean depth [m]	740
Water level	Unregulated
Length of shoreline [km]	2,000
Catchment area [km^2]	560,000

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-27-1).

§ Main islands (name and area) : Olkhon (ca. 730 km^2) and Greater Ushkany (9.4 km^2) (2).

§ Outflowing rivers and channels (number and names) : 1 (Angara R.) (1).

D2 CLIMATIC (2, 4)

§ Climatic data at Irkutsk, 1951-1980

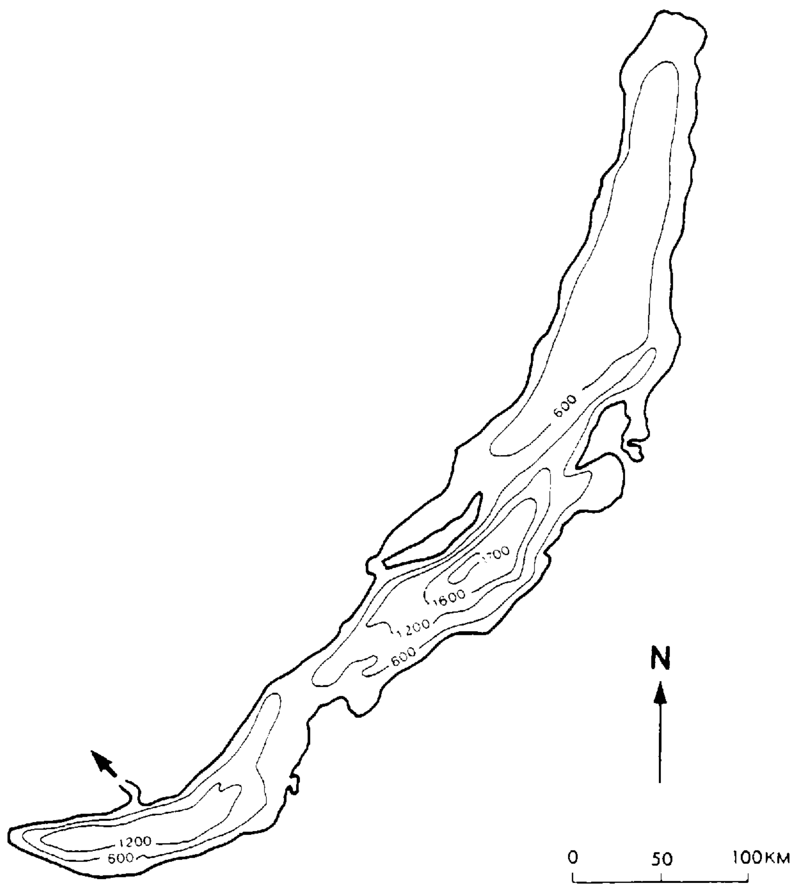
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-19.7	-17.6	-8.4	1.0	8.9	15.4	17.7	15.2	8.5	0.8	-9.4	-17.1	-0.4
Precipitation [mm]	15	8	11	19	27	69	109	86	46	27	17	20	453

§ Number of hours of bright sunshine : 2,046 hr yr^{-1}.

§ Solar radiation : 11.96 MJ m^{-2}day^{-1}.

§ Average depth of maximum snow accumulation : 0.28 m.

Fig. ASI-27-1 Bathymetric map [m] (3).



§ Water temperature

Fig. ASI-27-2 Depth / season isotherms [°C] at Bolshiye Koty, 1948 (a cold year)

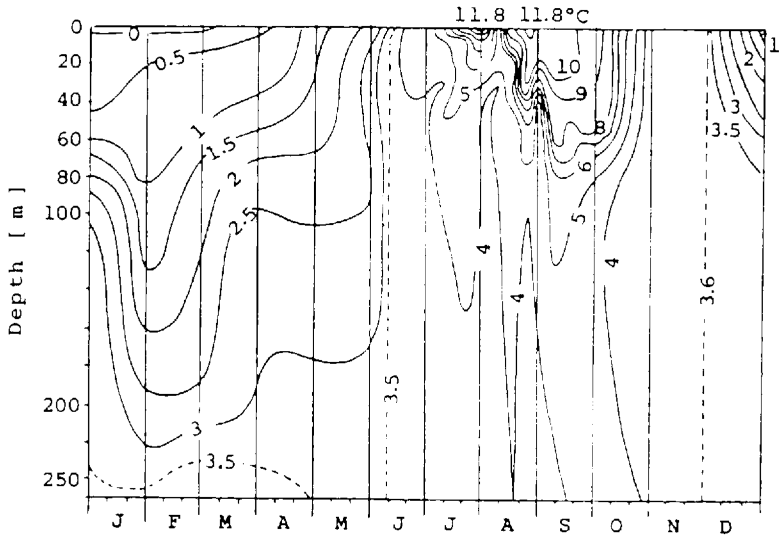
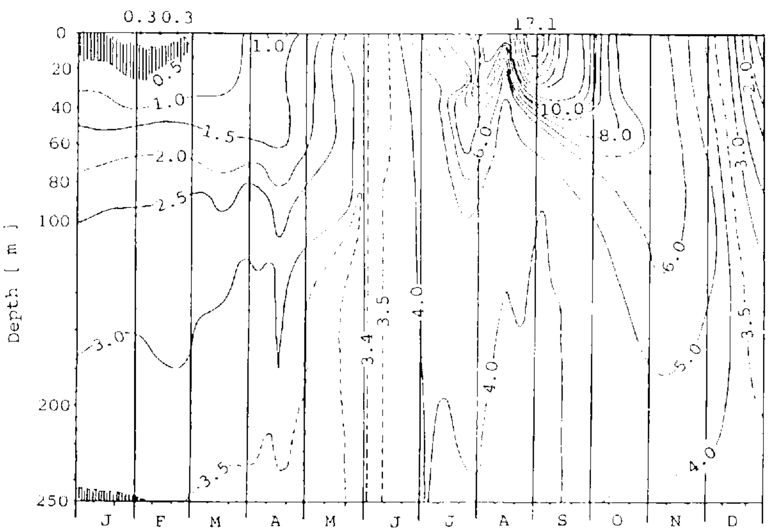


Fig. ASI-27-3 Depth / season isotherms [°C] at Bolshiye Koty, 1954 (a warm year) (2).

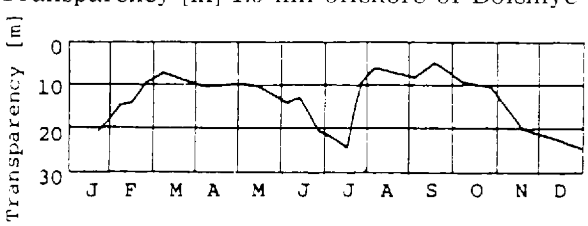


§ Freezing period : Jan.-May.
§ Mixing type : Dimictic.
§ Notes on water mixing and thermocline formation : Usually the thermocline is formed from July to August; the water tends to be homothermy at all depths in June and November.

E. LAKE WATER QUALITY

E1 TRANSPARENCY

Fig. ASI-27-4 Transparency [m] 1.5 km offshore of Bolshiye Koty, 1956 (2).



E2 pH (1)

§ Surface water : 7.2 7.8 (open area), 7.3-8.5 (Maloye More), 6.8-8.3 (Posolsky Sor).

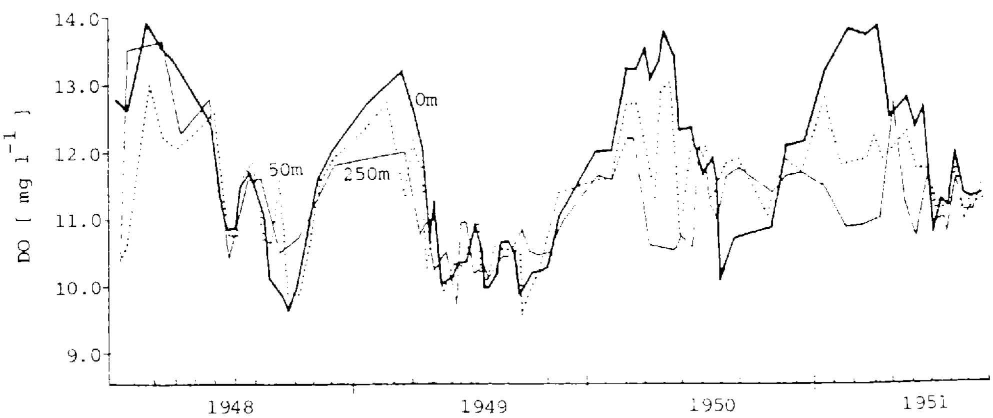
E4 DO [mg l^{-1}] (2)

Bolshiye Koty, 1952

Depth [m]	Mar	Apr	Aug	Sep
0	12.76	12.90	10.83	11.14
25	12.94	12.98	10.97	11.30
50	11.55	11.70	10.67	10.86
100	10.78	10.83	10.78	10.96
250	10.59	10.51	10.43	10.42
500	10.48	10.46	10.30	10.30
600	10.04	10.10	—	—
750	—	—	10.20	10.17
800	9.92	9.87	—	—
1,000	9.74	9.77	10.14	10.08
1,200	9.62	9.71	10.03	10.00
1,350	9.56	9.63	—	—

E10 PAST TRENDS

Fig. ASI-27-5 Trend of DO [mg l^{-1}], open water at Bolshiye Koty (2).



F. BIOLOGICAL FEATURES

F1 FLORA (2)

§ Emerged macrophytes : *Phragmites, Scirpus, Sparganium, Sagittaria.*

§ Floating macrophytes : *Lemna, Nuphar, Nymphaea.*

§ Submerged macrophytes : *Potamogeton, Myriophyllum, Ceratophyllum.*

§ Phytoplankton : *Peridinium baicalense, Gymnodinium baicalense, G. coeruleum, Ceratium hirundinella, Glenodinium* sp., *Mallomonas* spp., *Uroglena* sp., *Dinobryon cylindricum, Anabaena flos-aquae, A. limmermannii, Aphanizomenon flos-aquae, Gloeotrichia echinulata, Epichrysis melosirae, Fragillaria crotonensis, Melosira baicalensis, Asterionella formosa, Tabellaria fenestrata, Ceratoneis arcus. Stephanodiscus binderanus, Cyclotella baicalensis, C. minuta, Synedra ulna* var. *danica.*

F2 FAUNA (2, 5)

§ Zooplankton : *Epischura baicalensis, Macrohectopus branickii, Diaptomus graciloides, Heterocope appendiculata, Cyclops kolensis, C. baicalensis, Hislopia placoides, Daphnia longispina, Bosmina longirostris, Keratella quadrate, K. cochlearis, Kellicotia longispina Filinia terminalis, Collotheca* sp., *Conochilus* sp., *Vorticella* sp.

§ Benthos : Spongia (*Swartschewskia papyracea, Lumbomirskia baicalensis*), Polychaeta (*Manayunkia baicalensis*), Oligochaeta (*Peloscolex inflatus*), Mollusca (*Benedictia baicalensis, Baicalia angarensis, Pseudancylastrum sibiricum, Valvata baicalensis, Choanomphalus maackii*), Turbellaria (*Baicalarctia gulo, Sorocelis nigrofasciata, Blellocephala angarensis, Thysanoplana papaillosa*), Crustacea (*Bathynella baicalensis, B. magna, Asellus anquaticus, Abyssogrammarus sarmatus, Crypturopus pachytus*) Insecta (*Sergentia l. koschowi, Diamesa baicalensis*) (2).

§ Fish : *Comephorus baicalensis, Procottus jettelesi, Cottocomephorus grewingki, Asprocottus kozhowi, Paracottus kneri, P. kessleri, Abysscottus pallidus, Coregonus autumnalis migratorius, C. lavaretus baicalensis, Thymallus arcticus baicalensis, T. arcticus brevipinnis, Hucho taimen, Salvelinus alpinus erithrinus Brachymystax lenok, Rutilus rutilus lacustris, Leuciscus leuciscus baicalensis, L. idus* (2).

§ Mammal : *Phoca sibirica* (2).

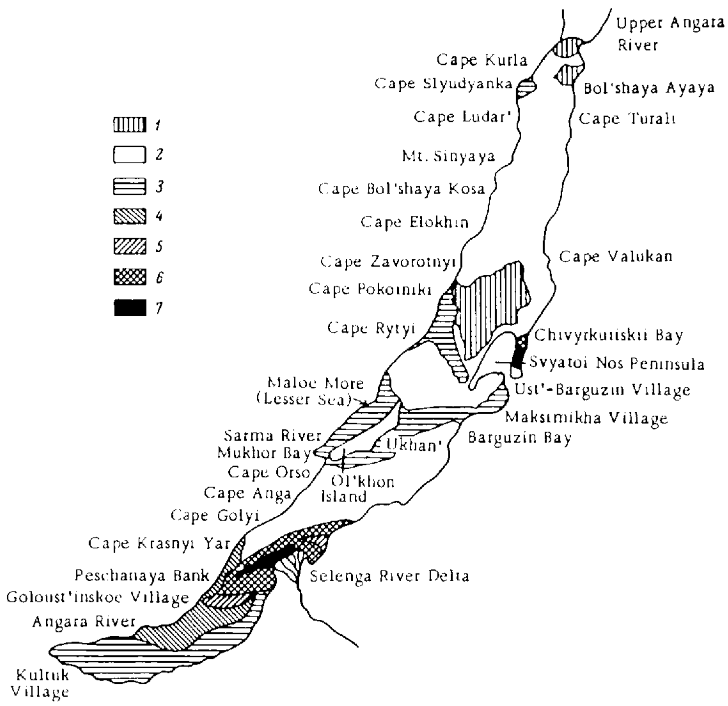
F3 PRODUCTION RATE

§ Annual productivity of pelagic organisms (1)

	Production rate [mg $m^{-2}yr^{-1}$]	Productivity/biomass ratio (P/B)
Phytoplankton	2,100	304
Bacteria	748	32
Zooplankton, phytophagous	178	13.5
Zooplankton, carnivorous	10	11
Fish, non-commercial (golomyanka, gobby)	4.1	0.8-1
Fish, commercial (omul, grayling)	0.15	0.2
Seal	0.01	0.12

§ Primary production rate

Fig. ASI-27-6 Photosynthetic activity of the phytoplankton in different parts of Lake Baikal during August 1964 (after Kuznetsov, Romanenko, and Glazunov) [mg C $m^{-2}day^{-1}$] (6).
1) 20-40 ; 2) 40-60 ; 3) 60-80 ; 4) 80-100 ; 5) 100-150 ; 6) 150-200 ; 7) 200-260.



F4 BIOMASS

§ Biomass of benthic animals (Chivyrkui Gulf, 1932) [g fresh wt. m^{-2}] (2)

	Littoral					Sublittoral and supra-abyssal		
Substratum	Sand	Sand	Sand with black silt	Black silt	Brown silt	Sand	Silt	Silt
Depth [m]	1 10	10-20	6-17	2-10	1.5 4	20-30	40-50	20-250
Gammaridae	4.24	3.78	15.60	12.20	5.80	0.85	5.65	2.01
Oligochaeta Polychaeta	5.89	4.26	22.40	7.90	0.60	0.86	20.13	3.24
Mollusca	16.81	21.15	10.40	9.30	2.50	10.50	0.10	0.03
Turbellaria	2.13	0.09	0.20	0.30	0.40	—	0.88	—
Hirudinea	0.04	—	1.50	3.20	2.20	0.08	0.04	—
Insecta	0.16	0.38	—	0.80	0.50	—	—	—
Total	29.27	29.96	50.10	33.70	12.00	12.29	26.79	5.28

§ Faunal biomass [metric tons per lake]: Zooplankton 462,000, zoobenthos ca. 700,000, fish ca. 230,000 (7).

§ Mean perennial indeces of biomass, production and fish catch (B. K. Moskalenko and A. M. Mamontov et al, 1978) (8)

	Biomass			Production			Catch		
	10^3t	%	kg/ha	10^3t	%	kg/ha	10^3t	%	kg/ha
Omul	30.0	13.4	9.7	10.0	5.1	3.2	7.3	55.7	2.3
Sor fish	20.0	8.9	6.5	8.0	4.1	2.6	4.0	30.5	1.3
Other food-fish	4.0	1.8	1.3	1.2	0.6	0.4	1.0	7.6	0.3
Bottom bullheads	10.0	4.5	3.2	10.0	5.1	3.2	—	—	—
Pelagic bullheads	10.0	4.5	3.2	15.0	7.7	4.8	0.8	6.1	0.3
Golomyanka	150.0	67.0	48.4	150.0	77.3	48.0	—		—
Total	224.0	100	72.4	194.2	100	62.4	13.1	100	4.2

F5 FISHERY PRODUCTS (2)

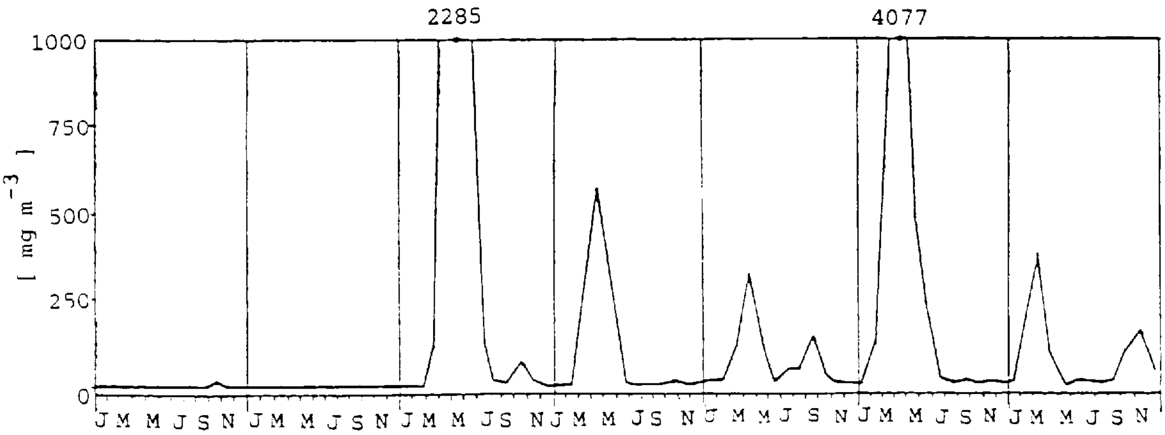
§ Annual fish catch in 1946-1955: 12,000-13,000 [metric tons].

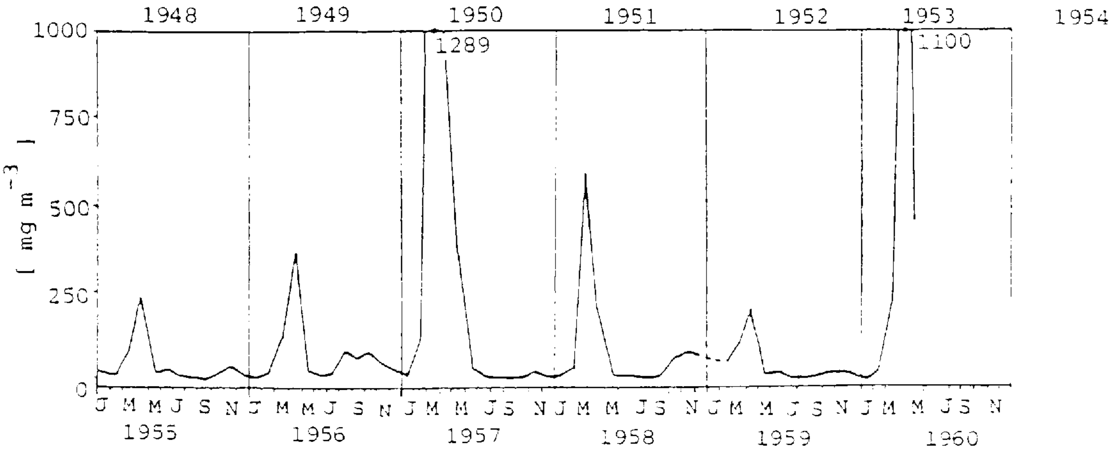
F6 PAST TRENDS

§ Perennial dynamics of phytoplankton (spring survey, maximum, 25 m layer) (8)

Year	Southern Baikal		Central Baikal		Northern Baikal	
	mg/m³	mg/m²	mg/m³	mg/m²	mg/m³	mg/m²
1964	2,830.5	70,762.5	1,972.3	49,307.5	250.8	6,270.0
1965	1,277.7	31,942.5	236.0	5,900.0	467.8	11,690.0
1966	84.0	2,100.0	2,425.0	6,062.5	29.2	730.0
1967	31.3	782.5	846.1	22,152.5	1,561.9	39,047.5
1968	4,163.4	104,085.0	1,859.1	46,477.5	894.6	22,365.0
1969	828.1	20,702.5	109.8	2,745.3	22.3	556.3
1970	46.0	1,150.5	70.8	1,770.5	13.7	341.3
1971	204.0	5,100.0	574.4	14,360.0	245.0	6,125.5
1972	426.0	10,650.3	148.8	3,720.8	338.1	8,453.5
1973	67.7	1,691.5	491.8	12,294.8	3,075.0	768.8
1974	2,379.5	59,487.5	311.4	7,785.0	97.4	2,435.8
1975	370.6	9,263.8	717.0	17,923.8	127.8	3,194.3
1976	1,575.3	39,381.8	687.7	17,193.8	778.2	19,456.0
1977	512.6	12,812.8	486.5	12,162.0	106.6	2,666.0
1978	226.3	5,657.5	551.5	13,788.0	103.3	2,581.3
1979	2,365.8	59,146.0	11,809.0	29,523.5	1,222.1	30,552.5
1980	628.8	15,720.5	602.0	15,048.8	52.8	131.9
1981	58.2	1,454.0	434.5	10,863.3	23.0	396.5
1982	1,394.3	34,857.5	2,341.8	58,543.8	176.4	4,409.5
Mean perennial	1,024.7	25,618.3	729.7	18,243.3	344.3	8,608.3

Fig. ASI-27-7 Past trend of the raw biomass of phytoplankton [mg m⁻³] in the 0-50 m layer of open water (average). After Antipova (2).





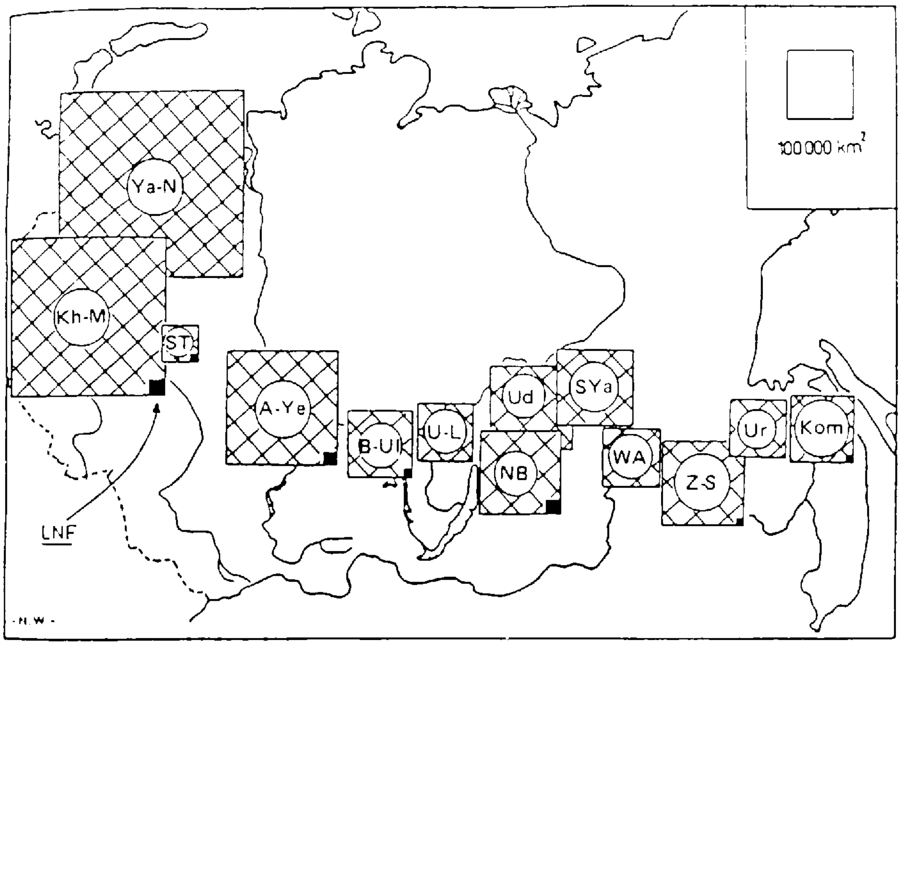
G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE SURROUNDING TERRITORIES (9)

	Area [ha]
Agricultural land	544,248*[1]
Crop land	14,504*[2]
Hay land and Pasture land	414,044*[2]

*[1] Areas of B-UI, U-L, NB and Ud are included.
*[2] Areas of U-L, NB and Ud are included. For abbreviations see the below map.

Fig. ASI-27-8 Industrial development areas of Siberia and the Far East (cross-hatched squares designate total area; black squares in lower right the area in agricultural land use). B-UI: Bratsk-Ust'-Ilimsk territorial-production complex. U-L: Upper Lena territorial-production complex. NB: North Baikal territorial-production complex. Ud: Udokan economic node.



§ Numbers of domestic animals in B-Ul, U-L, NB and Ud areas : Cattle 41,600, poultry 450,000.

§ Trends of change in land use

Siberia and the Soviet Far East are currently the scene of ambitious resource development programs : territorial-production complexes are being built up as the nuclei for the intensive industrial development of what were until recently virtually uninhabited areas, and a region rich in raw materials is to be opened up in the east by the construction of the Baikal-Amur Mainline. Manpower is being shifted to these pioneering areas, and new towns are rising in the taiga and in the wooded steppe.

An increasingly urgent issue that arises in connection with the growth of population in the eastern regions is the provision of food, especially perishables such as potatoes, vegetables, milk and meat.

The situation is to be remedied, especially with regard to the continuing growth of population, through implementation of the Soviet Union's Food Program, whose objectives have been outlined through the year 1990.

G3 POPULATION OF BURYAT ASSR, CHITA OBLAST AND IRKUTSK OBLAST (1985) (10)

	Population	Population density [km $^{-2}$]	Names of major cities
Urban	3,655,000		Irkutsk (597,000),
Rural	1,395,000	9.0	Ulan-Ude (335,000),
Total	5,060,000		Ulan-Bator

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : None (11).

§ Nitrogen and phosphorus loadings [t yr^{-1}] : T-N 286,000, T-P 62,000 (12).

J. WASTEWATER TREATMENTS (12)

J3 SANITARY FACILITIES AND SEWERAGE

§ Number of Industrial wastewater treatment systems : 1.

N. SOURCES OF DATA

* Printed in Japanese with the original titles in romanized Japanese in parentheses.

(1) Limnological Institute of the Siberian Branch, Academy of Sciences of the USSR (1979) Lake Baikal-Guidebook. 76pp. Publishing Office "Nauka", Moscow.

(2) Kozhov, M. (1963) Lake Baikal and Its Life. 344 pp. Dr. W. Junk Publishers, The Hague.

(3) Hutchinson, G. E. (1975) A Treatise on Limnology, Vol. 1. Part 1, Geography and Physics of Lakes. 540 pp. Wiley-Interscience, New York.

(4) Tokyo Astronomical Observatory (1986) Chronological scientific Tables (Rika Nenpyô). 1007 pp. Maruzen Co., Tokyo.*

(5) Okamoto, K & Horie, S. (1983) On the Zooplankton of Lake Baikal : A Preliminary Report. Jap. J. Limnol., 44(1) : 59-64.

(6) Kuznetsov, S. I. (1970) The Microflora of Lakes and its Geochemical Activity (ed. Oppenheimer, C. H.), pp. 503. University of Taxas press, Austin and London.

(7) Galazy, G. I. (1980) Lake Baikal and Its protection. Abstracts of the 21st Congress of International Association of Theoretical and Applied Limnology : 104.

(8) Galazy, G. I. & Linevich, A. A. (1988) Ecosystem of Lake Baikal. Report to the UNCRD/ILEC/UNEP Expert Group Workshop on River/Lake Basin Approach to Environmentally Sound Management of Water Resources, Otsu and Nagoya, February 1988. 18 pp.

(9) Wein, N. (1984) Agriculture in the Pioneering Regions of Siberia and the Far East : Present Status, Problems and Prospects. Soviet Geography, 25(8) : 592-620.

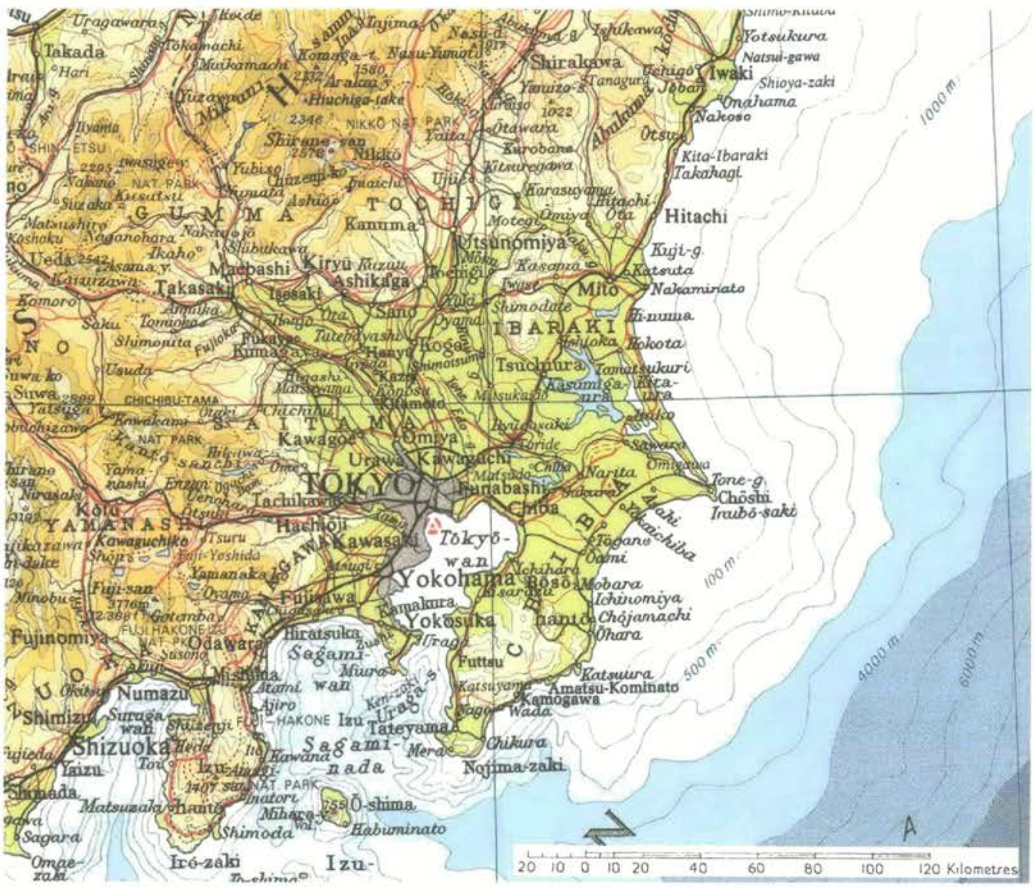
(10) Hausladen, G. (1987) Recent Trends in Siberian Urban Growth. Ibid, 28(2) : 71-89.

(11) Ghilarov, A. M. (1983) Report on Eutrophication Studies in the U. S. S. R. Water Res., 17(6) : 607-611.
(12) Olga Kojeva (1983) Present condition of environmental protection of Lake Baikal and other Siberian lakes (include reservoirs) (Baikaru-ko o hajimeto suru shiberia no koshô (chosuichi o fukumu) no kankyo hogo no genjô). Water Purification and Liquid Wastes Treatment. 24(11) : 889-893.*

TEGA-NUMA (LAKE TEGA)

Little stationary nets in the lake

Photo: A. Kurata



A. LOCATION

§ Chiba Prefecture, Japan.
§ 35°50′N, 140°3′E.

B. DESCRIPTION

Tega-numa derived from a valley eroded into the deluvial plateau during the last glacial period about 20,000 years ago, which became invaded by the sea in the hypsithermal period (5,000 years B. P.) and further left as an isolated freshwater body owing to the recession of the sea and the blocking by river washouts.

The lake is regarded as a great asset for the residents of Chiba Prefecture, since it provides an annual amount of 1.7 million cubic meters for irrigation, industrial and city water, besides serving as the fields for fisheries and recreation. The influx of immigrating population from the Tokyo metropolitan area, however, resulted in the rapid eutrophication of the lake since the early 1970's, though the water quality tended to remain more or less the same during the last several years. The eutrophication caused frequent blooms of blue-green algae (*Microcystis*) and reduced fish catch. Rice plants irrigated with the nutrient-rich lake water became liable to fall on the ground at harvest time due to excessive vegetative growth.

Only 34 % of the total population of 400,000 in the catchment area (150 km²) are provided with sewerage facilities, and unregulated discharge of household gray water became a major source of pollutant loads carried into the lake. The quality of effluents from industrial plants is regulated by setting limitation standards. Sewerage systems are being extended, while other measures for improving inflowing water quality are promoted, e.g. the purification of stream water by gravel filters, removal of nutrients by water hyacinth cultivation and contact filters, introduction of kitchen drain filters for reducing organic waste load discharged from individual househelds, etc.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km²]	6.5
Volume [10⁹m³]	0.0056
Maximum depth [m]	3.8
Mean depth [m]	0.86
Water level	Regulated
Length of shoreline [km]	38.0
Residence time [yr]	0.07
Catchment area [km²]	150.2

D. PHYSIOGRAPHIC FEATURES (Q)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. ASI-28-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Tega R.).

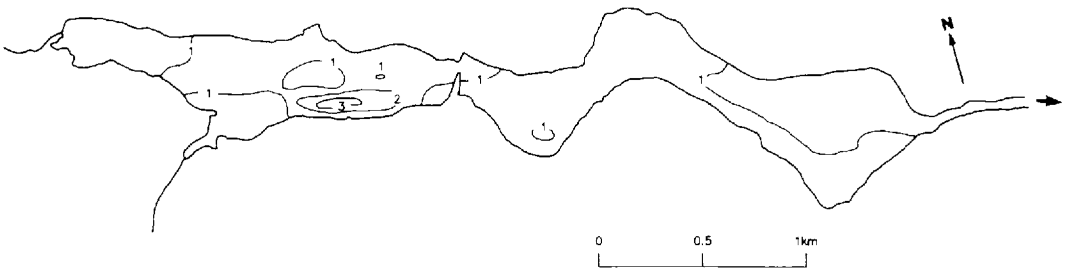
D2 CLIMATIC

§ Climatic data at Abiko, 1981-1985

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean temp. [°C]	2.6	3.4	6.6	12.5	17.5	19.6	24.1	26.5	21.5	16.0	10.4	5.3
Precipitation [mm]	23	68	110	122	90	192	102	105	167	149	78	22

§ Number of hours of bright sunshine (Abiko, 1981-1985) : 2,370 hr yr^{-1}.

Fig. ASI-28-1 Bathymetric map (1).



§ Water temperature [°C]
Center of the lake, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	3.7	5.4	8.2	16.8	19.6	22.3	26.2	28.4	25.1	19.9	12.0	6.6

§ Mixing type : Polymictic.
§ Notes on water mixing and thermocline formation : Thermocline formation is not observed.

E. LAKE WATER QUALITY (Q)

E2 pH

Center of the lake, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	9.2	9.0	9.0	9.4	8.8	8.4	8.9	9.0	9.1	9.0	9.1	9.2

E3 SS [mg l^{-1}]

Center of the lake, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	43	40	48	53	66	59	42	56	73	50	52	53

E4 DO [mg l^{-1}]

Center of the lake, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	16	17	16	14	9.6	8.6	11	9.3	11	12	14	14

E5 COD [mg l^{-1}]

Determined by $KMnO_4$ (acid) method.
Center of the lake, 1981 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	24	26	25	23	22	21	18	23	26	19	20	22

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]

Center of the lake, 1984-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	430	370	270	400	470	450	200	220	450	340	440	390

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]
Center of the lake, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	7.50	8.34	7.70	5.73	5.52	5.33	3.96	3.49	5.17	4.79	5.74	5.90

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]
Center of the lake, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	0.74	0.93	0.62	0.52	0.53	0.48	0.37	0.68	0.71	0.44	0.35	0.46

E9 PAST TRENDS

Fig. ASI-28-2 Trend of COD at the center of the lake.

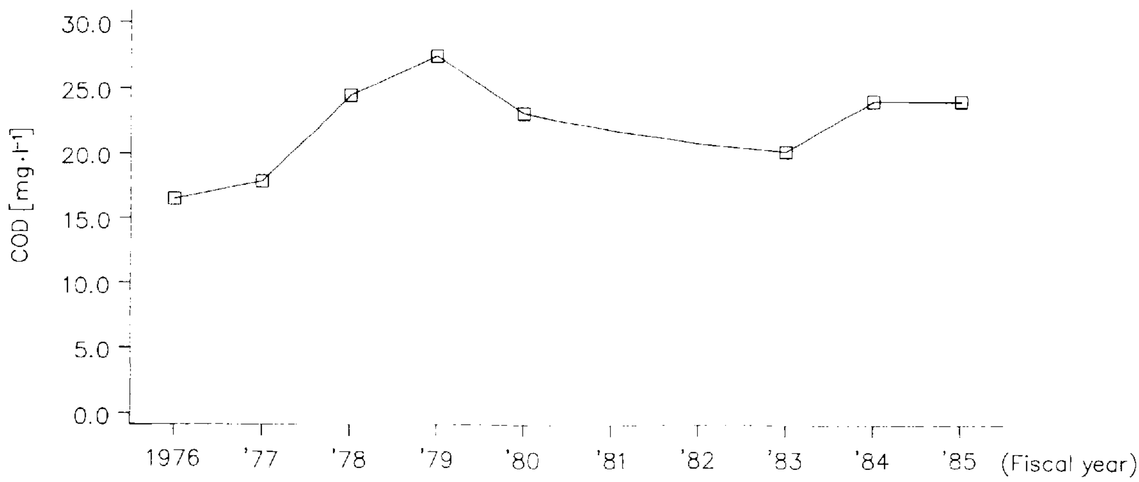


Fig. ASI-28-3 Trend of chlorophyll-a at the center of the lake.

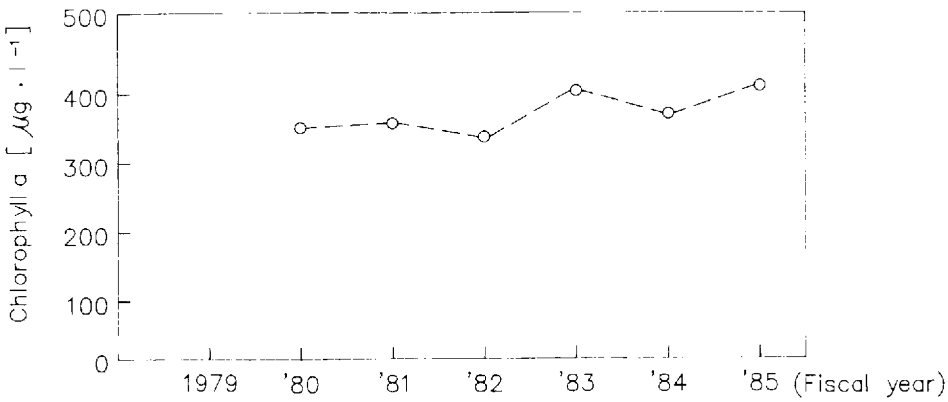
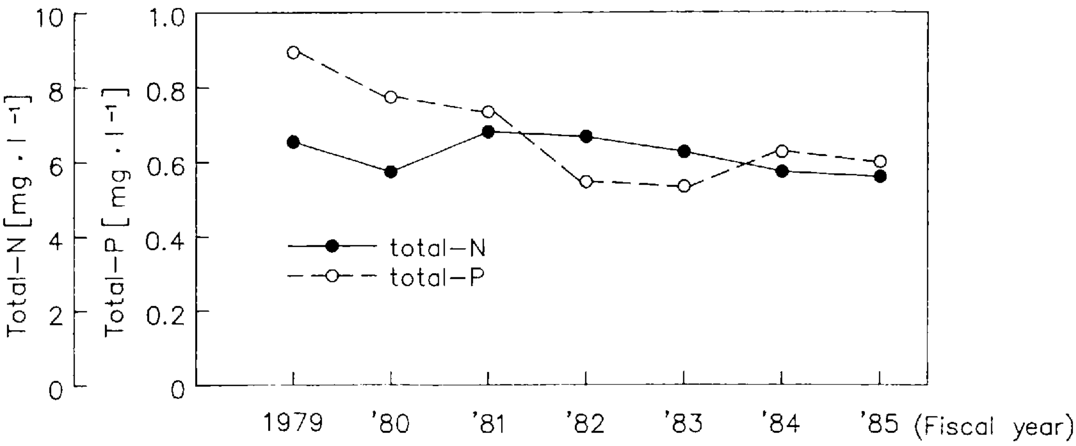


Fig. ASI-28-4 Trend of nutrients at the center of the lake.



F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes: *Phragmites communis, Zizania latifolia, Typha angustifolia, Nelumbo nucifera.*

§ Floating macrophytes: *Trapa natans* var. *japonica.*

§ Phytoplankton

Spring: green algae (*Chlamydomonas*).
Summer: blue-green algae (*Microcystis*).
Autumn and winter: diatoms (*Cyclotella*).

F2 FAUNA

§ Fish: *Pseudrasbora parva, Rodeus ocellatus ocellatus, Cyprinus carpio**, *Carassius auratus, Hypophthalmichthys molitrix, Anguilla japonica** (*ecomomically important).

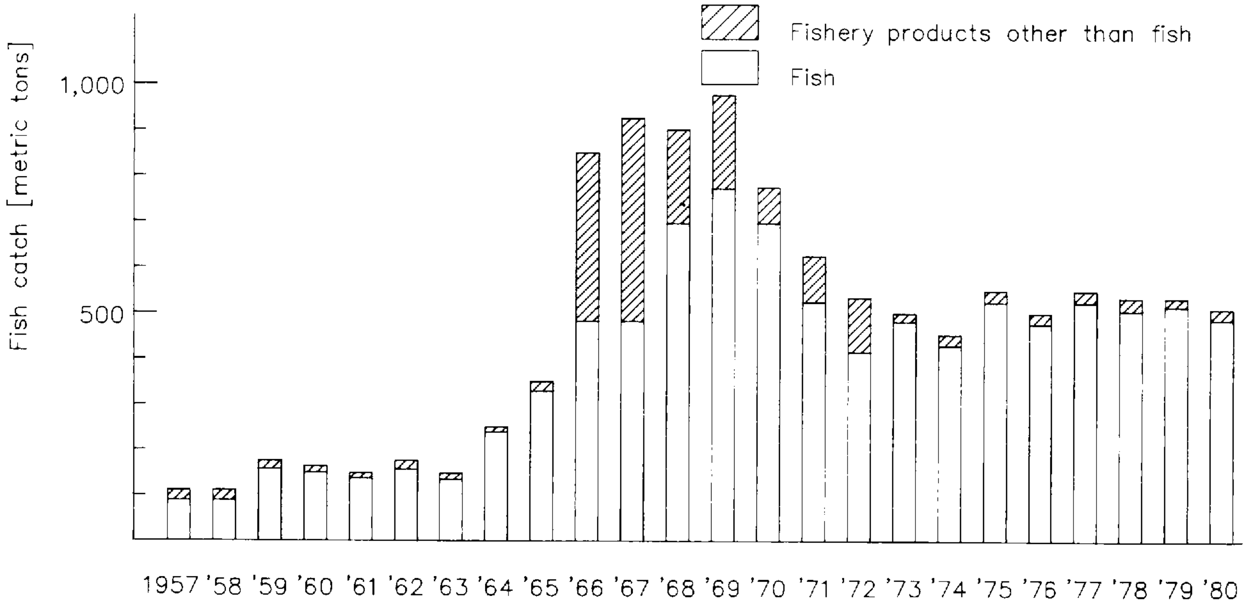
F5 FISHERY PRODUCTS

§ Annual fish catch in 1985: 440 [metric tons].

§ Fishery products other than fish in 1980: 8 [metric tons].

F6 PAST TRENDS

Fig. ASI-28-5 Trend of annual fish catch.



G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1985)

	Area [ha]	[%]
Natural landscape	3,960	26.4
Agricultural land	5,159	34.4
Settlement area	5,897	39.3
Total	15,016	100

§ Main kinds of crops : Rice.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1980)

	No. of persons engaged	No. of establishments
Primary industry	7,917	
Crop production	7,819	
Fisheries	74	
Others	24	
Secondary industry	50,069	2,270
Tertiary industry	101,560	9,844

§ Numbers of domestic animals in the catchment area : Cattle 686, swine 3,615, horse 161.

G3 POPULATION IN THE CATCHMENT AREA (1985)

	Population	Population density [km^{-2}]	Main cities
Urban	345,610	–	Kashiwa, Abiko,
Rural	53,440	–	Matsudo, Nagareyama,
Total	399,050	2,657	Kamagaya

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, fisheries, sightseeing and tourism (number of visitors in 1980 : 240,000), and recreation (sport-fishing).

H2 THE LAKE AS WATER RESOURCE (1985)

	Use rate [m^3day^{-1}]
Irrigation	138,000

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Serious.
§ Supplementary notes : Heavy siltation occurs at the mouths of Ôbori River and Ôtsu River flowing through urban areas.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Algal bloom (dominant species of algae, *Microcystis* spp.).
§ Nitrogen and phosphorus loadings to the lake (1985) [kg day^{-1}]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	433	1,436	–	496	2,369
T-P	69.6	213.7	–	23.2	306.5

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Severe pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS

	COD [kg day^{-1}]	[%]
None-point sources (agricultural, natural and dispersed settlements)	6,231	94.2
Point sources		
Municipal	142	2.1
Industrial	242	3.7
Total	6,615	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 68 % (nightsoil treatment for the rest 32 %).

§ Percentage of rural population with adequate sanitary facilities (on site treatment systems) : Nearly 100 %.

§ Municipal wastewater treatment systems
Number of secondary treatment systems : 2.

§ Number of industrial wastewater treatment systems : 114.

K. IMPROVEMENT WORKS IN THE LAKE (Q)

K1 RESTORATION

Dredging is carried out mainly at the mouths of inflowing rivers, Ôbori River and Ôtsu River.

K3 OTHERS

Harvest of *Microcystis*, planting and recovery of water hyacinth.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) For national laws see "Biwa-ko"

(2) Ordinance for Determining Effluent Standards on the Basis of Water Pollution Control Law (1976)

(3) Chiba Prefecture Environmental Pollution Control Ordinance (1971)

§ Responsible authorities

(2) Chiba Prefectural Government

(3) Chiba Prefectural Government

§ Main items of control

(2) BOD, COD

(3) BOD, COD

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Chiba Prefectural Laboratory of Water Pollution, Chiba

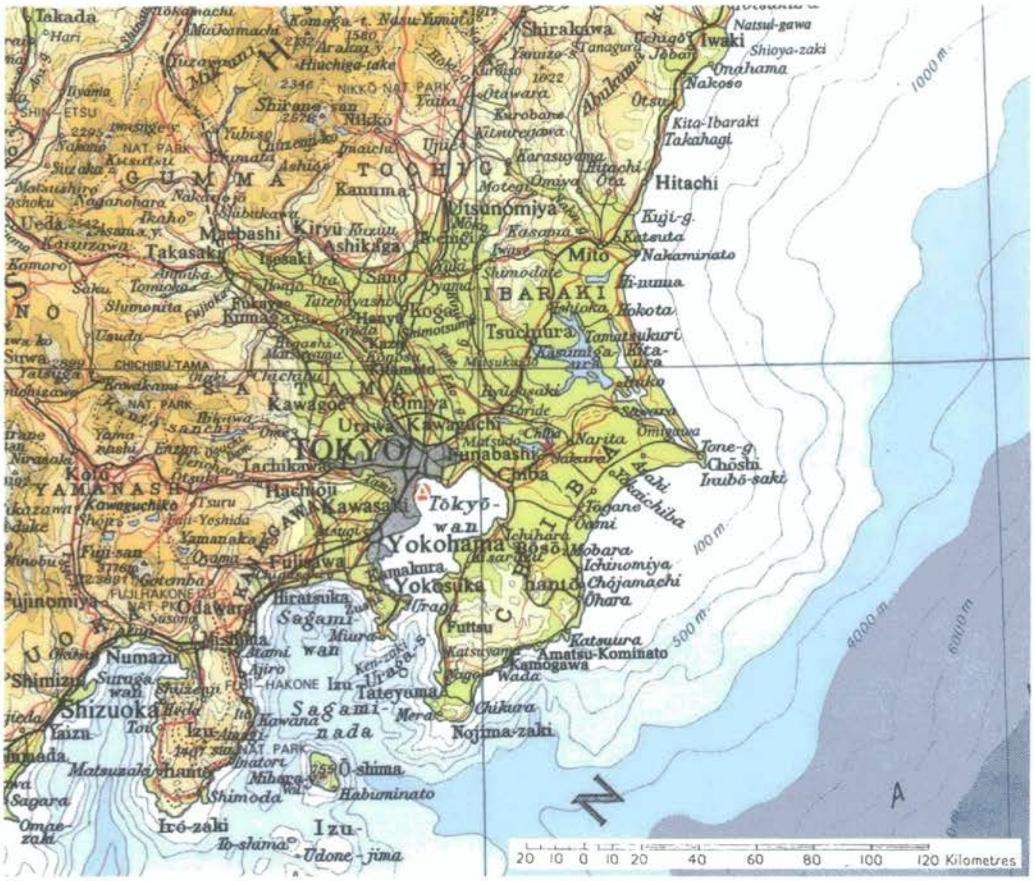
N. SOURCES OF DATA

*Printed in Japanese.
(Q) Questionnaire filled by Chiba Prefectural Government.
(1) Kobayashi, S. (1982) Journal of Water & Waste (Yôsui to Haisui), 24 : 965-976.*

INBA-NUMA (LAKE INBA)

A lake view on the artificial bank

Photo: A. Kurata



A. LOCATION

§ Chiba Prefecture, Japan.
§ 35°44′N, 140°11′E.

B. DESCRIPTION

This lake and Tega-numa (ASI-28) are shallow sister lakes which are more or less the same in their geological origin, physiographic conditions and recent environmental changes. Inba-numa had been a W-shaped lake of about 2,900 ha until the 1950's, but was completely reformed by the reclamation project which was started in 1963 and completed in 1969 for the purpose of flood control, rice field improvement and water resource development. The present lake consists of two parts, North and West Lake, connected with each other by creeks, measuring 1,155 ha in the summed area.

The lake is extensively utilized as a source of water for irrigation and industrial and urban waterworks. It serves as one of the prefectural nature parks providing for fisheries and recreational activities.

This lake experienced progressive eutrophication since the beginning of the 1970's when the population in its catchment area also began to increase rapidly. This was associated with the blooms of blue-green algae, overgrowth of water chestnuts, unpleasant odor of tap water, and other troubles. Although the domestic wastewater from an increasing number of households is the main cause of eutrophication, some 60 % of the total 54,000 inhabitants of the catchement area have not yet been covered by the existing sewerage system. Therefore, together with educational campaign to the public, various measures similar to the case of Tega-numa are being taken to reduce nutrient loads carried into the lake.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	11.55
Volume [10^9m^3]	0.277
Maximum depth [m]	2.5
Mean depth [m]	1.7
Normal range of annual water level fluctuation (regulated) [m]	0.8
Length of shoreline [km]	26.4
Residence time [yr]	0.08
Catchment area [km^2]	487.18

D. PHYSIOGRAPHIC FEATURES (Q)

D1 GEOGRAPHICAL

§ Sketch map (Fig. ASI-29-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Nagato R.).

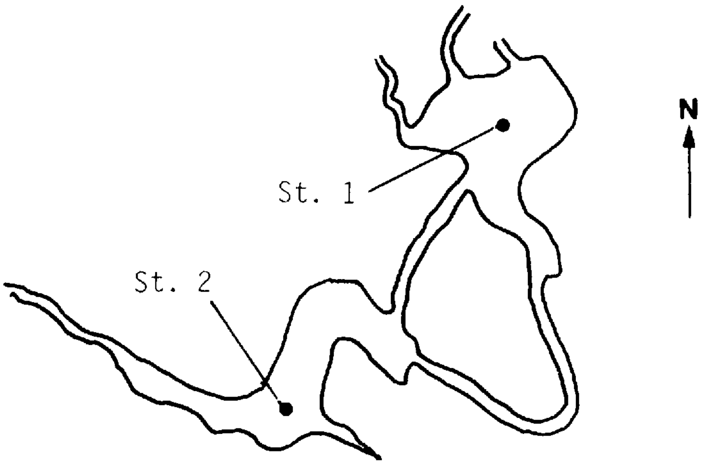
D2 CLIMATIC

§ Climatic data at Sakura, 1981-1985

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2.2	3.1	6.4	12.3	17.3	19.4	23.7	12.8	21.3	15.9	10.2	4.9	12.5
Precipitation [mm]	29	71	114	126	81	190	91	87	194	127	76	40	1,226

§ Number of hours of bright sunshine (Sakura, 1981 1985) : 2370 hr yr^{-1}.

Fig. ASI-29-1 Sketch map of the lake (Q).



§ Water temperature [°C]
Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	4.3	5.2	8.1	14.9	19.8	22.5	26.3	29.2	25.8	19.6	13.0	7.5

§ Mixing type : Polymictic.

E. LAKE WATER QUALITY (Q)

E2 pH

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	8.0	8.3	8.6	9.0	8.6	8.3	8.6	8.7	8.6	8.1	8.0	8.0

E3 SS [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	17	33	26	20	18	10	12	16	21	25	17	13

E4 DO [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	14	15	15	13	10	10	13	10	12	10	12	14

E5 COD [mg l^{-1}]

Determined by $KMnO_4$ (acid) method.
Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	11	12	12	12	11	10	10	14	14	11	9.6	11

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	93	125	141	186	130	113	127	129	157	170	162	198

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	2.25	2.92	3.05	2.63	1.79	1.97	1.64	1.56	2.00	2.41	2.73	2.96

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Station 1, 1981-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.2	0.12	0.13	0.13	0.13	0.12	0.12	0.10	0.14	0.14	0.13	0.098	0.11

E9 PAST TRENDS

Fig. ASI-29-2 Trend of COD.

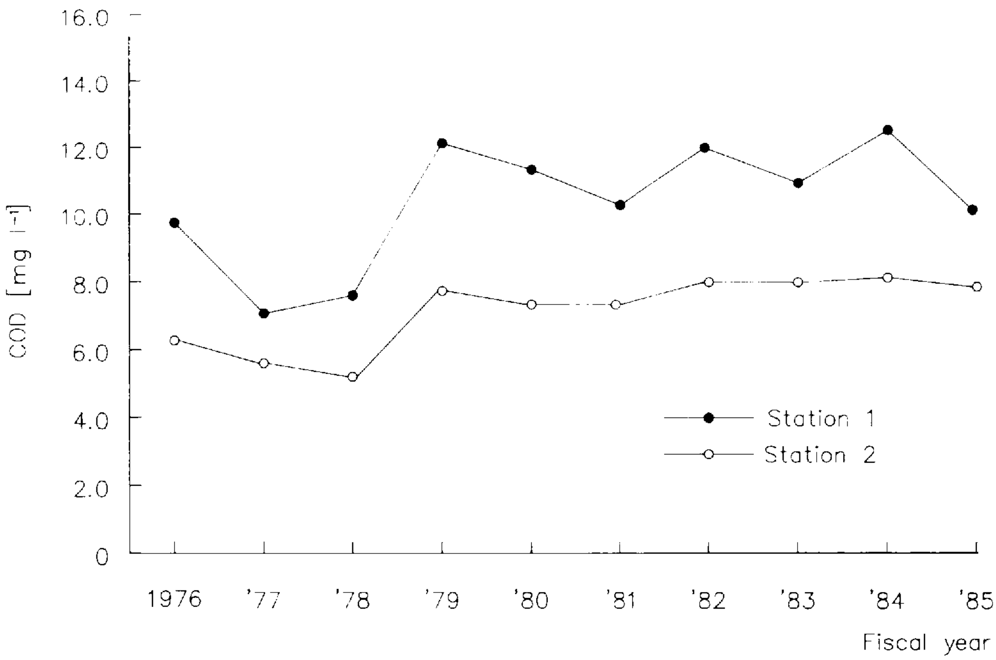


Fig. ASI-29-3 Trend of chlorophyll-a.

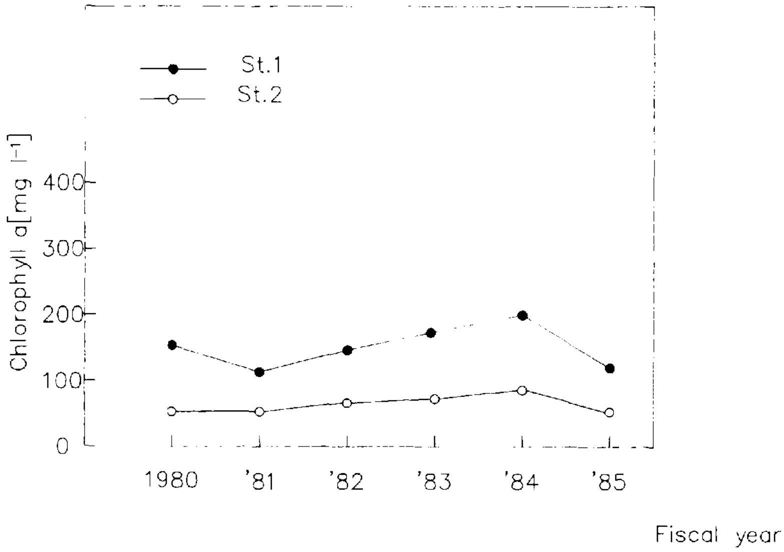
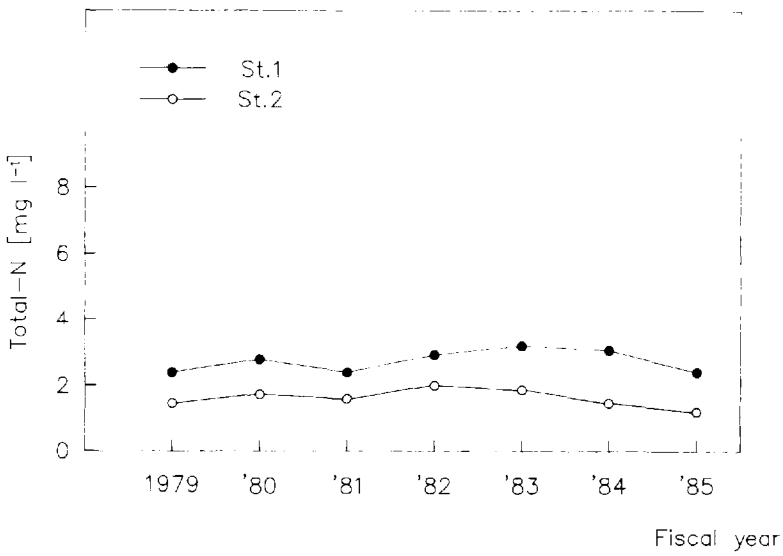
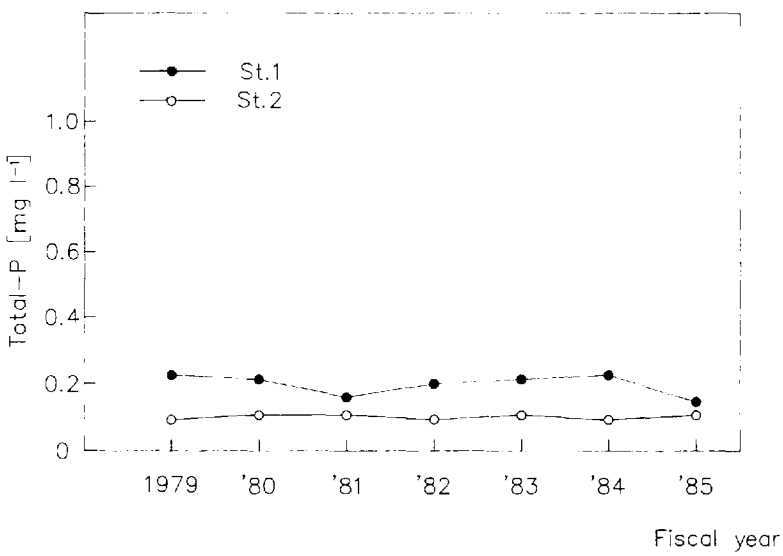


Fig. ASI-29-4 Trends of nutrients.





F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Emerged macrophytes : *Phragmites communis, Zizania latifolia, Typha angustifolia, Nelumbo nucifera.*

§ Floating macrophytes : *Nymphoides indica, N. peltata, Trapa incisa, T. natans* var. *japonica, T. natans* var. *rubeola, Hydrocharis dubia.*

§ Submerged macrophytes : *Ceratophyllum demersum, Potamogeton malaianus, Vallisneria gigantea, V. denseserrulata, Najas marina, Cabomba caroliniana, Elodea nuttallii.*

§ Phytoplankton : Blue-green algae (*Microcystis*), diatoms (*Cyclotella*), green algae (*Chlamydomonas*).

F2 FAUNA

§ Fish : *Cyprinus carpio**, *Acheilognathus morioka, Gnathopogon elongatus elongatus, Misgurnus anguillicaudatus, Hypomesus olidus**, *Hemiramphus sajori, Salangichthys microdon, Anguilla japonica, Sarcochelichthys variegatus, Opsariichthys uncirostris, Zacco platypus, Pungtungia herzi, Pseudogobio rivularis, Carassius**, *Gobius* (*economically important).

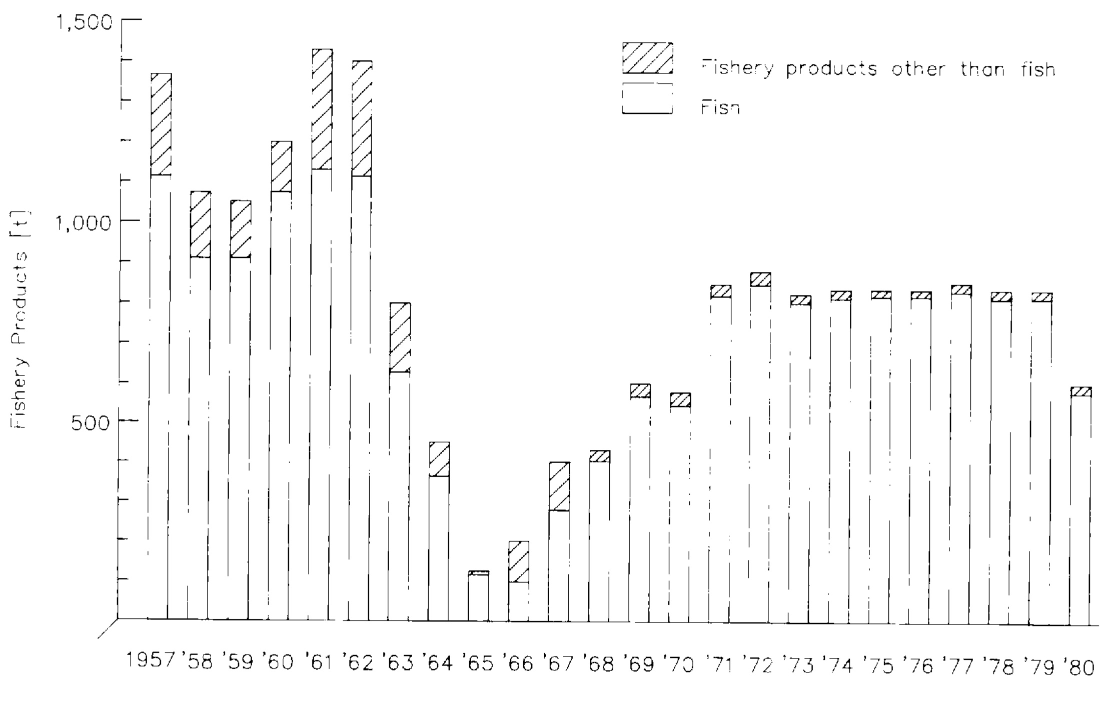
F5 FISHERY PRODUCTS

§ Annual fish catch in 1985 : 851 [metric tons].

§ Fishery products other than fish in 1980 : 31 [metric tons].

F6 PAST TRENDS

Fig. ASI-29-5 Trend of fish catch.



G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1980)

	Area [ha]	[%]
Natural landscape	16,395	33.7
Agricultural land	20,746	42.5
Settlement area	11,577	23.8
Total	48,718	100.0

§ Main kinds of crops: Rice.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1980)

	No. of persons engaged	No. of establishments
Primary industry	17,559	
Crop production	17,459	
Fisheries	85	
Others	15	
Secondary industry	41,375	2,099
Tertiary industry	92,014	9,945

§ Numbers of domestic animals in the catchment area: Cattle 12,911, swine 15,164, horse 125.

G3 POPULATION IN THE CATCHMENT AREA (1985)

	Population	Population density [km^{-2}]	Main cities
Urban	434,380	—	Sakura, Yachiyo, Chiba, Funabashi, Narita, Yotsukaidô, Kamagaya
Rural	105,790	—	
Total	540,170	1,109	

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism (380,000 visitors in 1980), recreation (sport-fishing) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1985)

	Use rate [10^3 m^3 yr^{-1}]
Domestic water	136
Irrigation	488
Industrial water	490
Power plant	—

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I2 TOXIC CONTAMINATION

§ Present status : No information.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Algal bloom (*Microcystis*), disturbed filtration in cleaning bed, foul smell of tap water.

§ Nitrogen and phosphorus loadings to the lake (1980) [kg day^{-1}]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	588	1,833		1,612	4,033
T-P	82.4	239.8	—	71.2	393.4

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF POLLUTANT LOADS :

	COD [kg day^{-1}]	[%]
None-point sources (agricultural, natural and dispersed settlements)	9,638	95.9
Point sources		
Municipal	117	1.2
Industrial	297	3.0
Total	10,052	100

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 55 % (nightsoil treatment for the rest 45 %).

§ Percentage of rural population with adequate sanitary facilities (on-site treatment systems) : Nearly 100 %.

§ Municipal wastewater treatment systems

Number of secondary treatment systems : 1.

Other types : 2.

§ Number of Industrial wastewater treatment systems : 113.

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION

Dredging is carried out at mouths of the inflowing rivers.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) For national laws see "Biwa-ko"

(2) Ordinance for Determining Effluent Standards on the Basis of Water Pollution Control Law (1976)

(3) Chiba Prefecture Environmental Pollution Control Ordinance (1971)

§ Responsible authorities

(2) Chiba Prefectural Government

(3) Chiba Prefectural Government

§ Main items of control

(2) BOD, COD

(3) BOD, COD

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Chiba Prefectural Laboratory of Water Pollution, Chiba

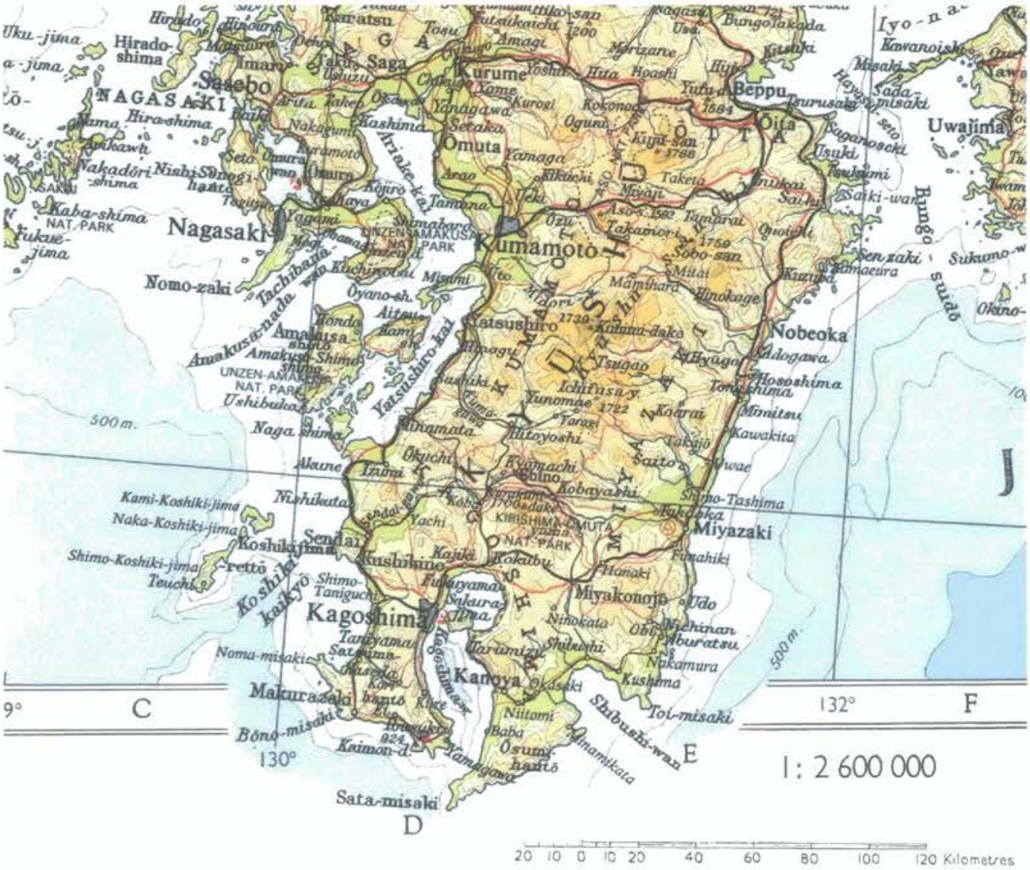
N. SOURCES OF DATA

(Q) Questionnaire filled by Chiba Prefectural Government.

IKEDA-KO (LAKE IKEDA)

A lake view with Mt. Kaimon in the background

Photo: A. Kurata



A. LOCATION

§ Kagoshima Prefecture, Japan.
§ 31°14′N, 130°34′E ; 88 m above sea level.

B. DESCRIPTION

Lake Ikeda is a caldera lake, located 40 km south of Kagoshima city. It has a surface area of 11 km^2 and a shoreline length of 15 km. The maximum depth amounts to 233 m. Together with Mt. Kaimon on its south side, it forms one of the most scenic spots of Southern Kyushu tourist zone, Kirishima-Yaku National Park.

The lake water quality was excellent until some years ago, but has been deteriorated due to the development of the surrounding areas since around 1955. The transparency of the lake measured 26.8 m in 1929, but decreased to about 5 m in recent years. Freshwater red tides have also been observed. There are resort facilities in the northeastern part of the lake, which attract 2.8 million tourists annually. The lake also serves for fish culture and irrigation. An irrigation project for 6,000 ha of agricultural field and 10,000 households was initiated in 1965 and the courses of three nearby rivers were diverted into the lake. The irrigation system has been in operation since 1982, resulting in a considerable amelioration of the lake water quality (Q).

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	10.95
Volume [$10^9 m^3$]	1.47
Maximum depth [m]	233
Mean depth [m]	135
Normal range of annual water level fluctuation (regulated) [m]	4
Length of shoreline [km]	15.1
Residence time [yr]	1.7
Catchment area [km^2]	40.73

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Bathymetric map (Fig. ASI-30-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Shin R.).

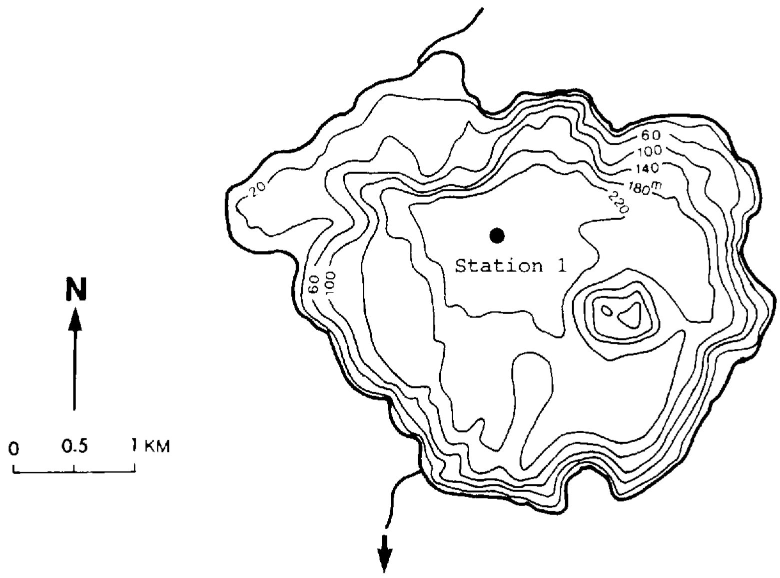
D2 CLIMATIC

§ Climatic data at Ibusuki, 1971-1980 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	8.7	9.4	12.1	16.6	20.0	23.7	27.3	27.8	24.9	20.4	15.3	10.5	18.1
Precipitation [mm]	98	134	179	249	291	459	243	182	244	128	77	114	2,439

§ Number of hours of bright sunshine : 2,411 hr yr^{-1}.

Fig. ASI-30-1 Bathymetric map (Q).



§ Water temperature [°C] (3, 4)
Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	10.4	–	15.6	–	23.0	–	–	29.3	23.3	–	14.2
15	–	10.2	–	13.0	–	13.9	–	–	22.9	22.9	–	14.2
30	–	10.2	–	10.8	–	11.0	–	–	11.5	11.5	–	11.0
100	–	10.2	–	10.1	–	10.2	–	–	10.4	10.2	–	10.3
200	–	10.2	–	10.1		10.2	–	–	10.4	10.2	–	10.3

§ Freezing period : None (Q).
§ Mixing type : Monomictic (Q).
§ Notes on water mixing and thermocline formation : The lake is thermally stratified between April and December. The stratification is especially remarkable between June and November. The thermocline is situated at 10-20 m depth (Q).

E. LAKE WATER QUALITY (3, 4)

E1 TRANSPARENCY [m]

Station 1, 1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	8.6	–	7.0	–	4.3	–	8.2		7.3	–	9.4

E2 pH

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	7.2	·	7.9		8.8	–	–	8.6	8.1	–	7.4
15		7.2	–	7.8	–	7.6	–	–	7.8	8.0	–	7.3
30	–	7.2	–	7.4	–	7.1	–	–	7.0	7.1	–	6.8
100	–	7.2	–	7.2	–	7.1	–	–	7.0	7.1	–	6.9
200	–	7.3	–	7.1	–	7.1	–	–	7.0	7.1	–	6.8

E3 SS [mg l^{-1}]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	<1	–	1	–	2			<1	1	–	<1
15		<1	–	1	–	2	–	–	1	1	–	1
30	–	<1	–	<1	–	<1	–	–	<1	<1	–	<1
100	–	<1	–	<1	–	<1	–	–	<1	<1	–	<1
200	–	<1	–	<1	–	<1			<1	<1	–	<1

E4 DO [mg l^{-1}]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	7.7	–	–	–	9.0	–		7.8	8.9	–	9.7
15	–	7.3		10.8	–	10.4	–	–	6.9	8.9	–	9.7
30	–	7.0	–	10.5	–	7.7		–	6.7	6.0	–	4.7
100		7.6	–	8.6	–	7.4	–	–	7.2	7.8	–	6.5
200	–	6.8	–	7.6	–	7.1	-	-	6.6	6.2	–	5.8

E5 COD [mg l^{-1}]

Determined by $KMnO_4$ method.

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	1.1	–	1.9	–	2.7	–	–	2.5	2.8	–	2.2
15	–	1.2	–	1.3	–	2.6	–	–	2.9	2.7	–	2.4
30	–	1.2	–	1.0	–	0.9	–	–	1.0	0.9	–	1.2
100	–	1.2	–	0.9	–	0.8	–	–	0.8	0.9	–	0.8
200	–	1.1	–	0.8	–	0.8	–	–	0.8	0.7	–	0.8

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	1.7	–	3.6	–	2.4	–	–	0.5	2.6	–	2.7
15	–	2.0	–	1.9	–	11.0	–	–	2.2	2.7	–	2.2
30	–	2.4	–	0.9	–	0.5	–	–	1.1	1.0	–	1.9
100	–	–	–	0.2	–	0.1	–	–	0.1	0.1	–	0.1
200	–	1.8	–	0.3	–	0.0	–	–	0.2	0.1	–	0.1

E7 NITROGEN CONCENTRATION

§ Total-N [$mg\ l^{-1}$]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	0.22	–	0.25		0.25	–	–	0.38	0.36	–	0.33
15	–	0.23	–	0.22	–	0.35	–	–	0.55	0.35	–	0.32
30	–	0.23	–	0.22	–	0.23	–	–	0.26	0.26	–	0.30
100	–	0.23	–	0.23	–	0.24	–	–	0.26	0.23	–	0.24
200	–	0.24	–	0.24	–	0.26	–	–	0.27	0.26	–	0.26

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$mg\ l^{-1}$]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	0.004	–	0.007	–	0.008	–	–	0.003	0.005	–	0.006
15	–	0.004	–	0.005	–	0.007	–	–	0.008	0.005	–	0.007
30	–	0.004	–	0.003	–	0.002	–	–	0.002	0.002	–	0.003
100	–	0.004	–	0.002	–	0.002	–	–	0.003	0.002	–	0.002
200	·	0.003	–	0.003	–	0.002		–	0.003	0.003		0.003

E9 CHLORINE ION CONCENTRATION [$mg\ l^{-1}$]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	8.7	–	7.9	–	7.9	–	–	7.8	8.1	–	7.9
15		8.7	–	7.9	–	8.0	–	–	7.9	8.0	–	7.9
30	–	8.8	–	7.9	–	7.9	–	–	7.8	8.0	–	7.9
100	–	8.7	–	7.9	–	7.9	–	-	7.8	8.1	–	7.9
200	–	8.8	–	7.8	–	7.9	–	–	8.0	8.0	–	7.9

E10 PART TRENDS

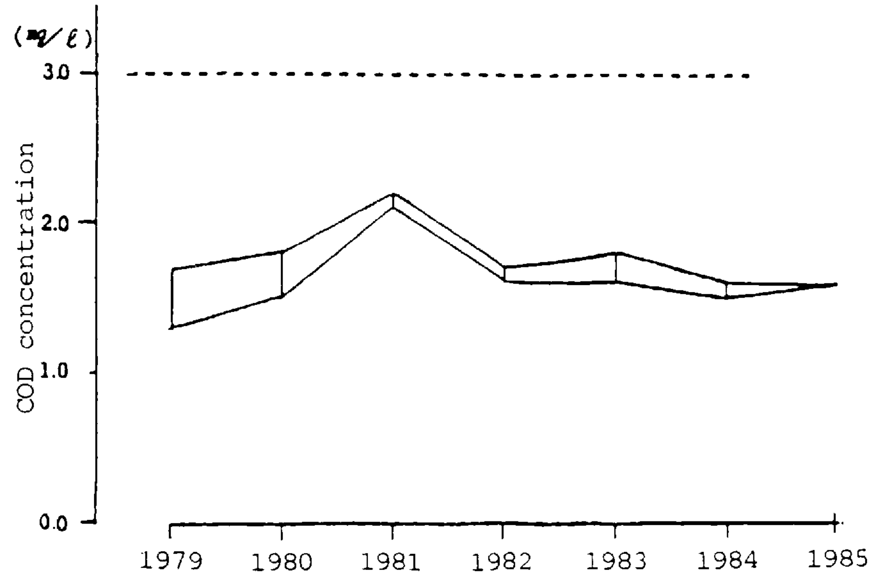


Fig. ASI-30-2 Past trend of COD.

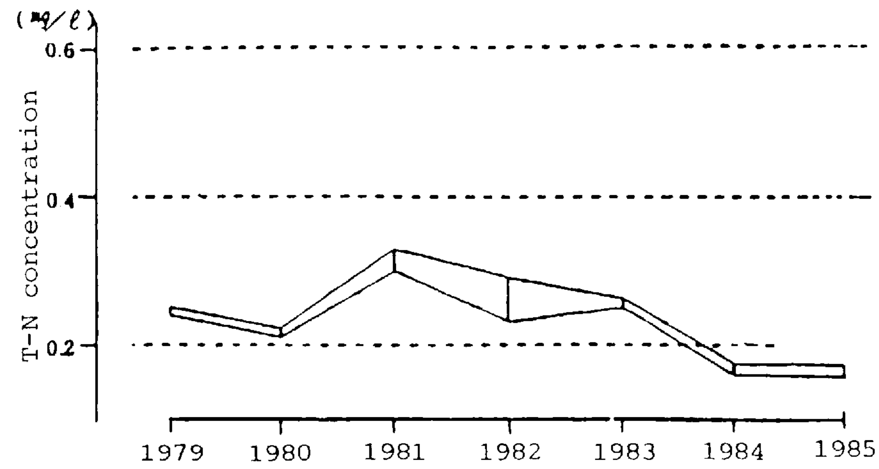


Fig. ASI-30-3 Past trend of T-N concentration.

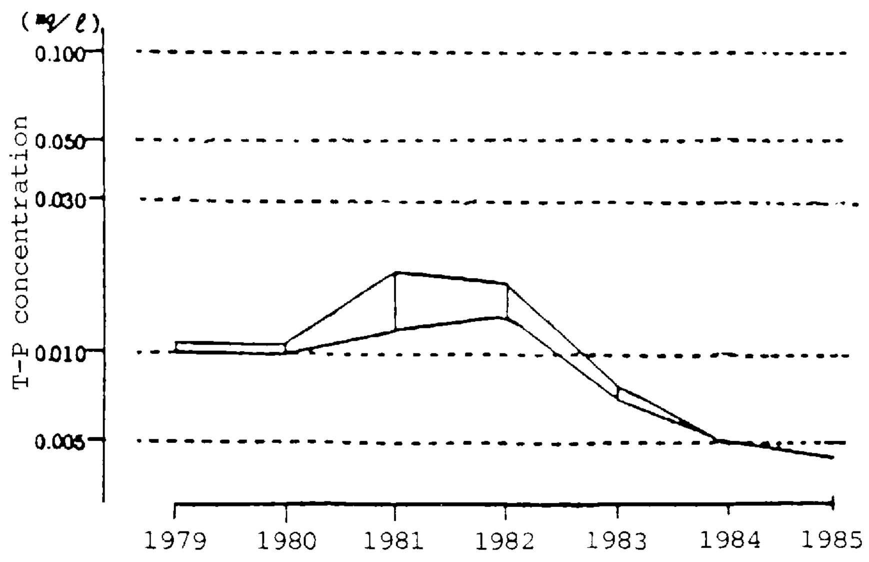


Fig. ASI-30-4 Past trend of T-P concentration.

F. BIOLOGICAL FEATURES (1)

F1 FLORA

§ Phytoplankton : Spring (*Cyclotella* sp., *Synedra* sp.) ; summer (*Cyclotella* sp., *Mougeotia* sp.) ; autumn (*Anabaena* sp.) ; winter (*Anabaena* sp., *Microcystis* sp.).

F2 FAUNA

§ Zooplankton : Spring (*Bosmina longirostris, Bosminopsis deitersi*) ; summer (*Conochilus hippocrepis*) ; autumn (*C. hippocrepis, B. longirostris*) ; winter (*B. longirostris*, Nauplius).

§ Benthos : *Palaemon paucidens, Pisidium parvum, Procladius* sp.

§ Fish : *Anguilla marmorata*, **A. japonica*, **Cyprinus carpio, Hypomesus transpacificus nipponensis, Plecoglossus altivelis* (*economically important).

F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in 1980 : 379 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1980) (6)

	Original basin		Newly added basin	
	Area [km^2]	[%]	Area [km^2]	[%]
Natural landscape	8.95	72.5	19.51	68.7
Agricultural land	1.36	11.0	5.59	19.7
Settlement area	0.44	3.6	0.37	1.3
Others	1.59	12.9	2.92	10.3
Total	12.34	100	28.39	100

§ Main types of woody vegetation : Evergreen broadleaf forest (*Pasania edulis, Castanopsis cuspidata*), pine forest (*Pinus thunbergii*), pine plantation (*P. thunbergii*) (5).

§ Main types of herbaceous vegetation : Grassland and weeds (5).

§ Main kinds of crops : Rice, sweet potato, radish and tea (5).

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (1980) (Q)

	Gross product per year [10^6yen]*	No. of persons engaged
Primary industry	8,900	8,127
Secondary industry	10,100	4,457
Tertiary industry	40,300	13,613

Data compiled from the statistics of the municipalities in the catchment area.

§ Numbers of domestic animals in the catchment area : Cattle 2,015, swine 947 and poultry 913,100.

G3 POPULATION IN THE CATCHMENT AREA (1980) (Q)

Total population	Population density [km^{-2}]	Main cities
3,434	84.3	None

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (6)

Source of water, sightseeing and tourism (number of visitors in 1980 : 2,870,000), recreation (sport-fishing) and fisheries.

H2 THE LAKE AS WATER RESOURCE (6)

	Use rate [$m^3 day^{-1}$]
Irrigation	19,233

I. DETERIORATION OF LAKE ENVIRONMENT AND HAZARDS (Q)

I2 TOXIC CONTAMINATION

§ Present status : None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Unusual algal bloom (*Peridinium* sp.).

§ Nitrogen and phosphorus loadings [kg day^{-1}], 1983

Sources	Industrial	Domestic	Agricultural	Natural	Fisheries	Total
T-N	18	14	49	35	48	164
T-P	5.1	3.5	2.1	0.6	14	25.3

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Significant pollution without wastewater treatment (Q).

J3 SANITARY FACILITIES AND SEWERAGE (10)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 0 %.

§ Percentage of rural population with adequate sanitary facilities (on site treatment systems) : 10 %.

K. IMPROVEMENT WORKS IN THE LAKE

K3 OTHERS (Q)

The area is expected to have a sewerage system in the near future under the special legislation.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Guidelines for promotion of grey water treatment, Kagoshima Prefecture (1983)

(2) Guidelines for water quality protection for the field irrigation project in Nansatsu District (1982)

(3) Rules of the Committee for Lake Ikeda Water Quality and Environmental Protection.

§ Responsible authorities

(1) Kagoshima Prefectural Government

(2) Kagoshima Prefectural Government

(3) Offices of Ibusuki City, Yamakawa Town, Ei Town and Kaimon Town, Kagoshima Prefecture

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Kagoshima Prefecture Environment Centre, Kagoshima
(2) Association for Prevention of Public Nuisances, Kagoshima

N. SOURCES OF DATA

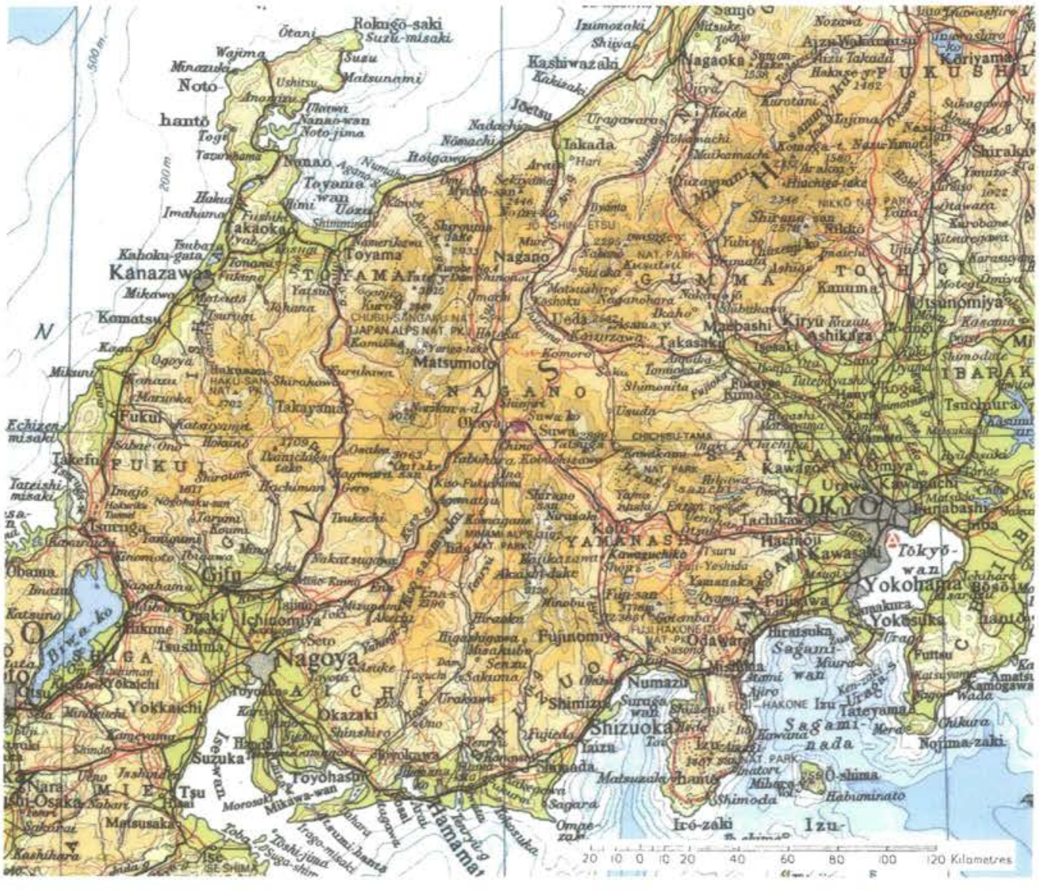
* Printed in Japanese. The titles are tentatively translated into English with the original titles in romanized Japanese in parentheses.

(Q) Questionnaire filled by Kagoshima Prefectural Government.
(1) Kagoshima Prefectural Government (1983) Lake Ikeda Water Quality and Environmental Management Plan (Ikeda-ko Suishitsu Kankyô Kanri Keikaku).*
(2) Kagoshima Prefectural Weather Bureau. Monthly Agricultural Weather Report (Nôgyô Kishô Geppô. Shôwa 46-56 nen Ban), 1971-1981.*
(3) Kagoshima Prefectural Government (1986) Water Quality Measurement Data in Public Water Bodies (Shôwa 60 Nendo Kôkyô Yosui-iki no Suishitsu Sokutei Kekka), 1985.*
(4) Data obtained from Kagoshima Prefecture Environment Centre.*
(5) Environment Agency (1987) The Second Natural Environment Protection Baseline Survey (Vegetation Survey), Existing Vegetation Map, Kagoshima Prefecture (Dai 2 kai Shizen Kankyô Hozen Kiso Chôsa (Shokusei Chôsa), Genzon Shokusei Zu, Kagoshima-ken). Japan Wildlife Center Tokyô.*
(6) Kagoshima Prefecture Water Quality Council, Lake Ikeda Committee (Kagoshima-ken Suishitsu Shingi-kai Ikeda-ko Bukai) (1985) On the Setting of Water Quality Standards for Total Nitrogen and Total Phosphorus (Ikeda-ko no Zen-Chisso oyobi Zen-Rin ni kakawaru Kankyô Kijun no Ruikei Kijun ni tsuite).*

SUWA-KO (LAKE SUWA)

A look down view from the northeast with Suwa City in the foreground

Photo: Nagano Prefectural Government



A. LOCATION

§ Nagano Prefecture, Japan.
§ 36°3′N, 138°5′E ; 759 m above sea level.

B. DESCRIPTION

Lake Suwa is a tectonic lake located on the central highland of Honshu at an altitude of about 760 m above sea level. A single stream, Tenryu River, drains the lake water into the Pacific Ocean. The lake surface remains frozen for 2-3 months during winter. Long straight rows of ice ridge locally called 'Omiwatari' sometimes traverse the frozen lake surface in the winter morning after a cold night.

The lake has been filled with sediments transported by rivers from its relatively wide drainage basin to become a typical eutrophic lake with an average depth of about 5 m. Nearly 30 % of the drainage basin are covered by forest vegetation, while the greater part of the population is concentrated in a few cities near the lake shore. The spectacular growth of industrial activity around the lake since the 1960's caused a very rapid hypertrophication of the lake as indicated by heavy blooms of *Microcystis* (blue-green algae) that take place every summer.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	13.3
Volume [$10^9 m^3$]	0.063
Maximum depth [m]	7.2
Mean depth [m]	4.7
Water level	Regulated
Length of shoreline [km]	15.9
Residence time [yr]	0.11
Catchment area [km^2]	515.3

D. PHYSIOGRAPHIC FEATURES

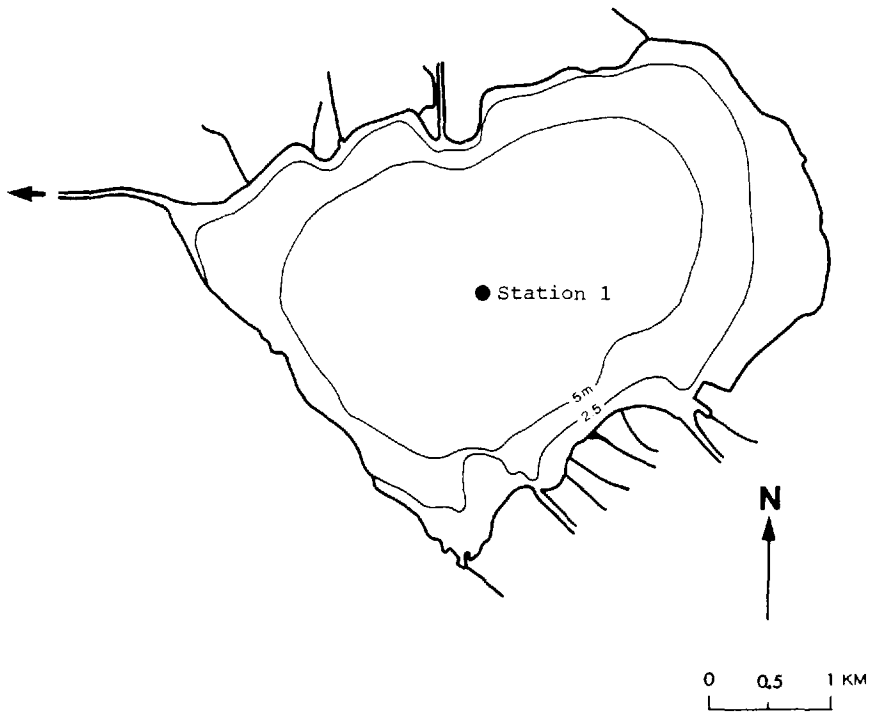
D1 GEOGRAPHICAL
§ Bathymetric map (Fig. ASI-31-1).
§ Main islands : None (1).
§ Outflowing rivers and channels (number and names) : 1 (Tenryu R.) (Q).

D2 CLIMATIC
§ Climatic data at Suwa, 1951-1980 (2, 3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-2.0	-1.2	2.6	9.3	14.3	18.3	22.2	22.9	18.6	12.1	6.4	1.3	10.4
Precipitation [mm]	47	55	84	120	117	205	219	141	179	112	67	41	1,386

§ Number of hours of bright sunshine (Suwa, 1951-1980) : 2,246.2 hr yr^{-1}.
§ Solar radiation (Matsumoto, 1973-1982) : 14.1 MJ $m^{-2}day^{-1}$.
§ Average depth of maximum snow accumulation (1954-1980) : 0.2 m.

Fig. ASI-31-1 Bathymetric map (1).



§ Water temperature [°C] (8)
Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	3.7*	11.4	16.6	19.7	23.2	26.7	22.5	15.8	10.9	3.6
5	–	–	3.5*	9.5	14.5	18.5	19.8	21.7	21.4	14.8	7.7	3.6

* 1984-1985.

§ Freezing period : Jan.-Feb. (8).
§ Mixing type : Dimictic.
§ Thermocline formation : From May to Aug. and from Jan. to Feb. (8).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (8)

Station 1, 1983-1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	1.5*	1.6	1.5	1.4	0.80	0.60	0.52	0.74	1.2	1.5

* 1984-1985.

E2 pH (8)

Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	8.3*	8.1	8.2	7.4	9.6	9.4	8.6	8.4	8.0	7.9
5	–	–	8.2*	7.7	7.7	7.1	8.0	6.7	6.8	7.6	7.5	7.9

* 1984-1985.

E3 SS [mg l^{-1}] (8)

Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5		–	11*	7	5	7	21	19	25	15	10	8
5	–	–	7*	5	5	8	9	12	17	14	11	9

* 1984-1985.

E4 DO [mg l^{-1}] (8)

Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	12*	11	9.7	9.4	13.7	12	8.7	9.0	9.5	11
5	–	–	13*	9.7	7.0	5.2	6.1	2.6	4.5	7.6	9.4	11

* 1984-1985.

E5 COD [mg l^{-1}] (8)

Determined by $KMnO_4$ method.

Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	5.6*	3.6	3.8	4.4	8.4	8.1	11.9	6.5	4.2	4.4
5	–	–	3.6*	2.7	3.6	3.7	3.7	4.8	6.9	4.5	4.2	4.4

* 1984-1985.

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (8)

Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	59*	33	24	23	90	193	101	39	36	54
5	–	–	41*	17	32	14	26	18	28	25	38	45

* 1984-1985.

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}] (8)

Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	0.69*	1.5	1.0	0.80	1.8	2.8	1.4	1.5	0.94	0.59
5	–	–	1.2*	1.4	1.2	0.94	0.98	1.4	0.97	1.3	1.0	0.76

* 1984-1985.

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}] (8)

Station 1, 1983-1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	0.097*	0.047	0.053	0.062	0.10	0.19	0.18	0.090	0.059	0.059
5	–	–	0.10	0.050	0.066	0.070	0.064	0.091	0.15	0.089	0.068	0.059

* 1984-1985.

E10 PAST TRENDS

Fig. ASI-31-2 Trend of transparency (4).

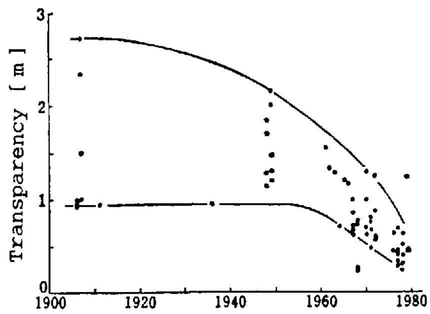


Fig. ASI-31-3 Trend of DO (4).

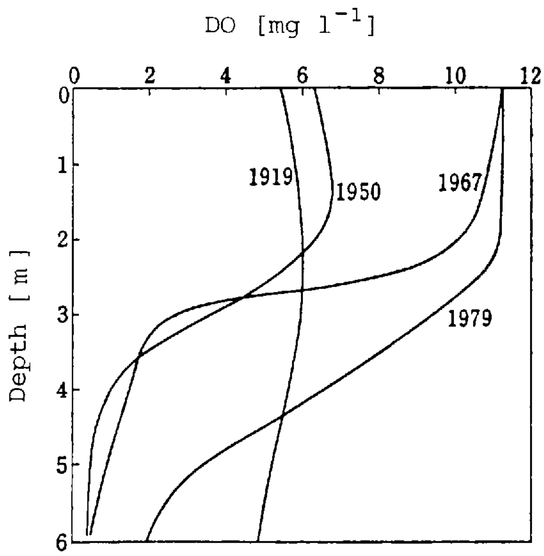


Fig. ASI-31-4 Trend of chlorophyll-a (5).

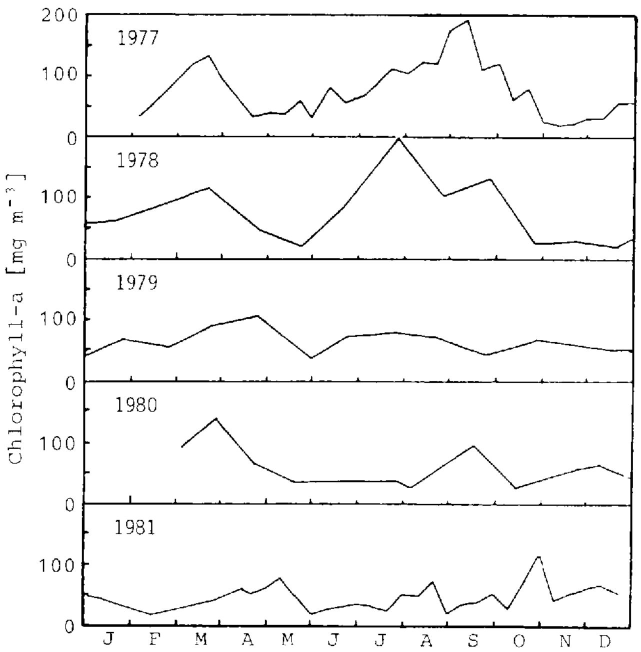


Fig. ASI-31-5 Trend of nitrogen concentration (5).

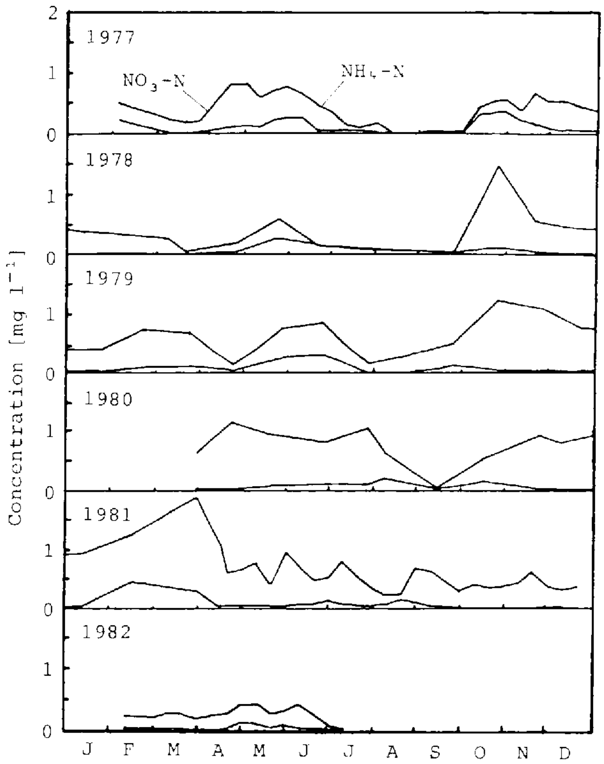
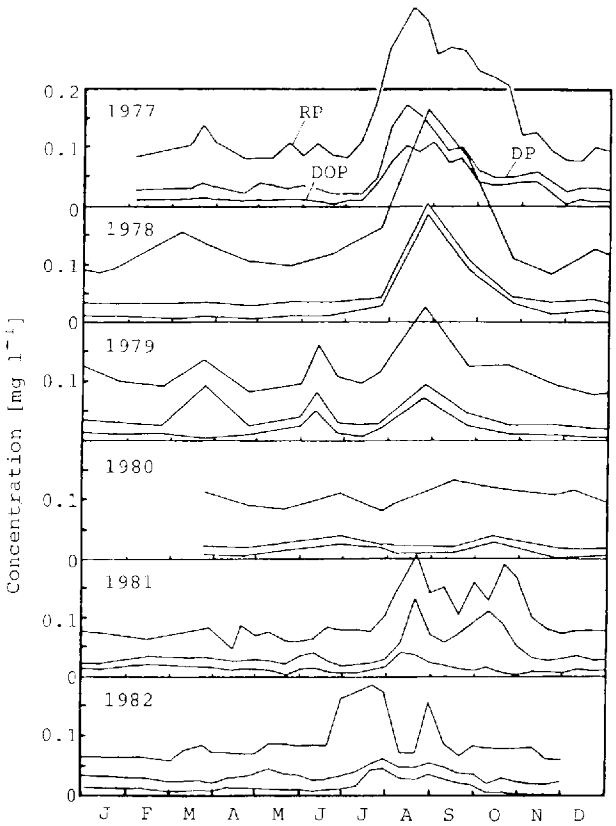


Fig. ASI-31-6 Trend of phosphorus concentration (5).
PP : Particulate P. RP : Reactive P. DOP : Dissolved organic P.



F. BIOLOGICAL FEATURES

F1 FLORA (4)

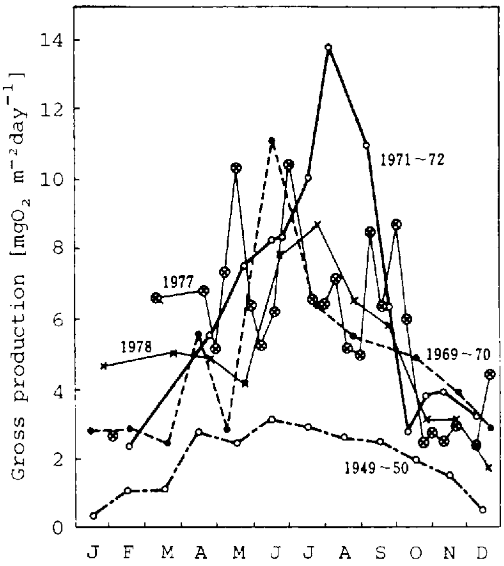
§ Emerged macrophytes : *Phragmites communis, Zizania latifolia, Nuphur japonicum.*
§ Floating macrophytes : *Trapa japonica, Hydrocharis asiatica, Nymphoides peltata.*
§ Submerged macrophytes : *Potamogeton maackianus, P. crispus, Vallisneria gigantea, Hydrilla verticillata.*
§ Phytoplankton : *Melosira japonica, Asterionella formosa, Microcystis aeruginosa, Anabaena spiroides.*

F2 FAUNA (4)

§ Zooplankton : *Brachionus calyciflorus, Keratella cochlearis, Synchaeta stylata, Filinia longiseta.*
§ Benthos : *Chipangopaludia japonica, Chipronomus plumosus, Tokunagayusurika akamushi, Limnodrilus gotoi, Branchiura sowerbyi.*
§ Fish : *Carassius carassius, Cyprinus carpio, Hypomesus olidus.*

F3 PRIMARY PRODUCTION RATE

Fig. ASI-31-7 Gross primary production rate (4).



F4 BIOMASS

Whole lake, Jul.-Aug. 1971 (4)

	Biomass [t dry wt.]
Bacteria	16
Phytoplankton	438
Macrophytes	121
Zooplankton	39
Benthos	69
Fish	6.2

Fig. ASI-31-8 Seasonal change of phytoplankton biomass (1970) (4).

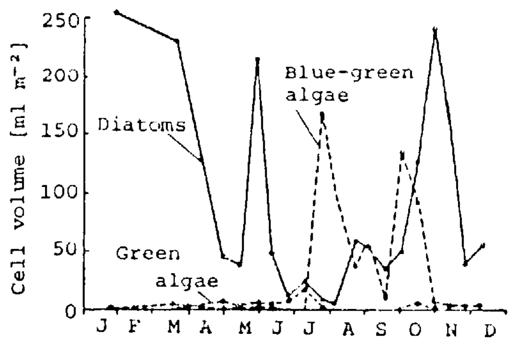


Fig. ASI-31-9 Seasonal change of zooplankton biomass (1970) (4).

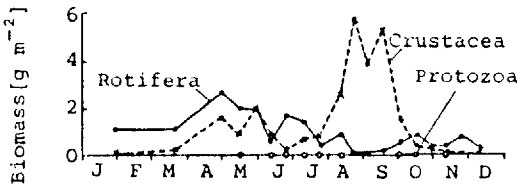
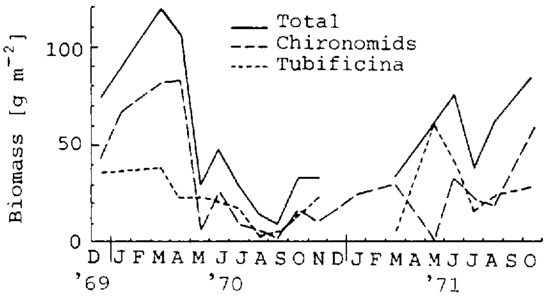


Fig. ASI-31-10 Seasonal change of benthos biomass (Dec. 1969-Oct. 1971) (4).



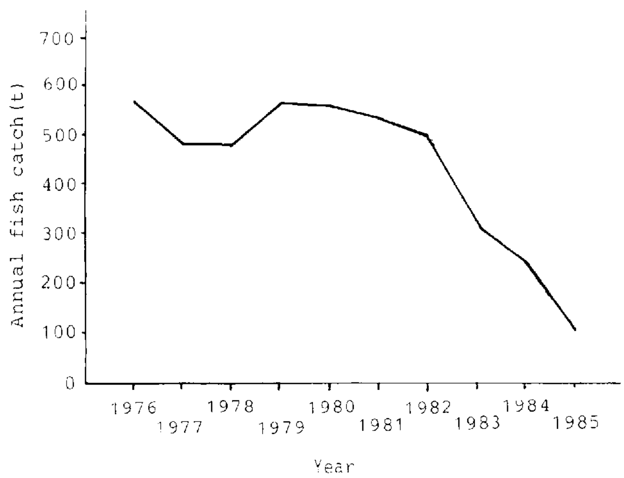
F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in 1985 : 201 [metric tons].

§ Fishery products other than fish in 1985 : 21 [metric tons].

F6 PAST TRENDS (Q)

Fig. ASI-31-11 Trend of annual fish catch.



G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1985) (Q)

	Area [ha]	[%]
Natural landscape		
Woody vegetation Herbaceous vegetation	37,073	71.9
Agricultural land	6,596	12.8
Settlement area	2,568	5.0
Others	5,296	10.2
Total	51,533	100.0

§ Main types of woody vegetation : Deciduous broadleaf forest (*Quercus mongolica* var. *grosseserrata, Q. serrata, Betula platyphylla* var. *japonica, B. ermanii*) ; conifer forest (*Abies veitchii, A. mariesii, A. homolepis, Tsuga diversifolia, Larix Kaempferi, Pinus densiflora*) ; conifer plantation (*Larix kaempferi, Pinus densiflora*) (7).

§ Main types of herbaceous vegetation : Grasslands, weeds and alipine plant communities (7).

§ Main kinds of crops : Rice, vegetables, beans and fodder crops (Q).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1978-1982) (Q)

	Gross product Per year [10^6 yen]	No. of persons engaged	No. of establishments
Primary industry			
Crop production	18,200	11,200	N.A.
Animal husbandry			
Fisheries	460	N.A.	N.A.
Others			
Secondary industry	631,900	51,400	2,935
Tertiary industry	438,900	8,500	4,956

§ Numbers of domestic animals in the catchment area : Cattle 4,447, swine 13,252, poultry 695.

G3 POPULATION IN THE CATCHMENT AREA (1985) (Q)

	Population	Population density [km^{-2}]	Main cities
Urban	145,053	—	Suwa, Okaya, Chino
Rural	32,227	-	
Total	180,280	339.4	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, sightseeing and tourism (number of visitors in 1985 : 5,240,000), fisheries, recreation (sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1985) (Q)

	Use rate
Industrial water	0.002 m^3/s
Others	
Fish culture	0.23 m^3/s

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION (Q)

§ Present status : None.

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication :

Unusual bloom of *Microcystis* (Jul.-Sep.).

Harms on fisheries due to the depletion of dissolved oxygen.

§ Nitrogen and phosphorus loadings [kg day^{-1}]
1984

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	498.2	549.5	572.2	659.0	2,233.9
T-P	143.2	70.3	57.9	32.6	304.5

I4 ACIDIFICATION (Q)
§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Significant development of the catchment area with some provision for municipal and industrial wastewater treatments, resulting in measurable discharge of pollution load into the lake.

J3 SANITARY FACILITIES AND SEWERAGE
§ Municipal wastewater treatment systems
Number of secondary treatment system : 1.
Number of other types (unaerobic digestion) : 3.

K. IMPROVEMENT WORKS IN THE LAKE (Q)

K1 RESTORATION
Suction dredging of bottom mud. Amounts dredged : 1.51×10^6 m^3 (1969-1980) and 0.5×10^6 m^3 (1981-1985).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED
§ Names of the laws (the year of legislation)
(1) For national laws see "Biwa-ko"
(2) Prefectural Government Code for Prevention of Public Nuisances
§ Responsible authorities
(2) Nagano Prefecture Government

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES
(1) Suwa Hydrobiological Station, Faculty of Science, Shinshu University
(2) Nagano Prefecture Research Institute for Hygenic and Environmental Studies

N. SOURCES OF DATA

* Printed in Japanese. The titles are tentatively translated into English with original titles in romanized Japanese in parentheses.

(1) Japan Map Center (ed) (1982) Collection of Maps of Japanese Lakes (Nihon no Koshô-zûshû) (Technical Data of National Geographical Institute, D・1-No. 221). National Geographical Institute, Tsukuba.*
(2) Meteorological Agency of Japan (1982) Meteorological Tables of Japan ; Monthly Means by Locations for 1951-1980 (Nihon Kikôhyô, Sono 2 ; Chiten-betsu, Tsuki-betsu Heinenchi, 1951-1980). 302 pp. Japan Meteorological Association, Tokyo.*
(3) Uchida, E., Asada, T. & Kawamura, T. (ed.) Handbook of Japanese Meteorology, Vol. II (Nihon Kishô-sôran, Gekan). 1,060 pp. Tôyô-keizaishinpô-sha, Tokyo.*
(4) Kurasawa, H. & Okino, T. (1983) Lake Suwa. Natural History and Limnology of Suwa District (Suwa no Shizen-shi, Rikusui-hen), pp. 113-176. Suwa Education Society (Inland Water Committee), Suwa.*

(5) Nakamoto, N. & Routine Observation Group (1983) Evaluation of available nutrients in the water of Lake Suwa by use of the MBOD bioassay (Suwa-ko ni okeru MBOD-hô ni yoru seibutu-riyô-kanô eiyô-busshitu-ryô no hyôka no kokoromi). Interim Report of the Lake Suwa Catchment Area Ecosystem Studies (Suwa-ko Shûsui-iki Seitaikei Kenkyû Keika-hôkoku): Kankyô-kagaku Kenkyû-hôkokushû B168-R12-8, 9 : 15-24.*

(6) Takeuchi, K., Masaki, F., Hiraide, T. & Okino, T. (1983) Materials of the regular observation in Lake Suwa (5). Seston, chlorophyll-a, primary production and community respiration (Suwa-ko teiten-kansoku siryô (5). Sesuton, kurorofiru-ryô, kiso-seisanryô oyobi biseibutsu-gunshû no sô-kokyû). Ibid., 9 : 69-78.*

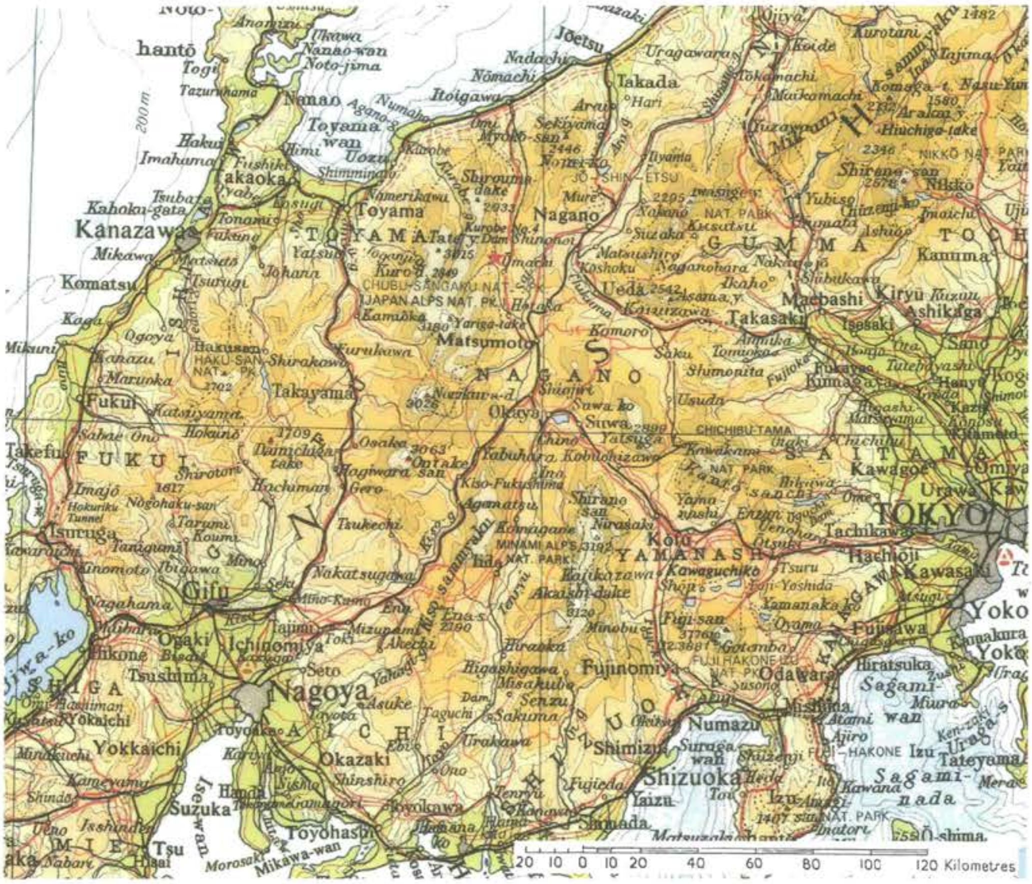
(7) Nagano Prefecture Vegetation Map Study Group (1973) Vegetation Map and Phytosociological Study of Nagano Prefecture, Vol. 1 (Nagano-ken no Shokusei-zu, Shokubutsu-shakaigaku-teki Kenkyû, 1). Nagano Prefectural Government, Nagano.*

(8) Nagano Prefectural Government (1986) Results of Water Quality Monitoring in the Public Water Bodies for 1983-1985 (Kôkyô-suiiki Suishitsu Sokutei Kekka, 1983-1985).*

KIZAKI-KO (LAKE KIZAKI)

Yachting on the lake in summer.

Photo: A. Kurata



A. LOCATION

§ Nagano Prefecture, Japan.
§ 36°33′N, 137°50′E ; 764 m above sea level.

B. DESCRIPTION

The so-called "Nishina Three Lakes", L. Aoki, L. Nakatsuna and L. Kizaki, are a chain of tectonic lakes about 30,000 years old. They are situated at the eastern foot of the Japanese Northern Alps along the remarkable tectonic zone or Fossa Magna which traverses the main island (Honshu) of Japan. L. Aoki (maximum depth 58 m) is oligotrophic, L. Nakatsuna (maximum depth 12 m) is eutrophic, and L. Kizaki (maximum depth 29.5 m) is mesotrophic, although these lakes are arranged linearly from north to south along the same water system. The trophic level of the water is apparently inversely correlated with depth. Since such nutritional dynamics lend themselves to comparative limnology, many studies have been carried out on the Nishina Three Lakes since the first voluminous work by A. Tanaka, "Studies on the Lakes of the Japanese Northern Alps (1930)".

The water level of L. Aoki in winter has been lowered by about 20 m since 1954, owing to the use of its water for power generation. Provision was also made to introduce cold water from a neighboring river running down from the Japanese Alps, thus radically changing the aquatic environment of L. Aoki. The water level of L. Kizaki also becomes lower by about 3 m in winter, and is recovered in spring by channeling water from L. Aoki. The transparency in L. Kizaki averaged about 5 m until 1950, but decreased to approximately 3 m since 1970. From the end of the 1970's, *Anabaena* has bloomed annually in July-August, and the coloration of surface water has also become frequent due to the increase of microorganisms which graze upon *Anabaena*. These evidences suggest that the trophic level of this lake has recently changed from mesotrophic to eutrophic.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	1.4
Volume [10^9m^3]	0.025
Maximum depth [m]	29.5
Mean depth [m]	17.9
Normal range of annual water level fluctuation (regulated) [m]	3
Length of shoreline [km]	7.0
Residence time [yr]	0.5
Catchment area [km^2]	22.4

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

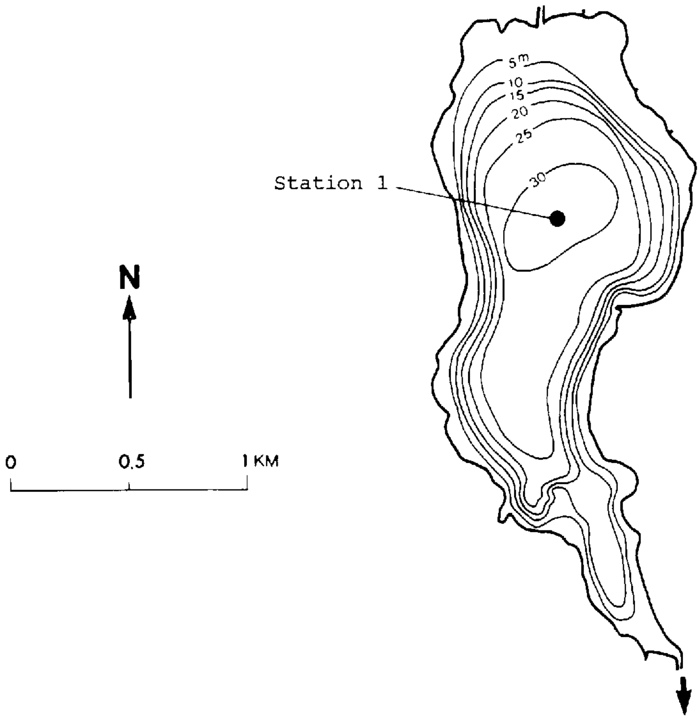
§ Bathymetric map (Fig. ASI-32-1).
§ Outflowing rivers and channels (number and names) : 1 (Nougu R.).

D2 CLIMATIC

§ Climatic data at Aoki-ko (1972-1980) (Q)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-3.5	-3.4	0.2	7.1	13.0	17.1	21.0	21.5	17.1	11.0	4.8	-0.5	8.8
Precipitation [mm]	184	171	148	160	136	218	180	179	164	112	144	157	1,953

Fig. ASI-32-1 Bathymetric map (1).



§ Water temperature [°C] (5)
Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	11.5	14.4	19.7	20.7	28.0	21.1	16.1	9.9	5.9
29	–	–	–	6.8	5.4	5.7	5.8	5.8	5.9	5.9	5.9	5.7

§ Freezing period : Jan.-Mar.
§ Mixing type : Dimictic.
§ Thermocline formation : May-Oct.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (5)

Station 1, 1985

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	–	2.5	4.0	3.5	3.5	6.5	7.5	7.5	10	5.0

E2 pH (5)

Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	7.4	7.3	9.2	7.2	7.5	7.4	7.7	7.8	6.8
29	–	–	–	6.6	6.6	6.5	6.4	7.6	6.4	6.5	7.8	6.8

E3 SS [mg l⁻¹] (5)

Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–		<1	2	2	2	1	3	2	2	1
29	–	–	–	<1	2	<1	4	4	4	3	4	2

E4 DO [mg l⁻¹] (5)

Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	11	10	9.9	9.6	8.5	8.6	9.4	9.5	8.9
29		–	–	8.5	8.6	6.1	3.1	0.8	0.9	1.0	0.2	6.2

E5 COD [mg l⁻¹] (5)

Determined by $KMnO_4$ method.

Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	2.3	2.1	3.0	1.2	1.6	1.3	<0.5	1.0	0.9
29	–	–	–	1.5	1.1	1.8	1.3	0.8	1.1	1.6	2.3	1.0

E6 CHLOROPHYLL CONCENTRATION [μg l⁻¹] (Q)

Station 1, 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	–	–	–		0.5	–	0.5	2.1	6.4	7.8	0.4	2.1
2	–	–	–	–	1.0	–	1.8	1.7	6.0	14.6	1.0	2.0
5	–	–	–	–	0.9		4.4	0.9	1.8	1.3	1.2	2.2
10		–	–	–	0.5	–	2.7	0.9	0.5	0.6	0.7	2.1
20	–	–	–	–	0.5	–	1.0	0.3	0.4	1.1	0.5	1.0

E7 NITROGEN CONCENTRATION

§ Total-N [mg l⁻¹] (5)

Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	0.47	0.49	0.36	0.27	<0.29	0.19	0.14	0.15	0.44
29	–	–	–	0.71	0.72	0.90	0.88	0.58	0.56	0.44	1.2	0.47

E8 PHOSPHORUS CONCENTRATION

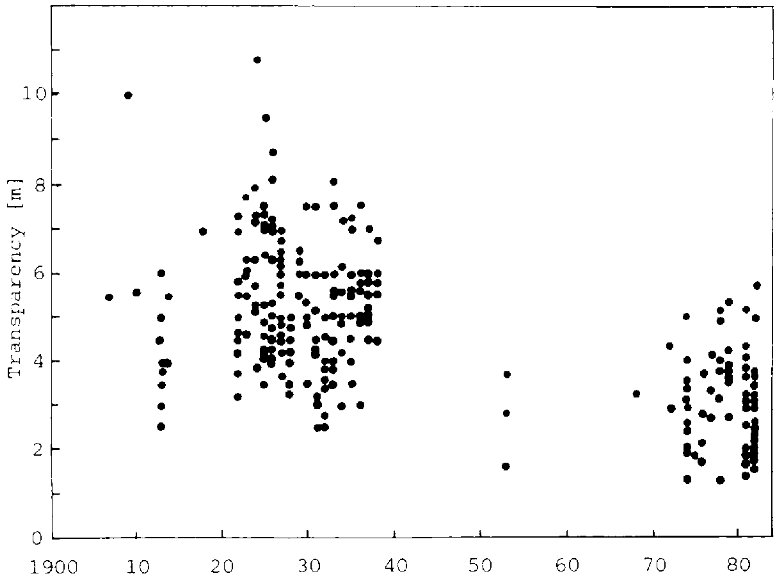
§ Total-P [mg l^{-1}] (5)

Station 1, 1985

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	–	–	–	0.012	0.015	0.007	0.005	0.035	0.006	0.005	0.004	0.008
29	–	–	–	0.009	0.009	0.015	0.011	0.005	0.010	<0.003	0.057	0.008

E10 PAST TRENDS

Fig. ASI-32-2 Trend of transparency (2).



F. BIOLOGICAL FEATURES

F1 FLORA (Q)

§ Emerged macrophytes : *Nelumbo nucifera, Zizania latifolia, Eleocharis kurokuwai, Phragmites communis.*

§ Floating macrophytes : *Nymphoides peltata, N. tetragona, Trapa japonica.*

§ Submerged macrophytes : *Ceratophyllum demersum, Hydrilla verticillata, Elodea nuttallii.*

§ Phytoplankton : *Anabaena* sp., *Fragilaria crotonensis, Melosira* sp.

F2 FAUNA (Q)

§ Zooplankton : *Conochilus* sp., *Cyclops vicinus. Alona quadrangularis, Colurella* sp.

§ Benthos : *Chironomus plumosus. Chaoborus* sp., *Tubifex* sp., *Tanytarsus* sp.

§ Fish : *Leuciscus hakonensis, Zacco platypus, Hypomessua transpacificus, Carassius* sp.

F5 FISHERY PRODUCTS

§ Annual fish catch : ca. 10 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (3)

	Area [km²]	[%]
Natural landscape		
Woody vegetation / Herbaceous vegetation	18.61	84.4
Agricultural land	1.12	5.1
Settlement area	0.65	2.9
Others	1.67	7.6
Total	22.05	100.0

§ Main types of woody vegetation: (4)
Deciduous broadleaf forest (*Fagus crenata, Quercus serrata, Q. mongolica* var. *grosseserrata, Betula ermanii*); evergreen conifer forest (*Thuja standishii, Tsuga diversifolia, Abies mariesii*); conifer plantation (*Larix kaempferi, Cryptomeria japonica*).

§ Main types of herbaceous vegetation: Grassland and alpine plant communities.

G3 POPULATION IN THE CATCHMENT AREA (1980) (3)

	Population	Population density [km^{-2}]	Main cities
Total	1,500	63	None

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Fisheries, tourism and recreation (swimming, sport-fishing, yachting).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I3 EUTROPHICATION

§ Nitrogen and phosphorus loadings [kg day^{-1}] (3)

Sources	Industrial	Domestic	Agricultural	Natural	Others	Total
T-N	1.80	2.64	9.39	16.09	8.86	38.78
T-P	0.135	0.439	0.428	0.643	0.514	2.159

I4 ACIDIFICATION

§ Extent of damage: None.

J. WASTEWATER TREATMENTS (Q)

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems: Not present.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)
(1) For national laws see "Biwa-ko"
(2) Prefectural Government Code for Prevention of Public Nuisances

§ Responsible authorities
(2) Nagano Prefectural Government

N. SOURCES OF DATA

* Printed in Japanese. The titles are tentatively translated into English with original titles in romanized in parentheses.

(Q) Questionnaire filled by Nagano Prefectural Government.

(1) Horiuchi, S., Anbe, Y. & Obata, H. (1963) Survey of Lake Kizaki basin with an ultrasonic detector (Gyogun-tanchiki ni yoru Kizaki-ko no kobon-chôsa). J. Geogr. (Chigaku Zasshi), 72 : 126-130.*

(2) Funakoshi, M. (Shinshu University) : Personal communication.

(3) Nagano Prefecture Anti-Public Nuisance Management Association (1985) Study on Nishina-sanko Water Quality Improvement Measures.

(4) Nagano Prefecture Vegetation Map Study Group (1975) Vegetation Map and Phytosociological Study of Nagano Prefecture, Vol. 2 (Nagano-ken no Shokusei-zu, Shokubutsu-shakaigakuteki Kenkyû, 2). Nagano Prefectural Government, Nagano.

(5) Nagano Prefectural Government (1985) Results of Water Quality Monitoring in Public Water Bodies (Kôkyô-suiiki Suishitsu Sokutei Kekka).

LAKE TAUPO

On the lakeshore at Taupo

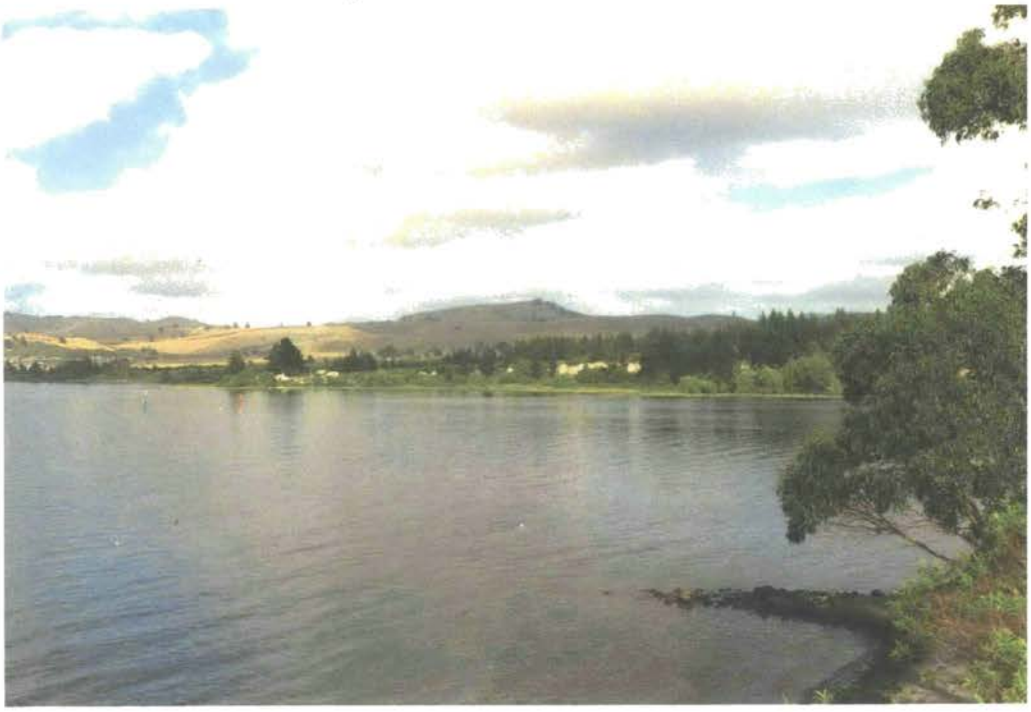
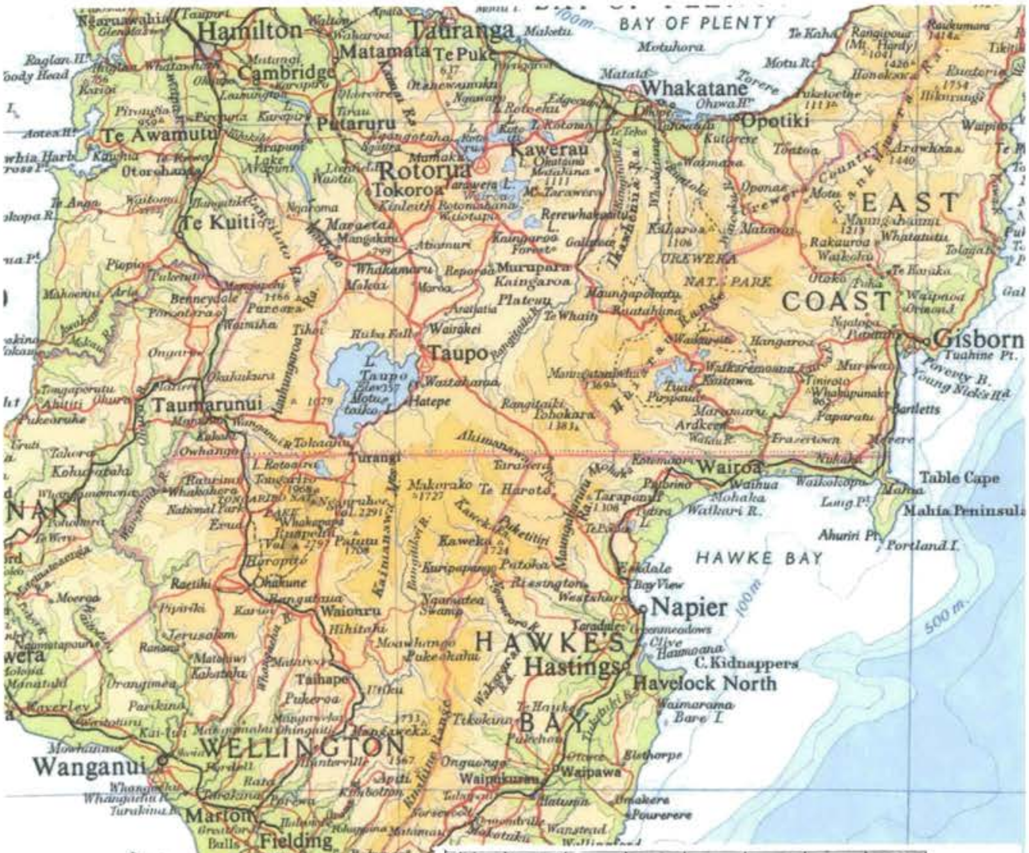


Photo: A. Kurata



A. LOCATION

§ South Auckland-Bay of Plenty, New Zealand.
§ 38°45′S, 175°55′E ; 357 m above sea level.

B. DESCRIPTION

Lake Taupo is located at the center of the North Island of New Zealand, and is the largest in that country. The drainage basin of the lake is characterized by a mild climate ; moderate temperature, light winds, cool summers, relatively warm winters and a fairly even distribution of rainfall throughout the year. The lake is surrounded by gently sloping hills which offer pasture for sheep. About 30 rivers flow into the lake, while the Waikato River is the only outlet. There are two towns, large and small, around the lake. Taupo is the main town which is located at the mouth of the Waikato River. Tall eucalypti, which are characteristic in New Zealand and Australia, are abundant on the lake shore of the town. The lake water is clear and highly transparent, with a maximum transparency of 21 m. The concentration of nitrogen and the nitrogen/phosphorus ratio of the water are remarkably low. This may be mainly attributed to the geology of the catchment area, and is responsible for the oligotrophic level of its productivity. The Koaro and the Toitoi are fish native to the lake. The Koaro, with a flat head and tough but slimy skin, was an important fish resource for the Maori living around the lake, but has become very scarce. On the other hand, artificially stocked rainbow trout is now abundant, and is primarily important for sport-fishing. The common smelt was also introduced to the lake between 1934 and 1940 after the average size of trout declined (2).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	616
Volume [10^{9}m^3]	60
Maximum depth [m]	164
Mean depth [m]	91
Water level	Regulated
Length of shoreline [km]	153
Residence time [yr]	10.6
Catchment area [km^2]	3,327

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. OCE-1-1).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Waikato R.).

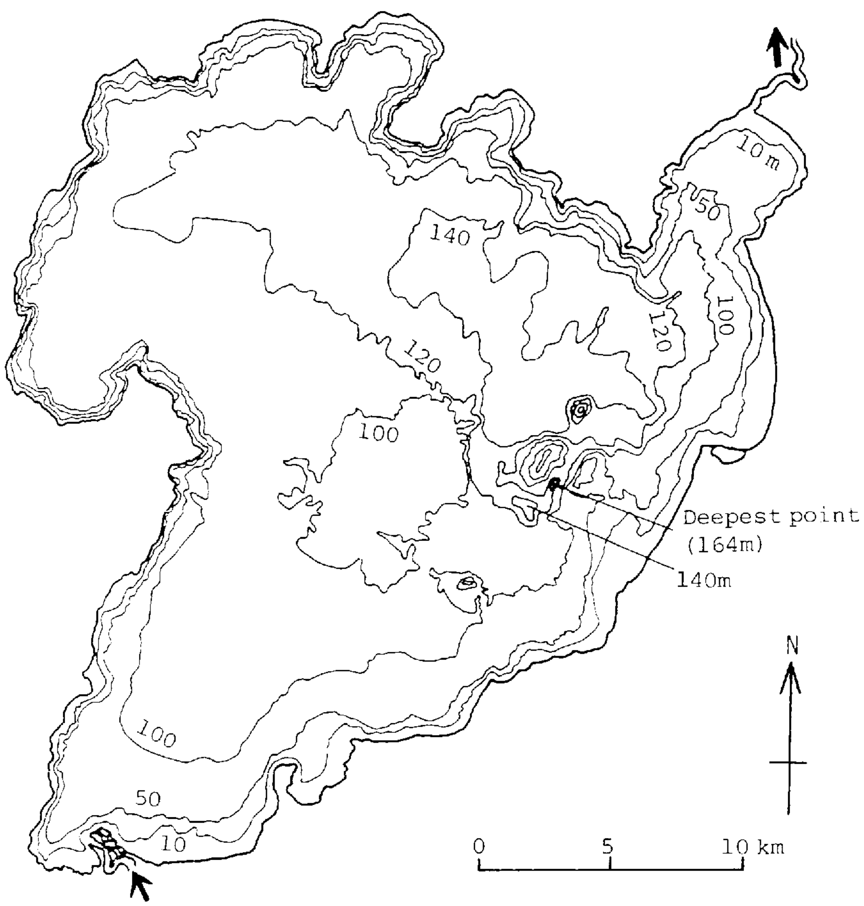
D2 CLIMATIC

§ Climatic data at Taupo, 1949 1970 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	17.1	17.3	15.6	12.5	9.6	7.3	6.3	7.4	9.3	11.5	13.5	15.6	11.9
Precipitation [mm]						Even distribution							1,200

§ Snowfall : None.

Fig. OCE-1-1 Bathymetric map (2).



§ Water temperature [°C]
Lake center, 1974-1976 (1)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	22	20	18	16	13	12	11	11	13	15	18	20

§ Freezing period : None.
§ Mixing type : Monomictic.
§ Thermocline formation : Dec.- Jun.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

Lake center, 1974-1976 (1)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	–	15	15	–	–	–	11	11	–	20	20

E2 pH, 1974-1976 (1)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	7.4	8.1	–	8.4	7.9	7.3	7.2	7.5	7.0	7.6	7.3	7.5

E3 SS [mg l^{-1}], Lake outlet : 0.5-1.0 (estimated range) (1).

E4 DO [mg l^{-1}], Lake center, 1974 1976 : Saturated at all times above 75m depth (1).

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}], 1975-1976 (3)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-30	1.0	1.0	1.0	0.8	1.0	1.2	1.7	2.8	2.4	2.0	1.2	1.1

E7 NITROGEN CONCENTRATION

§ NO_3-N [μg l^{-1}], 1975-1976 (3)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Epilimnion	0.6	2.2	1.0	0.3	0.4	0.3	1.0	1.0	0.4	0.6	0.8	0.4
Hypolimnion	14	17	18	17	20	21	23	2	3	1	7	9

§ NH_4-N [μg l^{-1}], 1975-1976 (3)

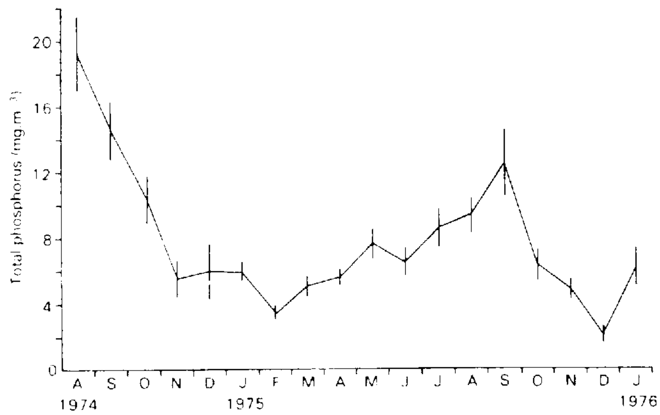
Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Epilimnion	14	7	5	4	2	2	2	6	2	4	–	9
Hypolimnion	7	6	5	2	1	2	3	3	3	5	–	6

E8 PHOSPHORUS CONCENTRATION

§ Total-P [μg l^{-1}], Lake center, mean for profile, 1975-1976 (3)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6	4	5	1	8	7	9	10	12	6	5	2

Fig. OCE-1-2 Trend of T-P at St. A (38°47′S, 176°02′E), St. B (38°52′S, 175°51′E) and St. C (38°44′S, 175°48′E) (vertical bars encompass 99% confidence limits) (3).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Submerged macrophytes : *Chara corallina, Nitella hyalina, N. flexilis, N. hookeri, Elodea canadensis, Lagarosiphon major, Potamogeton crispus.*

§ Phytoplankton : *Melosira granulata, Asterionella formosa, Chroococcus* spp., *Ankistrodesmus* spp., *Cyclotella* spp.

F2 FAUNA

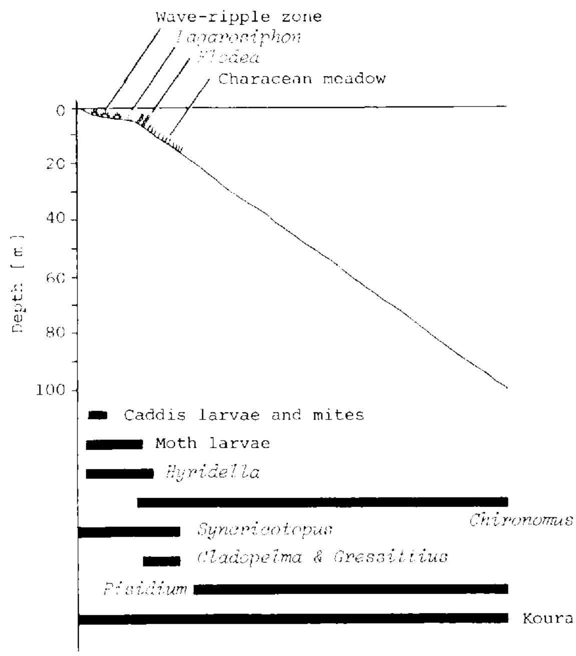
§ Zooplankton : Crustacea (*Boeckella propinqua, Macrocyclops albidus, Ceriodaphnia dubia, Bosmina meridionalis, Daphnia carinata*) : Rotifera (*Polyarthra vulagris, Pompholyx* sp., *Asplanchna brightwelli*).

§ Benthos : *Paranephrops planifrons, Chironomus zealandicus, Potamopyrgus antipodarum, Lymmaea stagnalis, Gyraulus corinna, Hyridella menziesi.*

§ Fish : *Galaxias brevipinnis, Gobiomorphus cotidianus, Retropinna retropinna, Salmo trutta, S. gairdneri.*

§ Supplementary notes on the biota (Fig. OCE-1-3)

Fig. OCE-1-3 Depth distribution of the most common invertebrate animals of the bottom sediments (2).



F5 FISHERY PRODUCTS

§ Annual fish catch in 1966-1967 : 671 [metric tons] (2).

F6 PAST TRENDS OF FISHERY PRODUCTION

Fig. OCE-I-4 Average weight of rainbow trout in anglers' bags in Lake Taupo ; catchment every five year since 1905. Separate points are shown for years 1911, 1917 and 1924. These years mark maximum peaks and troughs at a critical period of the fishery (2).

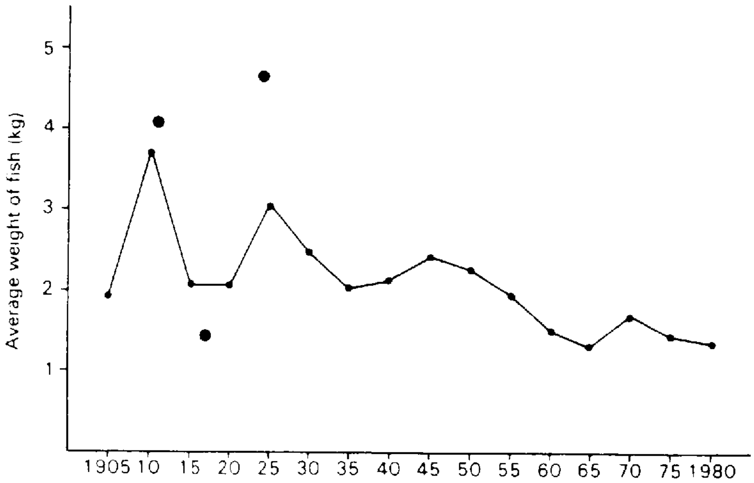
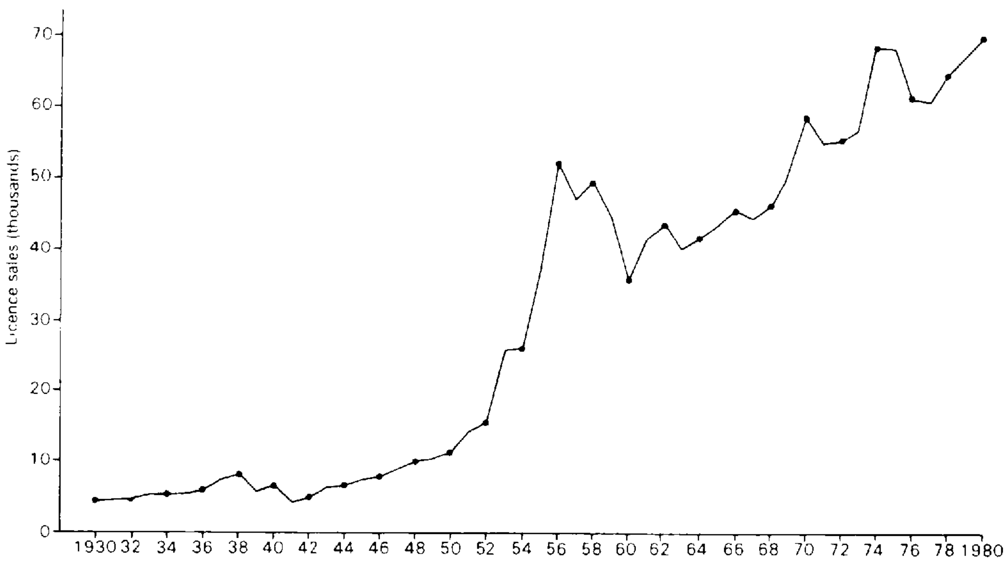


Fig. OCE-I-5 Total sales of fishing licences for Lake Taupo and catchment 1930/31 season to 1980/81 season (2).



G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1973) (Q1)

	Area [km^2]	[%]
Indigenous forest (including alpine and subalpine vegetation)	75.6	28
Tree plantation (exotic)	36.3	14
Scrub	69.8	26
Tussok grassland	33.7	13
Pasture	46.9	18
Urban area	3.2	1
Total	265.5	100

§ Main types of woody vegetation : Mixed evergreen broadleaf/conifer forest (*Nothofagus*, *Podocarpus*) ; pine plantation (*Pinus radiata*) ; lowland scrub (*Leptospermum*, *Coriaria*).

§ Main types of herbaceous vegatation : Tussock grassland ; clover-ryegrass pasture.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1982) (Q1)

	Number of persons engaged	Main products
Primary industry		
Agricultural	282	Meat, wool, logs and posts
Secondary industry		
Manufacturing	978	
Mining	9	
Others	572	
Tertiary industry	3,627	

G3 POPULATION IN THE CATCHMENT AREA (1982) (Q1)

	Population	Population density [km^{-2}]	Main cities
Total	25,500	7.7	Taupo, Turangi

H. LAKE UTILIZATION (Q1)

H1 LAKE UTILIZATION

Source of water, sightseeing and tourism, recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1982)

	Use rate [m^3 day^{-1}]
Domestic water	8,980
Power plant*	N. A.

* Waters of Taupo catchment and Waikato River provides a total of 1,371 MW of hydro-electric power.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication : Not any nuisance.

§ Nitrogen and phosphorus loadings to the lake (1973 1974) [t yr^{-1}] (Q1, 1)

Sources	Agricultural	Natural	Total
T-N	Minor	Major	657
T-P	Minor	Major	116

I4 ACIDIFICATION

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGE (Q2, 2)

§ Municipal wastewater treatment systems

Number of secondary treatment systems : 1 (more under construction ; activated sludge and oxidation pond).

Other types : Many of the urban communities near the shores of the lake use septic tanks to dispose of wastewater.

K. IMPROVEMENT WORKS IN THE LAKE

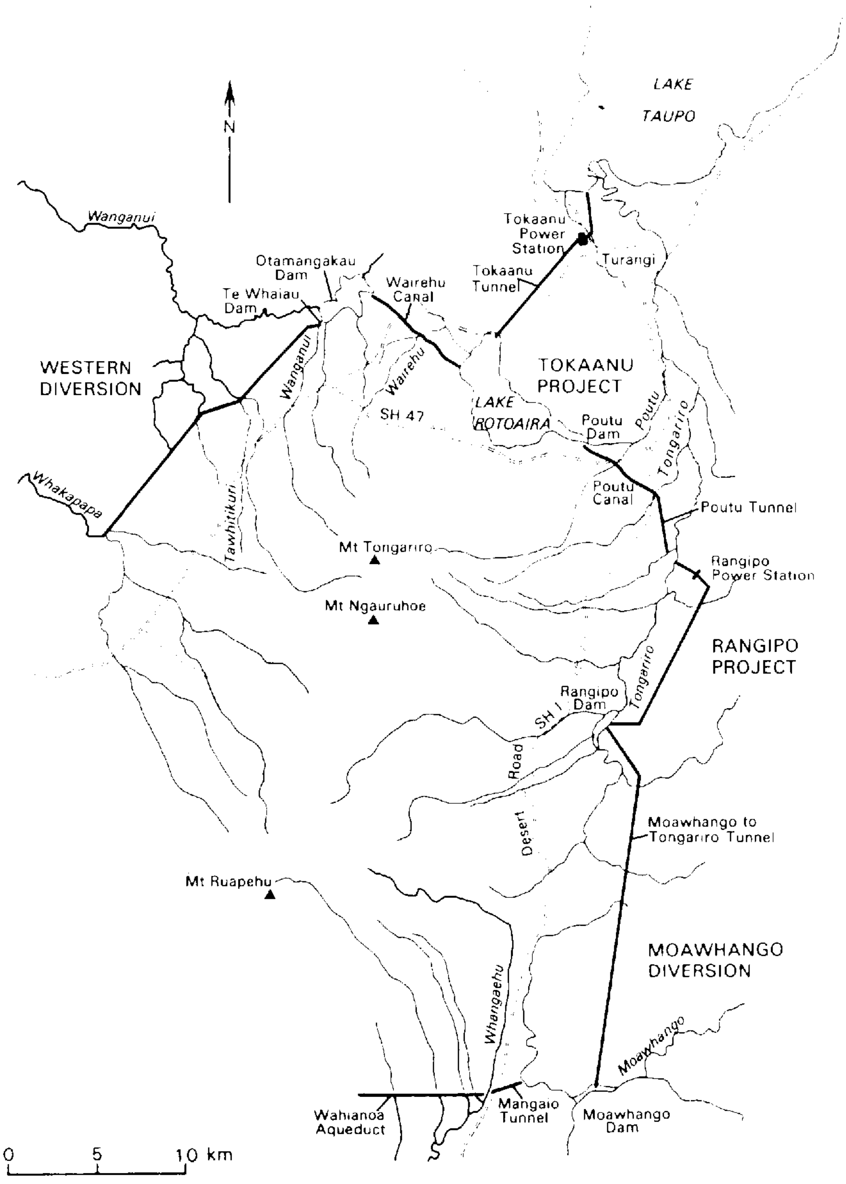
K1 RESTRATION (2)

Lake Taupo Catchment Control Scheme, Soil Conservation, Run-off Control and Water Management in the total catchment of 266,000 ha. Implementation period : 1974-1987. Approximate total cost : NZ$6,000,000.

L. DEVELOPMENT PLANS (Q2)

Water diversions and power stations are planned in the catchment area. The diagram of the Tongariro Power Development Scheme is shown in Fig. OCE-1-6.

Fig. OCE-I-6 Diagram of the Tongariro Power Development Scheme (Q2).



M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q1, Q2)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)
- (1) Soil conservation and Rivers Control Act (1941)
- (2) Water and Soil Conservation Act (1967)
- (3) Local Government Act (1974)
- (4) Town and Country Planning Act (1977)

§ Responsible authorities
- (1) Taupo County Council
- (2) Waikato Valley Authority
- (3) Tongariro United Council

§ Main items of control
- (1) Water rights
- (2) Soil conservation works
- (3) District schemes

(4) Clearance of ground cover by-law and subdivisional controls

M2 INSTITUTIONAL MEASURES

(1) Waikato Valley Authority
(2) Electricity Division, Ministry of Energy
(3) Department of Internal Affairs
(4) Federation of Lake Taupo Angling, Shooting and Boating Societies
(5) Lake Taupo Advisory Committee
(6) New Zealand Forest Service
(7) Department of Lands and Survey
(8) Tongariro-Taupo Parks and Reserves Board
(9) Taupo and Taumarnui County Councils

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Ministry of Works and Development
(2) DSIR-Taupo Research Laboratory
(3) Aquatic Weeds Section of Ministry of Agriculture and Fisheries
(4) Fisheries Research Division of Ministry of Agriculture and Fisheries
(5) Department of Internal Affairs-Wildlife Service

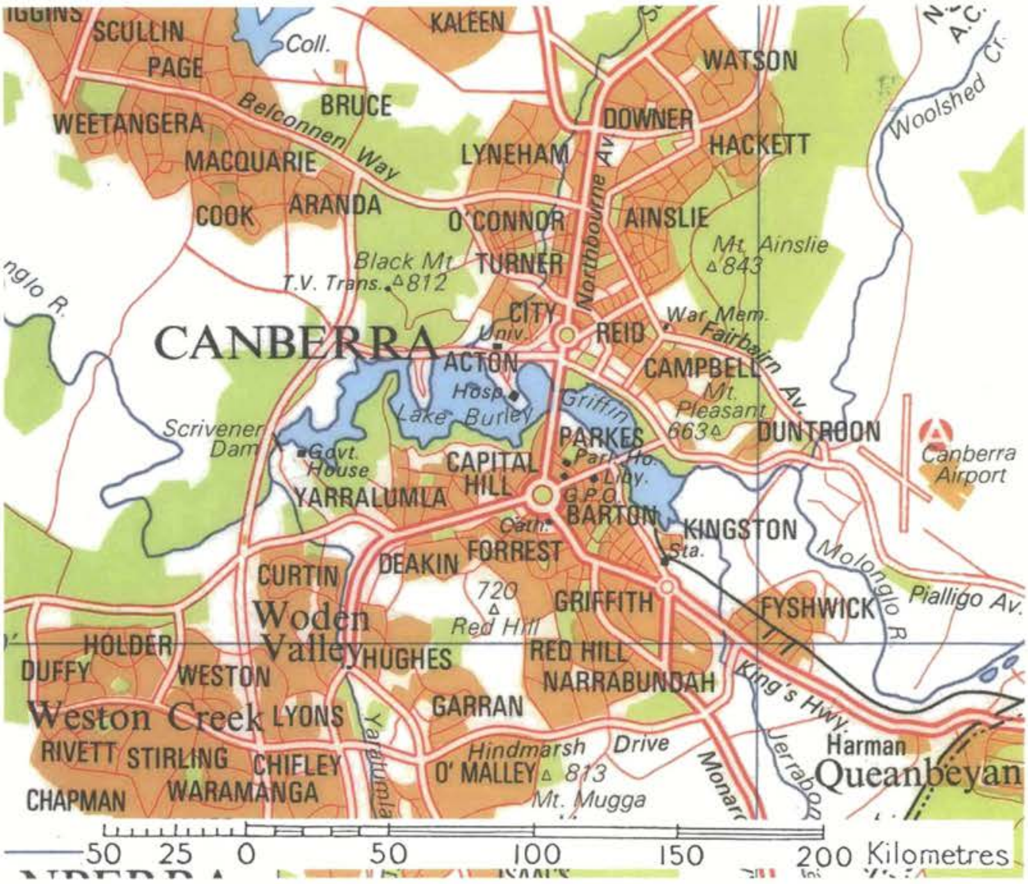
N. SOURCES OF DATA

(Q1) Questionnaire filled by the Department of Scientific and Industrial Research.
(Q2) Questionnaire filled by Dr. D. G. Smith, National Water and Soil Conservation Organization.
(1) Data supplied by Dr. M. Timperley, Ecology Division, Department of Scientific and Industrial Research.
(2) Forsyth, D. J. & Howard-Williams, C. (1983) Lake Taupo, Ecology of a New Zealand Lake. New Zealand Department of Scientific and Industrial Research, Information Series No. 158. 163 pp. Science Information Publishing Centre, DSIR, Wellington.
(3) White, E., Downes, M., Gibbs, M., Kemp, L., Mackenzie, L. & Payne, G. (1980) Aspects of the physics, chemistry, and phytoplankton biology of Lake Taupo. N. Z. J. Mar. Freshw. Res., 14 : 139-148.

LAKE BURLEY GRIFFIN

An aerial view of the whole lake

Photo: A. Kurata



A. LOCATION

§ Canberra A. C. T., Australia.
§ 35°17′S, 149°08′E ; 555.9 m above sea level.

B. DESCRIPTION

A small man-made lake in the central part of Canberra, the capital of Australia. The original lake emerged as part of the 1909 proposals for the site for the National Capital. In 1911, the competition for the design of the National Capital was carried out and Walter Burley Griffin, a city-planner from Chicago, won the prize in 1912. The lake name was dedicated to him. The plan of lay-out of the city was gazetted in 1925 including Griffin's lake.

A water feature, with three formal water basin, flanked on either side by an informal lake, was key element in Griffin's plan. National Capital Development Commission proceeded to the design and development of the lake on a two stage basis. The first stage which involved the construction of a dam, lake floor, two bridges, wharves, foreshore edges and basic landscape treatment and public facilities provision to over 843 ha of lake foreshores was officially commemorated by the Prime Minister of Australia on 17 October 1964. The second stage which is still in progress has involved detailed landscape development of the foreshores.

During both stages, an understanding of the hydraulics, water quality, ecology, biology and landscape of the lake has emerged. This understanding has had an important influence on landscape design.

The lake divides the city of Canberra into two parts, the northern section around Capital Hill for national government offices and the Diet Building, and the southern section around City Hill for down town with City Hall and shopping centers.

The commission won the Australian Institute of Landscape Architects inaugural "Award in Landscape Excellence" for its project "Lake Burley Griffin and Adjacent Parkland" in 1986. Further development of the lake foreshore is continuing in respirations of the Australian people for their National Capital (1).

C. PHYSICAL DIMENSIONS (Q1)

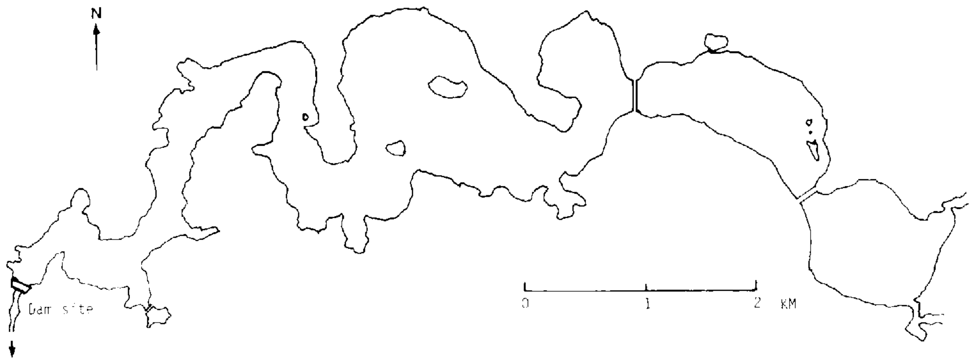
Surface area [km^2]	7.1
Volume [$10^6 m^3$]	33.2
Maximum depth [m]	17.4
Mean depth [m]	4.7
Water level	Regulated
Length of shoreline [km]	35.4
Residence time [yr]	0.2
Catchment area [km^2]	1,865

D. PHYSIOGRAFICAL FEATURES

D1 GEOGRAPHICAL (Q1)

§ Sketch map of the lake system (Fig. OCE-2-1).
§ Main islands : 3.
§ Outflowing rivers and channels (number and names) : 1 (Molonglo R.).

Fig. OCE-2-1 Sketch map of the lake (1).



D2 CLIMATIC (Q1)

§ Climatic data at Canberra, 1941-1960

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	20.2	19.4	17.5	12.9	8.9	6.4	5.5	6.7	9.3	12.1	15.2	18.4	12.7
Precipitation [mm]	63	59	60	47	59	47	43	40	43	72	63	55	651

§ Number of hours of bright sunshine : 2,622 hr yr^{-1}.
§ Snowfall : None.
§ Surface water temperature [°C]

Central Lake

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22	22	19	15	10	8	7	10	13	15	20	21

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (Q1)

Central lake, 1976-1977
Winter : 2.0 (1.4-2.4).
Summer : 1.4 (0.8-2.3).

E2 pH (Q1)

Central lake, 1976-1977
Winter : 7.5 (6.6-8.6).
Summer : 7.1 (6.4-7.7).

E4 DO [mg l^{-1}] (Q1)

Central lake, 1976-1977

	Winter	Summer
Surface	10.8 (9.4-12.5)	7.4 (6.7-7.8)
Bottom	10.6 (8.2-12.6)	5.1 (2.6 7.9)

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Central lake, 1979-1980

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
.034	.036	.034	.034	.036	–	–	–	–	–	.039	.082

F. BIOLOGICAL FEATURES

F1 FLORA (Q1)

§ Emerged macrophytes : *Typha* sp.

§ Floating macrophytes : *Azolla* sp.

§ Submerged macrophytes : *Potamogeton crispus, Vallisneria gigantea, Egeria densa.*

§ Phytoplankton : *Microcystis* sp., *Anabaena* sp., *Anacystis* sp., *Volvox* sp.

F2 FAUNA (Q1)

§ Zooplankton : Cladocera (*Bosmina* sp., *Ceriodaphnia* sp., *Daphnia* sp.), Cyclopoda (*Cyclops* sp.), Calanoida (*Boeckella* sp., *Calamoecia* sp.).

§ Fish : *Salmo gairdneri, S. trutta, Cyprinus carpio, Galaxias bongbong, Gambusia* sp.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (Q1)

	Area	
	[km²]	[%]
Woody vegetation	690	37
Agricultural land	1,116	60
Residential area	59	3
Total	1,865	100

§ Main types of woody vegetation (main species) : Savanna woodland, dry sclerophyll forest (*Eucalyptus* spp.).

§ Main types of herbaceous vegetation : *Poa* and *Stipa* grassland. Grazing mostly on native pasture (36%), cropping in ca. 1% and the rest is improved pasture (Q1, Q2).

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (Q2)

	Number of persons engaged	Main products
Primary industry		
Agriculture	3,000	Beef, lamb, wool.
Fisheries	40	
Secondary industry		
Manufacturing	3,000	
Mining	30	
Tertiary industry	9,000	

G3 POPULATION IN THE CATCHMENT AREA (1986) (2)

Total population	Population density [km^{-2}]	Main cities (population)
250,000	134.5	Canberra (250,000)

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q1)

Source of water, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (Q2) (1983)

§ Irrigation : 5.71 m^3sec^{-1}.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I3 EUTROPHICATION (Q2)

§ Nuisance caused by eutrophication

Unusual bloom of blue-green algae ; macrophyte blocking recreational use.

§ Nitrogen and phosphorus loadings [t yr^{-1}], 1983

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	2.5	74.5	240	132	449.0
T-P	0.5	12.7	12	6.6	31.8

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (d) Measurable pollution with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal and industrial wastewater treatment systems : 1 (activated sludge, trickle sludge and trickling filter) ; rate of treatment 15,068 m^3day^{-1}.

L. DEVELOPMENT PLANS

Two significant projects are currently in design : the National Museum of Australia on the western shore of Yarramundi Beach and major landscaping of the southern foreshore of Central Basin consequent to the Government's decision to build the new Parliament House on Capital Hill instead of the lake foreshore (1).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Name of the law

(1) Water pollution ordinance in preparation

K. IMPROVEMENT WORKS IN THE LAKE

§ Supplementary notes (Q1, Q2)

(1) Improvement works.

(2) Presently removing phosphorus in summer from upstream sewage effluent.

(3) Stabilization of old sulphide mine waste dump in 1974-1975.

N. SOURCES OF DATA

(Q1) Questionnaire filled by Dr. P. Collen, Canberra College of Advanced Education, Australia.

(Q2) Questionnaire filled by Dr. B. H. Pratt, Conservation & Agriculture, Department of Territories and Local Government, Australia.

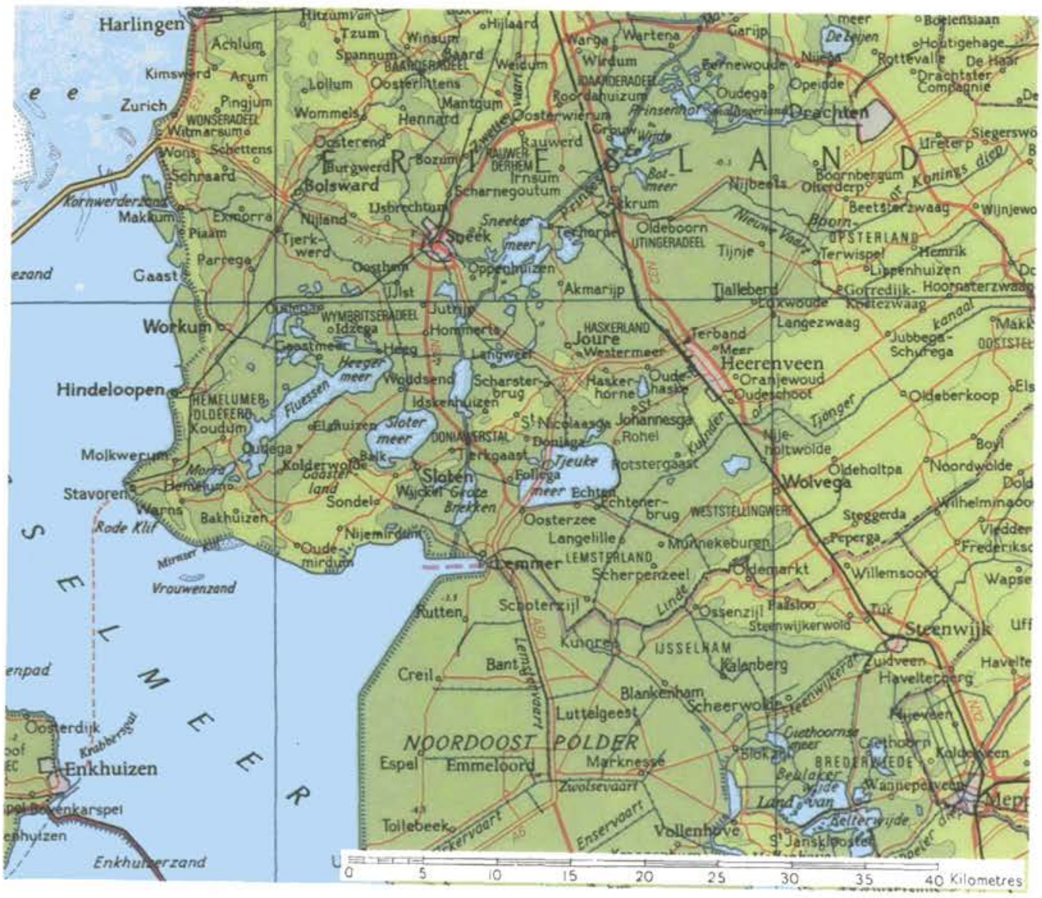
(1) National Capital Development Commission (1986) The Lake News, School Project Series, June 1986.

(2) National Capital Development Commission (1986) Canberra, From Limestone Plains to Garden City, The Story of the National Capital's Landscape, 92 pp.

TJEUKEMEER

A view at the lake shore

Photo: H. L. Golterman



A. LOCATION

§ Frieslands, the Netherlands.
§ 52° 54′ N, 5° 48′ E ; 1 m below sea level.

B. DESCRIPTION

Tjeukemeer, a man-made lake, is located at a beeline distance of about 80 km northeast from Amsterdam, beyond Ijsselmeer. Like many other lakes in the Netherlands, this freshwater lake has been built on polder or the land reclaimed from the sea, where sandy soil prevails and the landscape is strangely deficient in vegetation. The lake has a mean depth of 1.8 m, a maximum depth of 5 m, and the water surface lies 1 m below sea level. The surface, however, covers 21 km^2, displaying a great achievement in reclamation work which has gathered worldwide reputation.

The residence time of the lake water is fairly short (ca. 0.17 year) because of its shallow depth and small volume. Thermocline does not form throughout the year, and the lake may be frozen for two months during some winters. Transparency ranges from 0.5 m to 1.0 m, and the pH value is always above 8.0, often approaching 9.0. The phytoplankton biomass fluctuates from year to year, but tends to be elevated from May to September and may reach 400–500 mg/1. Blue-green and green algae predominate the phytoplankton community ; about 80% are blue-green from April to July and a similar dominance of green algae is observed from September to December. Eels are an important fishery product of this lake (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	21
Volume [10^6 m^3]	42
Maximum depth [m]	5
Mean depth [m]	2
Water level	Regulated
Length of shoreline [km]	ca. 25
Residence time [yr]	ca. 0.17

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. EUR-1-1).

D2 CLIMATIC

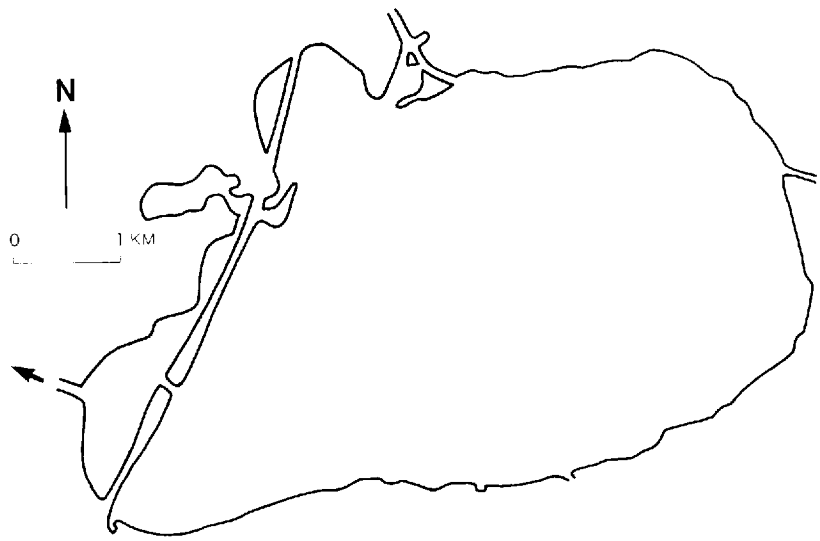
§ Climatic data at Den Helder*, 1931-1961 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2.5	2.4	4.4	7.6	11.3	14.5	16.7	17.1	15.2	11.2	7.2	4.3	9.5
Precipitation [mm]	65	46	39	40	38	37	64	71	75	90	83	65	714

*40 km west of the lake.

§ Number of hours of bright sunshine (Den Helder) : 1,665 hr yr^{-1}

Fig. EUR-1-1 Sketch map of the lake (Q).



§ Water temperature [°C], 1970 (Q)

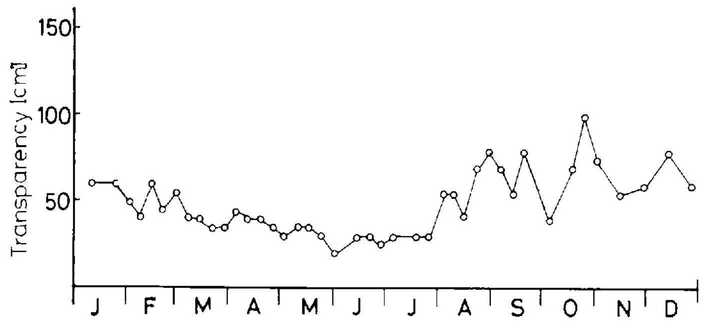
Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	4.5	4	5.5	8.5	13	17	19.5	17	14	12	3	5

§ Freezing period : 0-2 months (changes from year to year ; in some years not at all).
§ Notes on water mixing : Water always mixed.
§ Thermocline formation : None.

E. LAKE WATER QUALITY

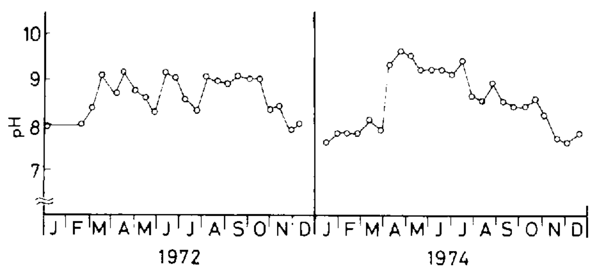
E1 TRANSPARENCY [m]

Fig. EUR-I-2 Annual change of transparency. 1977 (3).



E2 pH

Fig. EUR-I-3 Annual change of pH value (3).



E4 DO [mg l^{-1}], 1971 (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	11.3	12.5	12.4	12.3	9	9	8.7	10.5	9.5	9.8	10	12

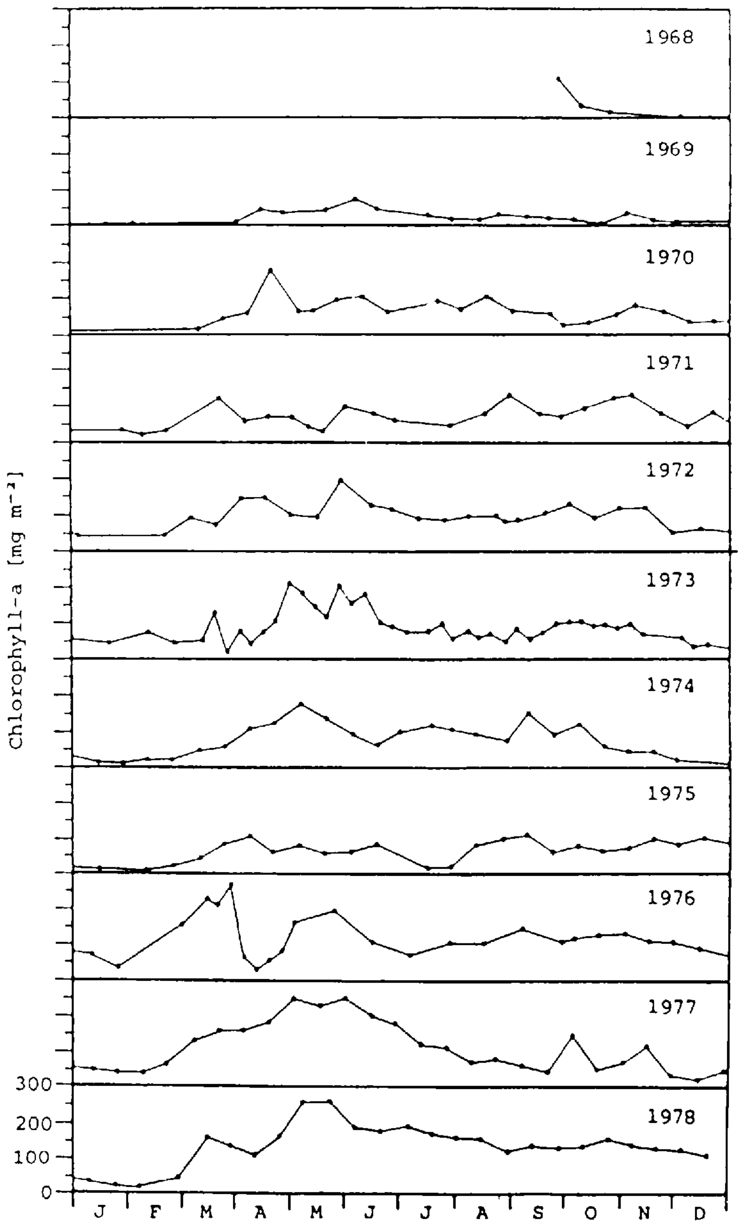
E5 COD [mg l^{-1}], 1971 (Q)

Determined by K_2CrO_4 method.

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	20	18	30	15	17	13	15	13	11	14	20	23

E6 CHLOROPHYLL CONCENTRATION

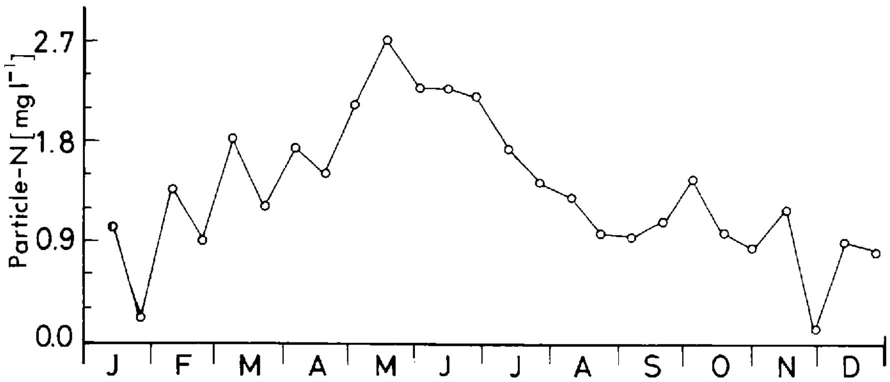
Fig. EUR-1-4 Past trend of chlorophyll concentration [$\mu g\ l^{-1}$] (4).



E7 NITROGEN CONCENTRATION

§ Particulate-N

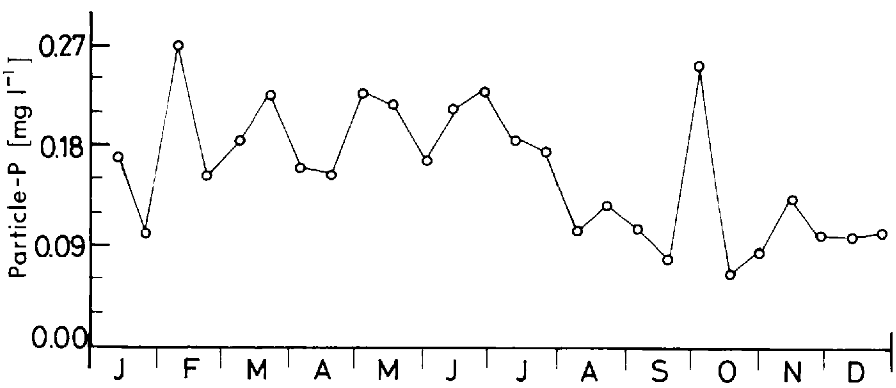
Fig. EUR-1-5 Annual change of particulate nitrogen concentration [mg l^{-1}], 1977 (3).



E8 PHOSPHORUS CONCENTRATION

§ Particulate-P

Fig. EUR-1-6 Annual change of particulate phosphorus concentration [mg l^{-1}], 1977 (3).



E9 CHLORINE ION CONCENTRATION [mg l^{-1}] (Q)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	35-40		—	—	—	100-150		—		-	35-40	—

E10 PAST TRENDS : No remarkable change (Q).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites* sp.

§ Submerged macrophytes : *Potamogeton* sp.

§ Phytoplankton : *Diatoma elongatum, Asterionella formosa, Senedesmus, Pediastrum, Microcystis aeruginosa, Anabaena, Lyngbya, Merismopedium, Chroococcus, Melosira* spp., *Chroomonas* sp., *Oscillatoria* sp. (4).

F2 FAUNA

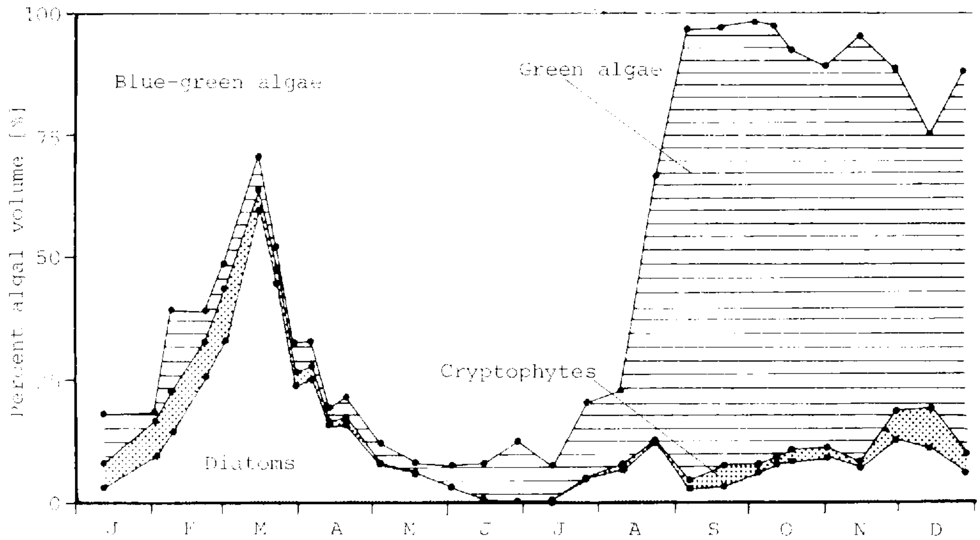
§ Zooplankton : *Daphnia hyalina*, *D. cucullata*, *Acanthocyclops robustus*, *Mesocyclops leuckarti* (5, 6).

§ Benthos : *Chironomus plumosus*, *C. anthracinus*, *Cladotanytarsus mancus*, *Glyptotendipes pallens*, *Polypedilum scalaenum*, *P. nubeculosum*, *Stictochironomus histrio* (7).

§ Fish : *Anguilla anguilla*, *Abramis brama*, *Rutilus rutilus*, *Blicca björkna* (8, 9).

§ Supplementary notes on the biota

Fig. EUR-I-7 Percent contribution of various algal groups to the total algal volume, 1977 (4).

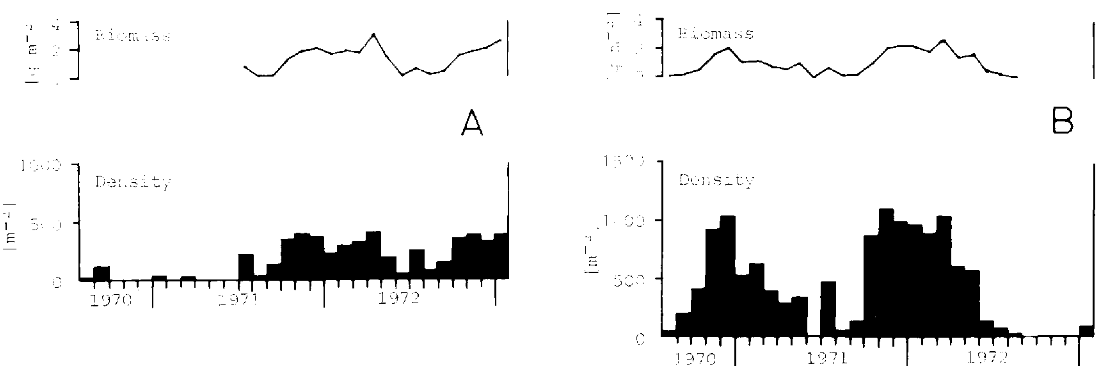


F4 BIOMASS

§ Biomass and production of important zooplankton (organic dry wt.) (5, 6)

	Mean biomass [mg m^{-2}]			Production [mg m^{-2}yr^{-1}]		
	1969	1970	1971	1969	1970	1971
D. hyalina	61.3	135.8	133.3	2,987.0	6,136.2	6,275.4
D. cucullata	9.8	8.8	15.6	389.3	222.2	570.4
A. robustus	31.0	43.6	48.0	2,892.5	3,967.0	3,911.6
M. leuckarti	6.4	8.7	16.4	380.3	506.0	876.0

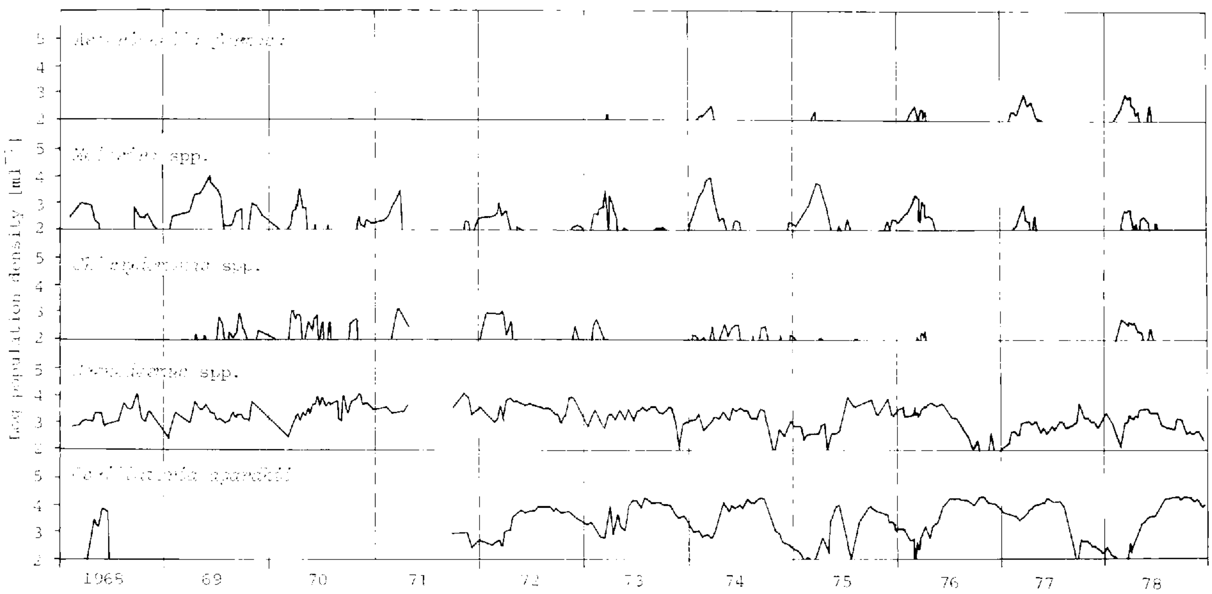
Fig. EUR-I-8 Biomass (dry wt.) and density of *Chironomus plumosus* (A) and *Glyptotendipes pallens* 4 th instar larvae (B) in the mud of the inshore zone (8).



F5 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE : Not recorded (Q).

F6 PAST TRENDS

Fig. EUR-I-9 Trend of population density of some important algal species (3).



G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA

	[%]
Agricultural land and meadows	95
Residential area	5
Total	100

§ Main kinds of crops : Grass.
§ Levels of fertilizer application on crop fields : Moderate.
§ Trends of change in land use in recent years : No changes.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE : Agriculture only.

G3 POPULATION IN THE CATCHMENT AREA : For a polder reservoir the concept of a catchment area is not relevant.

	Population	Mean population density [km^{-2}]
Total	N.A.	50-100

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Sightseeing and tourism (a few thousand visitors per year), recreation (yachting), fisheries, control polder water regime (storage in winter).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

I3 EUTROPHICATION

§ Nitrogen loadings to the lake [g m^{-2} yr^{-1}]

Sources	Industrial	Domestic	Agricultural and natural (gross ; measured together)	Year
T-N	–	–	2.73	1973
			3.69	1974
			1.77	1975

I4 ACIDIFICATION

§ Extent of damage : None ; the lake is well buffered.

I5 OTHER HAZARDS : None.

J. WASTWATER TREATMENTS (Q)

J1 GENERATION OF POLLTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF NUTRIENT LOAD

	Percentage
Non-point sources	100
Point sources	0
Total	100

J3 SANITARY FACILITIES AND SEWERAGES

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment system) or public sewerage : 95%.

§ Municipal wastewater treatment systems : No sewage water entering the lake.

§ Industrial wastewater treatment systems : No industry.

K. IMPROVEMENT WORKS IN THE LAKE

None (Q).

L. DEVELOPMENT PLANS

None (Q).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws

(1) Provincial Water Quality Criteria revised every 5 years

§ Responsible authorities

(1) Provincial Government

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Provincial Government "Friese Prov. Waterstaat", Leeuwarden.

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. H.L. Golterman, Station Biologique de la Tour du Valat, Arles.

(1) Leenen, J.D. (1982) Hydrology of Tjeukemeer. "Studies on Lake Vechten and Tjeukemeer, the Netherlands" (ed. Gulati, R.D. & Parma, S.), pp. 199–203. Dr. W. Junk Publishers, The Hague.

(2) Müller, M.J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306pp. Dr. W. Junk Publishers, The Hague.

(3) de Haan, H. (1982) Physico-chemical environment in Tjeukemeer with special reference to speciation of algal nutrients. "Studies on Lake Vechten and Tjeukemeer, the Netherlands" (see above), pp. 205–223.

(4) Moed, J.R. & Hoogveld, H.L. (1982) The algal periodicity in Tjeukemeer during 1968–1978. Ibid., pp. 223–234.

(5) Vijverberg, J. & Richter, A.F. (1982) Population dynamics and production of *Daphnia hyalina* Leydig and *Daphnia cuculata* (Sars) in Tjeukemeer. Ibid., pp. 235–260.

(6) Vijverberg, J. & Richter, A.F. (1982) Population dynamics and production of *Acanthocyclops rubustus* (Sars) and *Mesocyclops leuckarti* (Claus) in Tjeukemeer. Ibid., pp. 261–274.

(7) Beauttie, D.M. (1982) Distribution and production of the larval chironomid populations in Tjeukemeer. Ibid., pp. 275–286.

(8) de Nie, H.W. (1982) A note on the significance of larger bivalve molluscas (*Anodonta* spp. and *Dreissena* sp.) in the food of the eel (*Anguilla anguilla*) in Tjeukemeer. Ibid., pp. 287–306.

(9) Lammens, E.H.R.R. (1982) Growth, condition and gonad development of bream (*Abramis brama*) in relation to its feeding conditions in Tjeukemeer. Ibid., pp. 307–310.

(10) Golterman, H.L., Voerman, S. & de Nie, H.W. (1980) Fosfaat balans van let Tjeukemeer. H_2O, 6 : 116～122.

LAKE BALATON

From the rooftop of Balaton Limnological Research Institute, Tihany

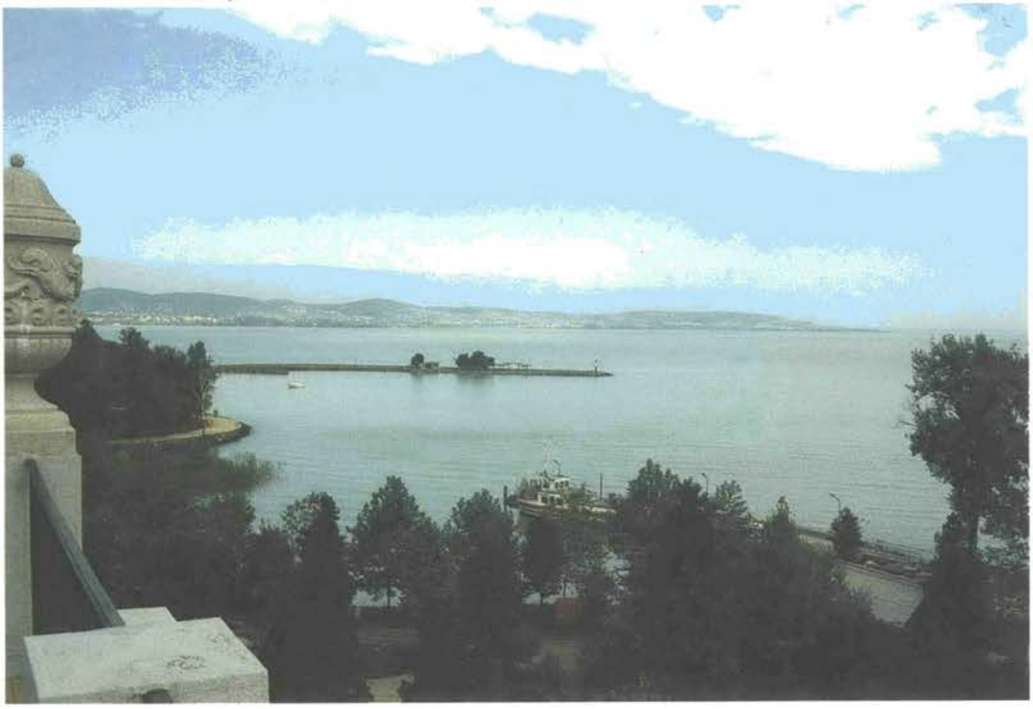
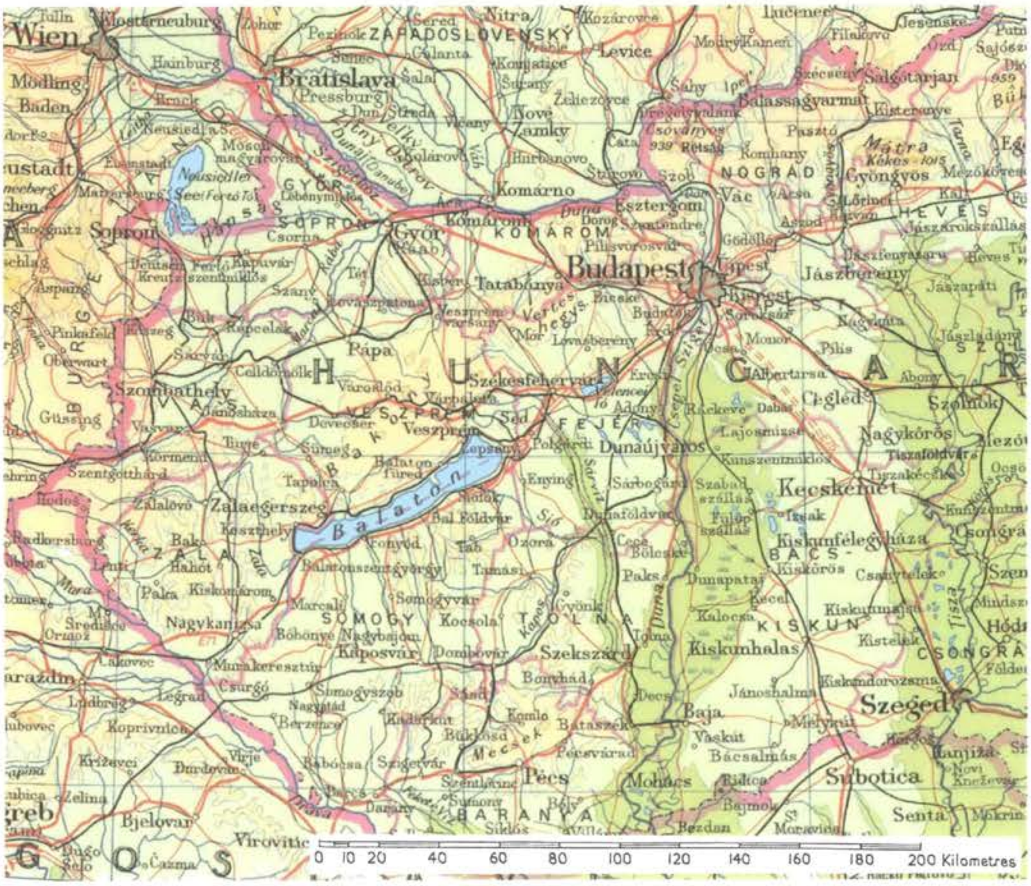


Photo : A. Kurata



A. LOCATION

§ Somogy and Veszprém, Hungary.
§ 46°42′-47°04′N, 17°15′-18°10′E ; 104.8 m above sea level (Adriatic).

B. DESCRIPTION

Lake Balaton was formed mainly by tectonic forces 12,000-20,000 years ago. Prior to the opening of Sió-canal in 1863, its water level was 3 m higher and its surface was about twice larger than at the present. With its surface area of 593km^2, Lake Balaton is the largest lake in Central Europe, but its mean depth is only 3.2 m.

The main inflow, the Zala River, empties into the southwestern end of the lake, while the Sió-canal drains the water from the eastern basin into the River Danube.

The lake is covered by ice in winter. In summer the average water temperature is 23°C. The strong waves swirl up much sediments, rendering the transparency low.

The major ions of the water are Ca^{2+}, Mg^{2+} and HCO_3^-. The pH is 8.4, rising to higher values during intensive primary production. Oxygen deficiency is formed only temporarily in the western part of the lake in calm summer periods with algal blooms.

The distribution of macrophytes is restricted by strong waves to a relatively narrow belt. Only 3 percent of the lake surface is covered by reeds, and even less by submerged macrophytes. The major primary producers are phytoplankton. Zooplankton is not abundant. Zoobenthos represents an important food for the fish. The annual commercial fish catch is 1200 tons.

The southern shore of the lake consists of sandy beach, while on the northern shore there are mountains of volcanic origin with old ruins on their tops and vineyards on their slopes. The picturesque landscape and the water ideal for swimming and other water sports attract 2 million tourists annually.

The sewage discharge from rapidly developing towns in the watershed, the growing use of fertilizers in agriculture and large animal farms increased the nutrient loading to the lake in the last decades. A rapid eutrophication became apparent by increased production and biomass of phytoplankton. Blooms of blue-green algae are frequent in the most polluted western part of the lake.

A eutrophication control program has been formulated, based on intensive scientific researches. Most of the municipal sewage is now diverted from recreational areas. Phosphorus removal was introduced at other sewage treatment plants. A reservoir was constructed to retain the nutrients carried by the Zala River. Pollution due to liquid manure was reduced. Construction of more reservoirs on major tributaries of the lake and a soil protection program are in progress (Q).

C. PHYSICAL DIMENSIONS

Surface area [km^2]	593
Volume [10^9m^3]	1.9
Maximum depth [m]	12.2
Mean depth [m]	3.25
Normal range of annual water level fluctuation (regulated) [m]	0.3
Length of shoreline [km]	236
Residence time [yr]	2
Catchment area [km^2]	5,181

D. PHYSIOGRAPHIC FEATURES (2)

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-4-1).

§ Main islands : None.

§ Outflowing rivers and channels (number and names) : 1 (Sió-canal).

D2 CLIMATIC

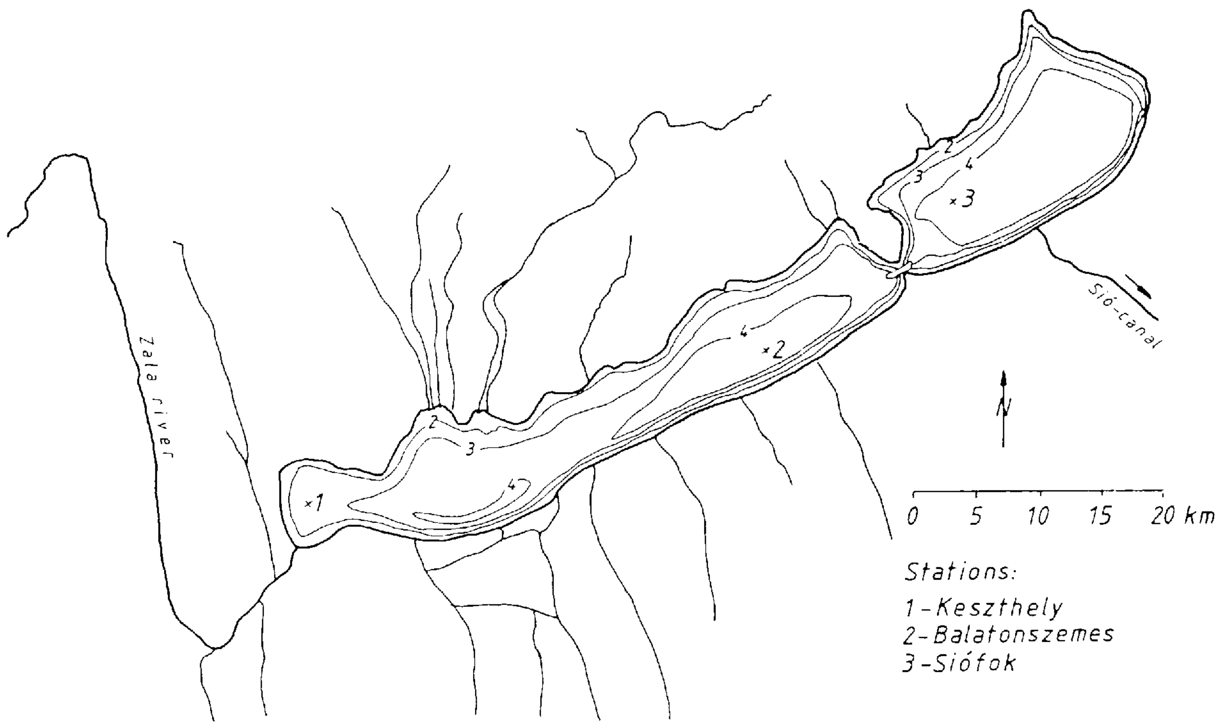
§ Climatic data at Siófok, 1947-1963 (temp.) and 1951-80 (prec.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	1.4	0.6	5.0	10.7	15.6	19.4	20.8	20.2	16.3	10.8	5.6	1.0	10.4
Precipitation [mm]	36.5	37.7	35.6	44.7	60.4	80.8	73.3	62.1	48.4	42.9	65.5	45.7	633.9

§ Number of hours of bright sunshine (Siófok, 1951-1980) : 2,052 hr yr^{-1}.

§ Solar radiation (Siófok, 1931-1960) : 12.2 MJ m^{-2} day^{-1}.

Fig. EUR-4-1 Bathymetric map (Q).



§ Water temperature [°C], 1947-1963

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		–	4.5	11.5	17.6	21.9	23.2	22.9	19.2	13.3	6.9	2.0

§ Freezing period : From 4 Jan. to 24 Feb., 1927-63.

§ Mixing type : Polymictic.

E. LAKE WATER QUALITY (3)

E1 TRANSPARENCY [m]

Station 1-3, 1979-1983

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Keszthely	—	—	0.49	0.38	0.50	0.47	0.50	0.35	0.41	0.46	0.50	0.65
Szemes	—	—	0.72	0.48	0.49	0.56	0.69	0.45	0.64	0.53	0.60	0.52
Siófok		—	0.71	0.45	0.45	0.71	0.67	0.55	0.69	0.70	0.57	1.25

E2 pH

8.4, rising to 8.9 in the western part of the lake during summer algal blooms.

E3 SS [mg l^{-1}], 1979 1983, at 1 m depth

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Keszthely	—	—	34.1	39.6	27.6	40.6	23.1	31.7	23.4	25.8	—	14.5
Szemes	—	—	20.7	22.2	22.5	13.9	16.4	29.1	13.5	22.6	56.0	13.4
Siófok		—	16.1	19.7	23.9	13.7	25.0	23.1	13.6	18.6	20.1	4.9

E4 DO [mg l^{-1}]

The dissolved O_2 concentration is usually close to the saturation level. Strong oversaturation at the surface and O_2 deficiency near bottom sediment are found only in the western part of the lake in calm summer periods during algal blooms.

E5 COD [mg l^{-1}], 1979-1983, at 1 m depth

Determined by $KMnO_4$ method.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Keszthely		—	7.86	8.60	6.50	7.38	9.80	7.72	7.96	8.00	8.07	9.80
Szemes	—	—	5.96	5.10	5.00	4.68	6.32	5.64	6.04	6.45	5.95	5.00
Siófok	—	—	4.88	4.80	4.02	3.26	4.70	4.46	4.46	4.67	4.43	4.90

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}], 1979-1983, at 1 m depth

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Keszthely	—	—	34.0	30.8	19.8	20.4	33.5	51.4	38.4	41.4	42.8	42.9
Szemes	—	—	12.4	19.4	10.6	7.4	8.8	22.6	19.5	16.7	15.4	16.1
Siófok	—	—	7.2	9.2	8.5	4.4	5.4	9.8	11.7	10.0	6.8	5.1

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}], 1979-1983, at 1 m depth

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Keszthely	–	–	1.81	1.85	1.23	1.50	1.39	2.01	1.51	1.57	1.72	1.94
Szemes	–	–	1.25	0.98	0.90	0.92	0.87	0.99	0.87	1.19	1.09	0.63
Siófok	–		0.93	0.80	0.72	0.61	0.70	0.79	0.71	1.07	0.69	0.59

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], 1979-1983, at 1 m depth

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Keszthely	–		0.075	0.089	0.068	0.089	0.101	0.104	0.114	0.089	0.143	0.078
Szemes		–	0.032	0.052	0.036	0.033	0.035	0.037	0.039	0.040	0.059	0.043
Siófok		–	0.024	0.028	0.034	0.022	0.027	0.028	0.033	0.043	0.031	0.028

F. BIOLOGICAL FEATURES

F1 FLORA (4)

§ Emerged macrophytes : *Phragmites australis, Typha latifolia.*

§ Floating macrophytes : *Lemna minor, L. trisulca, L. gibba, Spirodela polyrrhiza, Wolffia arrhiza, Hydrocharis morsus-ranae, Nymphaea alba, Nuphar luteum, Trapa natans.*

§ Submerged macrophytes : *Potamogeton perfoliatus, P. crispus, P. pectinatus, Najas marina, Stratiotes alloides, Ceratophyllum demersum, Myriophyllum spicatum.*

§ Phytoplankton : Spring (*Nitzschia acicularis, Cyclotella ocellata, C. bodanica, Stefanodiscus hantzschii*); summer, eastern part (*Ceratium hirundinella, Melosira granulata, Botryococcus braunii*); western part (*Anabaenopsis raciborskii, Anabaena spiroides, A. aphanizomenoides, Aphanizomenon flos-aquae*).

F2 FAUNA (5)

§ Zooplankton : *Polyarthra vulgaris, Keratella quadrata, Pompholyx sulcata, Daphnia cucullata, D. galeata, Eudiaptomus gracilis, Mesocyclops leucarti, Cyclops vicinus.*

§ Benthos : *Ectinosoma abrau, Darwinula stevensoni, Potamothrix hammoniensis, Tanypus punctipennis, Lithoglyphus naticoides, Dreissena polymorpha.*

§ Fish : *Abramis brama**, *Cyprinus carpio**, *Stizostedion lucioperca**, *Aspius aspius, Pelecus cultratus, Esox lucius, Anguilla anguilla** (*economically important).

F3 PRIMARY PRODUCTION RATE (6, 7)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total [g C m^{-2} yr^{-1}]
	[mg C m^{-2} day^{-1}]												
Keszthely (1973)	312	447	524	594	726	858	6,640	6,628	2,265	126	434	373	613
Szemes (1976)	127	96	447	432	496	988	1,551	1,132	841	386	214	159	210
Siófok (1977)	103	105	248	616	633	951	1,228	847	638	313	203	41	181

F4 BIOMASS

§ Zooplankton : 2.5 [g (dry wt.) m⁻²].
§ Zoobenthos : 2.7 [g (dry wt.) m⁻²].
§ Fish : *Abramis brama* 9578 [ton (wet wt.) per lake], *Stizostedion lucioperca* 578 [ton (wet wt.) per lake].

F5 FISHRY PRODUCTS

§ Annual fish catch in 1985 : 1,315 [metric tons].

F6 PAST TRENDS

Fig. EUR-4-2 Trend of increase of primary production in the Keszthely-basin (6).

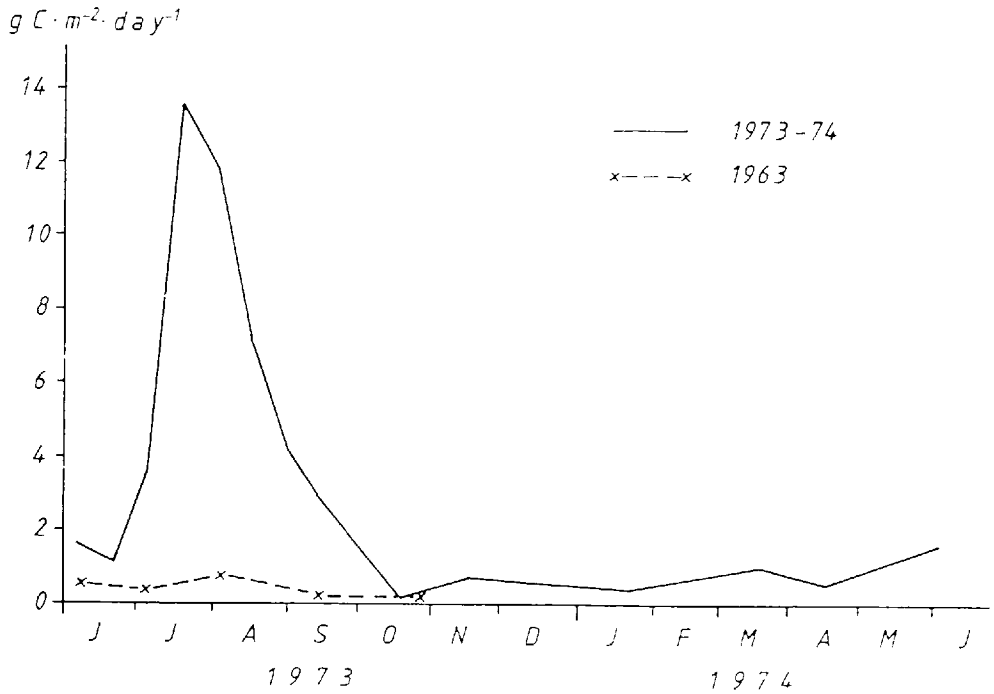


Fig. EUR-4-3 Trend of increase of algae counts in the Keszthely-basin (4).

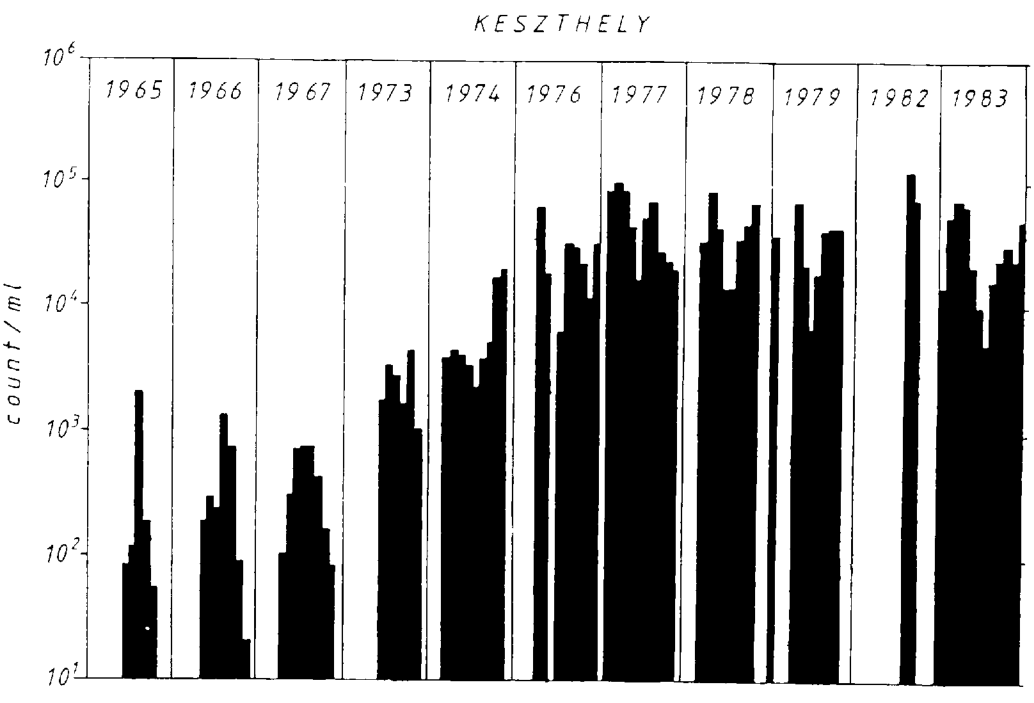


Fig. EUR-4-4 Trend of increase of algae counts in the Siófok-basin (4).

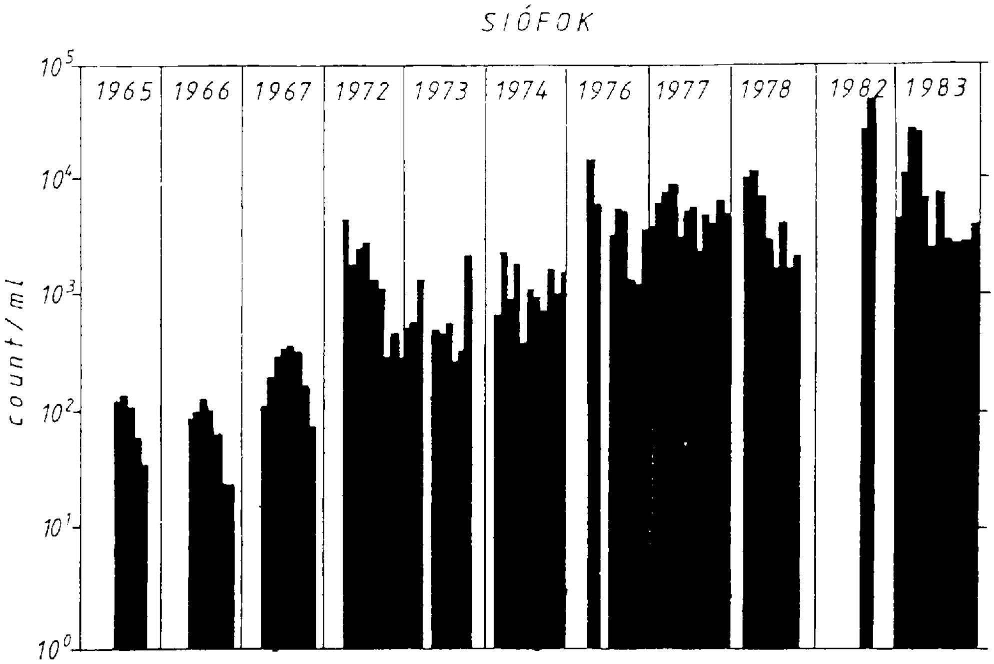


Fig. EUR-4-5 Trend of increase of phytoplankton biomass in the Keszthely-basin (4).

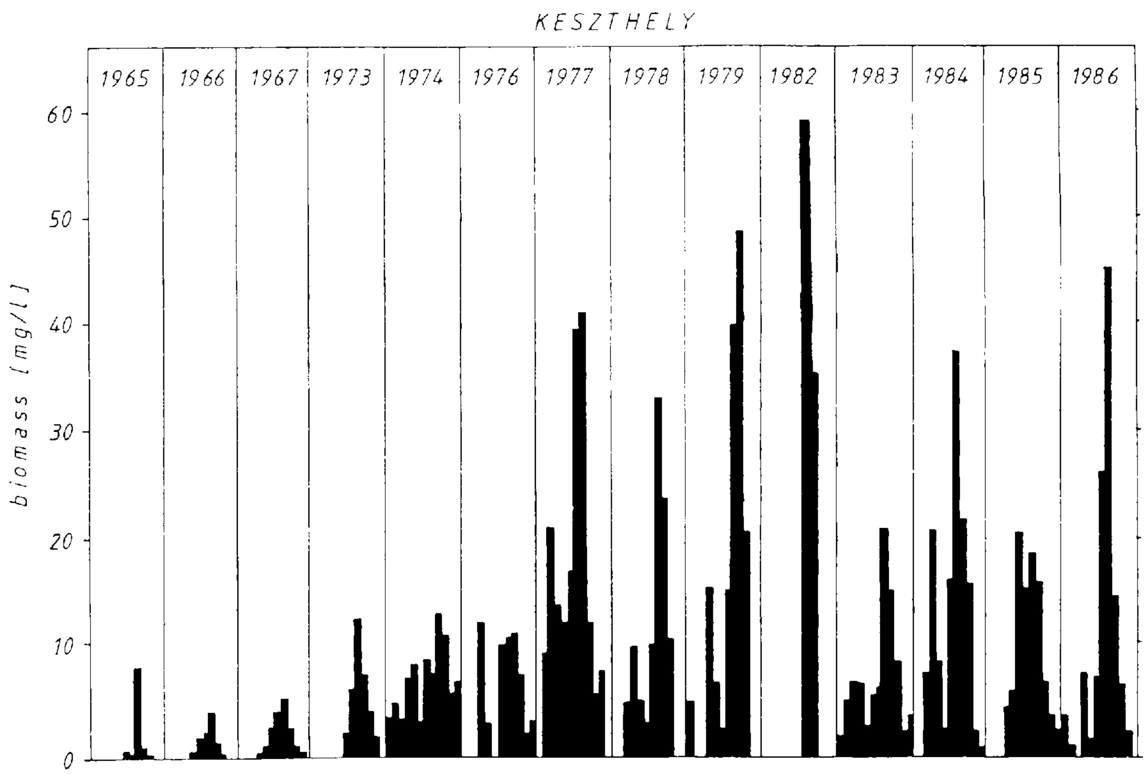
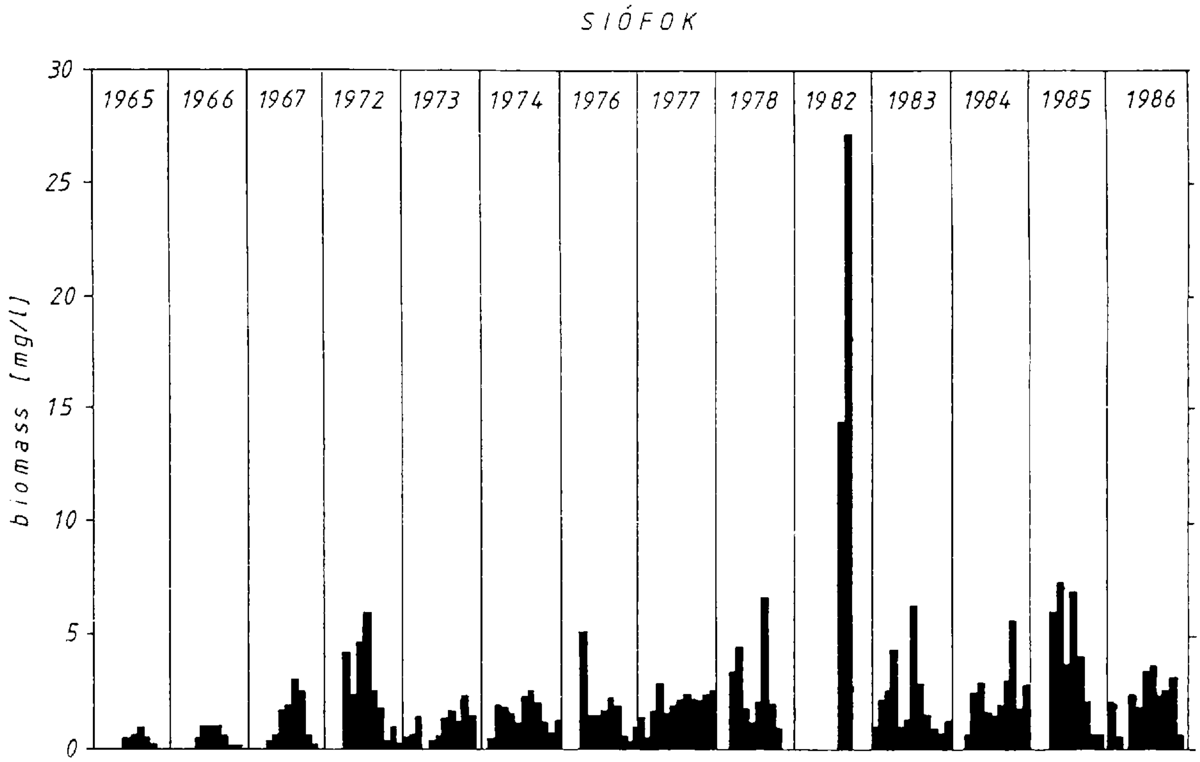


Fig. EUR-4-6 Trend of increase of phytoplankton biomass in the Siófok-basin (4).



G. SOCIO-ECONOMIC CONDITIONS (8)

G1 LAND USE IN THE CATCHMENT AREA (1982)

	Area [km²]	[%]
Natural landscape	1,811	35.0
Woody vegetation	1,343	25.9
Herbaceous vegetation	362	7.0
Swamp	106	2.0
Agricultural land	2,933	56.5
Crop field	2,428	46.9
Pasture land	505	9.7
Residential area	437	8.4
Others	—	—
Total	5,181	100.0

§ Main types of woody vegetation: Deciduous forest (*Carpinus betulus*, *Quercus petraea*, *Acer campestris*, *Quercus pubescens*, *Quercus cerris*, *Fraxinus ornus*).

§ Main kinds of crops: Wheat, maize, hay, grape and fruits.

§ Levels of fertilizer application on crop fields: Heavy (121 kg N + 90 kg P_2O_5 – 126 kg K_2O ha^{-1} yr^{-1}).

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (1980)

	No. of persons engaged	No. of establishments
Primary industry	46,400	
Animal husbandry		334
Secondary industry	65,200	741
Tertiary industry	78,900	

§ Numbers of domestic animals in the catchment area : Cattle 9×10^4, Sheep 1.1×10^5, Swine 2.2×10^5, Poultry 1.5×10^6.

G3 POPULATION IN THE CATCHMENT AREA

	Population	Population density [km^{-2}]	Main cities
Urban	180,500		Zalaegerszeg, Tapolca,
Rural	224,300		Marcali, Keszthely,
Total	404,800	64	Siófok, Balatonfüred

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, navigation and transportation, sightseeing and tourism (number of visitors in 1982 1.8×10^6), recreation (swimming, sport-fishing, yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE

	Use rate [$10^6 m^3\ yr^{-1}$]
Domestic water	8.6
Irrigation	2.5
Industrial water	10.4
Power plant	—
Others	—

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION (9)

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources (lake average)

Name of contaminant	Range of concentration [ppm] in[1]						Main Sources
	Water	Bottom mud	Fish[2]	Other organisms			
	1982	1984	1982	1982[3]	1982[4]	1982[5]	
Cu	(0.005)	(10)	(3.12)	(12.3)	(18.6)	(42.5)	Waste
Zn	(0.057)	(90)	(64.3)	(468)	(73.5)	(111)	dumps
Ca	(0.0008)	(1.5)	(0.65)	(3.7)	(3.99)	(1.47)	and
Hg	(0.0007)	(–)	(.36)	(1.22)	(1.88)	(1.08)	agri-
Pb	(0.002)	(30)	(3.59)	(48.5)	(22.1)	(12.3)	culture

Note *[1]For water on volume basis mg l^{-1} ; for bottom mud, fish and other organisms on dry weight basis mg kg^{-1}.

*[2]*Abramis brama*, muscle.

*[3]*Anodonta oygnea*, pill.

*[4]Chironomidae larvae, whole animals.

*[5]Crustacean plankton.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication: Unusual algal bloom (dominant species of algae *Aphanizomenon flos-aquae, Anabaenopsis raciborskii, Anabaena aphanizomenoides, Anabaena spiroides*).

§ Nitrogen and phosphorus loadings to the lake (1975 1981), whole lake basin [t yr^{-1}]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T N	–	382	1,973	–	3,148
T-P	–	89	150		314

§ Supplementary notes

The following measures are being taken to prevent further eutrophication.

(1) Development of sewerage and sewage treatment plants.
(2) Phosphorus removal at sewage treatment plants.
(3) Diversion of a greater part of treated effluents produced in recreational areas from the watershed of the lake.
(4) Establishment of reservoirs on larger tributaries to retain plant nutrients.
(5) Elimination of large livestock breeding farms from the watershed or the assurance of full agricultural utilization of their wastes (mainly liquid manure).
(6) Removal of the surface layer of lake sediments in areas of high phosphorus accumulation.
(7) Land reclamation and soil amelioration.

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTION IN THE CATCHMENT AREA : (f) Extensive development of the catchment area with provision for municipal wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 100%.

§ Percentage of rural population with adequate sanitary facilities : 100%.

§ Municipal wastewater treatment systems

No. of tertiary treatment systems : 6 ($64 \times 10^3 m^3$ day^{-1}) ; P removal by aluminium sulphate.

No. of secondary treatment systems : 17 ($75 \times 10^3 m^3$ day^{-1}).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Hungarian Water Act (1964)
(2) Environment Protection Act (1976)
(3) Revision of the Water Resources Development Program of the Lake Balaton Area (1979)
(4) Resolution of the Council of Ministers on Restoration of Water Quality of Lake Balaton (1983)

§ Responsible authorities

(1) National Water Authority
(2) Ministry of Public Health
(3) Ministry of Agriculture
(4) Ministry of Construction and Town Development
(5) National Authority for Environment Protection and Nature Conservation

M2 INSTITUTIONAL MEASURES

(1) National Water Authority.

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Balaton Limnological Research Institute of the Hungarian Academy of Sciences, Tihany
(2) Research Center for Water Resources Development
(3) National Public Health Institute
(4) Karl Marx University of Econimics
(5) Scientific and Design Institute for Urban Planning
(6) Institute for Environmental Protection

§ Supplementary notes : Thirty other research institutes, university chairs and other agencies participated in the research program coordinated by the above institutions.

N. SOURCES OF INFORMATION

(Q) Questionnaire filled by Dr. S. Herodek, Balaton Limnological Research Institute of the Hungarian Academy of Sciences, Tihany.

(1) Illés I. (ed) (1981) Our Lake Balaton. Natura Press, Budapest (in Hungarian).

(2) National Meteorological Service Data Bank.

(3) Research Centre for Water Resources Development—Data Bank.

(4) Vörös, L. (1985) Phytoplankton changes in space and time in Lake Balaton. D. Sc. Thesis (in Hungarian).

(5) Ponyi, J. E. (1986) Pelagic and benthic invertebrates of Lake Balaton and their ecology. D. Sc. Thesis (in Hungarian).

(6) Herodek, S. & Tamás, G. (1976) The primary production of phytoplankton in the Keszthely-basin of Lake Balaton in 1973 1974. Annal. Biol. Tihany, 42 : 175-190.

(7) Herodek, S., Vörös, L. & Tóth, F. (1982) The mass and production of phytoplankton and the eutrophication in Lake Balaton III. The Balatonszemes basin in 1976-1977 and the Siófok basin in 1977. Hidrol. Közl., 62 : 220 229 (in Hungarian with English summary).

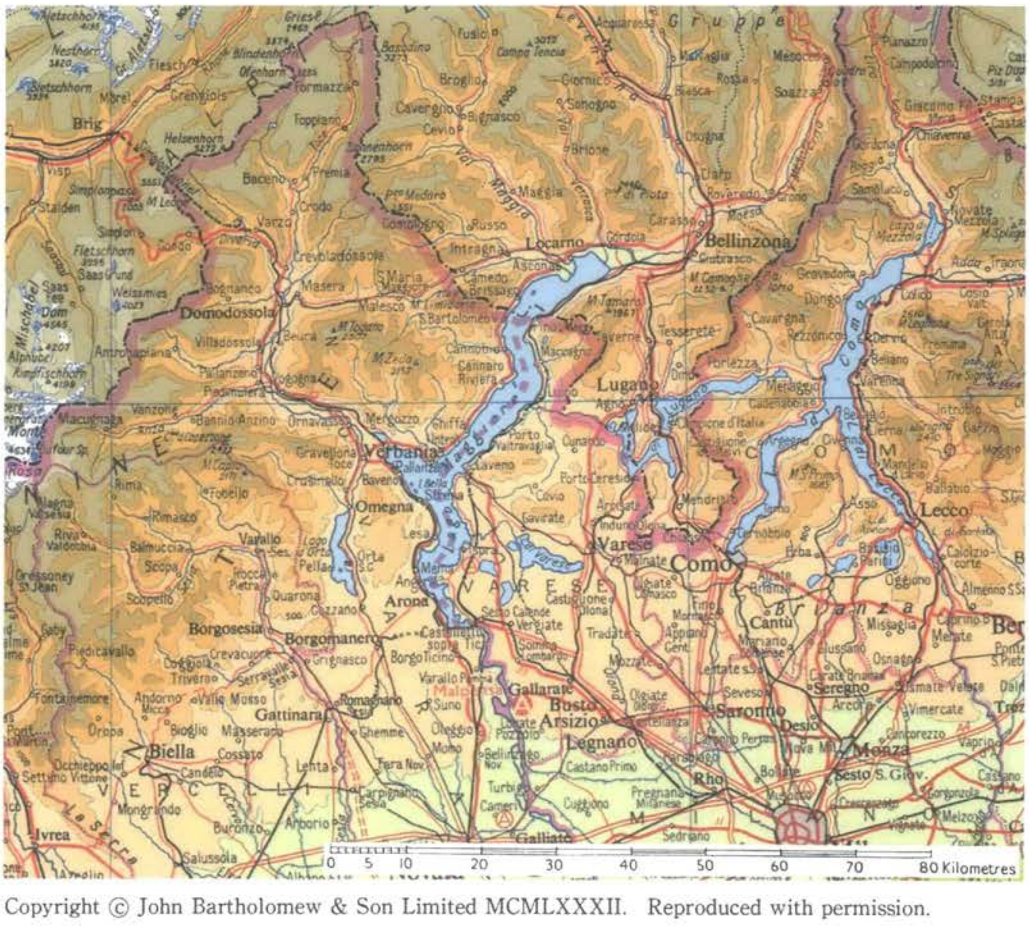
(8) National Authority for Environment Protection and Nature Conservation (1984) Balaton 1982.

(9) Salánki J., V. Balogh, K. & Berta E. (1982) Heavy metals in animals of Lake Balaton. Water Research, 16 : 1147-1152.

LAGO MAGGIORE (LAKE MAGGIORE)

Central part of the lake seen from the cableway of Laveno

Photo : A. Kurata



A. LOCATION

§ Novara and Varese, Italy ; and Ticino, Switzerland
§ 45°43′-46°11′N, 8°28′-52′E ; 193.9 m above sea level.

B. DESCRIPTION

Lake Maggiore is the second largest of Italian lakes, but may rank first in beauty. It is an internationally famous resort of Europe, with its picturesque and spectacular landscape, mild climate and luxuriant vegetation. The climate favors a beautiful botanic garden on the lake shore, with exotic and rare plants including even those from the subtropical zone. The lake has many islands and some of them are famous for their lovely parks and pretty villas.

L. Maggiore is 65 km long, 2-4.5 km wide and 370 m deep in its maximum depth. Recently, eutrophication has proceeded in part of the littoral zones, and inflowing waste water is now completely treated. More advanced plants with tertiary treatment are under construction. The concentration of inorganic nitrogen in the lake water has increased gradually since 1960. Those of reactive and total phosphorus also increased until 1977, but have since been decreasing. During the past ten years, the biomass and composition of phytoplankton, chlorophyll concentration and primary productivity have been quite stable, most probably as the result of the control of waste water discharge from the drainage basin.

C. PHYSICAL DIMENSIONS

Surface area [km^2]	212.5
Volume [$10^9 m^3$]	37.5
Maximum depth [m]	370
Mean depth [m]	176.5
Water level	Unregulated
Length of shoreline [km]	170
Residence time [yr]	4
Catchment area [km^2]	6,387

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-5-1).

§ Main islands : Brissago, Madre, Pescatori and Bella (1).

§ Outflowing rivers and channels (number and names) : 1 (Ticino R.) (Q).

D2 CLIMATIC

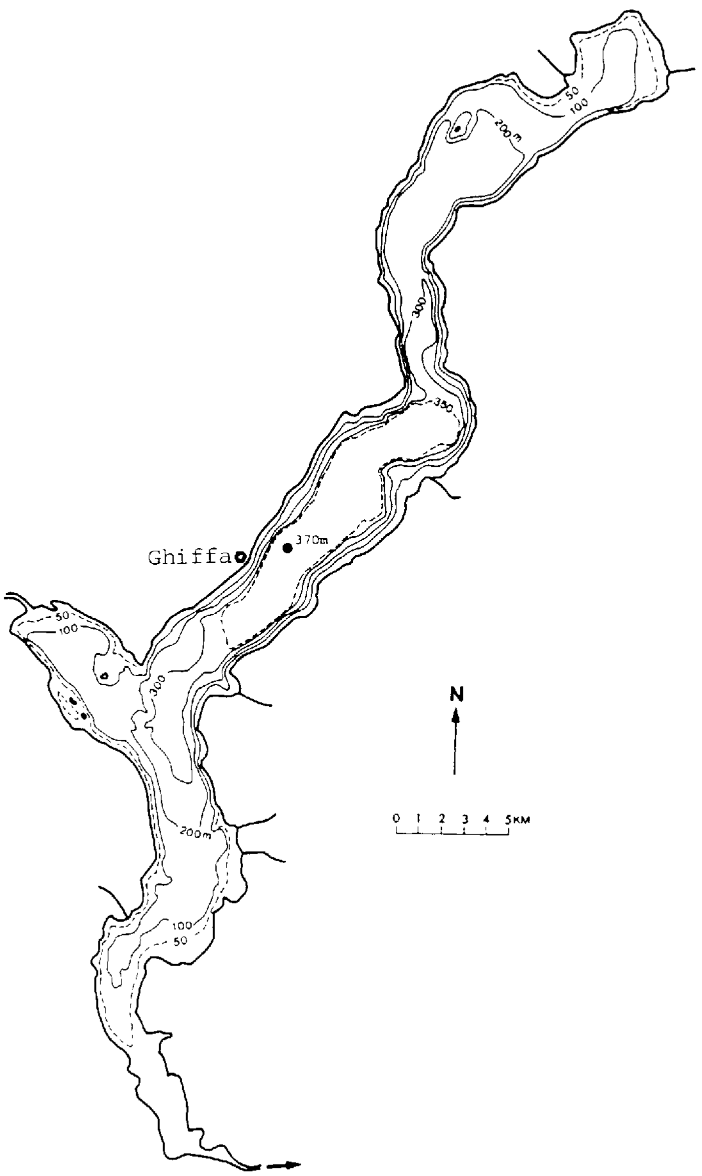
§ Climatic data at Pallanza, 1951-1980 (Q)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2.6	4.3	7.6	11.5	15.5	19.2	21.9	21.1	17.8	12.6	7.2	3.7	12.1
Precipitation [mm]	73	94	119	168	161	189	130	165	171	215	170	86	1,744

§ Number of hours of bright sunshine (1982) : 1985 hr yr^{-1} (Q).

§ Solar radiation (1982) : 12.27 MJ $m^{-2}day^{-1}$ (Q).

Fig. EUR-5-1 Bathymetric map (Q).



§ Water temperature (Fig. EUR-5-3 and 5-4).
§ Freezing period : None (Q).
§ Mixing type : Oligomictic.
§ Notes on water mixing and thermocline formation

Due to the large maximum and mean depth of the lake, as well as to the peculiar climatic conditions of the area, a complete overturn of the waters of Lake Maggiore does not occur every year. According to Piontelli and Tonolli (1964) and Vollenweider (1964), the layer usually involved in the winter overturn is 100 to 150 m deep, whereas a complete mixing occurs only every five to seven years (2).

E. LAKE WATER QUALITY

E1 TRANSPARENCY

Fig. EUR-5-2 Seasonal trend of transparency [m], 1985 (3).

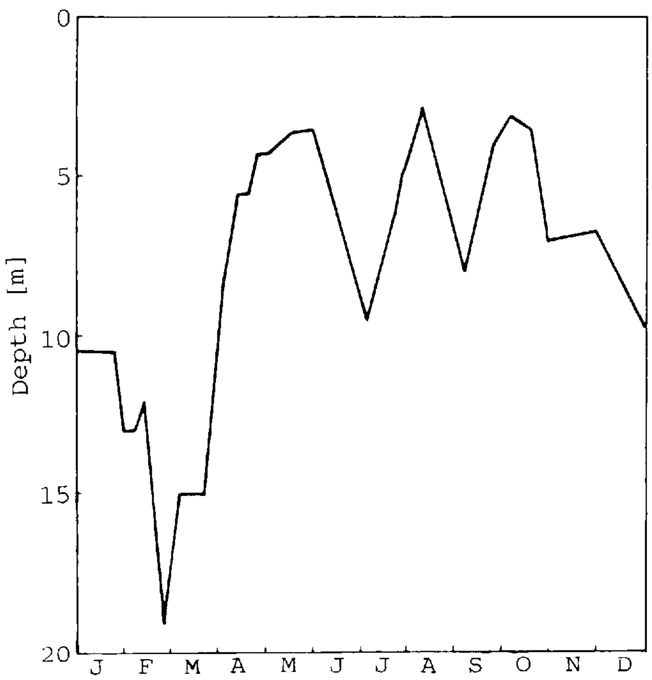


Fig. EUR-5-3 Seasonal change of water temperature (1962-1984, 1985) (3).

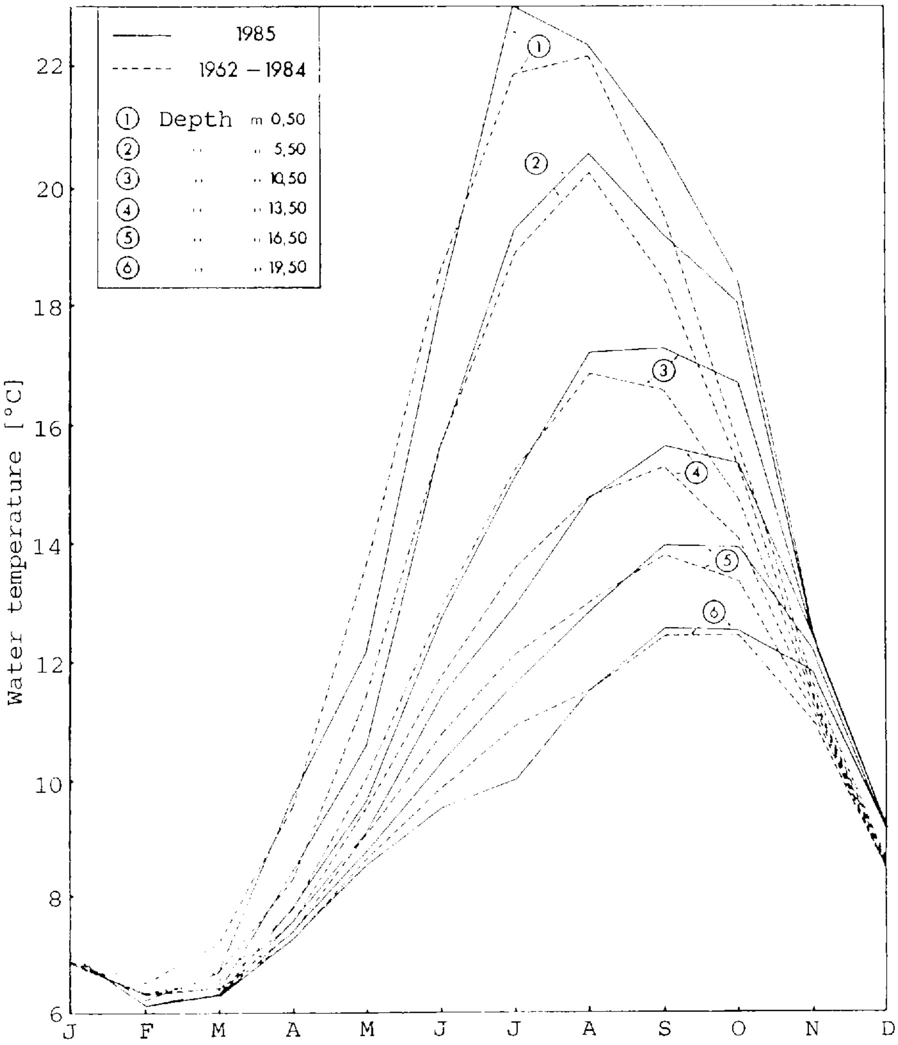
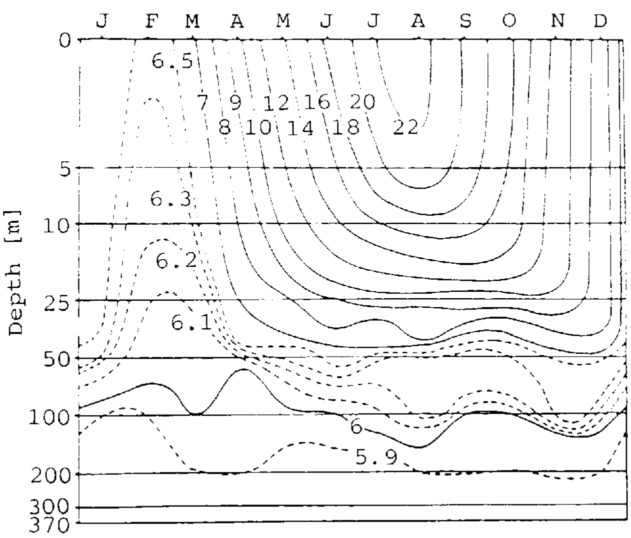
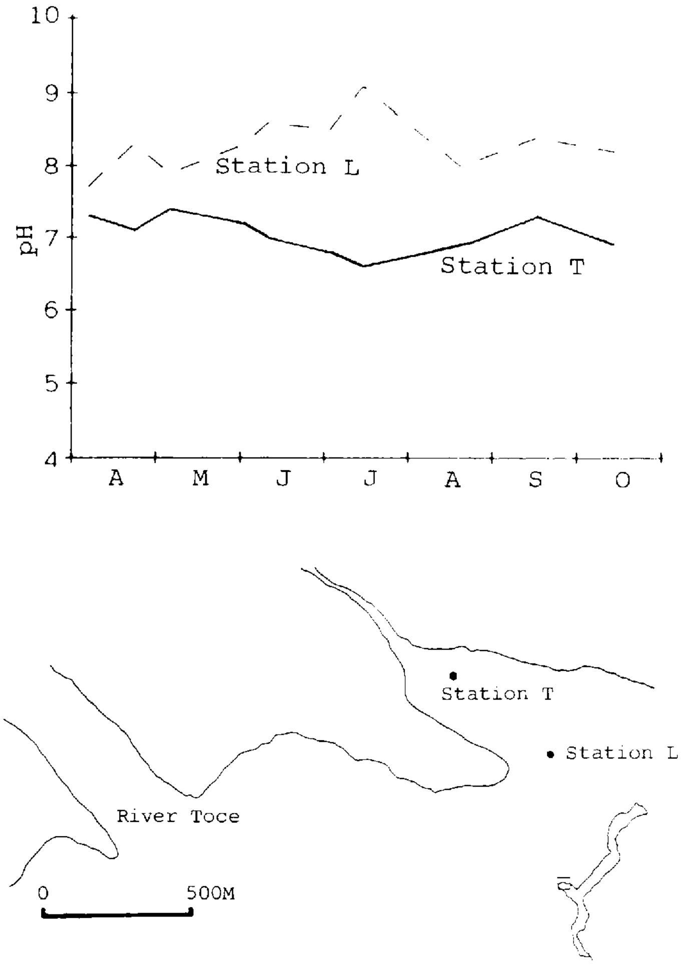


Fig. EUR-5-4 Depth / season isotherms: Mean values for 1962-1971. After Barbanti et al., 1974 (2).



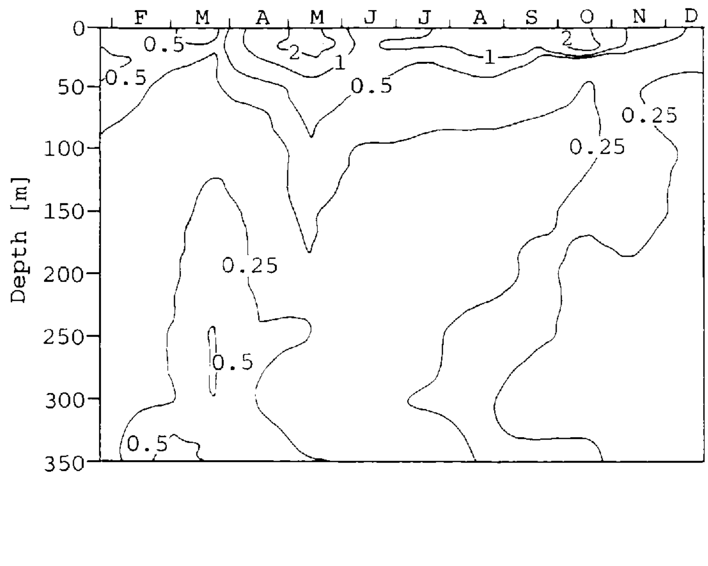
E2 pH

Fig. EUR-5-5 Seasonal trends of pH (1983-1984). Stations L and T are located in the map below (4).



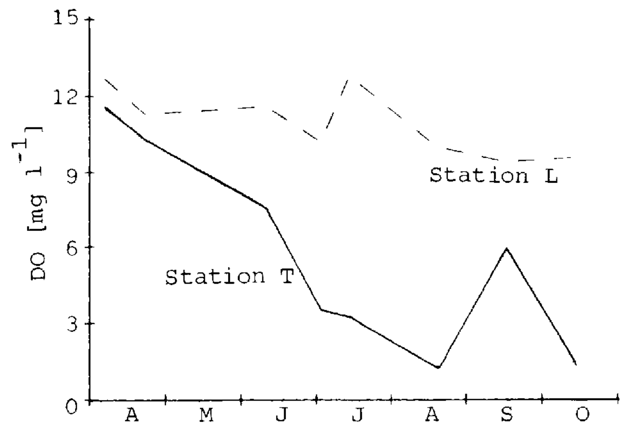
E3 SS

Fig. EUR-5-6 Depth / season isopleths of SS [mg l⁻¹], 1985 (3).



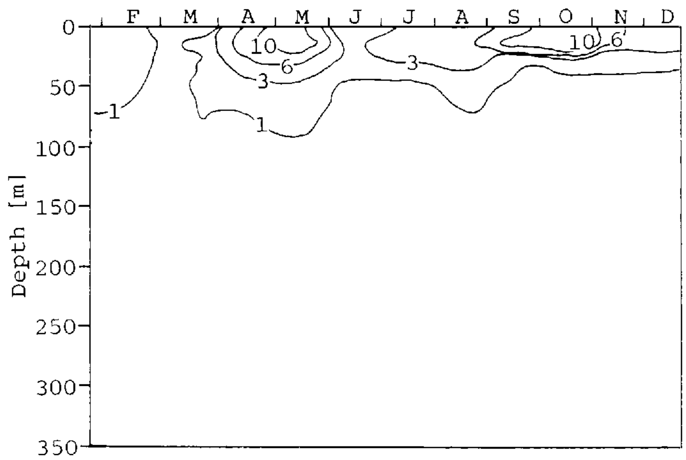
E4 DO

Fig. EUR-5-7 Seasonal trends of DO [mg l^{-1}], 1983-1984 (4).



E6 CHLOROPHYLL CONCENTRATION

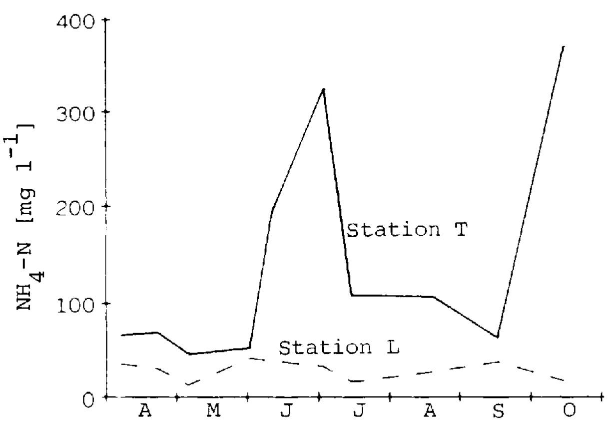
Fig. EUR-5-8 Vertical and seasonal distribution of chlorophyll concentration [μg l^{-1}], 1985 (3).



E7 NITROGEN CONCENTRATION

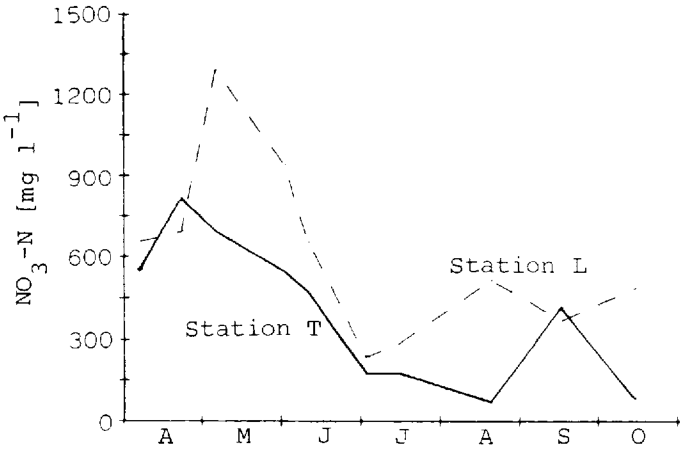
§ NH_4-N

Fig. EUR-5-9 Seasonal trends of NH_4-N concentration [mg l^{-1}], 1983-1984 (4).



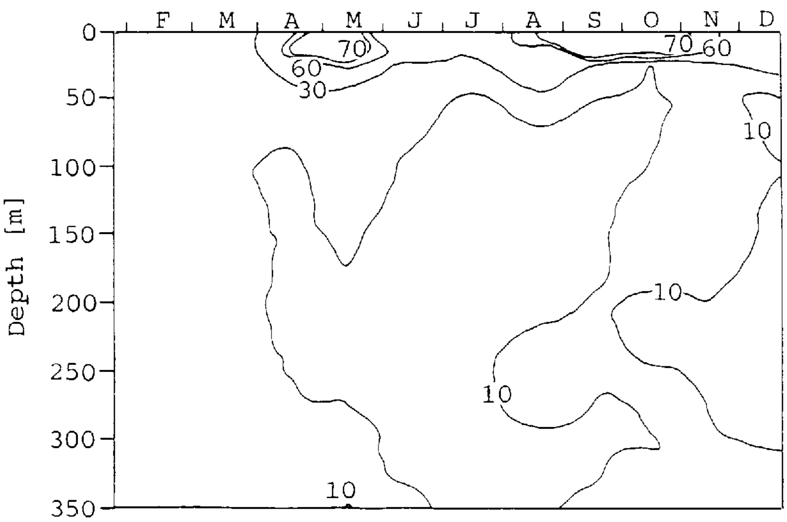
§ NO_3-N

Fig. EUR-5-10 Seasonal trends of NO_3-N concentration [mg l^{-1}], 1983-1984 (4).



§ PON

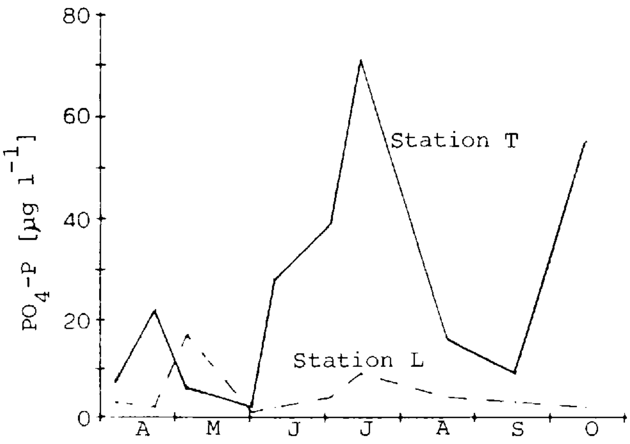
Fig. EUR-5-11 Vertical and seasonal distribution of PON [μg l^{-1}], 1985 (3).



E8 PHOSPHORUS CONCENTRATION

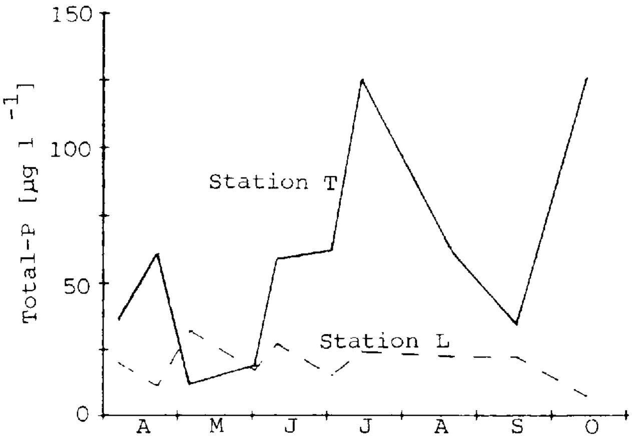
§ PO_4-P

Fig. EUR-5-12 Seasonal trends of PO_4-P concentration [$\mu g\ l^{-1}$], 1983-1984 (4).



§ Total-P

Fig. EUR-5-13 Seasonal trends of Total-P concentration [$\mu g\ l^{-1}$], 1983-1984 (4).



E10 PAST TRENDS

Fig. EUR-5-14 Trend of the mean concentration of DO in the whole lake column (3).

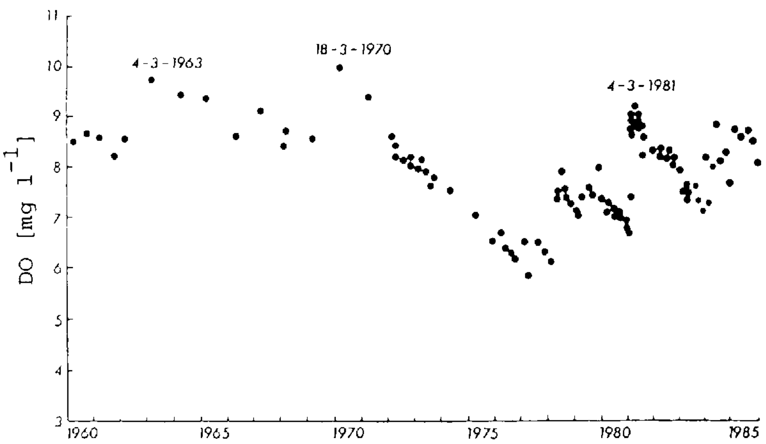


Fig. EUR-5-15 Trend of the mean concentration of NO_3-N in the whole lake column (3).

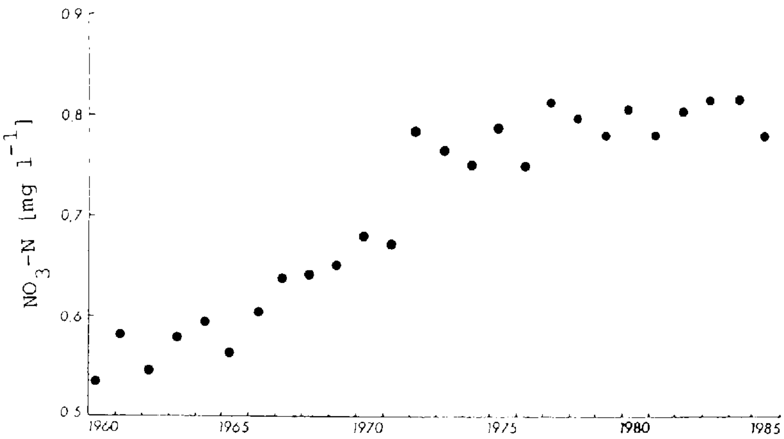
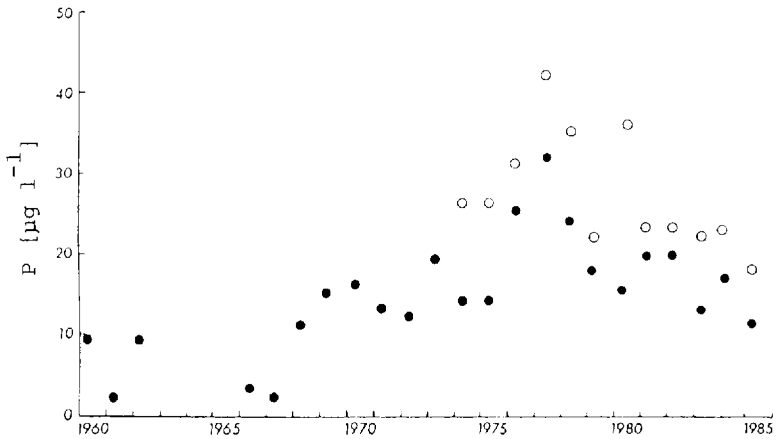


Fig. EUR-5-16 Trend of the mean concentrations of Total-P (o) and PO_4-P (●) in the whole lake column (3).



F. BIOLOGICAL FEATURES

F1 FLORA (Q)

§ Emerged macrophytes : *Phragmites australis, Schoenoplectus lacustris, Typha latifolia.*

§ Floating macrophytes : *Trapa natans* var. *verbanensis.*

§ Submerged macrophytes : *Lagarosiphon major, Elodea densa, Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton perfoliatus.*

§ Phytoplankton : *Oscillatoria rubescens, Microcystis aeruginosa, Asterionella formosa, Fragilaria crotonensis, Melosira islandica, M. varians, Cyclotella comensis, Synedra acus, Rhodomonas minuta, R. lacustris, Cryptomonas ovata, Ceratium hirundinella, Mougeotia* sp.

F2 FAUNA (Q)

§ Zooplankton : Copepoda (*Cyclops abyssorum, Mesocyclops leuckarti, Megacyclops viridis, Mixodiaptomus laciniatus, Eudiaptomus padanus*), Cladocera (*Daphnia hyalina, Diaphanosoma brachyurum, Bosmina coregoni, Leptodora kindtii, Bythotrephes longimanus*), Rotifera (*Asplanchna priodonta, Keratella cochlearis, Synchaeta pectinata, S. oblonga, Polyarthra dolichoptera-vulgaris, Conochilus unicornis, Pompholyx sulcata*).

§ Benthos : *Uncinais uncinata, Stylaria lacustris, Dero digitata, Nais elinguis, Branchiura sowerbyi, Potamothrix hammoniensis, Ilyodrilus templetoni, Limnodrilus hoffmeisteri, Spirosperma ferox, Psammoryctides barbatus, Tubifex tubifex, T. ignotus, Bothrioneurum vejdovskianum.*

F3 PRIMARY PRODUCTION RATE [g C m^{-2}day^{-1}] (Q)

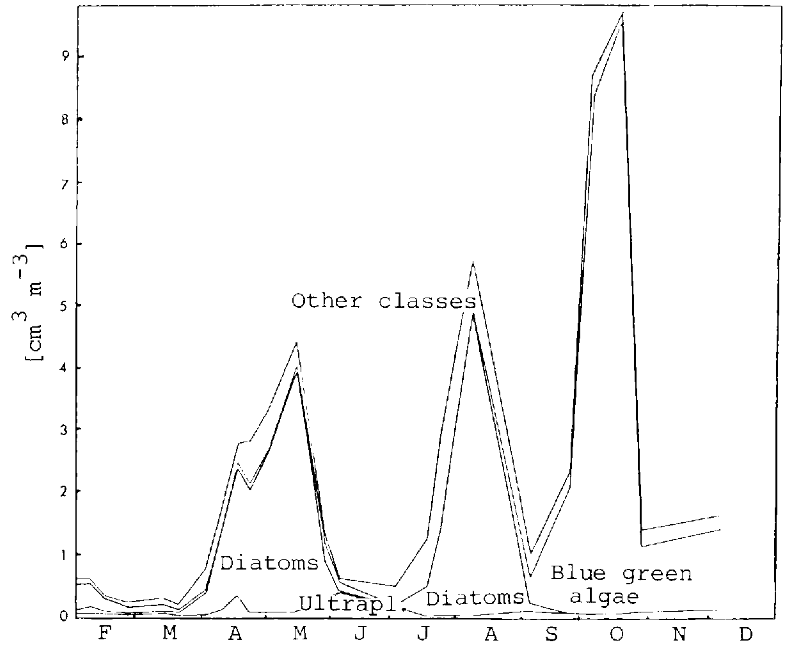
Lake center, 1981

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.07	–	1.88	1.15	0.97	0.98	1.37	0.88	–	0.83	–	–

F4 BIOMASS

§ Maximum biomass of *Trapa natans* var. *verbanensis* (August 1983) : 620 g (dry wt.) m^{-2} (Q).

Fig. EUR-5-17 Seasonal fluctuation in the biomass of phytoplankton (Station Ghiffa, 1985) (3).



§ Fish biomass [t (dry wt.)] (Q)

	1981	1982
Coregonus sp.	69.1	103.2
Alburnus alburnus alborella	42.7	85.0
Perca fluviatilis	2.3	3.5
Salmo trutta	1.7	1.3
Leuciscus cephalus	0.8	–
Esox lucius	0.1	–

F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in 1981–1982 : 155.1 [metric tons].

F6 PAST TRENDS (Q)

§ Past trend of phytoplankton community

The structure and biomass of phytoplankton community, chlorophyll-a concentration and primary productivity have been fairly stable during the last 10-15 years. The production rate has remained more or less the same at ca. 300 g C m^{-2}y^{-1} (^{14}C technique) during 1970–1981.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE DURING THE LAST 30 YEARS

Two submerged plant species, *Isoetes lacustris* and *I. echinospora*, which once grew in the lake are now absent.

The copepod, *Heterocope saliens*, and the cladocera, *Sida cristallina*, which lived in open water communities, have disappeared. In the same period, a cladoceran species, *Chydorus spahaericus*, colonized open waters occasionally during summers.

The benthic amphipod, *Niphargus foreli*, formerly abundant in the 100-370 m depth zone, is now completely missing. Among Oligochaeta, *Tubifex tubifex, Potamothrix hammoniensis* and *Stylodrilus heringianus* are new settlers, while *Spirosperma ferox* and *Bythonomus lemani* have badly declined.

Though copepods are still the major component of pelagical plankton community, cladocerans are gradually becoming more and more important.

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE DRAINAGE BASIN

	Area	
	[km^2]	[%]
Woody vegetation	1,301	19.8
Rocky outcrops and debris	1,334	20.3
Permanent snow and glacier	99	1.5
Lakes	312	4.8
Others	3,516	53.6
Total	6,562	100.0

§ Main types of woody vegetation (lake level to 2,000 m in altitude): Deciduous broadleaf forest (*Populus, Alnus, Quercus, Robinia, Castanea, Betula, Fagus*); Conifer forest (*Abies, Pinus, Picea, Larix*).

§ Main types of herbaceous vegetation: Meadow (*Arrhenatheretum elatioris* and *Trisetetum florescentis*); grazing ground.

§ Types of the other important vegetation: Shallow freshwter marsh; peat bog.

§ Main kinds of crops: Wheat, maize, barley, oat, potato.

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE

§ Agriculture: Number of persons engaged (excluding seasonal laborers) 11,542; number of establishments 30,424.

§ Mining: Number of persons engaged 139,903.

G3 POPULATION IN THE CATCHMENT AREA (1971)

Total population	Population density [km^{-2}]	Main cities
669,900	101.5	Locarno, Arona, Stresa, Pallanza, Intra

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, fisheries, navigation, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE

§ Use rates: 10 m^3sec^{-1} for domestic use, and 112 m^3sec^{-1} for industrial use.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I3 EUTROPHICATION

§ Nitrogen and phosphorus loadings [t yr^{-1}]

Total-N: 11,000

Total-P: 550

§ Nitrogen and phosphorus loadings from main inflowing rivers [t yr^{-1}] (3)

River	Total-N	Total-P
Maggia	1,400	17
Verzasca	370	3.8
Strona	870	9.8
Giona	78	1.2
Ticino immissaric	1,800	31
Cannobino	140	2.1
S. Bernardino	260	3.8
S. Giovanni	160	2.3
Toce (Ossola)	1,900	62
Erno	60	0.7
Vevera	81	6.4
Bardello	390	48
Boesio	180	9.0
Tresa	1,400	65
Total	9,100	261

J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (d) Measurable pollution with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal and industrial wastewater treatment systems: 14 major plants (treating 45% of total sewage activated sludge plus P and N removal) with several small plants without P and N removal.

§ Supplementary notes.

A system of treatment plants with tertiary treatment is under construction and will be completed presumably in a few years. This will purify all discharge waters from the western side of the lake and from Swiss part of the drainage basin. For the eastern side, the construction of treatment plants is expected to take longer time.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) National law Nr 319 (1976)

(2) National law Nr 650

§ Responsible authorities

Regional government and municipalities

N. SOURCES OF DATA

*The Italian titles are tentatively translated into English in parentheses.

(Q) Questionnaire filled by Dr. R. de Bernardi, Istituto Italiano di Idrobiologia, Pallanza.

(1) John Bartholomew & Son Ltd. (1985) The Times Atlas of the World, Plate 78. Times Books Ltd., London.

(2) de Bernardi R., Giussani,G. & Grimaldi, E. (1984) Lago Maggiore. "Ecosystems of the World 23; Lakes and Reservoirs" (ed. F. B. Taub), pp. 247-277. Elsevier Science Publishers, Amsterdam.

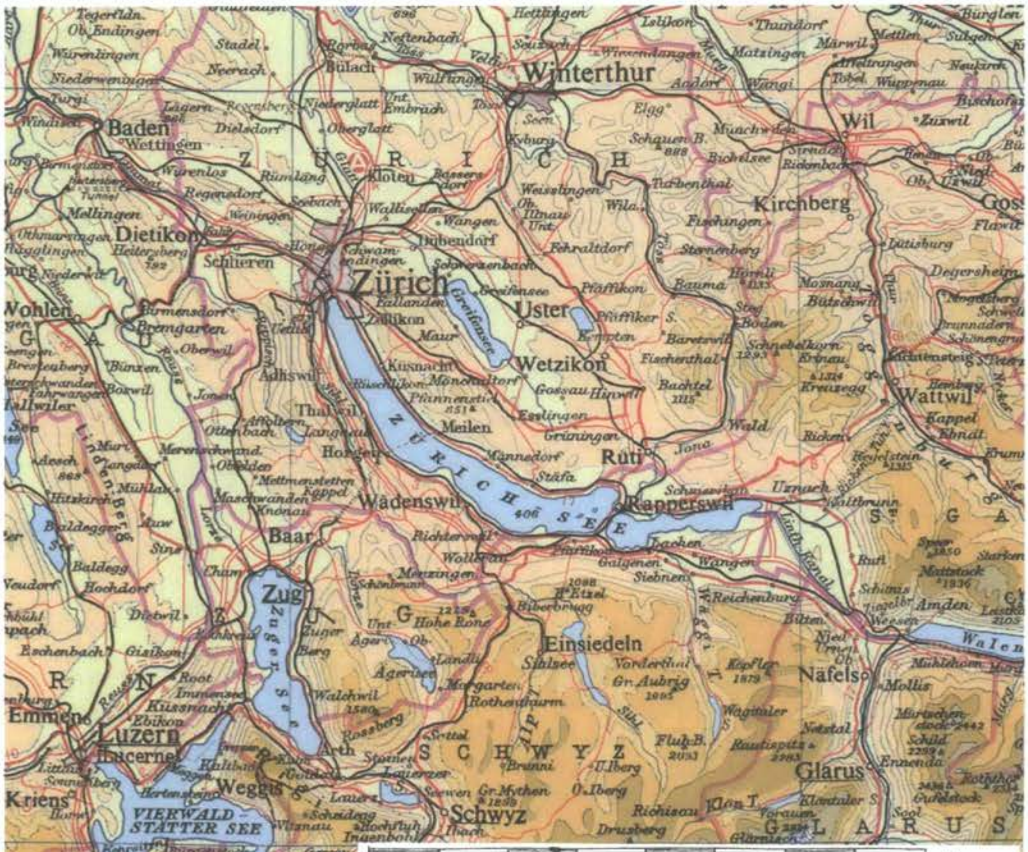
(3) Commissione Internazionale per la protezione delle acque italosvizzere (1987) Ricerche sull' evoluzione del Lago Maggiore, Aspetti limnologici Programma quinquennale 1983-1987, Canpagna 1985, pp. 144, Consiglio Nazionale delle Ricerche Istituto Italiano di Idrobiobogia (Water Quality Protection Committee of Italy and Switzerland: Report of the limnological survey of Lake Maggiore, Five-year project for 1983-1987. Italian Science and Technology Agency, Italian Institute of Hydrobiology), pp. 144. Pallanza.*

(4) Commissione Internazionale per la protezione delle acque italosvizzere (P. Guilizzoni e G. Galanti) (1987) Rapporto finale Biomassa, produzione e ciclo dei nutrienti nella zono umida di Fondotoce (Bacino delle Isoke Borromee-Lago Maggiore). Programma triennale 1983-1985. (Water Quality Protection Committee of Italy and Switzerland: Final report on biomass, primary production and nutrient circulation at Fondotoce area (Lake Maggiore, Borromee Island Region), Three-year project for 1983-1985. Italian Science and Technology Agency, Italian Institute of Hydrobiology), pp. 86. Pallanza.*

ZÜRICHSEE

A lakeside view

Photo : Shiga Prefectural Government



A. LOCATION

§ Zürich and Schwyz, Switzerland.
§ 47°15′N, 8°40′E ; 406 m above sea level.

B. DESCRIPTION (Q3)

The Lake Zürich consists of two parts, a longer one with a length of about 28 km and a smaller one with a length of about 12 km. The lake lies in a valley formed by a glacier in the last ice period. With the state capital, the city of Zürich at the end of the lake, hilly shore areas offer favorable sites to live. Owing to the sewage discharge from this area, the lake became eutrophic at the beginning of this century. With the construction of sewage treatment plants, which include mechanical, biological and chemical steps in the form of phosphorus flocculation and flocculation filtration for all the wastewater in the catchment area, the loading of organic material and phosphorus compounds has been reduced, and the trophic state has tended toward mesotrophic. For one hundred years Lake Zürich water has been used as an important drinking water resource for Zürich and for various villages in its surroundings. The lake has a great importance also as a large recreation area.

C. PHYSICAL DIMENSIONS (Q1)

Surface area [km^2]	65.1
Volume [$10^9 m^3$]	3.3
Maximum depth [m]	136.0
Mean depth [m]	51.0
Water level	Regulated
Residence time [yr]	1.1
Catchment area [km^2]	1,740.1

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q1)

§ Bathymetric map (Fig. EUR-6-1).

§ Main islands : None.

§ Outflowing rivers and channels (number and names) : 1 (Limmat R.).

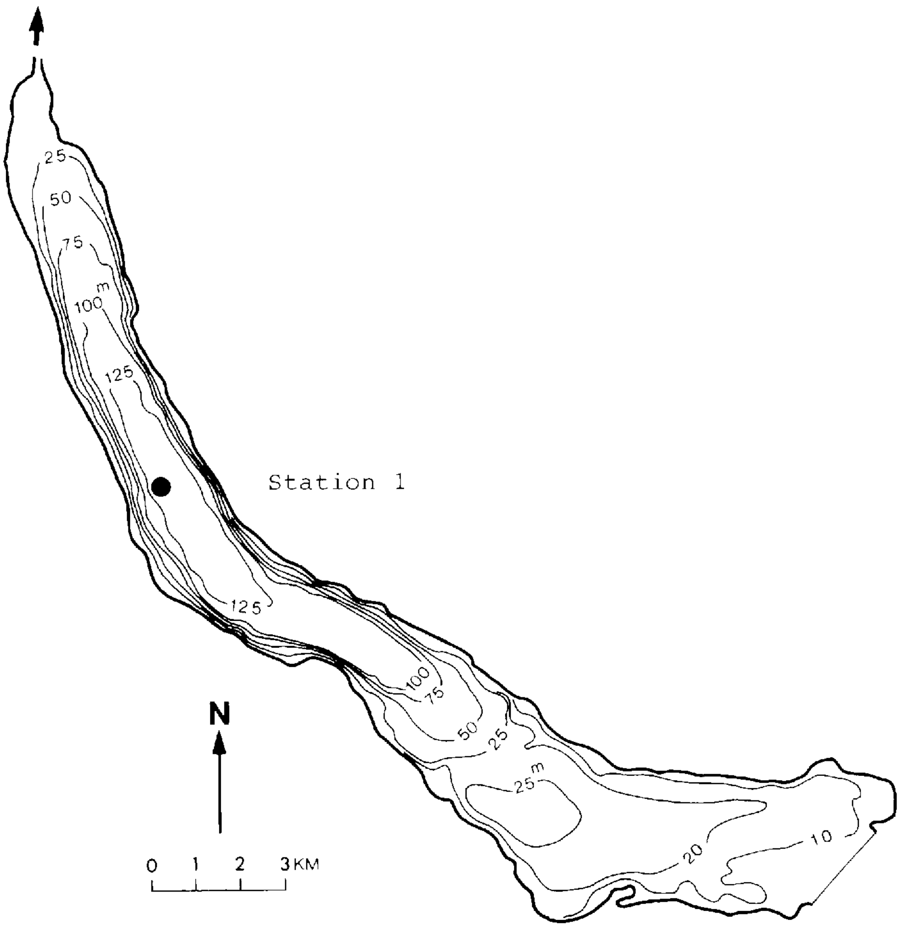
D2 CLIMATIC

§ Climatic data at Zürich, 1931-1960 (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-0.1	0.3	4.5	8.6	12.7	15.9	17.6	17.0	14.0	8.6	3.7	0.1	8.5
Precipitation [mm]	74	70	66	80	107	136	143	131	108	80	76	65	1,136

§ Number of hours of bright sunshine : 1,963 hr yr^{-1} (1).

Fig. EUR-6-1 Bathymetric map (Q1).



§ Water temperature

Fig. EUR-6-2 Depth / season isotherms [°C] at Station 1, 1983 (1).

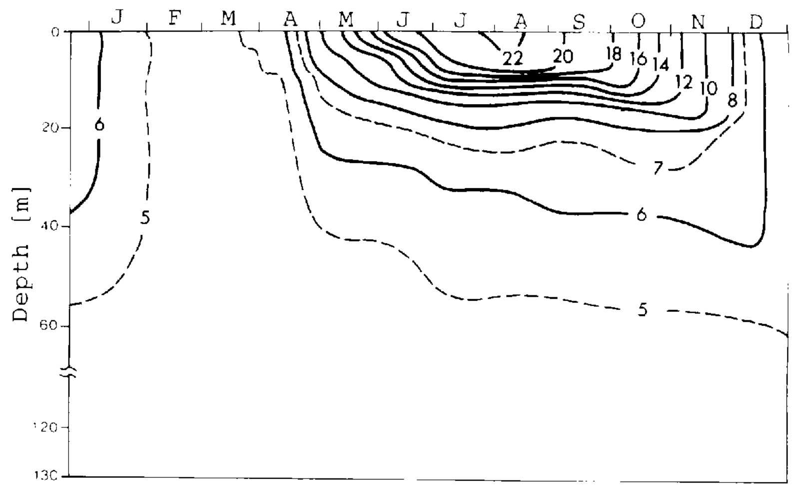
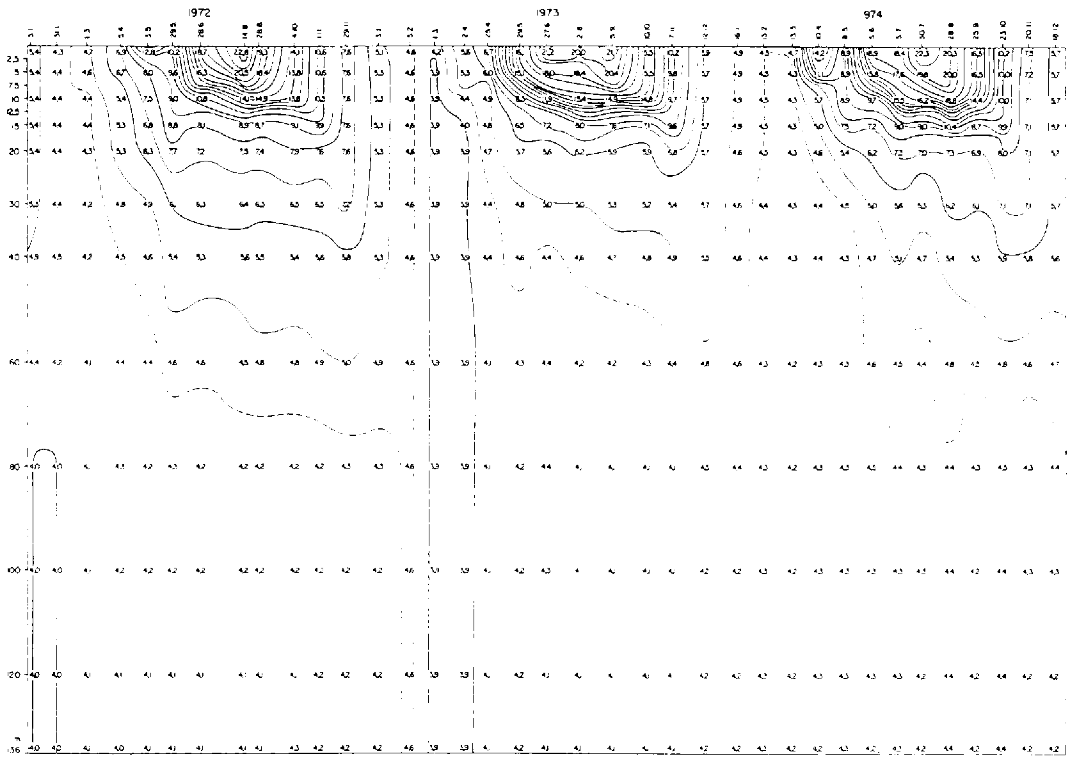


Fig. EUR-6-3 Seasonal variation of vertical water temperature [°C] distribution, 1972 -1974 (2).



§ Freezing period : Seldom (1).
§ Mixing type : Meromictic (1).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (Q1)

Station 1, 1983

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.9	8.0	8.0	4.4	3.4	5.9	4.3	2.4	3.3	4.6	5.5	5.5

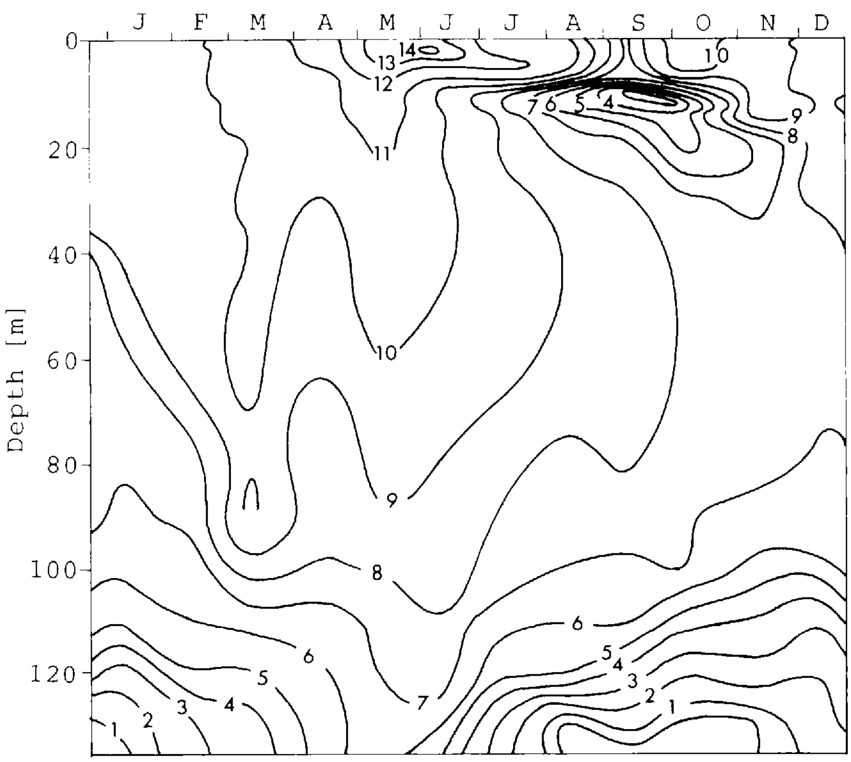
E2 pH (Q1)

Station 1, 1983

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	8.02	7.75	8.02	8.12	8.60	8.69	8.61	8.57	8.19	8.72	8.72	7.91

E4 DO

Fig. EUR-6-4 Vertical and seasonal distribution of DO [mg l⁻¹] (Q1).



E5 DOC [mg l^{-1}] (Q3)
Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.30	—	—	1.35	—	—	1.45		—	1.45	—	—
1	—	—	—	—	—	—	—	—	—	1.50		—
2.5	—	—	—	—	—	—	—	—	—	1.50	—	—
5	—	—	—	1.20	—	—	1.45	—	—	1.50	—	—
7.5	—	—	—	—	—	—	—	—	—	1.45	—	—
10	1.20	—	—	1.15	—	—	1.45	—	—	1.35	—	—
12.5	—	—	—	—	—	—	—	—	—	1.30	—	—
15	1.25	—	—	1.15	—	—	1.30	—	—	1.25	—	—
20	1.20	—	—	—	—	—	1.25	—	—	1.20		—
30	1.25		—	1.10	—	—	1.20	—	—	1.20	—	—
40	1.30	—	—	1.40	—		1.20	—	—	1.15	—	—
60	1.30	—	—	1.35	—	—	1.20	—	—	1.15	—	—
80	1.15	—	—	1.30	—	—	1.20	—	—	1.20	—	—
90	1.15	—	—	1.35	—	—	—	—	—	1.10	—	—
100	1.10	—	—	1.30	—	—	1.20	—	—	1.15	—	—
110	1.20	—	—	1.30	—	—	—	—	—	1.15	—	—
120	1.25	—	—	1.25	—	—	1.15	—	—	1.20	—	—
130	1.25	—	—	1.30	—		1.15		—	1.30	—	—
135	1.40	—	—	1.30	—	—	1.25	—	—	1.35	—	—

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (Q1)
Station 1, 1983

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.54	1.04	1.70	3.74	11.54	1.78	1.82	3.83	2.17	3.68	1.30	0.40
10	0.39	1.12	1.61	2.22	5.72	1.62	2.59	2.89	2.02	1.89	1.26	0.42
20	0.32	1.12	0.58	0.58	1.16	0.31	0.35	0.38	0.42	0.62	0.36	0.36
30	0.36	1.06	0.35	0.40	0.71	0.22	0.12	0.16	0.27	0.16	0.13	0.38
40	0.28	1.04	0.47	0.35	0.56	0.15	0.11	0.11	0.29	0.14	0.10	0.07
80	0.04	0.32	0.53	0.29	0.22	0.11	0.08	0.10	0.17	0.06	0.05	0.04
120	0.02	0.13	0.15	0.19	0.16	0.10	0.04	0.06	0.10	0.25	0.05	0.05
135	0.02	0.07	0.08	0.21	1.52	0.11	0.06	0.08	0.16	0.25	0.02	0.03

E7 NITROGEN CONCENTRATION (Q3)

§ NH_4-N [mg l^{-1}]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.025	0.005	<0.005	0.005	0.010	0.070	0.025	0.010	0.020	0.010	0.010	0.015
1	0.025	0.005	<0.005	0.005	0.015	0.070	0.025	0.010	0.015	0.010	0.015	0.015
2.5	0.025	0.005	<0.005	0.005	0.015	0.070	0.025	0.010	0.015	0.010	0.010	0.015
5	0.025	0.005	<0.005	0.005	0.020	0.075	0.025	0.015	0.015	0.010	0.010	0.015
7.5	0.025	0.005	<0.005	0.010	0.045	0.075	0.040	0.030	0.015	0.015	0.010	0.015
10	0.025	0.005	<0.005	0.010	0.035	0.005	0.020	0.035	0.010	0.010	0.010	0.015
12.5	0.025	0.005	<0.005	0.010	0.035	0.005	0.005	0.005	0.005	0.005	0.010	0.015
15	0.025	0.005	<0.005	0.010	0.035	0.005	0.005	0.005	0.005	0.005	0.010	0.015
20	0.030	0.005	0.005	0.005	0.005	0.005	<0.005	0.005	0.005	<0.005	<0.005	0.005
30	0.030	0.005	0.005	0.005	0.005	0.005	<0.005	0.005	0.005	<0.005	<0.005	0.005
40	0.030	0.005	0.005	0.005	0.005	0.005	<0.005	0.005	0.005	<0.005	<0.005	0.005
60	0.005	0.010	0.005	0.005	0.005	0.005	<0.005	0.005	0.005	<0.005	<0.005	0.005
80	0.005	0.005	0.005	0.005	0.005	0.005	<0.005	<0.005	0.005	<0.005	<0.005	0.005
90	0.005	0.005	<0.005	0.005	0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005
100	0.005	0.005	<0.005	0.005	0.005	0.005	<0.005	0.005	0.005	<0.005	<0.005	0.005
110	0.005	0.005	<0.005	<0.005	0.005	0.005	0.005	0.005	0.005	<0.005	<0.005	0.005
120	0.005	0.005	<0.005	<0.005	0.005	0.005	0.005	0.005	0.005	<0.005	0.005	0.005
130	0.040	0.005	<0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.200	0.180	0.200
135	0.300	0.010	0.005	0.010	0.005	0.005	0.005	0.090	0.135	0.300	0.320	0.370

§ NO_3-N [mg l^{-1}]

Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.690	0.735	0.760	0.770	0.615	0.655	0.530	0.375	0.385	0.370	0.515	0.555
1	0.705	0.745	0.750	0.770	0.625	0.660	0.530	0.385	0.365	0.365	0.520	0.555
2.5	0.685	0.740	0.750	0.775	0.615	0.650	0.530	0.375	0.365	0.365	0.515	0.555
5	0.690	0.735	0.750	0.775	0.615	0.665	0.540	0.420	0.370	0.370	0.520	0.555
7.5	0.680	0.710	0.755	0.775	0.695	0.690	0.660	0.490	0.380	0.380	0.515	0.550
10	0.695	0.735	0.760	0.785	0.740	0.780	0.775	0.760	0.765	0.640	0.515	0.555
12.5	0.695	0.730	0.765	0.795	0.755	0.775	0.860	0.865	0.865	0.845	0.515	0.550
15	0.705	0.715	0.760	0.790	0.760	0.775	0.865	0.860	0.870	0.855	0.515	0.545
20	0.695	0.730	0.755	0.780	0.775	0.770	0.860	0.905	0.875	0.845	0.780	0.800
30	0.700	0.735	0.760	0.785	0.775	0.770	0.850	0.860	0.855	0.840	0.800	0.830
40	0.715	0.760	0.750	0.785	0.780	0.770	0.835	0.845	0.855	0.825	0.810	0.840
60	0.855	0.745	0.775	0.790	0.785	0.770	0.835	0.845	0.845	0.820	0.805	0.830
80	0.845	0.755	0.775	0.790	0.775	0.770	0.845	0.840	0.850	0.820	0.800	0.825
90	0.840	0.745	0.800	0.785	0.780	0.765	0.845	0.850	0.855	0.825	0.805	0.830
100	0.850	0.785	0.810	0.790	0.785	0.770	0.855	0.845	0.855	0.825	0.815	0.830
110	0.845	0.780	0.815	0.800	0.785	0.775	0.860	0.850	0.865	0.855	0.815	0.835
120	0.865	0.780	0.815	0.800	0.785	0.785	0.845	0.865	0.880	0.650	0.815	0.855
130	0.805	0.790	0.815	0.805	0.785	0.795	0.870	0.925	0.830	0.580	0.670	0.635
135	0.575	0.780	0.800	0.790	0.785	0.805	0.895	0.755	0.595	0.480	0.535	0.500

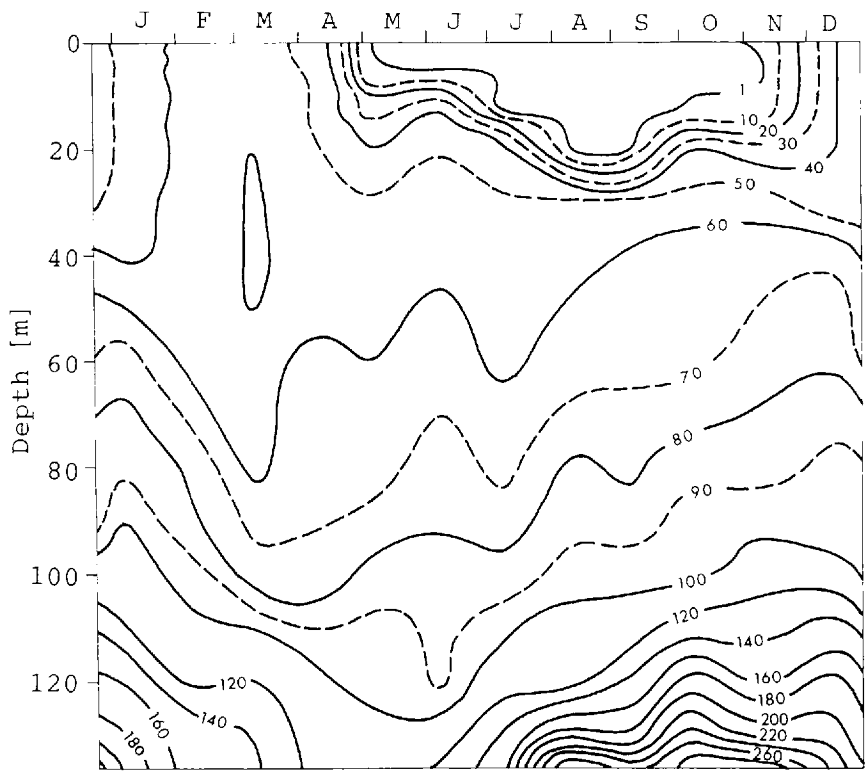
E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [μg l^{-1}]

Station 1, 1986 (Q3)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	27	42	35	48	2	10	4	5	2	1	<1	1
1	26	44	37	48	2	11	3	3	2	1	<1	1
2.5	27	45	37	50	2	9	8	2	2	<1	<1	1
5	27	45	37	50	1	11	2	3	2	<1	<1	1
7.5	28	45	39	47	2	17	7	2	2	<1	<1	1
10	28	46	43	48	13	12	5	2	2	<1	<1	1
12.5	29	46	44	47	23	27	2	3	3	<1	<1	1
15	27	46	45	46	28	37	12	2	2	<1	<1	<1
20	26	48	45	49	37	47	34	8	9	17	17	25
30	27	49	45	53	42	49	51	47	44	33	30	37
40	28	49	44	54	43	49	52	53	52	47	47	47
60	63	48	49	54	44	48	50	54	55	54	52	56
80	69	61	60	54	45	53	56	57	60	59	55	63
90	73	63	71	56	52	59	58	63	66	66	60	68
100	81	90	77	57	51	66	65	65	79	73	67	72
110	92	92	87	71	58	70	72	79	91	86	74	88
120	126	118	101	79	45	73	89	96	115	130	114	125
130	180	136	119	89	58	91	123	160	209	237	193	211
135	259	142	133	96	60	126	160	223	301	267	252	268

Fig. EUR-6-5 Vertical and seasonal distribution of PO_4-P [μg l^{-1}] at Station 1, 1983 (Q1).



§ Total-P [$\mu g\ l^{-1}$] (Q3)
Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	31	46	41	53	10	18	5	4	4	<1	3	1
1	31	49	43	50	12	15	4	2	4	<1	4	2
2.5	32	49	45	54	12	15	10	1	6	1	4	1
5	37	49	44	52	10	19	9	5	8	1	7	1
7.5	31	50	46	48	8	18	14	2	5	<1	4	1
10	31	50	54	49	22	17	10	5	7	<1	4	1
12.5	32	50	50	49	30	32	7	6	7	<1	4	1
15	32	50	51	49	37	43	20	4	5	<1	4	<1
20	32	51	50	52	48	50	42	9	15	17	24	25
30	32	52	52	53	52	59	60	48	47	34	40	37
40	32	53	51	56	50	54	60	53	53	49	51	47
60	66	52	55	55	51	54	55	54	56	56	54	57
80	71	64	65	55	55	58	64	55	61	61	58	67
90	74	65	76	58	60	61	64	62	68	68	64	70
100	83	92	82	58	58	71	73	65	79	76	71	74
110	94	90	90	74	64	75	77	78	92	91	82	89
120	130	119	101	79	66	80	94	95	118	140	117	142
130	191	136	121	89	76	103	130	160	209	254	197	218
135	263	142	135	96	78	128	165	223	305	291	260	282

E9 CHLORINE ION CONCENTRATION [$mg\ l^{-1}$] (Q3)
Station 1, 1986

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	4.2	4.2	4.0	4.4	4.2	3.5	3.4	2.7	3.1	3.0	3.7	4.
1	4.2	4.2	4.0	4.4	4.2	3.5	3.4	2.7	3.0	3.0	3.7	3.
2.5	4.2	4.2	4.0	4.4	4.2	3.5	3.4	2.6	3.0	3.0	3.7	3.
5	4.2	4.2	4.1	4.4	4.2	3.6	3.4	2.8	3.0	3.0	3.7	3.
7.5	4.2	4.2	4.1	4.4	4.5	4.2	3.4	2.4	3.0	3.1	3.7	3.
10	4.2	4.2	4.2	4.4	4.5	4.4	3.5	3.5	3.5	3.5	3.7	3.
12.5	4.2	4.2	4.2	4.4	4.6	4.4	4.1	4.1	4.0	4.0	3.7	3.
15	4.2	4.2	4.2	4.4	4.6	4.4	4.3	4.2	4.2	4.3	3.7	3.
20	4.2	4.2	4.3	4.4	4.5	4.4	4.4	5.4	4.4	4.4	4.3	4.
30	4.2	4.3	4.3	4.4	4.5	4.4	4.5	4.4	4.5	4.4	4.4	4.
40	4.4	4.3	4.3	4.4	4.5	4.4	4.5	4.4	4.5	4.4	4.5	4.
60	4.4	4.3	4.3	4.4	4.5	4.4	4.5	4.4	4.5	4.4	4.5	4.
80	4.4	4.3	4.4	4.4	4.5	4.4	4.5	4.4	4.5	4.5	4.5	4.
90	4.4	4.2	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.
100	4.4	4.3	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.
110	4.4	4.3	4.3	4.4	4.5	4.5	4.6	4.4	4.6	4.5	4.5	4.
120	4.4	4.5	4.2	4.4	4.5	4.5	4.5	4.4	4.6	4.5	4.5	4.
130	4.4	4.4	4.2	4.4	4.5	4.5	4.5	4.4	4.5	4.5	4.6	4.
135	4.4	4.4	4.1	4.4	4.5	4.5	4.5	4.4	4.5	4.5	4.5	4.

E10 PAST TRENDS

Fig. EUR-6-6 Trend of transparecy (means for January-March, 1897-1900 & 1936 1980) (3).

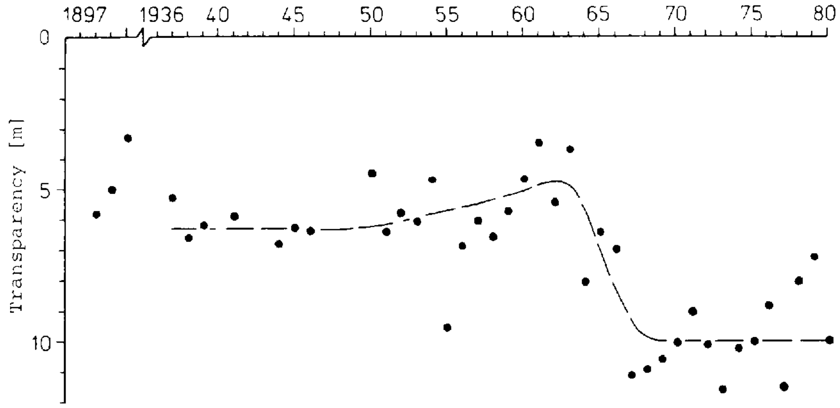


Fig. EUR-6-7 Trends of net hypolimnetic oxygen consumption during the stagnation period (○), and annual hypolimnetic oxygen minimum (●). Net hypolimnetic oxygen consumption is equivalent to annual maximum (spring) minus annual minimum (autumn) (3).

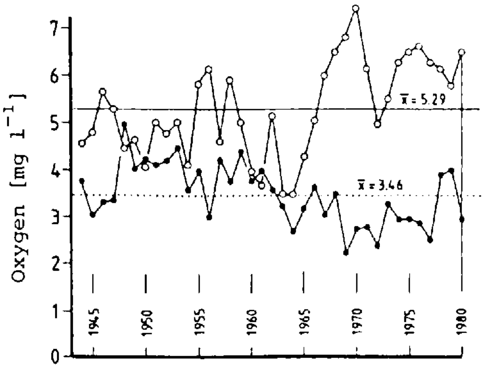


Fig. EUR-6-8 Trends of NO_3-N and PO_4-P in summer stagnation periods (2).

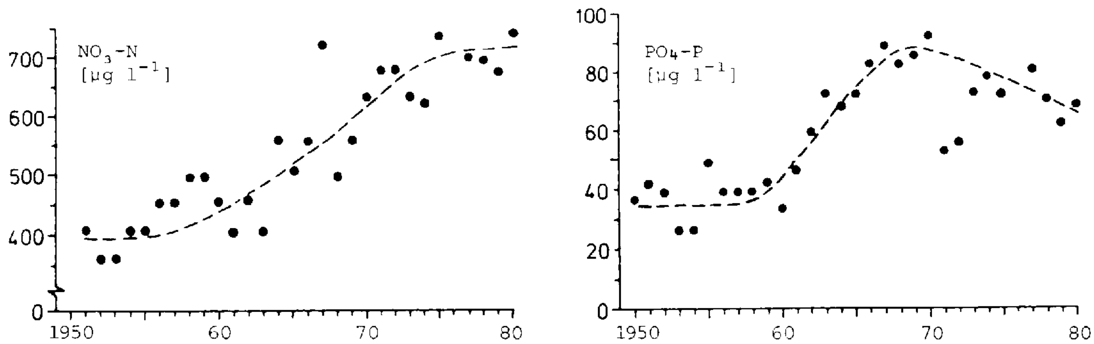


Fig. EUR-6-9 Past trend of annual averages of PO_4-P (0-136 m) (Q3).

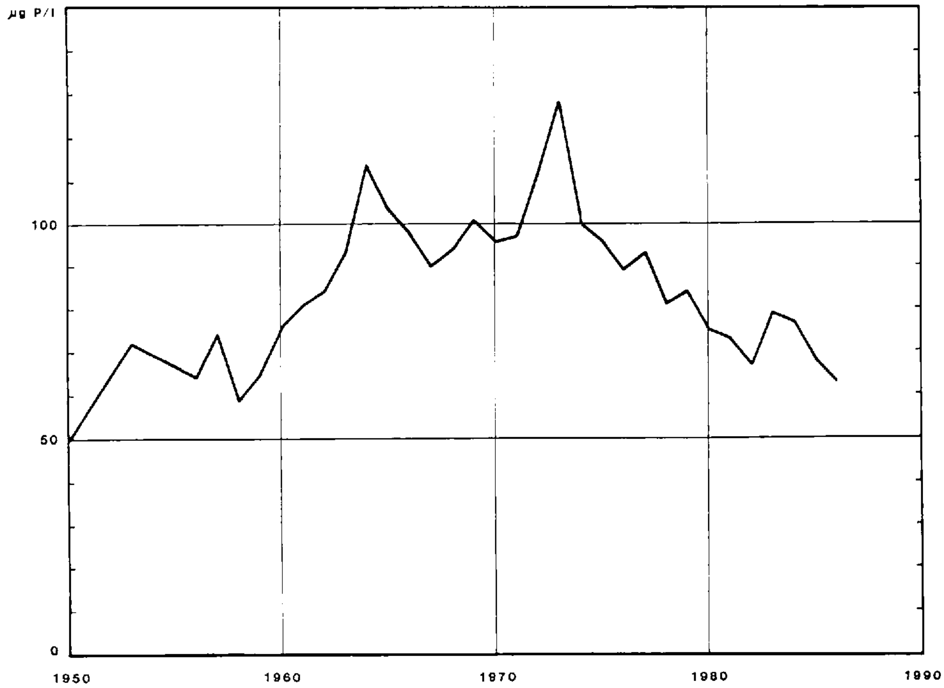
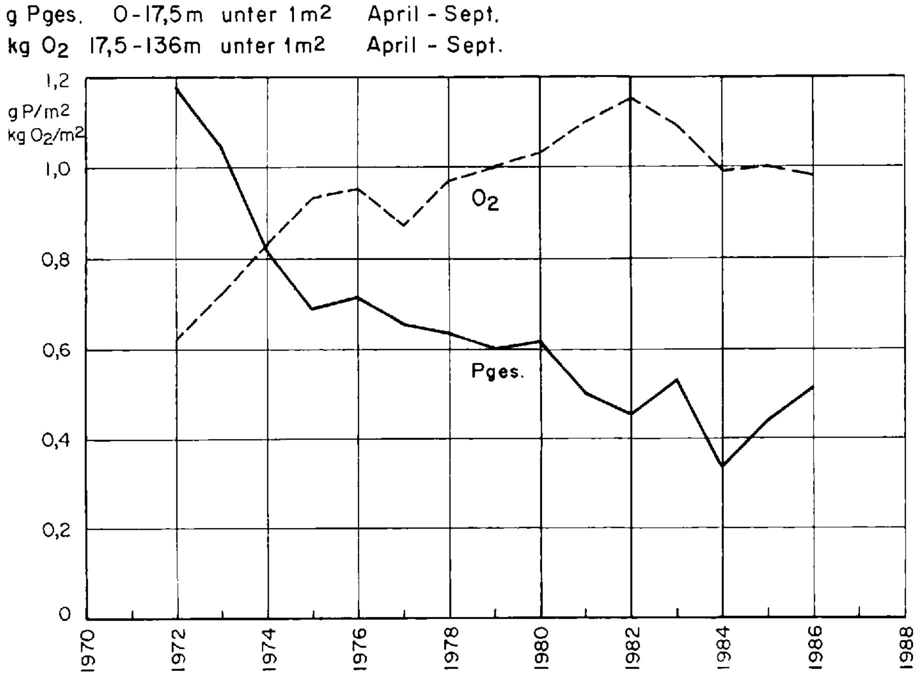


Fig. EUR-6-10 Past trends of total phosphorus in the eplilimnion and O_2 in the hypolimnion between April and September (Q3).



F. BIOLOGICAL FEATURES (Q1)

F1 FLORA

§ Emerged macrophytes : *Phragmites communis, Phalaris arundinacea, Schoenoplectus lacustris.*

§ Floating macrophytes : *Nymphaea alba, Nuphar luteum* (several places but mostly planted by inhabitants).

§ Submerged macrophytes : *Potamogeton pectinatus, P. perfoliatus, P. lucens, P. crispus, Elodea canadensis, Zannichellia palustris.*

§ Phytoplankton : *Anabaena flos-aquae, A. planctonica, Oscillatoria rubescens, Aphanizomenon flos-aquae, Pandorina morum, Sphaerocystis schroeteri, Mougeotia* sp., *Dinobryon divergens, Ceratium hirundinella, Cryptomonas ovata, Rhodomonas* sp., *Melosira granulata, Cyclotella comta, Stephanodiscus hantzschii, Tabellaria fenestrata, Fragilaria crotonensis, Asterionella formosa, Synedra acus.*

F2 FAUNA

§ Zooplankton : *Nassula aurea, Tintinnopsis lacustris, Epistylis rotans, Polyarthra platyptera, Keratella cochlearis, Keratella quadrata, Notholca longispina, Asplanchna priodonta, Synchaeta pectinata, Leptodora* sp., *Daphnia longispina, Bosmina longirostris, Diaptomous gracilis, Cyclops strenuus, Chaoborus crystallinus.*

§ Benthos : *Dugesia polychroa, Herpobdella octoculata, Helobdella stagnalis, Limnodrilus hoffmeisteri, Tubifex ignotus, Psammocryctes barbatus, Stylaria lacustris, Planaria* sp., *Bithynia tentaculata, Gyraulus albus, Lymnaea auricularia, L. peregra, Pisidium subruncatum, P. moitessierianum, P. nitidum, Dreissena polymorpha, Eucyclops serratulus, Paracyclops fimbriatus, Canthocamptus staphilinus, Caenis moesta, Polypedilum nubeculosum, Microtendipes* sp., *Limnochironomus pulsus, Eukjefferiella* sp., *Polycentropus flavomaculatus, Tinodes* sp.

§ Fish : *Anguilla vulgaris, Esox lucius, Salmo salvelinus, S. variabilis, Coregonus wartmanni, C. schinzi, Leuciscus rutilus, Abramis brama, Barbus fluviatilis, Tinca vulgaris, Cyprinus carpio, Lota vulgaris, Perca fluviatilis.*

F3 PRIMARY PRODUCTION RATE

§ Net primary production rate [mg C $m^{-2}day^{-1}$]
Station 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981	67	8	710	2,050	370	1,180	1,470	910	1,130	940	603	560	833
1982	390	420	210	760	460	1,450	2,430	1,070	1,070	380	610	140	783

F5 FISHERY PRODUCTS

§ Annual fish catch : 189.4 [metric tons].

F6 PAST TRENDS

Trends of net primary production rate and phytoplankton biomass (0-14 m) (Q1)

	1974	1975	1976	1977	1978	1979	1980	1981	1982
Primary production rate [g C $m^{-2}yr^{-1}$]	350	230	390	230	250	280	180	305	290
Phytoplankton biomass [mg l^{-1}]	–	–	2.56	2.23	2.05	3.34	2.48	1.35	2.87

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1980) (Q2)

	Area	
	[km^2]	[%]
Woody vegetation	400.2	23
Other natural landscape	243.6	14
Agricultural land	922.3	53
Settlements	88.0	5
Others	104.4	6
Total	1,758.5	100

§ Main types of woody vegetation: *Picea abies, Abies alba, Fagus silvatica, Quercus robur, Pinus silvestris, Larix decidua* (Q1).

§ Main types of herbaceous vegetation: Fertilized meadow land (*Agrostis, Bromus, Poa, Festuca, Lolium, Avena*) (Q1).

§ Levels of fertilizer application on crop fields: Moderate.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (Q1)

§ Main products of agriculture: Wheat, grape, vegetables and dairy products.

§ Main kinds of manufacturing products: Textile, machinery and metal.

G3 POPULATION IN THE CATCHMENT AREA (1984) (Q1)

Total population	Population density [km^{-2}]	Main cities (population)
ca. 500,000	ca. 217	Zürich*(423,000), Stafa, Thalwil, Horgen, Wadenswil, Küsnacht, Meilen.

*Not all the city area is included in the catchment area.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q1, Q2)

Source of water, fisheries, navigation, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1983) (Q1)

	Use rate [m^3 sec^{-1}]
Domestic water*	2.2
Industrial water	0.07

*The lake serves as a source of drinking water for 700,000 people comprising the city of Zürich, its suburbs and lakeshore communities.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q3)

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION (Q3)

§ Present status : Detected but not serious.

§ Main contaminants, their concentrations and sources

Station 1, 1986

Name of contaminants	Concentrations [ppb] Water	Main sources
I. I. I. Trichloroethane	0.01	Industrial
Trichloroethene	0.01	Industrial
Tetrachloroethene	0.02	Industrial
Afrazin	0.06	Different pollution sources

I3 EUTROPHICATION (Q3)

§ Nuisance caused by eutrophication : Unusual algal bloom (*Aphanizomenon flos-aquae* and *Stephanodiscus* hantzschii).

§ Phosphorus loadings [ton yr^{-1}]

1984

Sources	Rivers	Treated sewage	Stormwater tank	Untreated sewage	Precipitate	Total
T-P	78	38	4	3	5	128

I4 ACIDIFICATION (Q3)

§ Extent of damage : None.

J. WASTEWATER TREATMENTS (Q1, Q3)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Extensive coverage of pollution sources by treatment systems.

J3 SANITARY FACILITIES AND SEWERAGE

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) or public sewerage : 90%.

§ Municipal wastewater treatment systems (rate of treatment : 130,000 m^3 day^{-1})

Number of quarternary treatment systems : 2.

Number of tertiary treatment systems : 15 (activated sludge, with chemical precipitation of phosphorus).

§ Supplementary notes : About 90% of sewage is treated in existing wastewater treatment systems. All of the 17 treatment plants will have a flocculation filtration process at the end.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (Q1, Q2)

§ Names of the laws (the year of legislation)

(1) Law of Water Rights, Canton of Zürich (1901) (similar for Canton of Schwyz)

(2) Federal Law on Water Pollution Control, Federal Government (1971)

(3) Law on the Introduction of the Federal Law of Water Pollution Control, Canton of Zürich (1974) (similar for Canton of Schwyz)

(4) Ordinance on Waste Water Disposal, Federal Government (1975)

(5) Law on Fisheries, Canton of Zürich (1976)

§ Responsible authorities

Governments of Cts. of Zürich and Schwyz (Directorates of Hydraulic Constructions, Water Pollution Control, Fisheries, and Sanitation)

§ Main items of control

Supervision of planning, maintenance and efficiency of water and waste treatment plants, and analysis of public waters (Cantonal Laboratories Zürich and Schwyz ; City Water Supply Zürich)

M2 INSTITUTIONAL MEASURES

(1) Water Supply Zürich, Quality Control

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gerwässerschutz (EAWAG, part of the Swiss Federal Institute of Technology), Dübendorf

(2) Limnoligical Station at Kilchberg, University of Zürich.

N. SOURCES OF DATA

(Q1) Questionnaire filled by Prof. K. Wuhrman, Institut für Gewässerschutz und Wassertechnologie, Dübendorf.

(Q2) Questionnaire filled by Dr. P. Liechti, Bundesamt für Umweltschutz, Zürich.

(Q3) Questionnaire filled by Dr. U. Zimmermann, Wasserversorgung Zürich, Zürich.

(1) Müller, M. J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306 pp. Dr. W. Junk Publishers, The Hague.

(2) Zimmermann, U. (1975) Gas-Wasser-Abwasser, 55(9) : 473-480.

(3) Schanz, F. & Thomas, E. A. (1981) Reversal of eutrophication in Lake Zurich. Water Quality Bulletin, 6(4) : 108-112 & 156.

LAC LÉMAN (LAKE OF GENEVA)

A view on the lakeshore

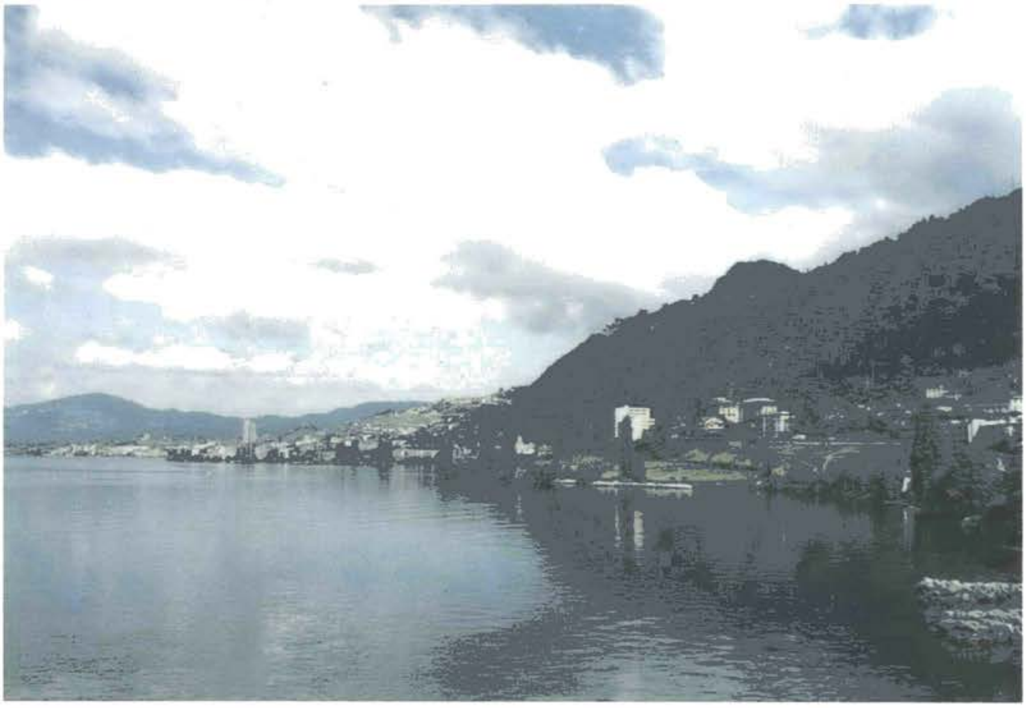
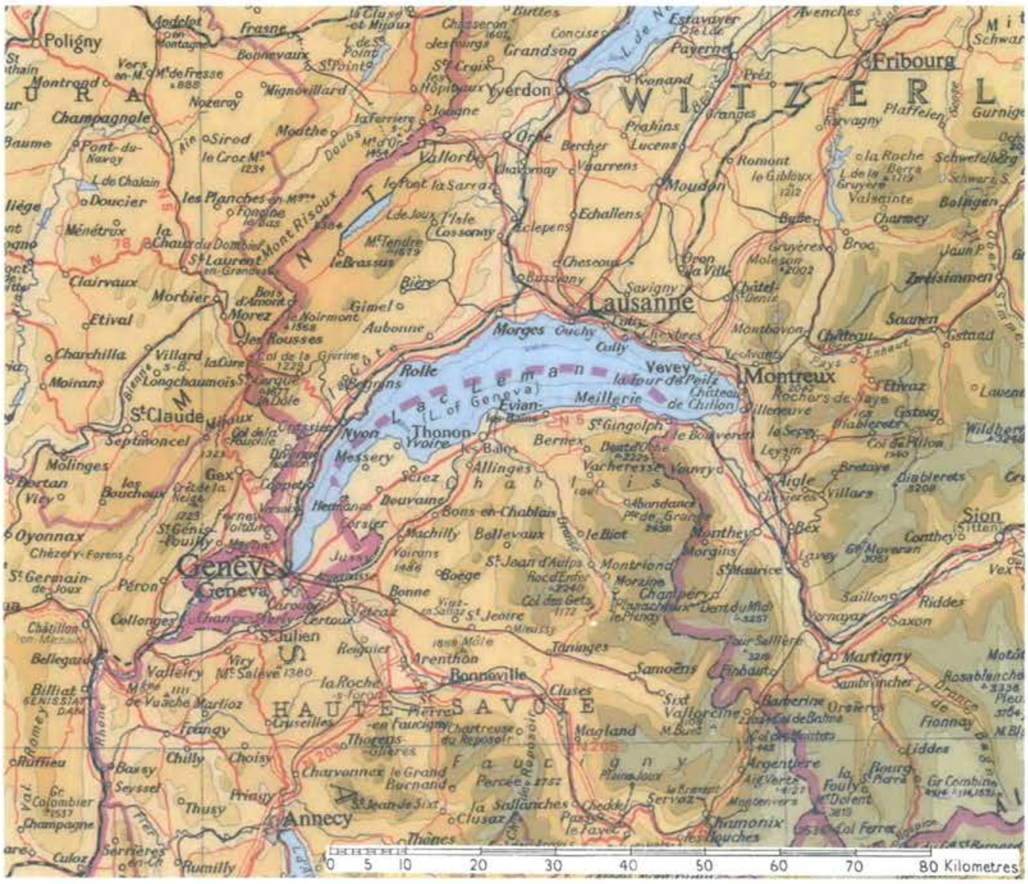


Photo: Shiga Prefectural Government



A. LOCATION

§ Vaud and Valais, Switzerland ; and Haute-Savoie, France.
§ 46°12′-31′N, 6°10′-56′E ; 372 m above sea level.

B. DESCRIPTION

Lake of Geneva is shared by Switzerland along the northern shore and France along the southern shore. Geneva, the city of international politics and tourism, is located at the west end of this semilunar lake, while the well-known resort town of Montreux is at the east end. In-between these cities, Lausanne, a cultural center of western Switzerland, is on the northern shore, and Evian, a town famous for its superior mineral water, is situated in the middle of the southern shore. The climate is gentle with mild winters and comfortable summers, and the surrounding area is particularly known for the well-managed picturesque scenery and resorts set among this natural splendor.

The Rhone River flows southward from the west end of the lake to the Mediterranean Sea. The lake is deep and has a comparatively large water volume for its surface area. The drainage basin is also fairly wide, including about a half of the Walliser Alps and the Berner Alps. Therefore, nutrient loading from natural sources is more or less equivalent in amount to that from industrial and domestic waste water. The dissolved oxygen concentration in the bottom water as well as the transparency has been dropping in recent years. These measurements clearly indicate the progress of eutrophication in the lake. At present, approximately 700,000 people get drinking water from the lake, so that the water quality is under strict legal control by the cantons surrounding the lake.

C. PHYSICAL DIMENSIONS (Q1)

Surface area [km^2]	584.2
Volume [$10^9 m^3$]	88.9
Maximum depth [m]	309.7
Mean depth [m]	152.7
Length of shoreline [km]	167
Residence time [yr]	11.8
Catchment area [km^2]	7,975.3

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHYCAL

§ Bathymetric map (Fig. EUR-7-1).
§ Main islands : None (1).
§ Outflowing rivers and channels (number and names) : 1 (Rhone R.) (Q1).

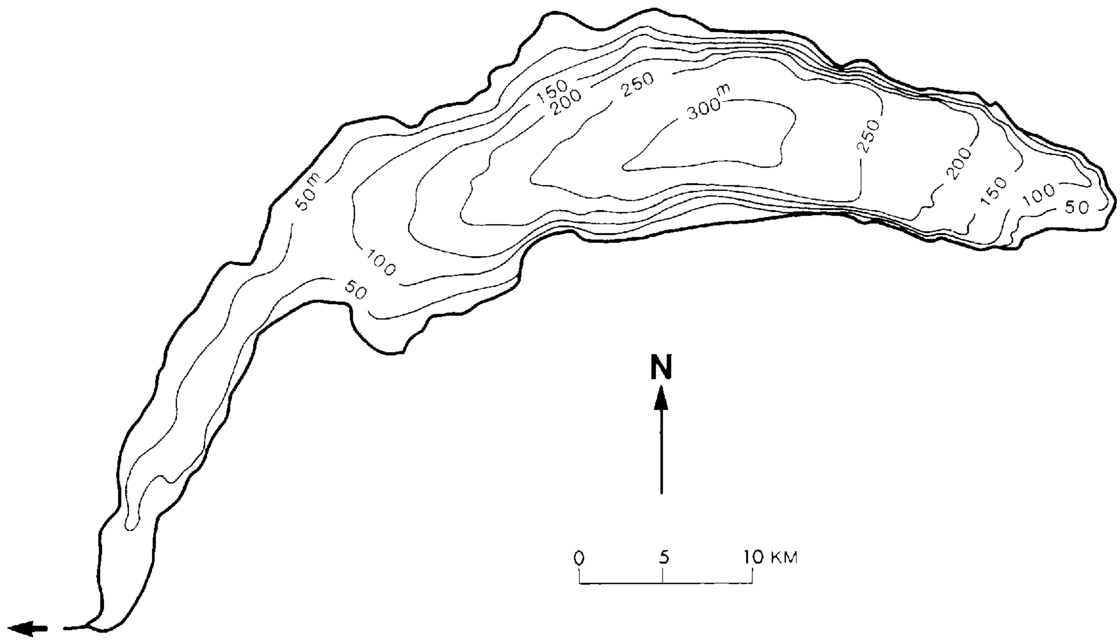
D2 CLIMATIC

§ Climatic data at Genêva, 1931 1960 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	1.1	2.2	6.1	10.1	14.1	17.8	19.9	19.1	15.8	10.3	5.7	2.1	10.3
Precipitation [mm]	63	56	55	51	67	89	64	94	99	72	83	59	852

§ Number of hours of bright sunshine : 2,036 hr yr^{-1} (2).
§ Solar radiation : 11.42 MJ $m^{-2}day^{-1}$ (Q1).

Fig. EUR-7-1 Bathymetric map (1).



§ Water temperature [°C] (Q1)
1968-1969

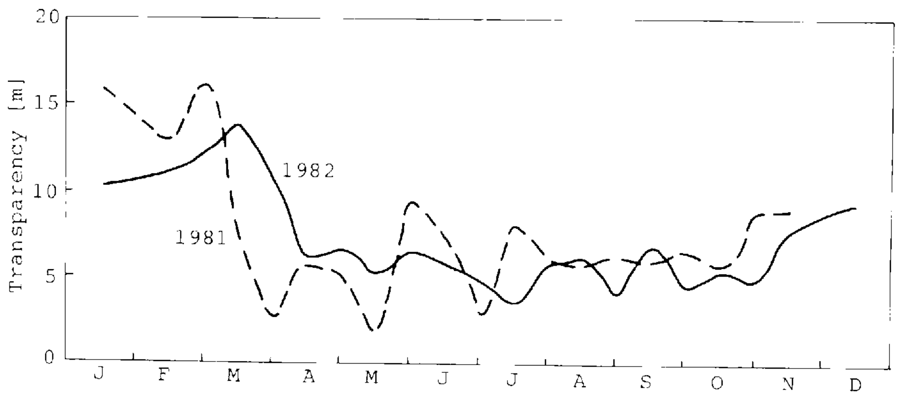
Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	5.9	5.4	6.5	18.9	13.0	16.0	20.4	19.8	18.3	15.7	11.3	7.2

§ Freezing period : None (Q1).
§ Mixing type : Monomictic.

E. LAKE WATER QUALITY

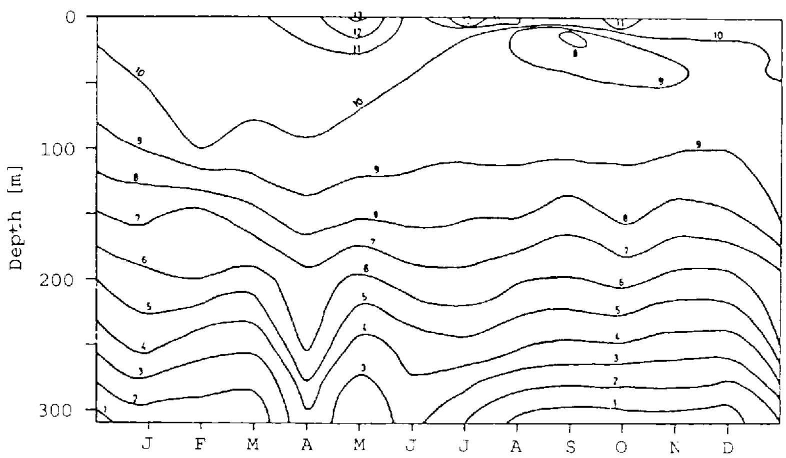
E1 TRANSPARENCY

Fig. EUR-7-2 Transparency [m] at Grand Lac, main basin (3).



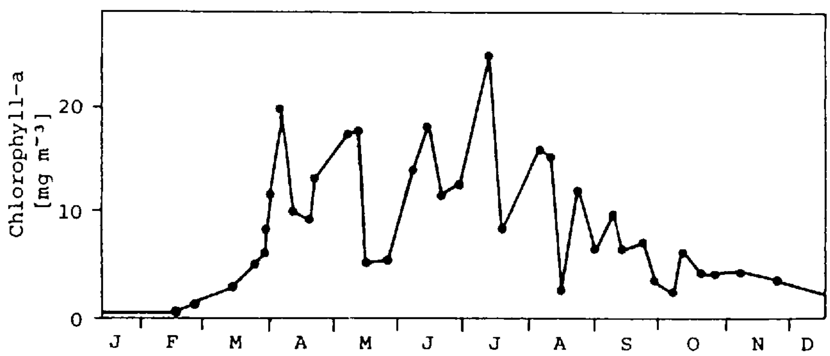
E4 DO

Fig. EUR-7-3 DO [mg l^{-1}] at Grand Lac, 1978 (1).



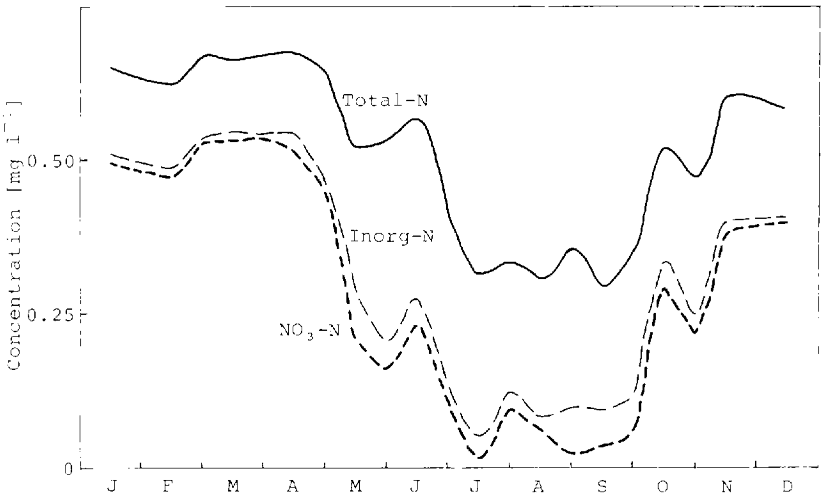
E6 CHLOROPHYLL CONCENTRATION

Fig. EUR-7-4 Chlorophyll-a concentration [μg l^{-1}] in the trophogenic layer, 1976 (1).



E7 NITROGEN CONCENTRATION

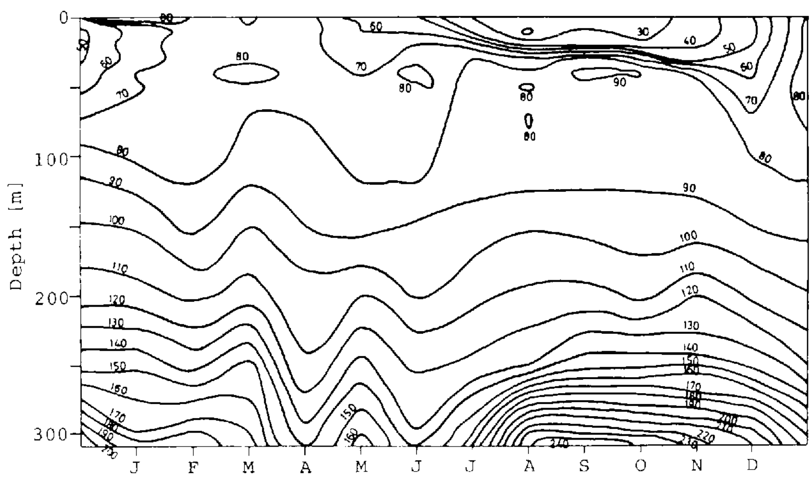
Fig. EUR-7-5 Nitrogen concentrations [mg l^{-1}] at Grand Lac, 1982 (3).



E8 PHOSPHORUS CONCENTRATION

§ Total-P

Fig. EUR-7-6 Time-depth distribution of Total-P [$\mu g\ l^{-1}$] at Grand Lac, 1978 (3).



E10 PAST TRENDS

§ Trend of Chlorophyll-a (0-10m) [mg m⁻³] (3)

1976	1977	1978	1979	1980	1981	1982
7.3	4.7	4.9	4.8	4.7	7.5	5.2

Fig. EUR-7-7 Trend of transparency [m] (4).

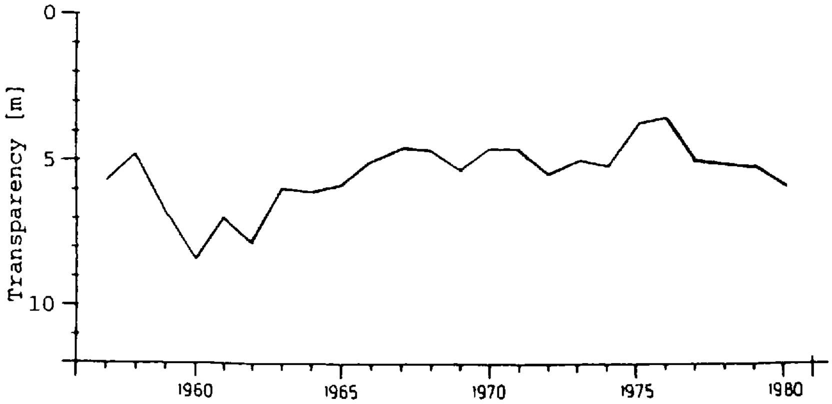


Fig. EUR-7-8 Trend of DO [mg l^{-1}] at 300m depth (4).

Fig. EUR-7-9 Trend of NH_4-N concentration [mg l^{-1}] (1).

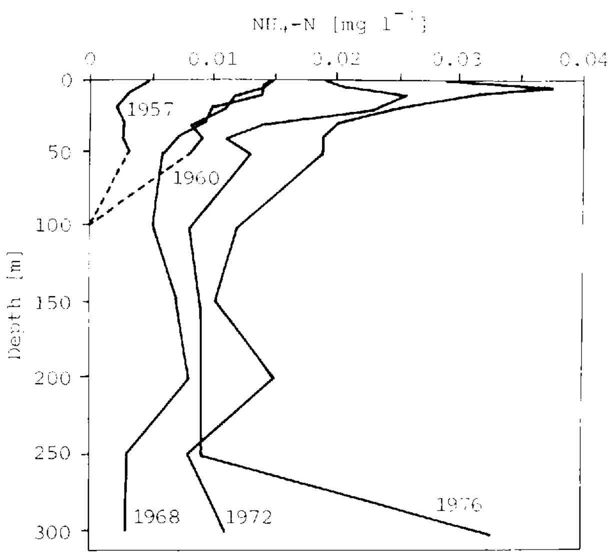


Fig. EUR-7-10 Trend of NO_3-N concentration [mg l^{-1}] (1).

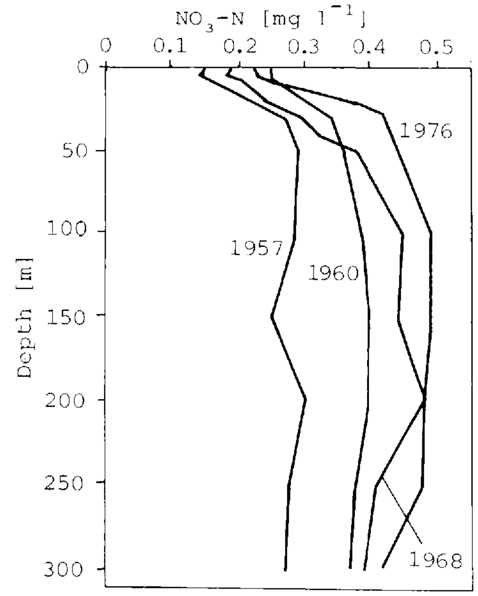
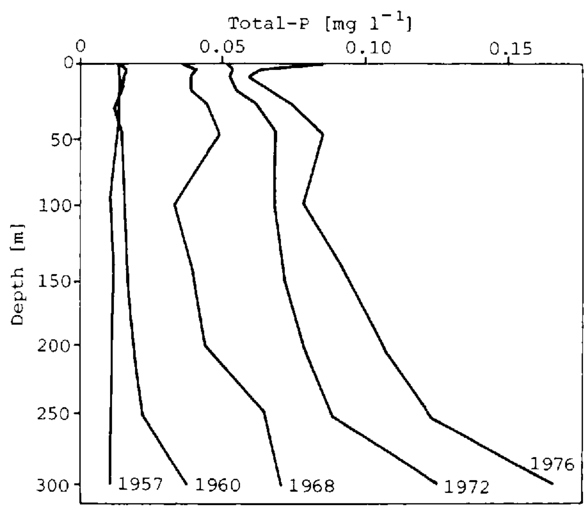


Fig. EUR-7-11 Trend of Total-P concentration [mg l^{-1}] (1).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites communis, Typha latifolia, Schoenoplectus lacustris* (Q1, 5).

§ Floating macrophytes : *Potamogeton nodosus, Nymphaea alba, Nuphar luteum, Polygonum amphibium* (Q1, 5).

§ Submerged macrophytes : *Potamogeton pectinatus, P. perfoliatus, P. lucens, Zannichellia palustris, Myriophyllum spicatum* (Q1, 5).

§ Phytoplankton : *Asterionella formosa* (dominant period in 1982 : Jan.-Jun.), *Synedra acus* (May), *Ceratium hirundinella* (Jul., Sep.), *Melosira binderana* (Sep.), *Fragilaria crotonensis* (Aug.), *Oscillatoria rubescens* (Oct., Nov., end of Dec.), *Aphanizomenon flos-aquae* (end of Oct., beginning of Dec.) (3, 6).

F2 FAUNA

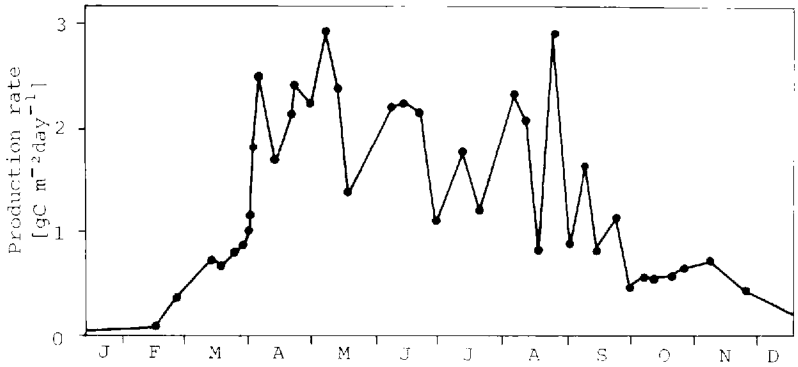
§ Zooplankton : *Keratella cochlearis, K. quadrata, Notholca caudata, Epistylis lacustris, Synchaeta pectinata, Daphnia longispina* (7).

§ Benthos : *Polycelis tenuis, Dugesia tigrina, D. lugubris, Dendrocoelum lacteum, Dreissena*

polymorpha, Asellus aquaticus (1).
§ Fish : *Perca fluviatilis, Coregonus* sp., *Salmo trutta, Lota lota* (Q1).

F3 PRIMARY PRODUCTION RATE

Fig. EUR-7-12 Primary production rate in the trophogenic layer, 1976 (1)



F5 FISHERY PRODUCTS (Q1)
§ Annual fish catch in 1982 : 347.9 [metric tons].

F6 PAST TRENDS (3)
§ Trend of primary production rate [gC $m^{-2}yr^{-1}$]

1976	1977	1978	1979	1980	1981	1982
223	174	157	170	205	231	230

G. SOCIO-ECONOMIC CONDITIONS (Q2)

G1 LAND USE IN THE CATCHMENT AREA
§ Main types of woody vegetation : Conifer forest.
§ Main types of herbaceous vegetation : Meadows and pasture lands.
§ Main kinds of crops : Grape (south slope) ; maize, beet and potato (Midland area and Rhone Valley) ; occasionally large orchards and vegetable growing.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

	Number of persons engaged (1980)	Main products and main kinds of industry
Primary industry		
Agriculture	30,000	
Fisheries	100	
Secondary industry		Chemicals, metals, machinery, and electrical machinery

G3 POPULATION IN THE CATCHMENT AREA (1980)

Population	Mean population density [km^{-2}]	Names of major cities (population)
950,000	119	Genève* (174,000), Lausanne, Montreux

* Not all the city area is included in the drainage basin.

H. LAKE UTILIZATION (Q2)

H1 LAKE UTILIZATION

Source of water, fisheries, navigation, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1980)

	Use rate [$m^3 sec^{-1}$]
Domestic water	2.38
Power plant	N.A.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q2)

I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual algal bloom: *Oscillatoria rubescens.*

§ Nitrogen and phosphorus loadings [t yr^{-1}]

T-N: 1,300 (1982).

T-P: 1,270 (1980), 1,180 (1981), 1,350 (1982).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q2)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Federal law on the Protection of Water against Pollution (Water Protection Law) (1971)

§ Responsible authorities

(1) Cantonal and Federal authorities

N. SOURCES OF DATA

(Q1) Questionnaire filled by Dr. Eichenberger, Feldmeiden.

(Q2) Questionnaire filled by Office Fédéral de la Protection de l'Environnement, Bern.

(1) Lachavanne, J.-B. (1980) Les manifestations de l'eutrophisation des eaux dans un grand lac profond, le Léman (Suisse). Schweiz. Z. Hydrol., 42(2): 127-154.

(2) Müller, M. J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306pp. Dr. W. Junk Publishers, The Hague.

(3) Balvay, G., Blanc, P., Burkard, P., Burrus, D., Corvi, C., Druart, J.-C., Giger, W., Monod, R., Pelletier, J., Revaclier, R., Schnydrig, J.-P., Thelin, L., Vernet, J.-P. & Viel, M. (1982) Rapports, sur les Études et Recherches Entreprises dans le Bassin lémanique, Programme quinquennal 1981-1985, Campagne, 1982. 182pp. Commission Internationale pour la Protection des Eaux du Léman contre la Pollution, Lausanne.

(4) Commission Internationale pour la Protection des Eaux du Léman contre la Pollution (1980) Le léman, un Lac á Protéger ! 31pp. Lausanne.

(5) Lachavanne, J.-B. (1977) Evolution de la flore et de la vegetation aquatiques du Leman. Coden: Cndlar, 32(1): 121-132.

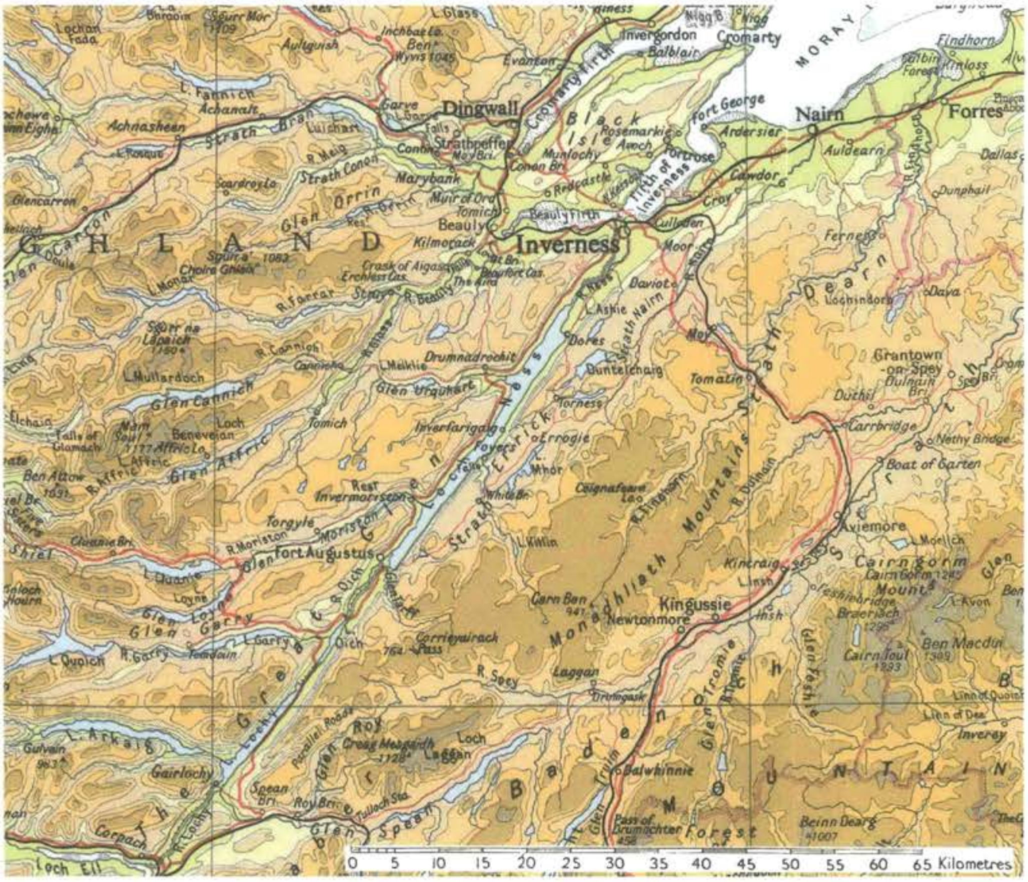
(6) Naef, J. & Martin, P. (1983) Arch. Sc. Geneve, 36(3): 479-500.

(7) Martin, P. & Naff, J. (1978) Plancton du lac Leman (caracteristique de l'annee 1977). Séance, 26 octobre: 98-108.

LOCH NESS

A lake view with Urquhart castle

Photo: M. Kumagai



A. LOCATION

§ Highland, Scotland, U. K.
§ 57°15′N, 4°30′W ; 15.8 m above sea level.

B. DESCRIPTION

Loch Ness is an extremely narrow and long lake, extending from the northeast to the southwest in the Inverness area of north Scotland. The lake is about 39 km long, but only 1.5 km wide, and has a maximum depth of 230 m and a mean depth of 132 m. Its water volume is the largest, and the surface area is the second largest next to Loch Lomond, in this country. The lake water flows out to Moray Firth through the Ness River. It is known as one of the most scenic lakes of this country, with an old ruined castle on the lakeside and surrounding mountain view. The lake is also so famous for the "Nessy", a world-famous unidentified organism. Investigations on Nessy have been carried out since 1962 by the Loch Ness Investigation, a voluntary organization with some scientists.

The drainage basin is still rich in woodlands and grasslands, having a low population density of 1.8 km^{-2}. Nutrients inflow to the lake, therefore, is still in low level and the water remains oligotrophic and transparent. However, it is anxious that eutrophication may be caused by many tourists attracted by Nessy and by increasing acitivity of residents in the drainage basin.

C. PHYSICAL DIMENSIONS

Surface area [km^2]	56.4
Volume [$10^9 m^3$]	7.45
Maximum depth [m]	230
Mean depth [m]	132
Water level	Regulated
Length of shoreline [km]	86
Residence time [yr]	2.81
Catchment area [km^2]	1,775

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-8-1).

§ Main islands : None.

§ Outflowing rivers and channels (number and names) : 1 (Ness R.) (1).

D2 CLIMATIC

§ Climatic data at Achnashellach* (13-year average) (3)

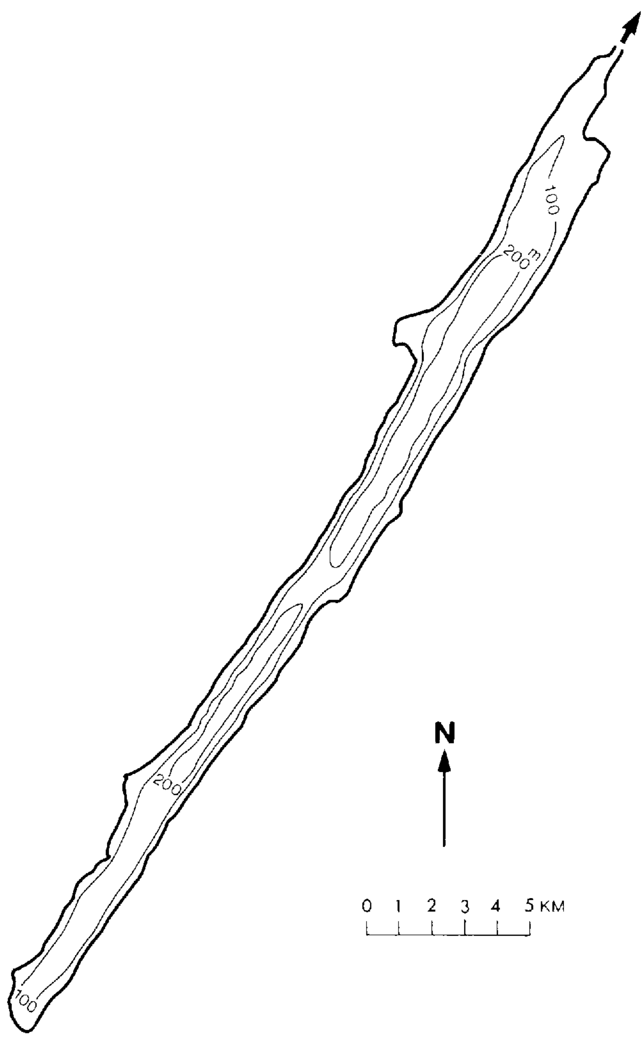
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	2.8	3.2	5.2	6.9	10.1	12.4	13.8	13.6	11.6	8.7	5.7	4.1	8.2
Precipitation [mm]	232	177	127	156	93	114	148	150	189	234	196	242	2,058

* ca. 50 km west of the lake.

§ Number of hours of bright sunshine (Achnashellach) : 1,374 hr yr^{-1} (3).

§ Period of snowfall (lake side) : 15–20 day yr^{-1} (2).

Fig. EUR-8-1 Bathymetric map (2).



§ Water temperature [°C] (2)
Dec. 1977-Nov. 1978

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	5.7	5.6	5.6	6.3	7.5	10.0	12.5	13.5	12.5	10.6	9.8	8.0
75	5.7	5.6	5.6	6.3	5.8	6.6	7.5	6.3	6.5	6.7	7.3	8.0

§ Freezing period : None.
§ Thermocline formation : May-October.

E. LAKE WATER QUALITY

E1 TRANSPARENCY (4)
Nov. 1977-Oct. 1978 : 3.6-4.6 m.

E2 pH (4)
Nov. 1977-Oct. 1978

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	–	6.7	6.7	–	6.8	–	6.6	6.5	–	6.6	–	6.8

E6 CHLOROPHYLL CONCENTRATION [mg m^{-3}] (5)
Nov. 1977-Oct. 1978

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	–	0.2	0.2	–	0.3	–	1.6	1.7	–	0.9	–	0.3

E7 NITROGEN CONCENTRATION
§ NO_3-N & NO_2-N [mg l^{-1}] (4)
Nov. 1977-Oct. 1978

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-10	–	0.12	0.10	–	0.09	–	0.09	0.09	–		0.14	0.13

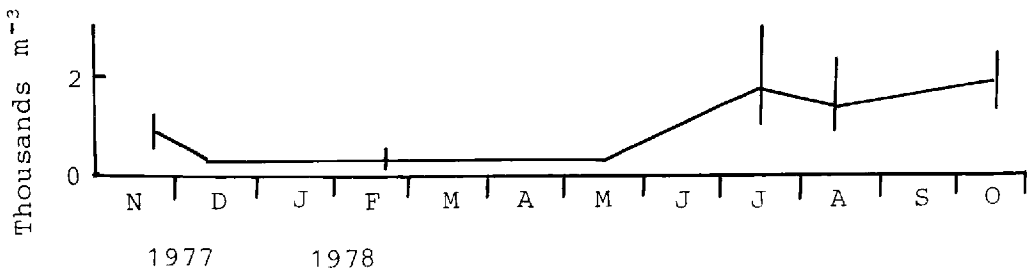
E8 PHOSPHORUS CONCENTRATION
§ PO_4-P (4)
Nov. 1977-Oct. 1978 : Less than 10 μg l^{-1}.

F. BIOLOGICAL FEATURES

F1 FLORA
§ Emerged macrophytes : *Scutellaria galericum, Veronica scutellata, Carex rostrata, Menyanthes trifoliata, Mentha aquatica, Potentilla palustris* (6).
§ Submerged macrophytes : *Myriophyllum alterniflorum* (6).
§ Phytoplankton : *Oscillatoria* sp., *Elakatothrix* sp., *Melosira* sp., *Rhizosolenia eriensis, Asterionella formosa, Tabellaria fenestrata, T. flocculosa* (5).

F2 FAUNA
§ Zooplankton : *Daphnia hyalina, Bosmina coregoni, Diaptomus gracilis, Cyclops abyssorum* (7).
§ Benthos : *Lumbriculus variegatus, Cloeon simile, Amphinemura sulcicollis, Chloroperla torrentium, Sigara dosalis, Stylaria lacustris, Asellus aquaticus, Nemoura avicularis* (8, 9).
§ Fish : *Lampetra planeri, Salmo salar, S. trutta, Salvelinus alpinus, Esox lucius, Anguilla anguilla, Gasterosteus aculeatus* (10).

Fig. EUR-8-2 Seasonal changes in total crustacean zooplankton [10^3 cells m^{-3}] from November 1977 to October 1978 (7).



G. SOCIO-ECONOMIC CONDITIONS (1)

G1 LAND USE IN THE CATCHMENT AREA

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	247.9	14.3
Rough	1,354	78.3
Agricultural land	32.6	1.9
Urban	7.5	0.4
Others	86.2	5.1
Total	1,728.2	100.0

G3 POPULATION IN THE CATCHMENT AREA

	Population	Population density [km^{-2}]	Main cities
Total	3,100	1.8	Inverness

J. WASTE WATER TREATMENT

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

J3 SANITARY FACILITIES AND SEWERAGE

§ Public wastewater treatment systems

Number of plants : 8.

N. SOURCES OF DATA

(1) Maitland, P. S. (1981) Introduction and catchment analysis. The Ecology of Scotland's Largest Lochs, Lomond, Awe, Ness, Morar and Shiel (ed. Maitland, P. S.), pp. 1-28. Dr. W. Junk Publishers, The Hague.

(2) Smith, I. R., Lyle, A. A. & Rosie, A. J. (1981) Comparative physical limnology. Ibid., pp. 29-66.

(3) Müller, M. J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306 pp. Dr. W. Junk Publishers, The Hague.

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LAKE SKADAR

A view from lakeside hill

Photo:CAR & DRIVER

A. LOCATION

§ Yugoslavia ; and Albania.
§ 42°10′N, 19°20′E ; 5 m above sea level.

B. DESCRIPTION

Lake Skadar is the largest lake in the Balkan district, situated at the southern end of the Dinaric Alps on the border of Yugoslavia and Albania. It lies about 100 km to the southeast of the famous scenic town of Dubrovnik on the coast of the Adriatic Sea. To the southwest of the lake rise high mountains, while to the northeast stretches a wide swamp. There are many islands in the western part of the lake and a number of spots where ground water spouts up from the bottom (Okos). The lake is considered to have been formed by dissolution of limestone in a tectonic basin during the Tertiary or Quarternary period. It is a shallow lake with 8 m maximum depth and 5 m mean depth.

The Moraca River, which is the largest inflowing stream with cold water heavily loaded with suspended solids, has a great influence upon the transparency and water quality of this lake. The Bojana River flows out from the south end and drains into the Adriatic Sea. The phosphate concentration in the lake water is low, and the low transparency is attributed to the large amount of suspended solids in the inflowing water. The lake is rich in fish and waterfowl fauna.

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	372.3
Volume [10^9m^3]	1.93
Maximum depth [m]	8.3
Mean depth [m]	5
Normal range of annual water level fluctuation (regulated) [m]	2
Length of shoreline [km]	207
Catchment area [km^2]	5,490

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-9-1).

§ Outflowing rivers and channels (number and names) : 1 (Bojana R.).

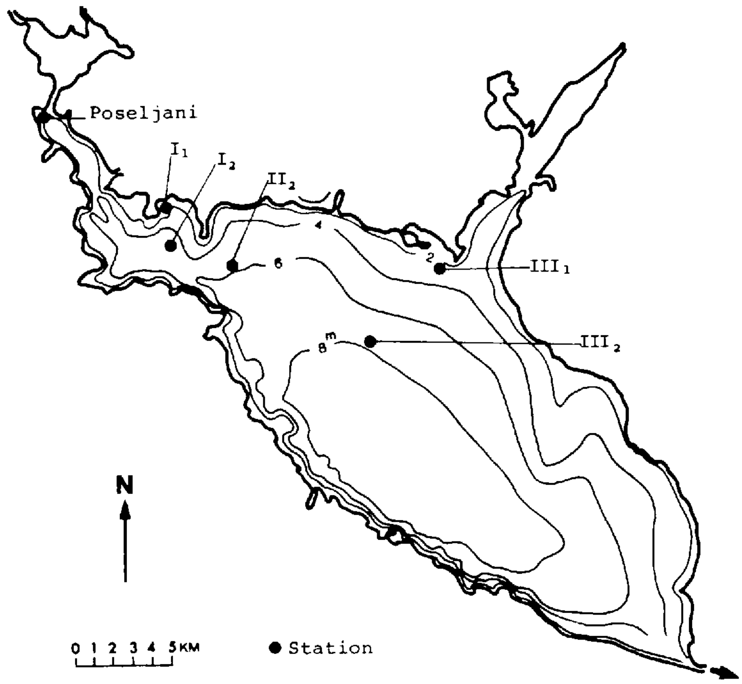
D2 CLIMATIC

§ Climatic data at Skadar (temperature 13-year mean ; precipitation 50-year mean) (3).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	3.9	5.8	9.2	13.1	18.1	21.7	25.0	24.7	20.8	16.1	10.6	6.7	14.7
Precipitation [mm]	137	140	157	132	89	48	46	28	99	198	208	154	1,436

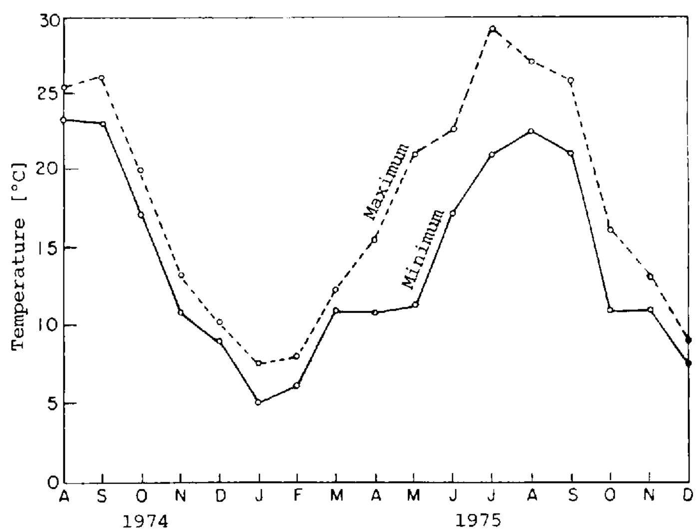
§ Number of hours of bright sunshine (Skadar) : 2,533 hr yr^{-1}.

Fig. EUR-9-1 Bathymetric map (1).



§ Water temperature

Fig. EUR-9-2 Water temperature [°C] (Aug. 1974-Dec. 1975) (4).



§ Freezing period: Only twice in recent years (Feb. 1954 and 1956).
§ Thermocline formation: Not formed.

E. LAKE WATER QUALITY

E1 Transparency (Radus, 1977): 4 m (5).

E2 pH (6)
1972-1973

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I_1	7.2	–	7.2	8.2	7.9	–	–	8.0	8.0	8.2	8.0	–
I_2	7.8	–	8.1	8.1	8.1	–	–	8.2	8.2	8.1	8.0	–
II_2	7.8	–	7.8	7.5	–	–	–	8.0	8.2	8.5	8.2	–
III_1	7.8	–	8.2	8.1	8.1	–	–	8.2	–	–	–	–
III_2	8.1	–	8.1	8.2	8.2	–	–	–	8.0	8.3	–	–
Poseljani	8.2	–	8.2	–	–	–	–	8.0	8.0	8.1	–	–

E7 NITROGEN CONCENTRATION (6)
§ NH_4-N [mg l^{-1}]
1972-1973

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I_1	.000	.000	–	.004	.080	.002	.020	.020	.030	.030	.010	.240
I_2	.010	.000	–	.000	.030	.000	.016	.030	.020	.000	.020	.030
II_2	–	.020	–	.000	.000	.003	.020	.020	.000	.020	.020	.020
III_2	.000	.000	–	.000	.000	.000	.050	.050	.020	.050	.010	.010
Poseljani	.004	.004	–	–	–	.000	.020	.020	.030	.030	.080	.080

§ NO_3-N [mg l^{-1}]*
1972-1973

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I_1	.113	.068	.034	.041	.057	–	.045	.003	.079	.057	.158	.102
I_2	.102	–	–	.170	.188	–	.034	.004	.068	.045	.136	.079
II_2	.041	–	–	.170	–	–	.027	.005	.181	.079	.136	.072
III_2	–	.057	.090	–	.045	–	.027	.003	.192	.045	.102	–
Poseljani	.045	.045	.045	–	.000	–	.027	.003	–	.045	–	.057

* Converted from the original determination of NO_3.

E8 PHOSPHORUS CONCENTRATION (6)
§ PO_4 [mg l^{-1}]
1972-1973

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I_1	.008	.002	–	.001	.002	–	.003	.002	.006	.002	.003	.007
I_2	.002	.000	–	.002	.002	–	.003	.017	.007	.000	.002	.007
II_2	.002	–	–	.000	.014	–	.003	.005	.003	.010	.010	.007
III_2	.002	.003	–	.002	.002	–		–	–	.003	.002	.007
Poseljani	.003	.002	–	–	.012	–	–	.004	.004	.002	.040	.003

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Scirpus lacustris, Phragmites communis, Typha angustifolia* (7).
§ Floating macrophytes : *Nymphaea alba, Nuphar luteum, Trapa natans* (7).
§ Submerged macrophytes : *Myriophyllum, Ceratophyllum, Potamogeton* spp. (7).
§ Phytoplankton : *Cyclotella glomerata, C. planctonia, Pediastrum, Ceratium hirundinella, Microcystis, Merismopedia, Dinobryon divergens, D. bavaricum* (8).

F2 FAUNA

§ Zooplankton : Rotatoria, Cladocera, Copepoda, Protozoa (9).
§ Benthos : Chironomidae, Oligochaeta, Bivalvia, Gastropoda (10).
§ Fish : *Alburnus, Cyprinus, Chondrostoma, Anguilla, Salmo, Rutilus, Alosa, Pachychilon, Mugil, Scardinius* (11).

N. SOURCES OF DATA

(1) Beeton, A. M. (1981) General introduction. The Biota and Limnology of Lake Skadar (ed. Karaman, G. S. & Beeton, A. M.), pp. 15-17. University of "Veljko Vlahovič", Smithonian Institution of Washington, and Center for Great Lakes Studies/University of Wisconsin, Titograd.
(2) Lasca, N. P., Radulovič, V., Ristič, R. J. & Cherkauer, D. S. (1981) Geology, hydrology, climate and bathymetry of Lake Skadar. Ibid., 17-38.
(3) Air Ministry Meteorological Office (1958) Tables of Temperature, Relative Humidity and Precipitation for the World. Part III. Her Majesty's Stationery Office, London.
(4) Beeton, A. M. (1981) Water masses, thermal conditions and transparency of Lake Skadar. The Biota and Limnology of Lake Skadar (see above), pp. 38-55.
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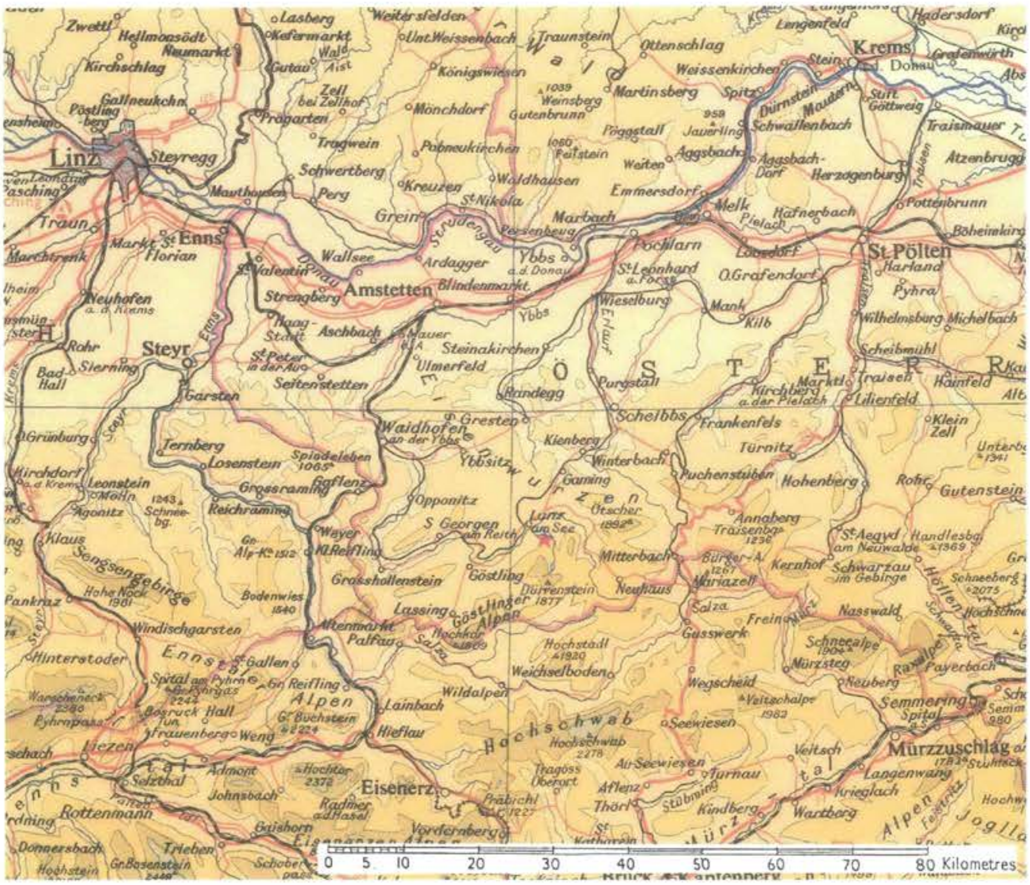
(7) Ristič, J. & Vizi, O. (1981) Synoptic survey of the dominant macrophytes in Lake Skadar. Ibid., pp. 117-125.
(8) Petkovič, S. (1981) Phytoplankton. Ibid., pp. 163-189.
(9) Petkovič, S. (1981) Zooplankton. Ibid., pp. 191-199.
(10) Karaman, G. S. & Nedič, D. (1981) Zoobenthos of Lake Skadar. Ibid., pp. 222-246.
(11) Stein, R. A., Mecom, J. O. & Ivanovič, B. (1981) Commercial exploitation of fish stocks in Lake Skadar, 1947-1976. Ibid., pp. 343-354.

LUNZER SEE

A view of the whole lake

Photo: H. Löffler



A. LOCATION

§ Nieder-Österreich, Austria.
§ 47°51′N, 15°04′E ; 608 m above sea level.

B. DESCRIPTION (Q)

Lunzer Untersee (Lower Lunz Lake) is of glacial origin, and located approximately 120 km southwest of Vienna. There are two small neighboring lakes, Mittelsee (Middle Lake) and Obersee (Upper Lake) in the upstream of the Seebach, the main inflowing river to Untersee. The lake is only 0.7 km^2 wide, has a maximum depth of 33.7 m, and a fairly short residence time (0.7 year). The nutritional level of the lake water is still oligotrophic, but the littoral zone has recently been eutrophicated considerably, with remarkable changes in the aquatic flora.

Ninety percent or more of the total drainage basin area consist of karstic plateau and the forests of Norway spruce and European beech. The density of year-round population in the drainage basin is low (11/km^2), but summer visitors may amount to 8,000/day at the maximum. Domestic waste water of this district has been diverted to preserve the quality of the lake water.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	0.68
Volume [$10^6 m^3$]	13
Maximum depth [m]	33.7
Mean depth [m]	20.0
Water level	Unregulated
Length of shoreline [km]	4.15
Residence time [yr]	0.3
Catchment area [km^2]	27.0

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

§ Bathymetric map (Fig. EUR-10-1).

§ Main islands : None.

§ Outflowing rivers and channels (number and names) : 1 (Seebach-Ausrinn R.).

D2 CLIMATIC (Q)

§ Climatic data at Lunz Biological Station (20-year average)

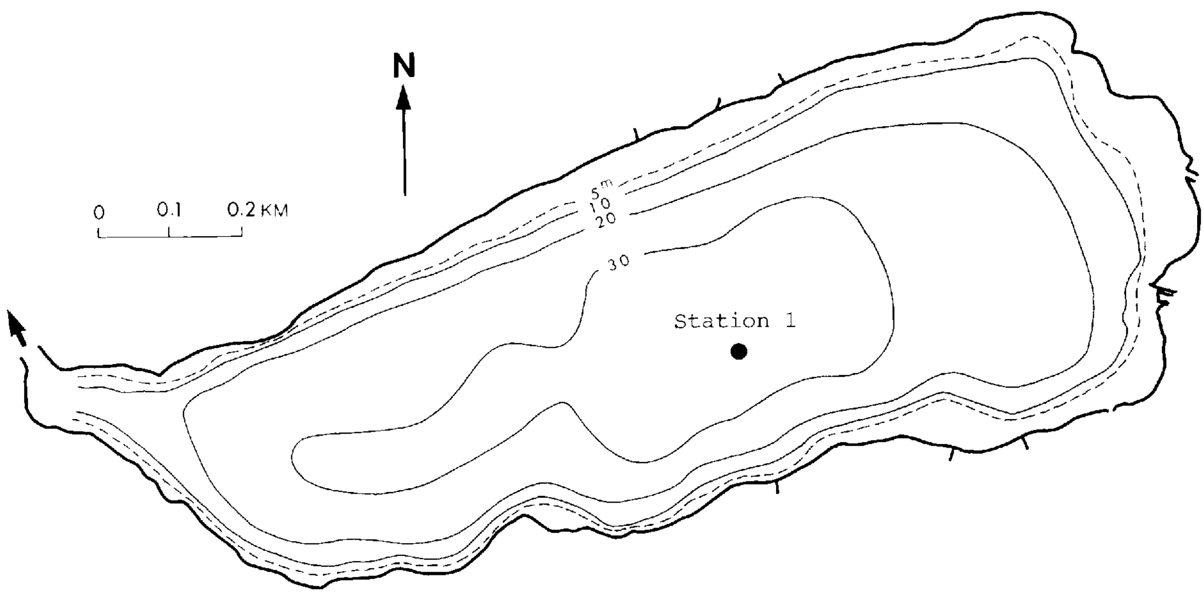
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-4.5	-2.1	1.9	6.6	11.1	14.3	16.1	15.4	12.7	7.5	2.2	-1.6	6.6
Precipitation [mm]	108	121	109	132	148	200	243	193	116	117	107	114	1,706

§ Hours of bright sunshine (Lunz Biological Station, 1927-1948) : 1,312 hr yr^{-1}.

§ Period of snowfall (1927-1948) : 1 Nov.-15 Apr.

§ Depth of maximum snow accumulation (1981) : 1.25 m.

Fig. EUR-10-1 Bathymetric map (Q).



§ Water temperature [°C] (Q)
Station 1, 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.4	2.5	4.5	7.6	10.7	12.9	11.9	13.9	12.4	9.8	5.8	2.6
5	3.6	3.2	4.0	7.6	9.4	11.3	11.5	13.7	12.1	9.8	5.8	2.7
10	3.6	3.4	3.9	6.3	7.6	9.4	9.8	11.0	10.8	9.8	5.8	2.8
15	3.6	3.4	3.7	5.2	5.6	6.7	9.0	9.0	8.8	9.8	5.8	3.0
20	3.6	3.4	3.7	4.6	5.0	5.4	5.8	5.5	5.8	5.8	5.8	3.0
30	3.9	3.4	3.7	4.2	4.5	4.6	5.0	4.9	4.9	5.0	5.7	3.5

§ Freezing period : From December to March.

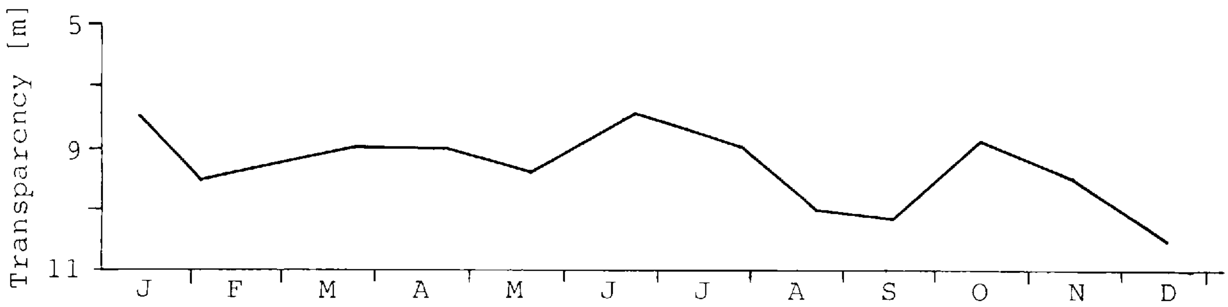
§ Thermocline formation : From middle of May to early October.

§ Notes on water mixing and thermocline formation : Strong effect of flushing by the tributary Seebach.

E. LAKE WATER QUALITY

E1 TRANSPARENCY

Fig. EUR-10-2 Seasonal trend of transparency [m], Station 1, 1981 (2).



E2 pH (1)

Station 1, 1981

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	7.7	7.5	7.7	7.6	7.6	7.9	7.7	7.4	7.4	7.4	7.2	7.7

E4 DO [mg l^{-1}]

Station 1, 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	10.8	12.4	13.9	15.1	14.7	12.3	11.4	11.5	12.0	12.2	11.7	11.7
5	10.8	12.4	14.7	14.9	14.8	11.8	11.9	11.7	12.4	12.6	10.3	11.5
10	10.9	12.2	13.8	15.5	15.7	12.3	11.7	12.1	11.8	12.6	9.9	11.8
15	10.9	12.2	12.8	13.9	13.9	12.0	11.9	11.5	11.4	12.2	10.1	11.4
20	10.9	11.9	12.7	12.6	12.0	10.2	9.5	8.9	9.1	9.3	9.9	11.4
30	10.9	11.1	10.8	11.2	9.8	6.7	6.0	5.1	3.5	2.9	9.5	11.2

E6 CHLOROPHYLL CONCENTRATION [mg m^{-2}] (Q)

0-20 m, integrated sample, 1975

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.77	1.65	0.73	3.1	5.8	1.6	1.3	1.2	2.6	2.4	1.2	1.4

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}]

Station 1, 1981

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5.3	14.0	5.0	7.0	5.3	6.0	5.7	8.0	7.3	5.7	5.7	6.7
5	5.7	8.3	7.0	9.0	5.3	8.7	7.7	8.0	10.3	8.0	5.0	6.7
10	5.7	8.7	6.3	7.3	6.0	5.0	6.7	5.7	4.0	6.3	5.7	8.0
15	5.7	8.3	5.7	5.0	6.0	3.7	7.0	6.7	3.7	5.0	6.7	6.7
20	6.3	9.3	7.0	5.3	5.7	4.0	4.0	2.7	3.7	4.7	5.7	6.7
30	6.7	16.3	10.7	8.7	8.0	4.0	4.7	4.3	10.7	14.0	6.0	6.3

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites australis, Scirpus lacustris* (Q).

§ Submerged macrophytes : *Elodea canadensis, Potamogeton praelongus, P. perfoliatus, P. pusillus, P. pectinatus* (Q).

§ Phytoplankton : *Mallomonas akrokomos, Dinobryon divergens, Cyclotella operculata, Stephanodiscus alpinus, Rhodomonas minuta, Cryptomonas ovata* (3).

F2 FAUNA

§ Zooplankton : Rotifera (*Keratella cochlearis, Polyarthra vulgaris, P. maior*) ; Cladocera (*Daphnia longispina hyalina*) ; Copepoda (*Eudiaptomus gracilis*) (3).

§ Fish : *Salvelinus alpinus, Phoxinus phoxinus, Gobio gobio, Cottus gobio* (Q).

F3 PRIMARY PRODUCTION RATE

§ Net primary production rate [mgC $m^{-2}day^{-1}$], 1976 (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
184.4	–	140.9	440	320	462	119	231	270	186	137	90	233

F4 BIOMASS

Fig. EUR-10-3 Phytoplankton biomass [g m^{-3}], 1981 (2).

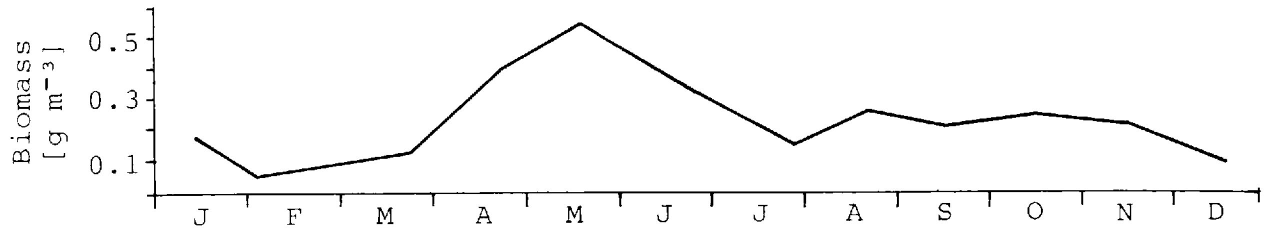


Fig. EUR-10-4 Percent contribution of various algal groups to the total algal volume, 1981 (2).

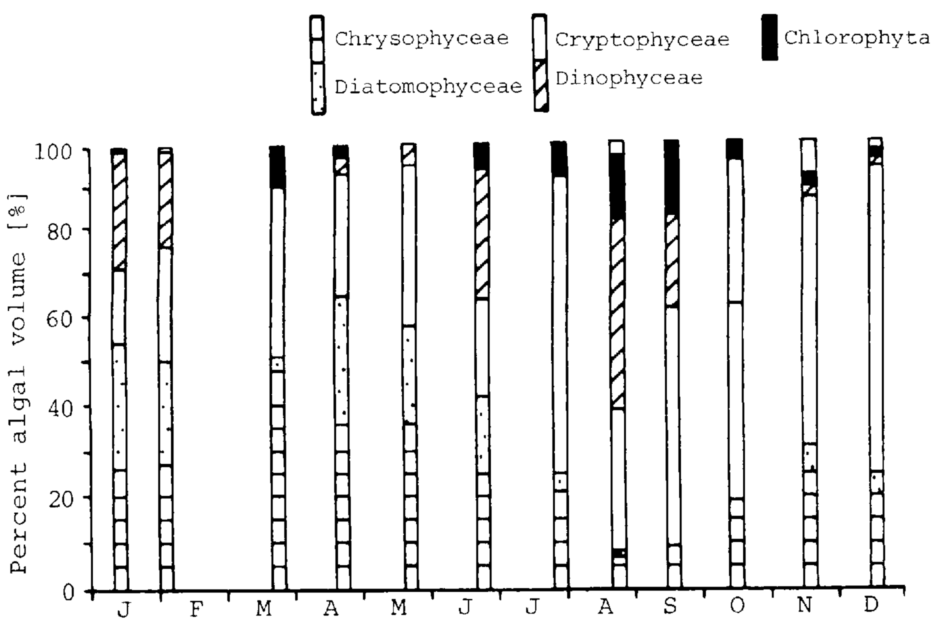
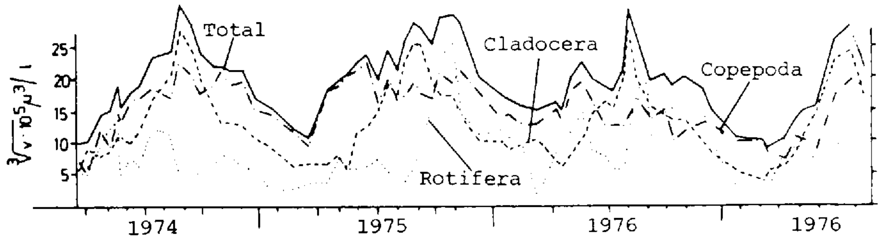


Fig. EUR-10-5 Zooplankton biomass (cell volume, lake center) (3).



F5 FISHERY PRODUCTS

§ Annual fish catch : Not estimated, sport-fishing only (Q).

F7 REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (Q)

No change in the plankton, but change in the littoral zone toward eutrophication ; less species in diatoms and Cyanophyceae and more green algae.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1978) (Q)

	[km²]	[%]
Woody vegetation	17.4	64.6
Rocky barrens	7.6	28.3
Agricultural land, meadows	1.8	6.5
Settlements	0.2	0.6
Total	27.0	100.0

§ Main types of woody vegetation : *Picea abies, Fagus silvatica, Acer montana, Larix decidua.*

G3 POPULATION IN THE CATCHMENT AREA (1970)

Total population	Population density [km $^{-2}$]	Notes
300	11	In summer up to 8,000 tourists per day

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Tourism and recreation (swimming, sport-fishing).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : None.

I3 EUTROPHICATION (Q)

§ Total-P loading to the lake (1981) : 0.394 t yr^{-1}.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

Secondary treatment system (activated sludge) for domestic wastewater present. The treated effluent is diverted to the outside of the lake's drainage basin.

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. G. Malicky, Lunz Biological Station, Lunz.

(1) Pambalk, I. & Schlott, G. (1982) Österr. Eutrophieprogramm : Fortsetzung der Untersuchungen des OECD-Projektes (Temperatur, Sauerstoff, Phosphor, pH, Leitfähigkeit). Jber. Biol. Stat. Lunz, 5 : 111-115.

(2) Malicky, G. (1982) Das Phytoplankton des Lunzer Untersee im Jahr 1981. Jber. Biol. Stat. Lunz, 5 : 125-127.

(3) Ruttner-Kolisko, A. (1978) Durchflutung und Produktion im Lunzer Untersee. Jber. Biol. Stat. Lunz, 1 : 98-115.

WINDERMERE

A view on the lakeshore at The Ferry House

Photo: T. Nakajima

A. LOCATION

§ Cumbria, England, U. K.
§ 54°20′N, 2°57′W ; 39 m above sea level.

B. DESCRIPTION

Windermere is the largest of many picturesque lakes formed by the activity of the Pleistocene ice sheet in the Lake District National Park of northwest England. The park is studded not only with lakes but also with peaks including the highest in England (Sea Fell, 978 m) and with historical and archeological relics, producing a very attractive landscape.

The lake is long and narrow from the north to the south, and an island in the central part divides the whole lake into the north and the south basin. Hilly highland stretches behind the shoreline and is used for grazing grounds and woodlands. There are two towns, Ambleside and Windermere, along the northeastern shore. The Freshwater Biological Association's Windermere Laboratory established in 1902 is situated in the midst of western shore.

There are so many lakes, Rydal Water, Grassmere, Esthwaite Water and so forth, in the drainage basin, and the water of these lakes flows into Windermere. Although the pH value of rain water in this area averages 4.4, that of lake water has been very stable since 1928 around 7.0. The present trophic level of the lake is mesotrophic, but eutrophication is proceeding gradually owing to the influx of nutrients from farms and residential areas.

C. PHYSICAL DIMENSIONS

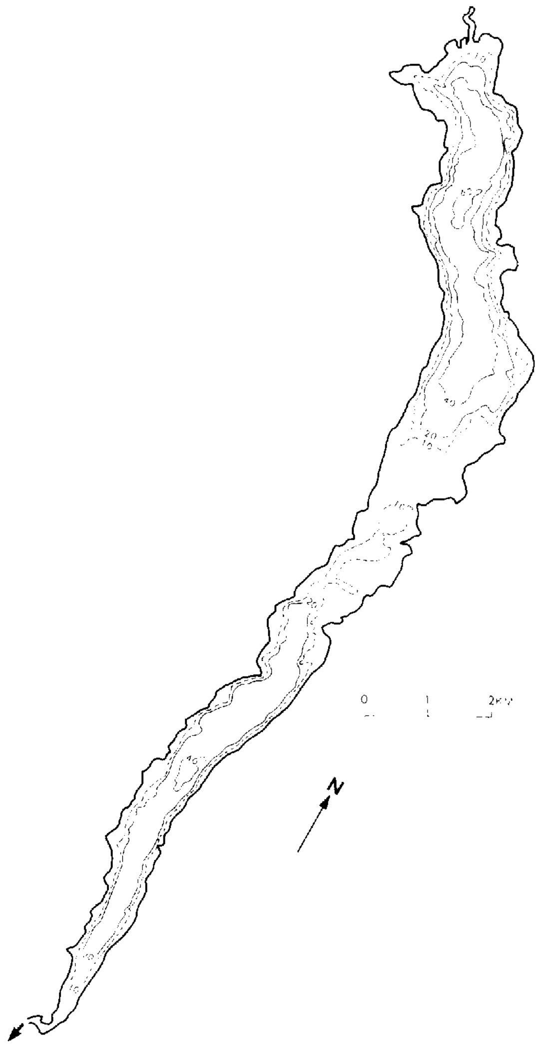
Surface area [km²]	14.8
Volume [$10^6 m^3$]	315
Maximum depth [m]	64
Mean depth [m]	21.3
Water level	Unregulated
Length of shoreline [km]	17
Residence time [yr]	
Catchment area [km²]	231

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-11-1).
§ Main islands : Belle.
§ Outflowing rivers and channels (number and names) : 1 (Leven R.) (3).

Fig. EUR-11-1 Bathymetric map (2).



D2 CLIMATIC (4)

§ Climatic data at *Manchester, 1951 1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	3.7	3.9	5.7	8.1	11.4	14.3	15.6	15.6	13.6	10.6	6.4	4.7	9.5
Precipitation [mm]	67	52	51	50	60	63	78	85	76	69	77	78	805

* ca. 110 km south of the lake.

Fig. EUR-11-2 Precipitation at Wraymires Hatchery (ca. 3 km west of the lake center) (1).

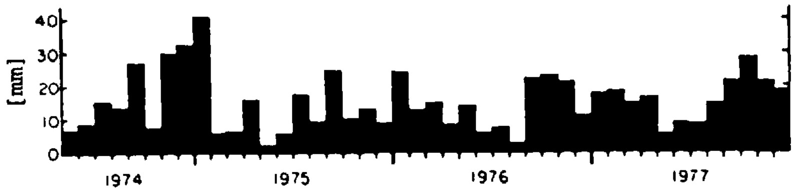
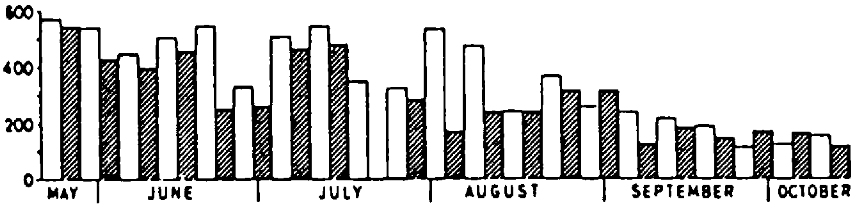


Fig. EUR-11-3 Radiation (weekly means). Open bar 1977, shaded bar 1978 [cal cm^{-2}day^{-1}] (5).

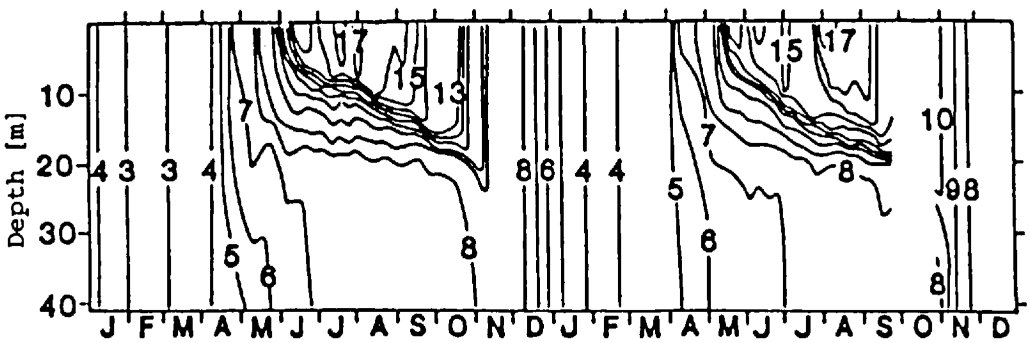


§ Water temperature [°C]

Wray Castle Boathouse, The Ferry House, 1933-1975 (6).

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	4.8	3.9	4.8	7.2	11.1	15.8	17.4	17.3	15.1	11.8	8.4	6.2

Fig. EUR-11-4 Seasonal and vertical distribution of water temperature [°C] (South Basin, 1979-1980) (7).



§ Freezing period : None.

§ Mixing type : Monomictic.

§ Thermocline formation : June-early November.

E. LAKE WATER QUALITY

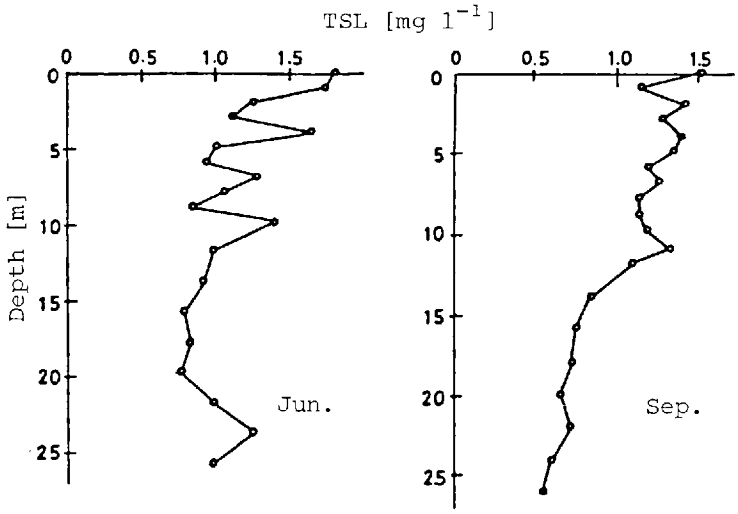
E2 pH

South Basin, 0-10 m, 1974-1977

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.0	7.0	7.0	7.2	7.3	7.3	7.5	8.3	7.3	6.9	6.9	6.9

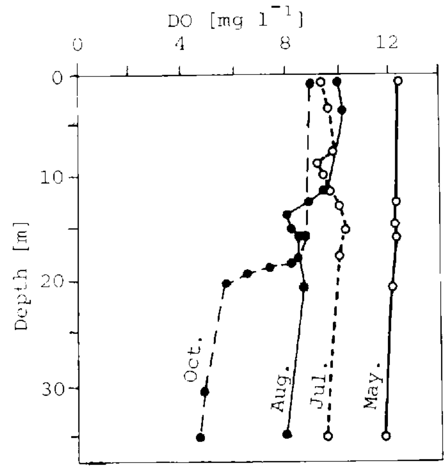
E3 SS

Fig. EUR-11-5 Total suspended load [mg l^{-1}], North Basin, 1980 (9).



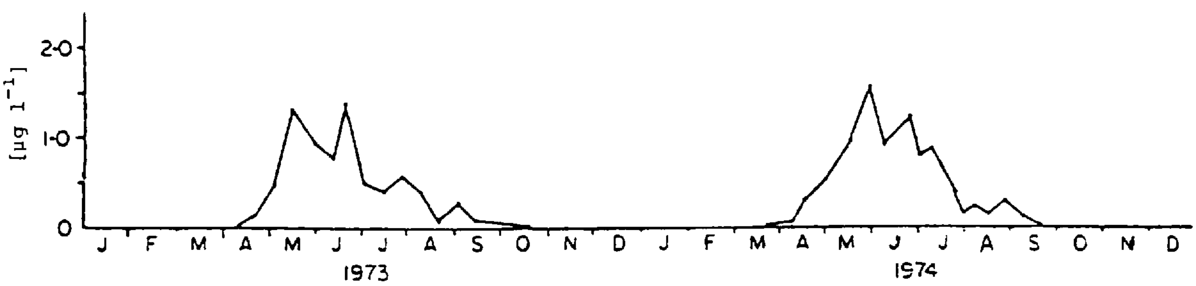
E4 DO

Fig. EUR-11-6 Seasonal trend of DO profile [mg l^{-1}], South Basin, 1979 (10).



E6 CHLOROPHYLL CONCENTRATION

Fig. EUR-11-7 Chlorophyll-a concentration, South Basin, 0.7 m [mg m^{-3}] (10).



E7 NITROGEN CONCENTRATION

Fig. EUR-11-8 NH_4-N and NO_3-N concentrations [$\mu g\ l^{-1}$], South Basin, 0 7 m (10).

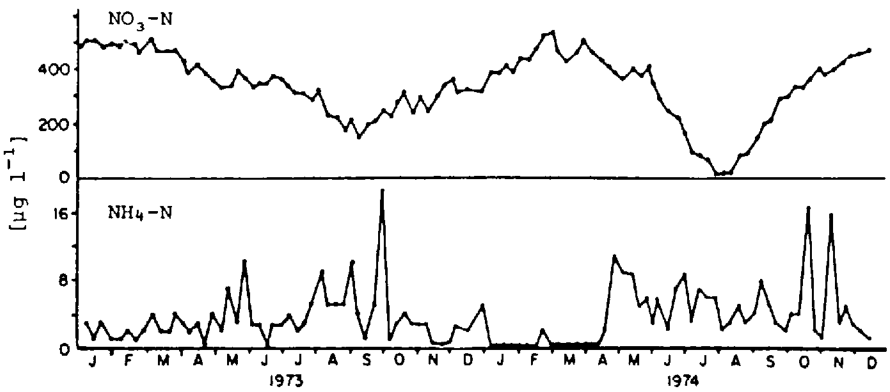
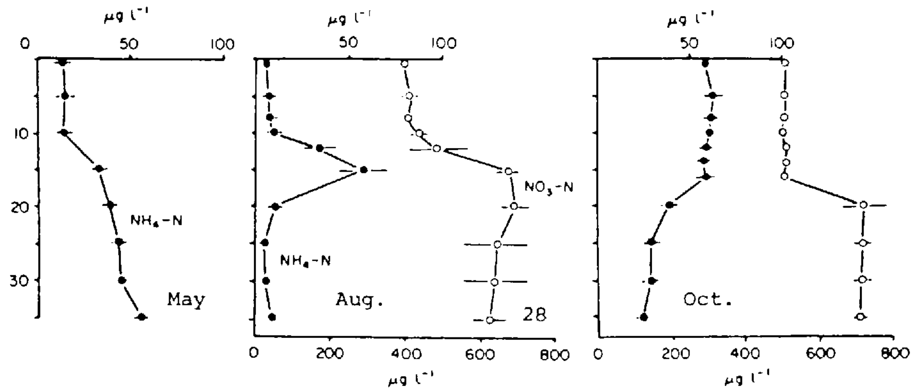


Fig. EUR-11-9 Vertical distribution of N concentrations [$\mu g\ l^{-1}$], South Basin, 1979 (10).



E8 PHOSPHORUS CONCENTRATION

Fig. EUR-11-10 Total-P and SRP concentrations [$\mu g\ l^{-1}$], South Basin, 0-7 m (10).

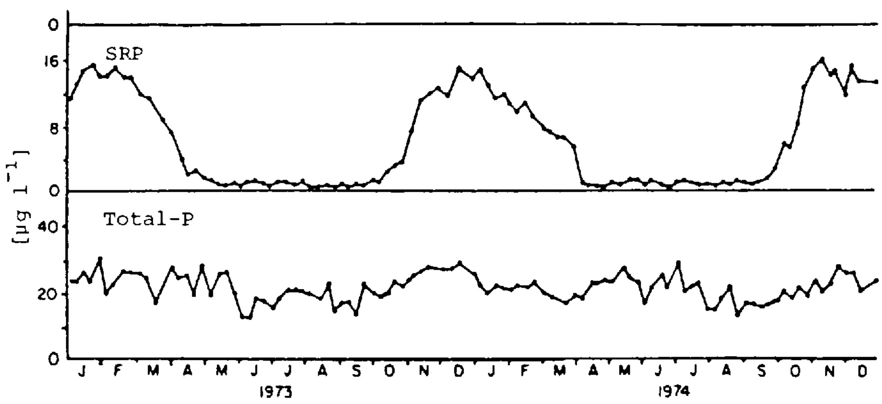
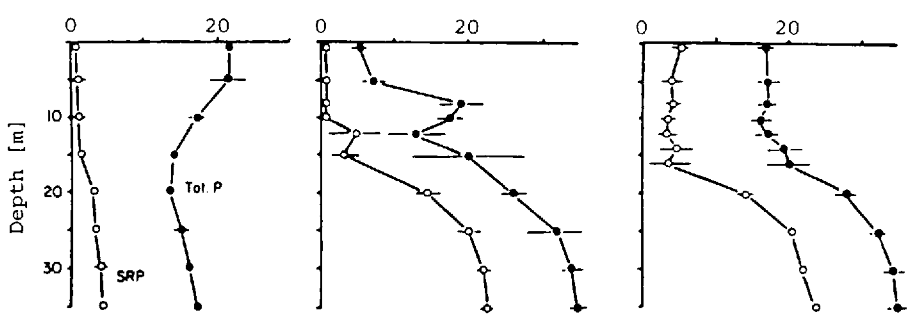
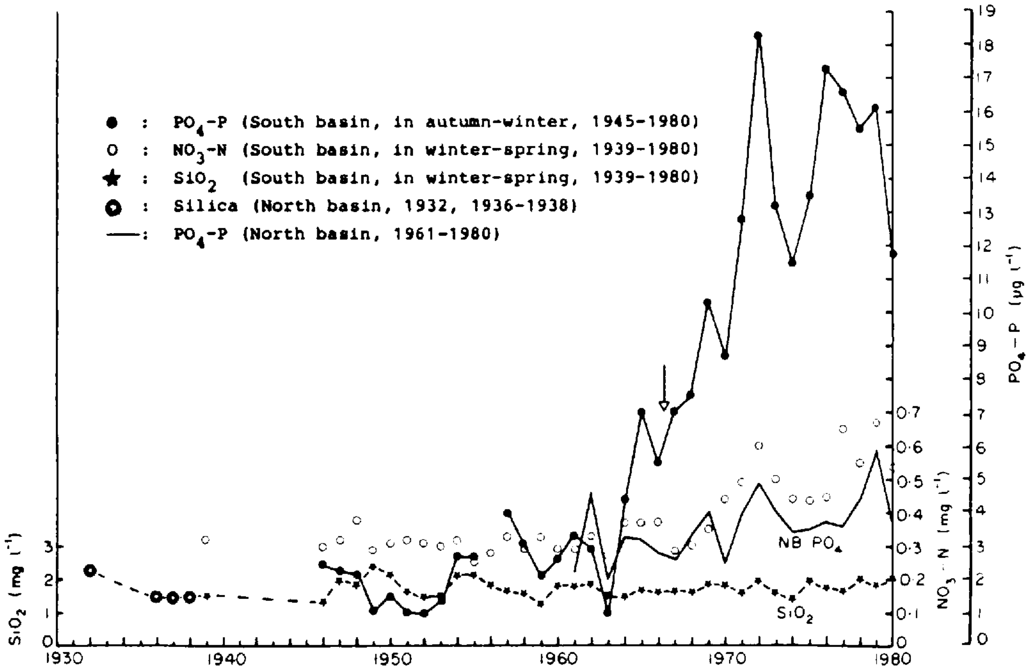


Fig. EUR-11-11 Vertical distribution of P concentrations [$\mu g\ l^{-1}$], South Basin, 1979 (10).



E9 PAST TRENDS

Fig. EUR-11-13 Trends of solutes in the lake water (1).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites australis, Typha angustifolia, Scirpus lacustris, Phalaris arundinacea, Carex elata* (11).

§ Floating macrophytes : *Nymphaea* sp., *Potamogeton natans* (11).

§ Submerged macrophytes : *Potamogeton perfoliatus, P. gramineus, Elodea canadensis, E. nuttalli, Myriophyllum alterniflorum* (11).

§ Phytoplankton : *Asterionella formosa, Cosmarium* spp., *Tabellaria flocculosa, Fragilaria crotonensis, Cyclotella meneghiniana, Oscillatoria limnetica, Melosira italica* (7, 9, 12).

F2 FAUNA

§ Zooplankton : *Cyclops abyssorum, Mesocyclops leuckarti* (13).

§ Benthos : Isopoda (*Ascellus aquaticus*), Platylminthes (*Dendrocoelum lacteum*), Neuroptera (*Sialis lutaria*), Ephemeroptera (*Caenis* sp.), *Crangonyx, Gammarus*, Oligochaetes, Chironomids (14, 15).

§ Fish : *Salvelinus alpinus, Salmo trutta, Anguilla anguilla, Phoxinus phoxinus, Perca fluviatilis, Esox lucius, Salmo salar, Rutilus rutilus, Scardinius eryhrophthaimus, Tinca tinca, Coltus gobio, Noemacheilus barbatulus, Gasterosteus aculeatus* (16).

F4 BIOMASS

Fig. EUR-11-14 Biomass of zooplankton [mg l^{-1}], South Basin (10).

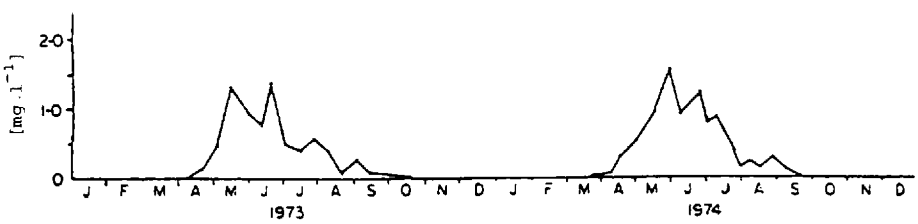
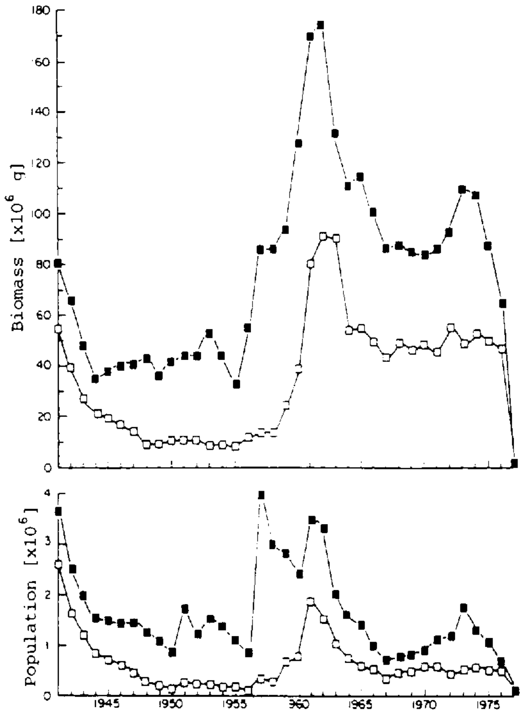


Fig. EUR-11-15 Trends of the biomass and population of perch (17).



N. SOURCES OF DATA

*Printed in Japanese.

(1) Sutcliffe, D. W., Carrick, T. R., Heron, J., Rigg, E., Talling, J. F., Woof, C. & Lund, J. W. G. (1982) Long-term and seasonal changes in the chemical composition of precipitation and surface waters of lakes and tarns in the English Lake District. Freshwater Biol., 12 : 451-506.

(2) Ramsbottom, A. E. (1976) Depth Charts of the Cumbrian Lakes. Freshwater Biological Association Scientific Publications No. 33. 39pp.

(3) Hutchinson, G. E. (1957) A Treatise on Limnology, Vol. 1. Part 1. Geography and Physics of Lakes. John Wiley & Sons, Inc., New York.

(4) Tokyo Astronomical Observatory (ed.) (1986) Chronological Scientific Tables, 1007 pp. Maruzen Co., Tokyo.*

(5) Davison, W., Heaney, S. I., Talling, J. F. & Rigg, E. (1980) Seasonal transformations and movements of iron in a productive English lake with deep-water anoxia. Schweiz. Z. Hydrol., 42 : 196-224.

(6) Kipling, C. & Roscoe, M. E. (1977) Surface Water Temperature of Windermere (1933-1975). Freshwater Biological Association Scientific Publications No. 2. 60pp.

(7) Reynolds, C. S., Marison, H. R. & Butterwick, C. (1982) The sedimentary flux of phytoplankton in the south basin of Windermere. Limnol. Oceanogr., 27 : 1162-1175.

(8) Carrick, T. R. & Sutcliffe D. W. (1982) Concentrations of Major Ions in Lakes and Tarns of the English Lake District (1953-1978). Freshwater Biological Association Scientific Publications No. 16. 170pp.

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(10) George, D. G. (1981) The spatial distribution of nutrients in the South Basin of Windermere. Freshwater Biol., 11 : 405-424.

(11) Stokoe, R. (1983) Aquatic Macrophytes in the Tarns and Lakes of Cumbria. Freshwater Biological Association Scientific Publications No. 18. 60pp.

(12) Reynolds, C. S. (1980) Phytoplankton assemblages and their periodicity in stratifying lake systems. Holarct. Ecol., 3 : 141-159.

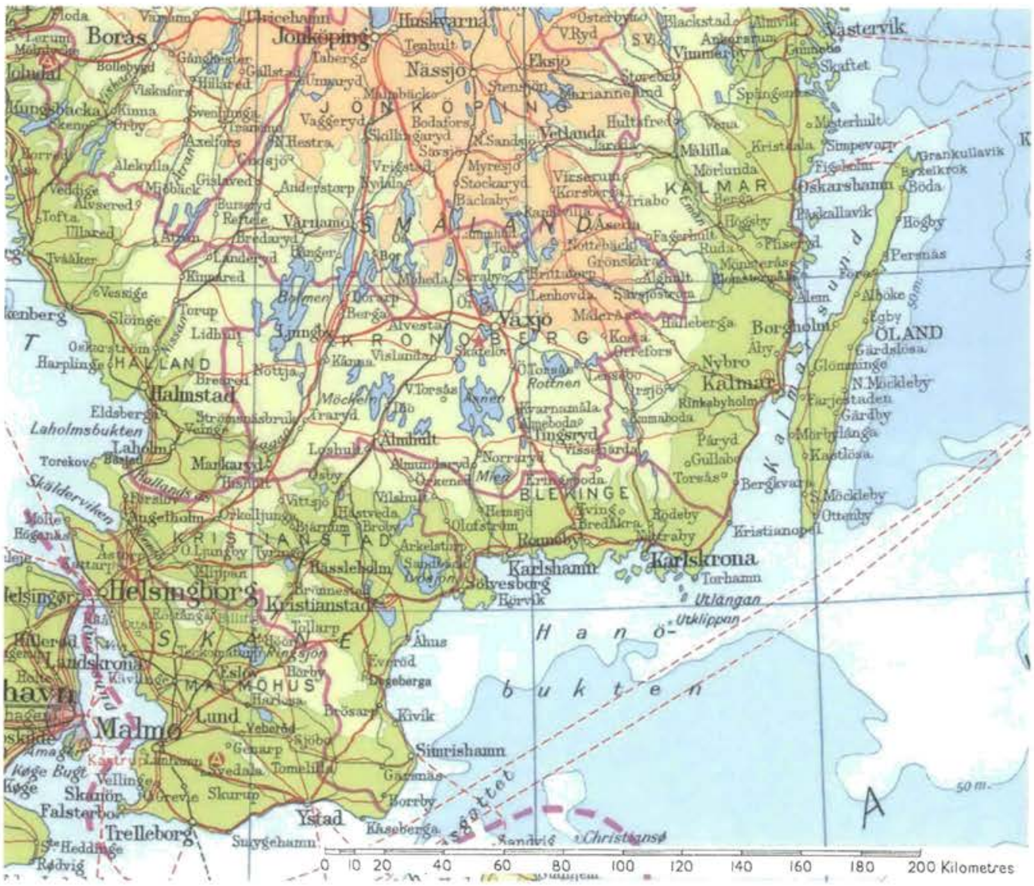
(13) Smyly, W. J. P. (1978) Strategies for co-existence in two limnetic cyclopoid copepods. Verh. Internat. Verein. Limnol., 20 : 2501-2504.

(14) Marcus, J. H., Sutcliffe, D. W. & Willoughby, L. G. (1978) Feeding and growth of *Asellus aquaticus* (Isopoda) on food items from the littoral of Windermere, including green leaves of *Elodea canadensis*. Freshwater Biol., 8 : 505-519.
(15) Macan, T. T. & Silva, P. K. (1979) On the occurrence of *Dendrocoelum lacteum* (Muller) and *Asellus aquaticus* (L.) as predator and prey in the stony substratum of Windermere. Arch. Hydrobiol., 86 : 95-111.
(16) Bagenal, T. B. (1982) Experimental manipulations of the fish populations in Windermere. Hydrobiologia, 86 : 201-205.
(17) Craig, J. F., Kipling, C., Le Cren, E. D. & McCormack, J. C. (1979) Estimates of the numbers, biomass and year-class strengths of perch (*Perca fluviatilis* L.) in Windermere from 1967 to 1977 and some comparisons with earlier years. J. Animal Ecol., 48 : 315-325.

LAKE TRUMMEN

A view from the lakeside hill near Teleborgs Slott.

Photo: A. Kurata



A. LOCATION

§ Växjö, Kronoberg, Sweden.
§ 56°52′N, 14°50′E. ; 161.2 m above sea level.

B. DESCRIPTION

The small lake Trummen is in the city of Växjö in the south Swedish upland. The lake was oligotrophic till the beginning of this century, but the increase of population, domestic sewage and industrial waste water resulted in progressive eutrophication. The intense bloom of blue-green algae was observed annually in the lake. Expanding growth of reeds and killing of fish due to oxygen deficiency proceeded. In 1958 municipal sewerage and industrial waste water were diverted, but without expected effects. A restoration research project was thereafter planned by scientists from the Institute of Limnology of Lund University in cooperation with the Växjö authorities.

Suction dredging, the main part of the restoration project, was carried out in 1970-1971. Approximately 60 cm of FeS-rich black and brown mud was removed from the lake bottom and transfered to specially prepared depositing ponds through pipelines. The depositing ponds covered a total area of 18.5 ha with surrounding embankments about 4.8 km in total length. The total cost, including for preliminary survey, dredging, embankment and other treatments, amounted to 2,575,000 Sw. Kr.

The Trummen project drew world-wide attention, being the first successful example of large-scale restoration of a lake where sediment pumping was employed. The lake is being visited by many administrators and scientists from various parts of the world who are interested in the study of this excellent achievement in applied limnology.

C. PHYSICAL DIMENSIONS

Surface area [km^2]	1
Volume [$10^6 m^3$]	1.26
Maximum depth [m]	2.5
Mean depth [m]	1.6
Water level	Regulated
Length of shoreline [km]	6.6
Residence time [yr]	0.4
Catchment area [km^2]	13

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. EUR-12-1).
§ Main island : Arnö.
§ Outflowing rivers and channels (number and names) : 1 (Vällebäcken R.).

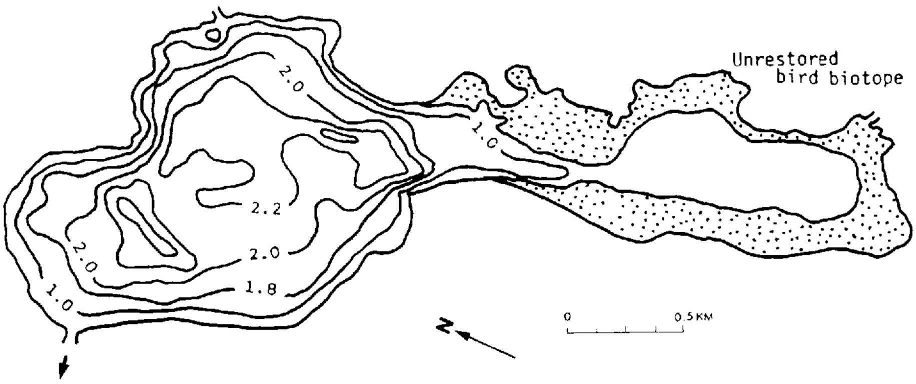
D2 CLIMATIC

§ Climatic data at Kalmar, 1931-1960 (3).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	1.4	-1.6	0.2	4.7	9.5	14.5	17.4	16.7	13.2	8.6	4.3	1.4	7.3
Precipitation [mm]	37	27	25	28	36	36	56	55	47	43	43	38	471

§ Number of hours of bright sunshine (Kalmar, 1931-1960) : 1,833 hr yr^{-1}.

Fig. EUR-12-1 Bathymetric map (1).



§ Water temperature : Mean of the warmest month (July) 16°C ; mean of the coldest month (February) -2°C ; annual mean 6.2°C.
§ Freezing period : From Dec. to Mar., 120 day yr^{-1}.
§ Thermocline formation : Not formed.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], 1970-1976. 0.35-0.85 (4)

1987. 0.3 (Q)

E2 pH, 1972 (4)

Depth [m]	Winter	Spring	Summer	Autumn
Surface	5.6	5.4	6.7	6.5

1987 (Q)
0.5 m 7.5

E4 DO [mg l^{-1}], 1972 (4)

Depth [m]	Winter	Spring	Summer	Autumn
Surface	10.5	8.0	8.0	11.5

E5 COD [mg l^{-1}] 1987 (Q)

Determined by $KMnO_4$ method.
0.5m 17.5

E6 CHLOROPHYLL CONCENTRATION [mg m^{-3}], 1972 (4)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	–	–	–	113	68	43	51	106	58	14	21	–

1987 (Q)
0.5m 91

E7 NITROGEN CONCENTRATION

§ Total-N [mg l^{-1}], 1972 (4)

Winter	Spring	Summer	Autumn
0.87	0.50	0.76	0.54

1987 (Q)
0.5m 1.73

E8 PHOSPHORUS CONCENTRATION

§ Total-P [mg l^{-1}], 1972 (4)

Winter	Spring	Summer	Autumn
0.11	0.09	0.16	0.09

1987 (Q)
0.5m 0.106

E9 PAST TRENDS

Fig. EUR-12-2 Past trend of transparency (1)

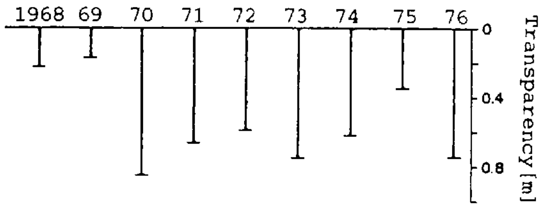


Fig. EUR-12-3 Trend of Total-N and Total-P concentrations in surface water in percentages of the mean values for 1968-1969 (1).

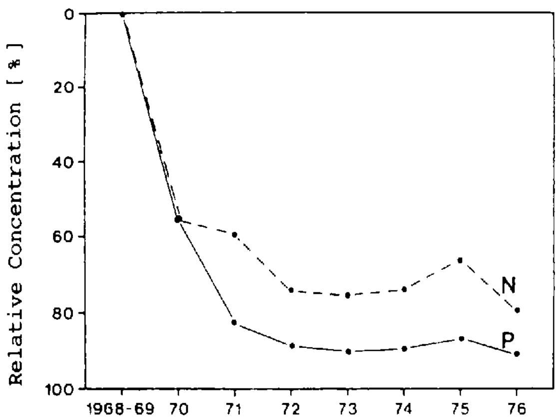
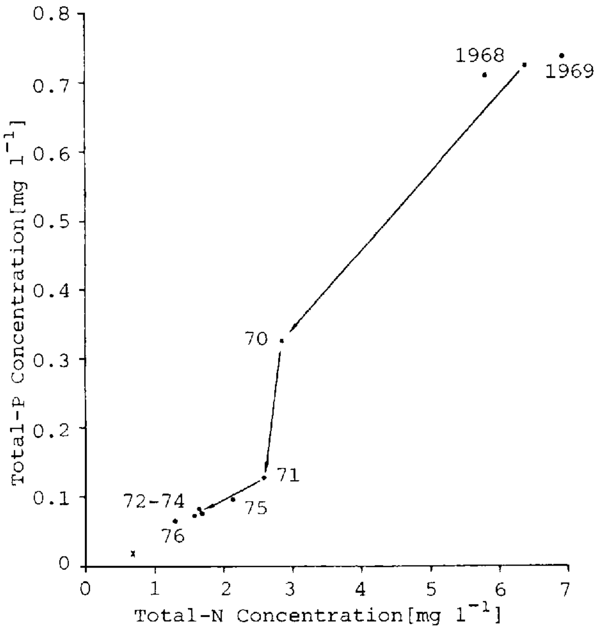


Fig. EUR-12-4 Trend of Total-N/Total-P ratio. The cross mark represents the mean value for 60 lakes in Kronoberg County in 1972 (1).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites communis, Typha latifolia, Juncus bulbosus* (1).

§ Submerged macrophytes : *Potamogeton obtusifolius, Utricularia* sp., *Nitella* sp. (1).

§ Phytoplankton : *Aphanizomenon gracile, Aphanocapsa delicatissima, Oscillatoria limnetica* var. *acicularis, Pediastrum biradiatum, P. angulosum, Staurodesmus* spp., *Closterium* spp., *Teilingia granulata, Dinobryon cylindricum, Mallomonas acarioides striatula, Melosira* spp., *Asterionella formosa, Cyclotella* spp., *Rhizosolenia longiseta* (2).

F2 FAUNA

§ Zooplankton : *Anuraeopsis fissa, Filinia longiseta, Trichocerca pusilla, Chydorus sphaericus, Bosmina longirostris, Keratella cochlearis, K. quadrata* (2).

§ Benthos : Oligochaeta, Chironomidae, Hirudinea, Ephemeroptera, *Anodonta cygnea* (1).
Esox lucius, Perca fluviatilis, Rutilus rutilus, Abramis brama, Blicca bjoerkna (1).

F3 PRIMARY PRODUCTION RATE [mg C m^{-2}day^{-1}], 1972 (4)

Apr	May	Jun	Jul	Aug	Sep
512	880	870	1,911	2,035	1,247

F4 BIOMASS

§ Phytoplankton biomass [mg (fresh wt.) l^{-1}], 1969

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.3	0.6	0.8	6.8	10.2	90.4	29.1	29.0	49.9	16.9	10.7	–

F6 PAST TRENDS

Fig. EUR-12-5 Trend of phytoplankton production. Black: passing through a 10μm mesh net. Shaded: passing through a 45μm mesh net.

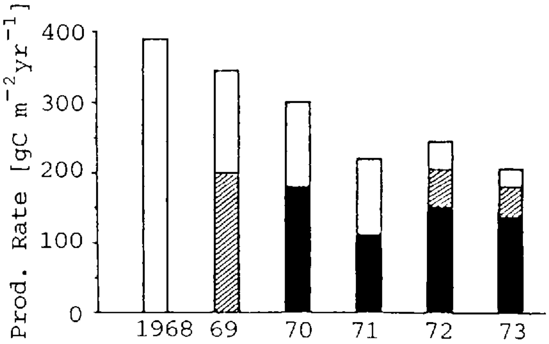
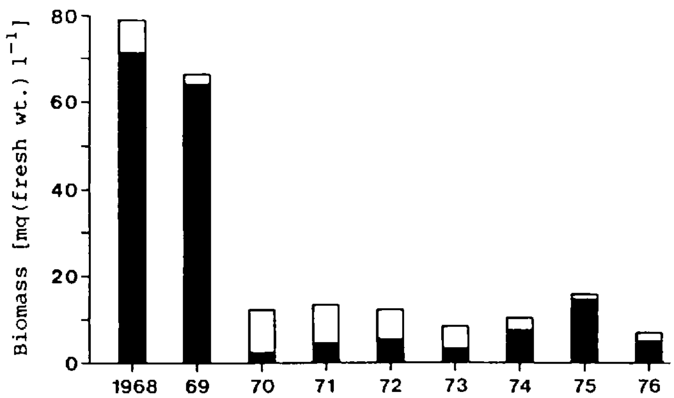


Fig. EUR-12-6 Trend of the weighted mean biomass of total phytoplankton (whole column) and blue-green algae (black column) in summer (15 June-15 September) (1).



F7 NOTES OF THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (1. 2. 5)

§ There was a drastic decrease in phytoplankton biomass from the start of restoration in 1970 and onwards.

§ Before the restoration, blue-green algae were most important in the lake's planktonic community, dominating during summer and forming very dense bloom. In 1970, however, their biomass was reduced to 5% of the pre-restoration value.

§ Improved light conditions have created a colonization of such submerged plants previously not found in the lake as *Potamogeton obtusifolius* and *Nitella*. The mussel, *Anodonta cygnea*, has returned after many years' disappearance.

G. SOCIO-ECONOMIC CONDITIONS

G3 POPULATION IN THE CATCHMENT AREA (Q)

Total population	Population density [km^{-2}]	Main cities (population)
53,000	4,077	Växjö (53,000)

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Fisheries, tourism and recreation (swimming, sport-fishing, yachting), bird-watching.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : None.

I2 TOXIC CONTAMINATION

§ Present status : None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication :

Unusual algal bloom (*Anabaena, Microcystis*) in 1940-1970.
Foul smell of tap water in 1940-1970.
Harms on fish in 1940-1970.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTRATION

A 0.6 m thick layer of bottom sediment rich in FeS was removed by suction dredging in 1970-1971.

K2 AERATION

The sewage effluent into the lake was diverted in 1957-1958, but was not effective to inhibit plankton blooms.

K3 OTHERS

As the result of the dredging and removal of the main part of macrophyte vegetation, the lake ecosystem changed drastically. Concentrations of P and N were reduced by 90% and 70%, and phytoplankton biomass by 85-90%.

N. SOURSES OF DATA

(Q) Questionnaire filled by Anna Tolstoy, Laboratoriet för miljökontroll, Statens Naturvårdsverk, Sweden.

(1) Länsstyrelsen i Kronobergs Län & Växjö Kommun (ed.) (1977) Sjön Trummen i Växjö; Förstörd-Restaurerad-Pånyttfödd. 32 pp. Växjö.

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LAKE CHILWA

A view at the shore

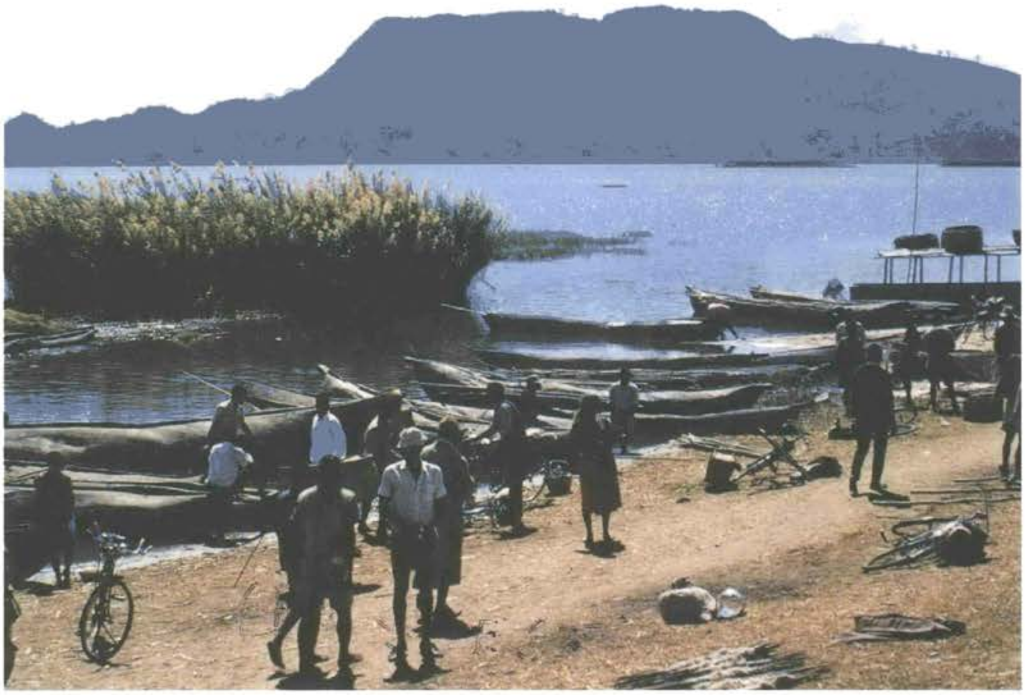
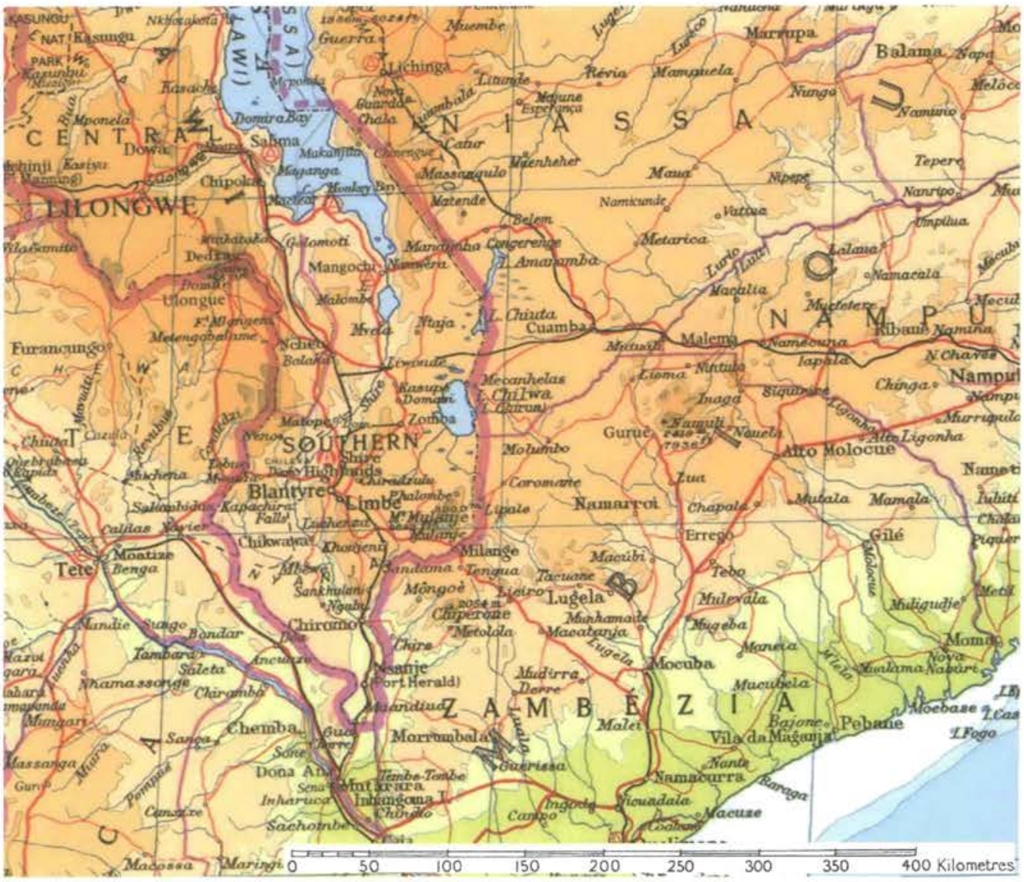


Photo: C. Howard-Williams



A. LOCATION

§ Southern, Malawi, and Niassa, Mozambique.
§ 15°20′S, 35°40′E ; 622 m above sea level.

B. DESCRIPTION

Lake Chilwa (sometimes called Shilwa) is a shallow lake (maximum depth 2.7 m) on the border between Malawi and Mozambique in the southeastern part of the African continent. The water surface measures 1,750 km^2. Being in a tectonic depression south of L. Niassa, at the southern end of the Great Rift Valley, it lacks an outflowing stream ; thus the water level fluctuates widely due to the balance between rainfall and evaporation. Four steps of lacustrine terraces encircle the lake and indicate its development history. In the age when the highest terrace, now at an altitude of 650 m, was formed, the lake may have been nearly three times as large its present size, being then connected with the Indian Ocean by an outlet river.

The northern half of the lake is now fringed by a vast area of swampy vegetation dominated by a species of cattail, *Typha domingensis*, while alkaline mud deposits are found along the southernmost part. The drainage basin, with abundant production of rice, tobacco, groundnut and other crops, supports a population of about 400,000 people. Fishery is extensively carried on in the lake with an annual catch of some 20,000 tons.

C. PHYSICAL DIMENSIONS (1, 2)

Surface area [km^2]*	ca. 1,750
Volume [10^9m^3]	ca. 1.8
Maximum depth [m]	ca. 2.7
Mean depth [m]	ca. 1.0
Normal range of annual water level fluctuation (unregulated) [m]	5 -10
Length of shoreline [km]	ca. 200
Catchment area [km^2]	7,500

* Including swamp area ; open water area ca. 600 km^2.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. AFR-1-1).

§ Outflowing rivers and channels : None (1).

D2 CLIMATIC

§ Climatic data near the lake (1961-1971) (1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. *1 [°C]	27	26	25	24	22	20	19	21	23	26	27	28	26
Precipitation *2 [mm]	320	201	157	46	26	6	1	2	2	13	79	205	1,058

*1 : At Khanda, 10 km west of the lake.

*2 : At Mpyupyu Prison Farm, 15 km west of the lake.

§ Number of hours of bright sunshine (Makoka, 45 km west of the lake, 1965 1976) : 2,612 hr yr^{-1}.

§ Solar radiation (Khanda, 1967-1971) : 22.9 MJ $m^{-2}day^{-1}$.

Fig. AFR-1-1 Bathymetric map (1, after McLachlan et al., 1972).

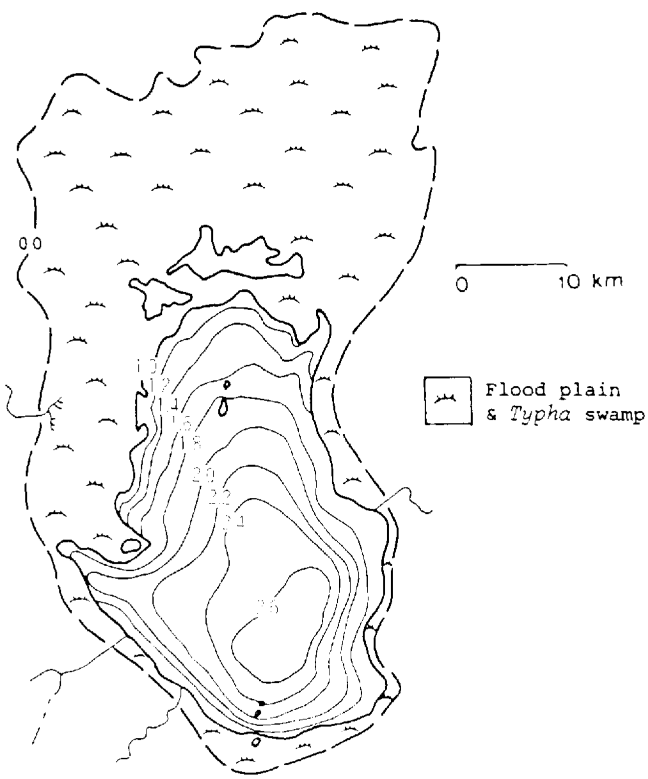
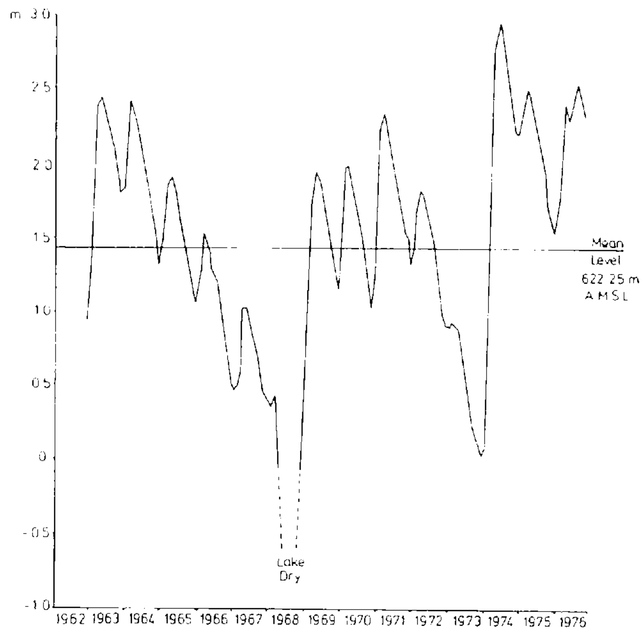


Fig. AFR-I-2 Mean monthly water levels at Kachulu (1).



§ Water temperature (3)

Cooler months (Jun.-Aug.): ca. 20 °C.
Hot dry months (Apr.-May, Sep.-Nov.): 25-30 °C.
Hot wet months (Dec.-Mar.): Frequently above 30 °C.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], 1970 (4)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.06	0.08	0.04	0.04	0.07	0.07	0.08	0.07	0.07	0.06	0.09	0.11

E2 pH, 1970 (4)

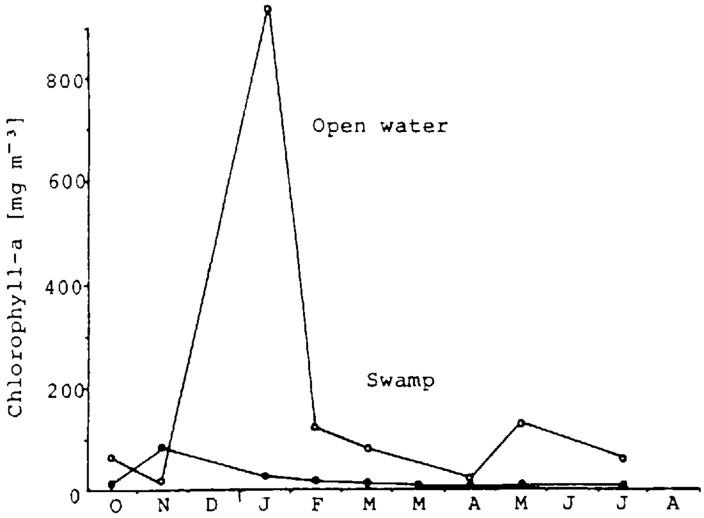
Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	8.5	8.2	8.5	8.6	8.7	8.6	8.6	8.7	8.7	8.8	8.8	8.8

E4 DO [mg l^{-1}], 1970 (4)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Surface	4.2	5.6	6.4	7.4	7.1	7.8	10.0	8.5	8.3	7.7	7.6

E6 CHLOROPHYLL CONCENTRATION

Fig. AFR-1-3 Seasonal change of chlorophyll-a (Oct. 1971–Aug. 1972) (5).



E7 NITROGEN CONCENTRATION

§ NO_3-N [mg l^{-1}]*, 1970 (4)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.03	–	–	–	–		–	0.04	0.11	0.03	0.13	0.08

* Converted from the original determination of NO_3^-.

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l^{-1}]*, 1970 (4)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.66	1.21	1.14	1.27	0.95	1.08	1.01	1.31		2.09	2.22	1.70

* Converted from the original determination of PO_4^{3-}.

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Typha domingensis*, *Aeschynomene pfundii*, *Cyperus alopecuroides*, *Vossia cuspidata* (6).

§ Floating macrophytes : *Nymphaea caerulea*, *Pistia stratiotes*.

§ Submerged macrophytes : *Ceratophyllum demersum*, *Utricularia* spp. (6).

§ Phytoplankton : *Oscillatoria* sp., *Trachelomonas* spp., *Euglena spirogyra*, *Phacus* sp., *Cyclotella* sp., *Nitzschia* sp., *Anabaena* sp., *Scenedesmus quadricauda*, *Peridinium* sp. (7).

F2 FAUNA

§ Zooplankton : *Diaphanosoma excisum*, *Tropodiatomus kraepelini*, *Daphnia barbata*, *Moina micrura Ceriodaphnia cornuta*, *Mesocyclops leukarti* (8).

§ Benthos : *Nilodrum brevibucca*, *N. brevipalpis*, *Ecnomus* sp., *Dipseudopsis* sp., *Lanistes ovum*, *Bulinus globosus*, *Biomphalaria* sp. (9).

§ Fish : *Barbus paludinosus*, *Clarias gariepinus*, *Sarotherodon shiranus chilwae*, *Haplochromis callipterus*, *Hemigrammopetersius barnardi* (10).

F3 PRIMARY PRODUCTION RATE

§ Net shoot production by *Typha* in littoral swamp (4)

Shoot biomass (max.-min) : 2,537-1,122 g (dry wt.) m^{-2}.

Net shoot production rate: 1,580 g $m^{-2}yr^{-1}$.

Whole lake production rate: 0.8×10^6 t yr^{-1}.

These productivity estimates are based on Kvet's (1971) study on *Typha angustifolia* of central Europe, and may be seriously underestimated for tropical conditions.

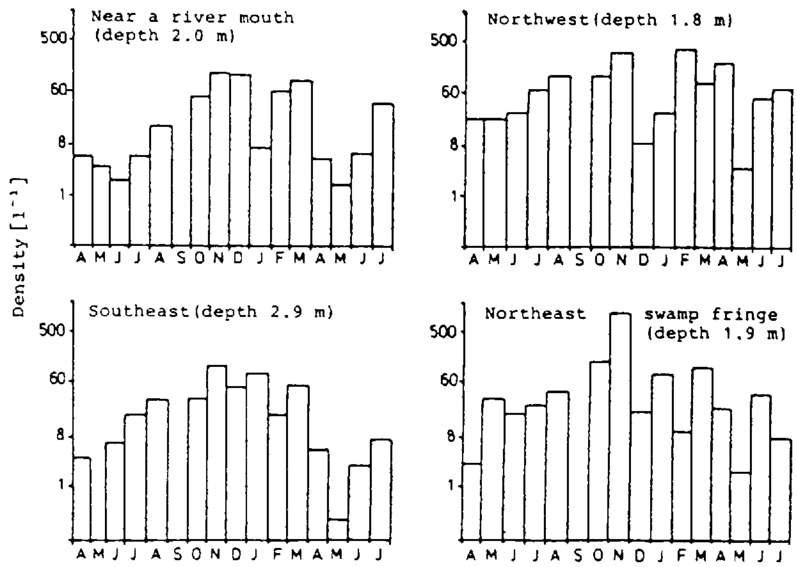
F4 BIOMASS

§ Biomass and population density of epipelic algae in the drying phase (7).

	18 Dec. 1967	3 Jan. 1968	9 Jan. 1968
Biomass [mg (chlorophyll-a) m^{-2}]	15.5	17.4	56.5
Population density*[cm^{-2}]	–	0.9×10^6	6.5×10^6

* Blue-green algae almost 100 %.

Fig. AFR-I-4 Population density of total zooplankton (Apr. 1975-Jun. 1976) (8).



§ Approximate animal biomass (dry weight) in three main benthic habitats during the recovery phase (9).

	Biomass [mg m^{-2}]	Area of habitat [km^2]	Whole lake biomass [kg]
Permanent swamp	300	600	180,000
Temporary swamp	4,000	80	320,000
Mud of lake bed	3,000	100	300,000
Total	7,300	780	569,400

F5 FISHERY PRODUCTS

§ Annual fish catch in 1977: 21,342 [metric tons] (11).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (12)

§ Main kinds of crop plants: Rice (seasonally inundated land), tobacco, groundnut (on higher ground), cotton, maize, millet, cassava, bean, pea, vegetables and fruits.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (11, 12)

§ Main products and main kinds of industry

Agricultural products: Rice, groundnut and tobacco (main cash crops); cotton, bean, pea, cassava, vegetables, fruits and cattle.

Fisheries products : *Barbus* (48 % of total catch, 1977), *Claris* (30 %), *Sarotheradon* (12 %) and others (10 %).

Forestry : Pine (*Pinus patula*) and eucalypt plantations.

Manufacturing : Ship-building (plank boat for fisheries), lumbering, leather and pottery industry.

G3 POPULATION IN THE CATCHMENT AREA (1977) (12, 13)

Total population	Population density [km⁻²]	Main cities (population)
382,900	51.1	Zomba (20,000)

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (11)

Fisheries.

N. SOURCES OF DATA

(1) Lancaster, N. (1979) The physical environment of Lake Chilwa. "Lake Chilwa" (ed. Kalk, M., McLachlan, A. J. & Howard-Williams, C.), pp. 17-39. Dr. W. Junk Publishers, The Hague.

(2) Agnew, S. (1979) The people and the land. Ibid., pp. 309-342.

(3) Beadle, L. C. (1981) The Inland Waters of Tropical Africa, p. 358. Longman Group Ltd., London.

(4) McLachlan, A. J. (1979) The aquatic environment, chemical and physical characteristics of Lake Chilwa. "Lake Chilwa" (ed. Kalk, M., McLachlan, A. J. & Howard-Williams, C.), pp. 59-78.

(5) Howard-Williams, C. (1979) Interactions between swamp and lake. Ibid., pp. 231-245.

(6) Howard-Williams, C. (1979) The distribution of aquatic macrophytes in Lake Chilwa ; annual and long-term environmental fluctuations. Ibid., pp. 107-122.

(7) Moss, B. (1979) Algae in Lake Chilwa and the waters of its catchment area. Ibid., pp. 93-103.

(8) Kalk, M. (1979) Zooplankton in Lake Chilwa : adaptations to changes. Ibid., pp. 123-141.

(9) McLachlan, A. J. (1979) Decline and recovery of the bentic invertebrate communities. Ibid., pp. 143-160.

(10) Furse, M. T., Kirk, R. C., Morgan, P. R. & Tweddle, D. (1979) Fishes : distribution and biology in relation to changes. Ibid., pp. 175-208.

(11) Furse, M. T., Morgan, P. R. & Kalk, M. (1979) The fisheries of Lake Chilwa. Ibid., pp. 209-229.

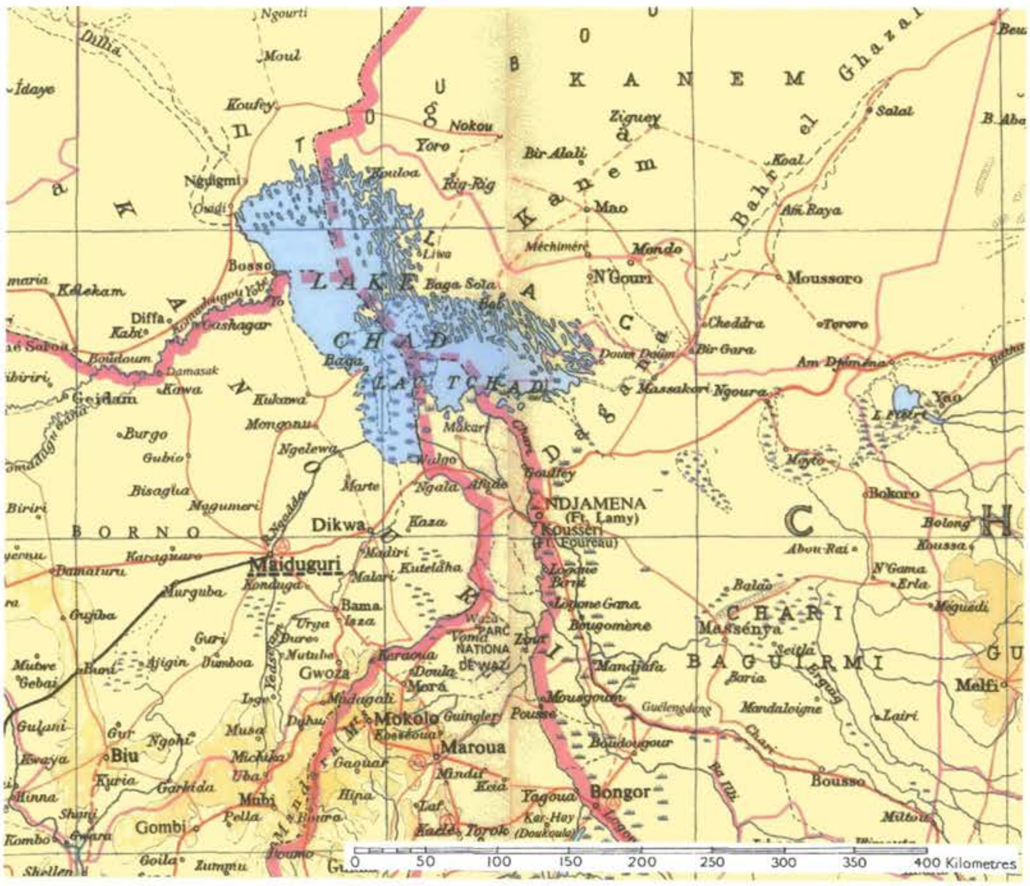
(12) Agnew, S. (1979) Fishing and fish trading ; socio-economic studies. Ibid., pp. 345-368.

(13) Kalk, M. (1979) Focus on social problems. Ibid., pp. 419-432.

LAKE CHAD

A tour boat on the lake

Photo: N. Hata



A. LOCATION

§ Lac and Chari Baguirmi, Chad ; Nord, Cameroon ; Borno, Nigeria ; Diffa, Niger.
§ 12°20′-14°20′N, 13°00′-15°20′E ; 280m above sea level.

B. DESCRIPTION

Being on the southern fringe of the Sahara Desert in north-central Africa, Lake Chad extends over the territories of four countries : Chad, Niger, Nigeria and Cameroon. Owing to the supply of river water from the highlands to the south, it remains a freshwater lake under the prevailing arid climate. Apparently no river flows out from the lake, though some water is said to percolate along the dry bed of the Gazal River to feed the oases of the Bodélé Depression about 40 km to the northeast.

The water level is variable as it is influenced by the rainfall fluctuation both seasonally and annually. The lake size was five times its present size (ca. 20,000 km^2) several thousand year ago, while the drought years in the 1970's made the northern half of the lake (Northern Basin) completely dry and turned the Southern Basin into a densely vegetated area with scattered swamps and open pools (Fig. AFR-2-1).

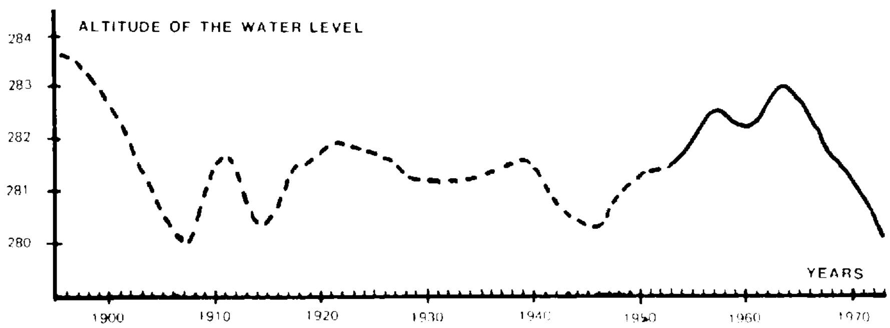
L. Chad is very shallow even in normal years, averaging 1.5 m in depth. It is fringed by a zone of swampy vegetation dominated by reeds (*Phragmites* spp.), papyrus (*Cyperus papyrus*) and cattail (*Typha australis*). These water plants often form dense thickets or floating mats even in the lake center. Local inhabitants use the stems of papyrus as material for canoe making. There are many small islands formed by the invasion of moving sand dunes near the northeastern coast ; some of them are inhabited and utilized as bases for fishing.

Besides the products of agriculture, livestock grazing and fishery, the drainage basin of L. Chad is known for its yield of natural soda , an activity that contributes to keeping the lake water fresh (Q2).

C. PHYSICAL DIMENSIONS (Q1, Q2)

Surface area [km^2]	10,000-25,000
Volume [10^9m^3]	72
Maximum depth [m]	10 11
Mean depth [m]	4-8 (N. Basin) 2-4 (S. Basin)
Normal range of annual water level fluctuation (unregulated) [m]	1
Length of shoreline [km]	500 800
Residence time [yr]	2 (N. Basin) 0.5 (S. Basin)
Catchment area [km^2]	2,426,370

Fig. AFR-2-1 Past trend of lake water level [m a.s.l.] (3).



D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. AFR-2-2).
§ Main islands : Kindjera, Kalom, Kofia, Kika, Dabouroum, Tebour, Ngelea, Isseirom, Malal (Q2).
§ Outflowing rivers and channels (number and names) : 1 (Bahr el Gazal ; drainage only occasional) (Q2).

D2 CLIMATIC

§ Climatic data at Bol Dune (Q2).

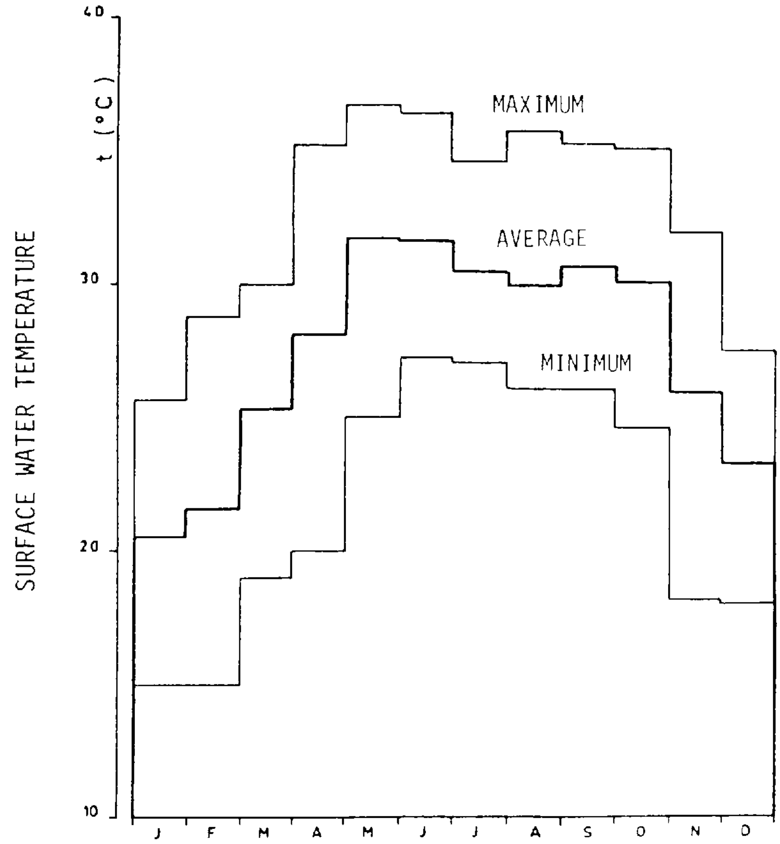
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C] (13-year average)	14.0	15.1	19.4	24.2	25.9	26.6	25.3	24.2	24.7	22.6	18.4	14.6	21.3
Precipitation [mm] (28-year average)	0	0	0	1	12	18	76	210	56	12	0	0	384

§ Number of hours of bright sunshine (Bol Dune, 3-year mean) : 3402.2 hr yr^{-1}.
§ Solar radiation : 22.6 MJ m^{-2} day^{-1}.

Fig. AFR-2-2 Bathymetric map (1).

§ Water temperature

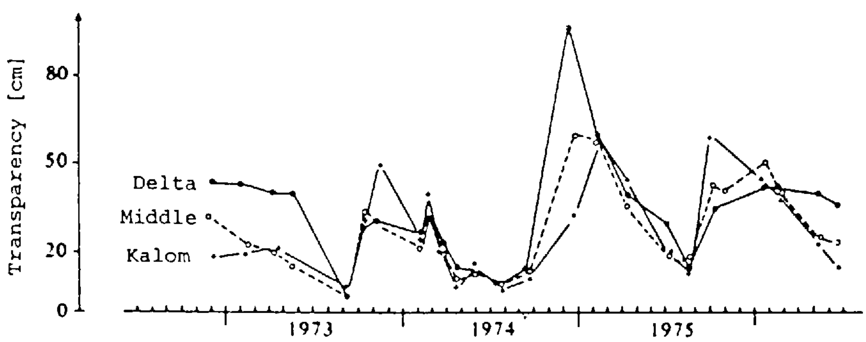
Fig. AFR-2-3 Seasonal trend of surface water temperature [C], Bol-Île, 1956 1960 (Q1).



E. LAKE WATER QUALITY

E1 TRASPAPENCY

Fig. AFR-2-4 Trend of transparency, Southern Basin (3).



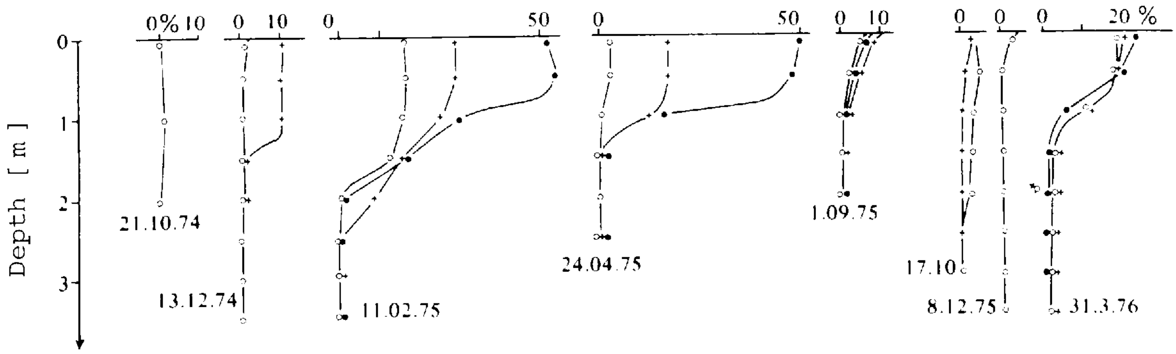
E2 pH

Southern Basin, 1976 (3)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	7.2	7.2	–	–	7.5	7.5	–	7.7	–	7.7	–	7.9

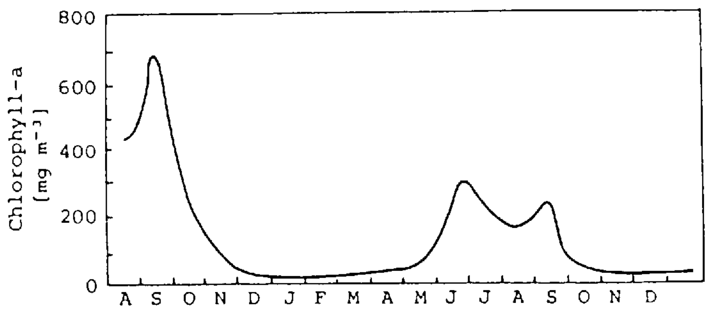
E4 DO

Fig. AFR-2-5 Changes in DO percent saturation, Southern Basin (3).



E6 CHLOROPHYLL CONCENTRATION

Fig. AFR-2-6 Seasonal change of chlorophyll-a, Southern Basin, 1973-1974 (4).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Phragmites australis* subsp. *altissimus, Typha australis, Vossia cuspidata, Cyperus papyrus, C. laevigatus, Leersia hexandra, Echinochloa* sp. (5).

§ Floating macrophytes : *Pistia stratiotes, Lemna perpusillla, Spirodela polyrhiza, Azolla africana, Nymphaea* spp., *Ipomoea aquatica, Neptunia oleracea* (5).

§ Submerged macrophytes : *Potamogeton* spp., *Vallisneria* sp., *Ceratophyllum demersum, Utricularia* spp. (5).

§ Phytoplankton : *Closterium aciculare, Pediastrum, Botryococcus, Mycrocystis, Anabaena, Melosira granulata, Surirella muelleri* (6).

F2 FAUNA

§ Zooplankton : *Diaphanosoma excisum, Daphnia barbata, Ceriodaphnia cornuta, Moina micrura, Bosmina longirostris, Tropodiaptomus incognitus, Thermocyclops neglectus, T. incisus circusi, Mesocyclops leuckarti* (4).

§ Benthos : Insecta (*Gyptochironomus stilifer, Cloeon fraudu lentum*), Oligochaeta (*Alluroides tanganikae*), Nematoda, Mollusca (*Cleopatra bulimoides, Corbicula africana*) (7).

§ Fish : *Schilbe* spp., *Citharinus citharus, C. distichodoides, Labeo coubie, Alestes* spp., *Synodontis* spp., *Tilapia* spp., *Heterotis niloticus* (6).

F3 PRIMARY PRODUCTION RATE

§ Biological production in four main natural regions [kg ha^{-1} yr^{-1}] (2)

<table>
<tr><th rowspan="2"></th><th colspan="2">South Basin</th><th colspan="2">North Basin</th></tr>
<tr><th>Open water</th><th>Archipelago</th><th>Open water</th><th>Archipelago</th></tr>
<tr><td>Phytoplankton (gross production)</td><td colspan="4">18,000</td></tr>
<tr><td>Copepoda</td><td>159</td><td>438</td><td colspan="2">792</td></tr>
<tr><td>Mollusca</td><td>77</td><td>30</td><td>353</td><td>136</td></tr>
</table>

F4 BIOMASS

§ Biomass in four main natural regions [kg (dry wt.) ha^{-1}] (2)

<table>
<tr><th rowspan="2"></th><th colspan="2">South Basin</th><th colspan="2">North Basin</th></tr>
<tr><th>Open water</th><th>Archipelago</th><th>Open water</th><th>Archipelago</th></tr>
<tr><td>Phytoplankton</td><td>0.09</td><td>4.13</td><td>3.84</td><td>7.28</td></tr>
<tr><td>Macrophytes</td><td colspan="4">11,000</td></tr>
<tr><td>Zooplankton</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Copepoda</td><td>2.5</td><td>6.9</td><td colspan="2">8.9</td></tr>
<tr><td>Benthos</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Molluscs</td><td>25.8</td><td>10.6</td><td>64.2</td><td>33.6</td></tr>
<tr><td>Worms</td><td>2.0</td><td>0.8</td><td>8.0</td><td>1.8</td></tr>
<tr><td>Insects</td><td>0.1</td><td>0.6</td><td>2.1</td><td>1.8</td></tr>
</table>

F5 FISHERY PRODUCTS

§ Annual fish catch in 1972 : 130–141 $\times 10^3$ [metric tons] (Q2).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (Q2)

§ Main types of woody vegetation : Savannah, mountain and accacia, forests especially on the watersheds of main river basins.

§ Main types of herbaceous vegetation : Swamps of sedges on banks of lake and estuaries of main rivers ; also floating *Pistia* on the lake.

§ Types of other important vegetation : Occasional palm clumps of *Borassus*, *Hyphaene thebaica* and date.

§ Main kinds of crops and/or cropping systems : Millet, sorghum, maize, rice, onions, tomatoes ; mixed cropping and market gardening.

§ Levels of fertilizer application on crop fields : Moderate.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (Q2)

§ Main products and main kinds of industry

Agriculture : Cotton, groundnut, cassava and millet.

Fisheries : *Alestes baremoze* and *A. dentex*.

Manufacturing : Cotton spinning, brewing, leather industry, machinery, milling and food industry.

Mining : Soda.

G3 POPULATION IN THE CATCHMENT AREA (Q2)

§ Total population : N. A.
§ Main cities (population) : N'Djamena (400,000), Kano, Maiduguri, Maroua.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q2)

Navigation and transportation, fisheries.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES (Q2)

(1) Lake Chad Basin Commission (L. C. B. C.), N' Djamena
(2) Lake Chad Research Institute (L. C. R. I.), Maiduguri

N. SOURCES OF INFORMATION

(Q1) Questionnaire filled by Mr. Olusegun C. Irivboje, Water Resources Section, Lake Chad Basin Commission, N'Djamena.

(Q2) Questionnare filled by Dr. M. Nakashima, International Development Center of Japan, Tôkyô.

(1) Carmouze, J.-P. & Lemoalle, J. (1983) The laucustrine environment. "Lake Chad" (ed. Carmouze, J.-P., Durand, J.-R. & Lévêque, C.), pp. 27-64. Dr. W. Junk Publishers, The Hague.

(2) Carmouze, J.-P., Durand, J.-R., & Lévêque C. (1983) The laucustrine ecosystem during the "Normal Chad" period and the drying phase. Ibid., pp. 527-560.

(3) Carmouze, J.-P., Chantraine, J. M. & Lemoalle, J. (1983) Physical and chemical characteristics of the waters. Ibid., pp. 65-94.

(4) Saint-Jean, L. (1983) The zooplankton. Ibid., pp. 199-232.

(5) Iltis, A. & Lemoalle, J. (1983) The aquatic vegetation of Lake Chad. Ibid., pp. 125-143.

(6) Serruya, C. & Pollinger, V. (1983) Lakes of the Warm Belt. 569pp. Cambridge University Press, Cambridge.

(7) Lévêque, C., Dejoux, C. & Lauzanne, L. (1983) The benthic fauna ; ecology, biomass and communities. "Lake Chad" (see above), pp. 233-272.

LAKE SIBAYA

Fishing on the shore

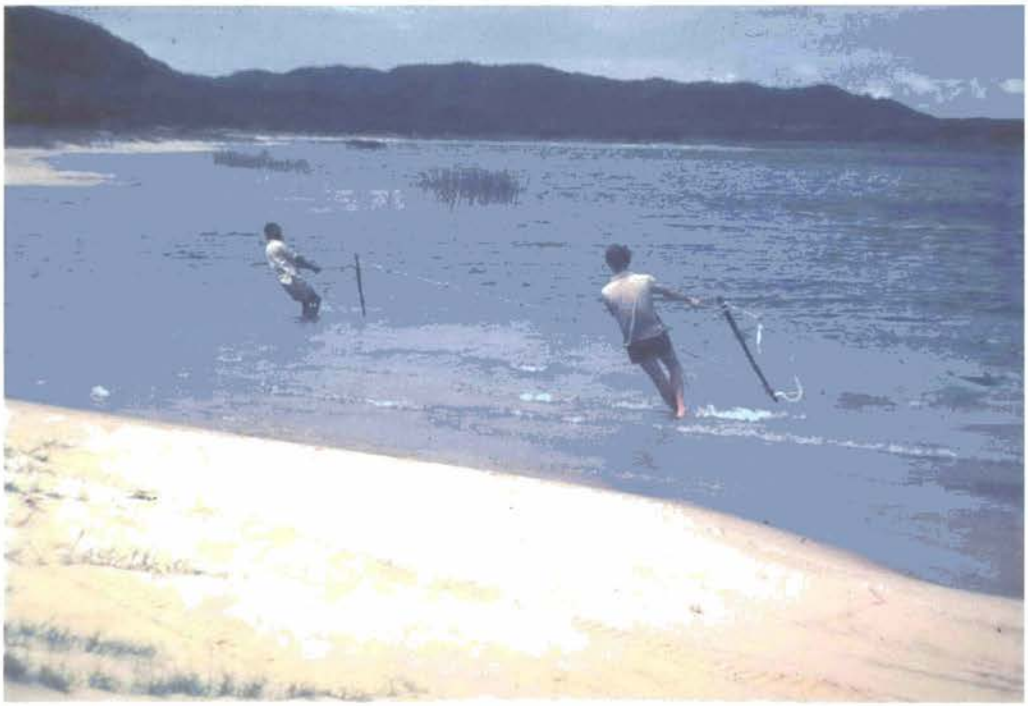


Photo: Department of Environment Affairs and Fisheries, The Republic of South Africa

A. LOCATION

§ Natal, South Africa.
§ 27°20′S, 32°20′E ; 23.35 m above sea level.

B. DESCRIPTION

Lake Sibaya is situated on the coast of the Indian Ocean in Natal Province, South Africa, near the boundary of Mozambique. The lake is surrounded by indented shorelines and has two elongated bays extending to the north and west. The surface area and mean depth are 77.5 km^2 and 12.6 m. It is separated from the sea by coastal dunes only 2 km in width, and was presumably derived from an old lagoon which later became isolated by sand deposition. The water level is now 23 m above the sea surface, and fluctuates widely depending on rainfall and evaporation, because of the lack of outflowing rivers.

L. Sibaya and its surrounding area are known for the wealth of fauna containing not a few rare species and more than 200 species of birds, hippopotamus, crocodile, etc. Some 1,500 inhabitants on the lake coast live on agriculture and fishery, keeping traditional ways of fishing. Fishery products are partly exported to the other districts.

In the drainage basin, natural forests still survive mainly on sand dunes, but have been destroyed steadily owing to firewood harvest and clearing for agriculture. On the north and south sides of the lake, on the other hand, plantations of eucalypt and pine are expanding partly for use as pulp wood (1, 2, 9).

C. PHYSICAL DIMENSIONS (1, 2)

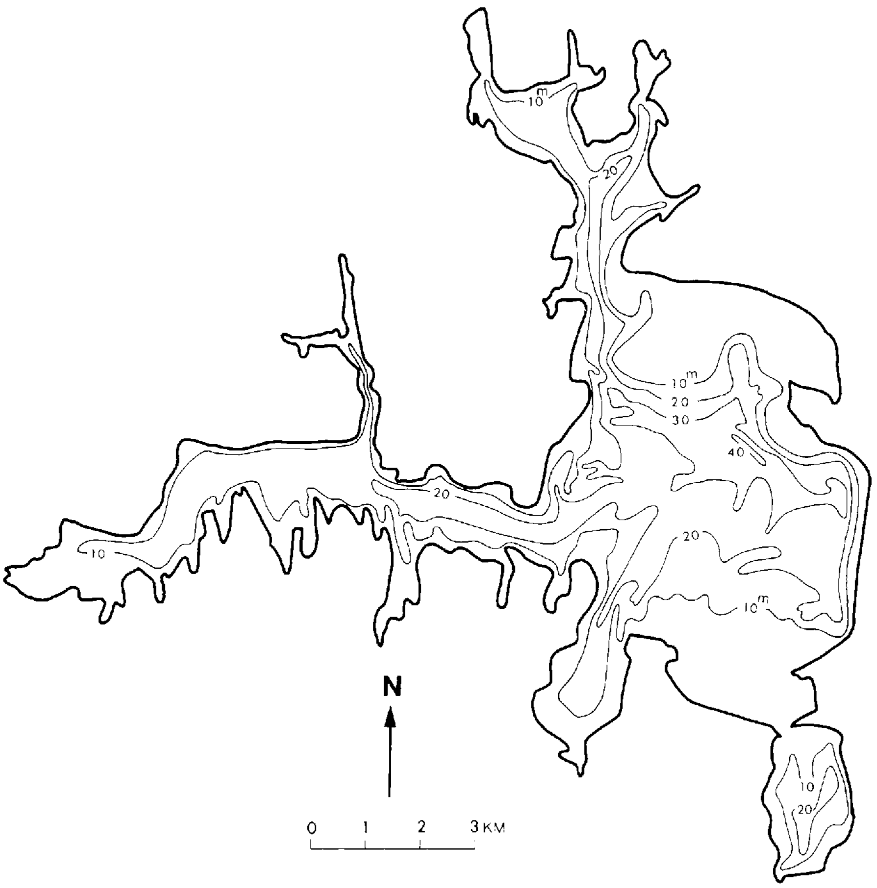
Surface area [km^2]	77.5
Volume [$10^6 m^3$]	981
Maximum depth [m]	43.0
Mean depth [m]	12.6
Water level	Unregulated
Length of shoreline [km]	126.9
Catchment area [km^2]	465

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (1)

§ Bathymetric map (Fig. AFR-3-1).
§ Main islands : None.
§ Outflowing rivers and channels : None.

Fig. AFR-3-1 Bathymetric map (1).



D2 CLIMATIC

§ Climatic data at Maputo*, 1931-1960 (3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	25.4	25.5	24.6	23.1	20.6	18.5	18.2	19.2	20.6	22.2	23.4	24.7	22.2
Precipitation [mm]	130	124	97	64	28	27	13	13	38	46	86	103	768

* About 150 km north of the lake.

§ Number of hours of bright sunshine : 2,748 hr yr^{-1} (3).

Fig. AFR-3-2 The mean monthly air temperature [°C] (4).

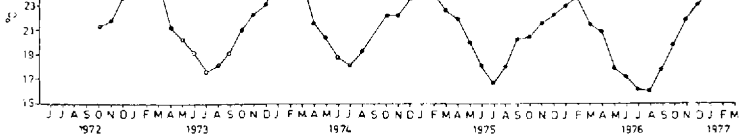
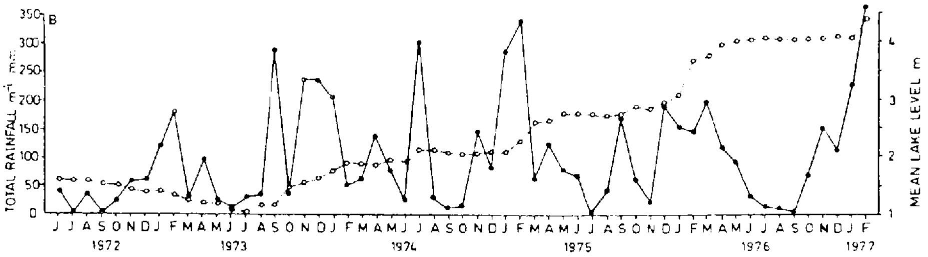
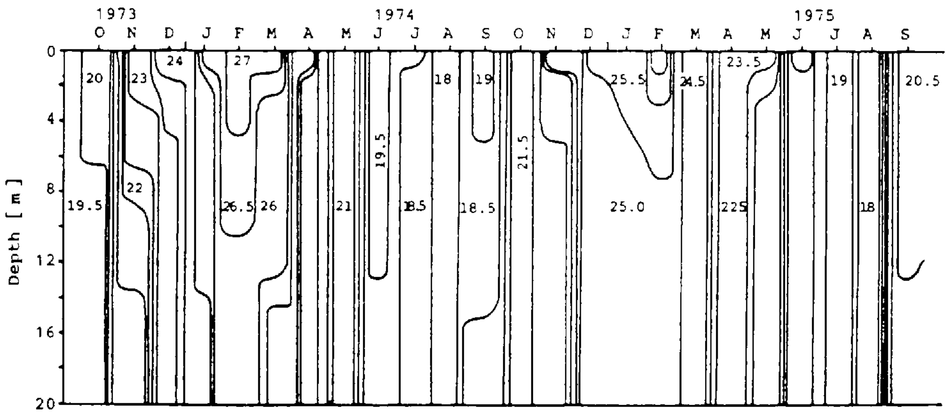


Fig. AFR-3-3 Variation in rainfall and mean lake level (4).



§ Water temperature

Fig. AFR-3-4 Seasonal and vertical distribution of water temperature [°C] (4)



§ Freezing period : None (4).
§ Mixing type : Polymictic (4).

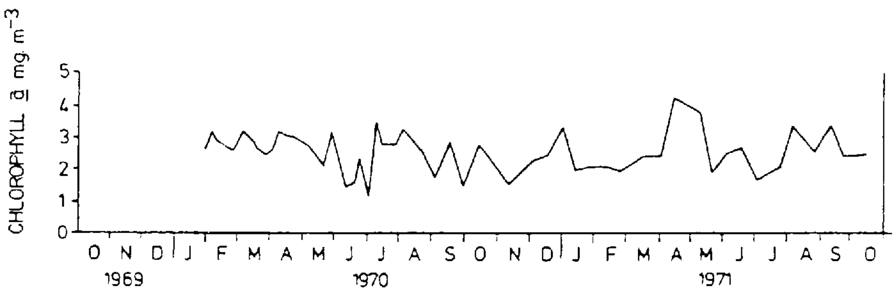
E. LAKE WATER QUALITY

E4 DO [mg l^{-1} (%)] (4)

Depth [m]	Jan. 1967	Jul. 1967	Jan. 1968	Mar. 1970	Jan. 1977
0	7.6(95)	8.9(100)	7.3(95)	7.9(99)	8.0(100)
5	7.8(98)	8.9(100)	7.5(96)	–	–
10	8.0(100)	8.7(97)	6.8(87)	–	7.5(94)
15	8.1(102)	8.5(95)	6.4(82)	7.7(97)	
20	8.1(102)	8.4(94)	–		7.4(93)
25	–	8.4(94)	–	–	
30	6.9(85)	8.4(94)	–	7.0(88)	6.9(87)
35	6.6(82)	8.4(94)	–	–	4.8(60)
38	–	–	5.4(68)	–	–
39	–	–	–	–	4.5(57)

E6 CHLOROPHYLL CONCENTRATION

Fig. AFR-3-5 Seasonal variation in chlorophyll-a (5).



E7 NITROGEN CONCENTRATION

§ Kjeldahl-N [$\mu g\ l^{-1}$]: 11.2-28.0 (4).

§ NO_3-N [$\mu g\ l^{-1}$]: 17-32 (1967): 50 (1979) (4).

E8 PHOSPHORUS CONCENTRATION

§ SRP (soluble reactive P) [$\mu g\ l^{-1}$] (4)

Year	SRP
1967	25-55
1968	10-20
1970	14-25
1979	9

E9 CHLORIDE ION CONCENTRATION [$mg\ l^{-1}$] (4)

Year	Cl^-(no. of samples)
1967-68	136-138(34)
1970-71	132-149(36)
1975	125-127(5)
1979	142(3)

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes: *Cyperus natalensis, Phragmites mauritianus, Scirpus littoralis, Typha latifolia* (7).

§ Floating macrophytes: *Nymphaea caerula, N. capensis* (7).

§ Submerged macrophytes: *Ceratophyllum demersum, Myriophyllum spicatum, Najas pectinata, Potamogeton pectinatus, P. schweinfurthii, Utricularia inflexa* (7).

§ Phytoplankton: *Closterium* spp., *Synedra acus, Anabaenopsis* sp., *Melosira granulata, Anabaena* sp. (6).

F2 FAUNA

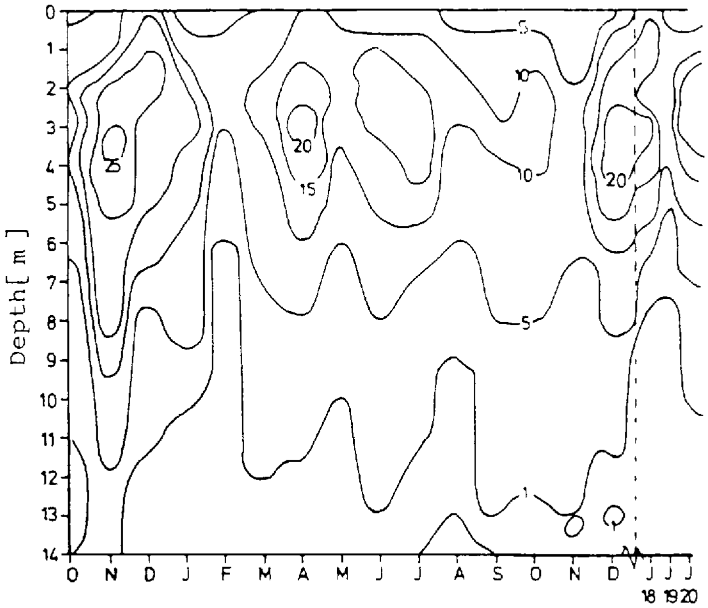
§ Zooplankton: *Pseudodiaptomus hessei, Thermocyclops emini, T. crassus consimilis, Bosmina longirostris, Moina* sp. (8).

§ Benthos: *Apseudes digitalis, Grandidierella lignorum, Corophium trienonyx, Cyathura carinata, Melanoides tuberculatus* (8).

§ Fish: *Pseudocrenilabrus philander**, *Sarotherodon mossambicus**, *Tilapia rendalli sweirstrae, T. sparrmanii**, *Croilia mossambica, Silhouettea sibayai, Clasias gariepinus** (*economically important) (9).

F3 PRIMARY PRODUCTION RATE

Fig. AFR-3-6 Seasonal and vertical distribution of gross primary production rate (Oct. 1973-Jan. 1975) [mg C $m^{-3}hr^{-1}$] (6).

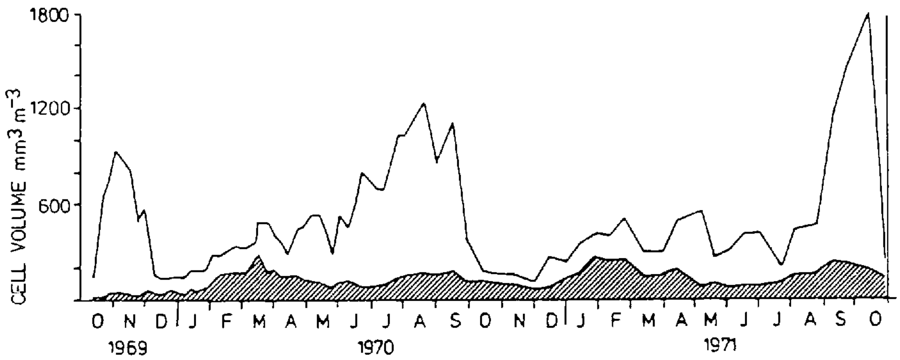


F4 BIOMASS

§ Aboveground biomass of macrophytes (7)

	Mean biomass [g m^{-2}]	Area [km^2]	Total biomass [t]
Emerged	417.7	6.06	2,531
Submerged	417.1	16.21	6,761

Fig. AFR-3-7 Seasonal variation of net phytoplankton biomass. ☐ *Closterium* spp., ▨ others (5).



G. SOCIO-ECONOMIC CONDITIONS (2)

G1 LAND USE IN THE CATCHMENT AREA

§ Main types of woody vegetation: Plantation of pine and eucalypt (ca. 70 km^2).

§ Main kinds of crops: Maize, potato, sweet potato, groundnut, millet, kaffricorn, cassava, bean, banana, pumpkin, calabash and pawpaw.

G2 INDUSTRIES IN THE CATCHMENT AREA

§ Secondary industry : Pulp mills.

G3 POPULATION IN THE CATCHMENT AREA

The coastal zone (within 5 km from the shore) has a population of 1,451 and 631 huts.

H. LAKE UTILIZATION (2)

H1 LAKE UTILIZATION

Fisheries.

H2 THE LAKE AS WATER RESOURCE

A considerable number of inhabitants use water piped from the western arm of the lake to Mseleni Mission Hospital. Use rate (1975) : 0.002 m^3sec^{-1}.

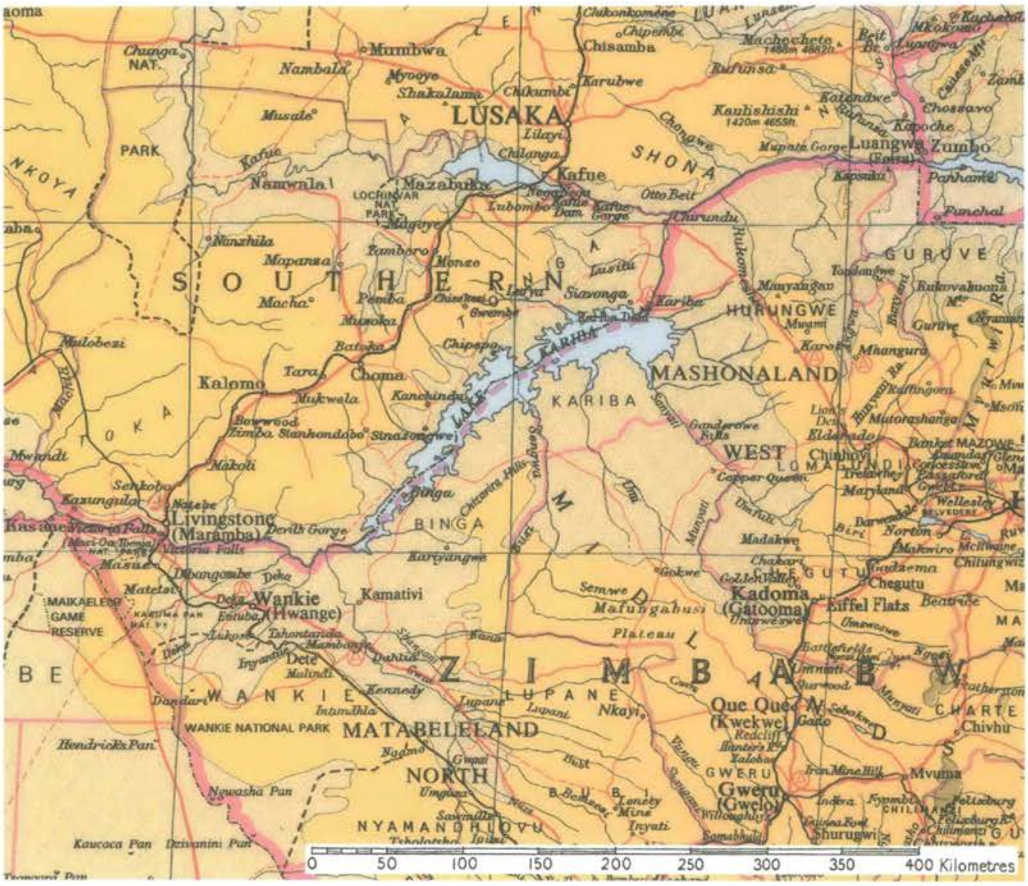
N. SOURCES OF DATA

(1) Hill, B. J. (1979) Bathymetry and hydrology of Lake Sibaya. Lake Sibaya (ed. Allanson, B. R.), pp. 21-33. Dr. W. Junk Publishers, The Hague.
(2) Bruton, M. N. (1979) The utilization and conservation of Lake Sibaya. Ibid., pp. 286-312.
(3) Müller, M. J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306pp. Dr. W. Junk Publishers, The Hague.
(4) Allanson, B. R. (1979) The physico-chemical limnology of Lake Sibaya. Lake Sibaya (see above), pp. 42-74.
(5) Hart, R. C. & Hart, R. (1977) Arch. Hydrobiol., 80(1) : 85-107.
(6) Allanson, B. R. (1979) The phytoplankton and primary productivity of the lake. Lake Sibaya (see above), pp. 75-89.
(7) Howard-Williams, C. (1979) Distribution, biomass and role of aquatic macrophytes in Lake Sibaya. Ibid., pp. 88-107.
(8) Hart, R. C. (1979) The invertebrate communities : zooplankton, zoobenthos and littoral fauna. Ibid., pp. 108-161.
(9) Bruton, M. N. (1979) The fishes of Lake Sibaya. Ibid., pp. 162-245.

LAKE KARIBA

Kariba town people fishing on the lake

Photo: C. H. D. Magadza



A. LOCATION

§ Southern, Zambia ; Matabeleland North and Mashonaland West, Zimbabwe.
§ 16°28'-18°04'S, 26°42'-29°03'E ; 485 m above sea level.

B. DESCRIPTION

In 1961, the damming of the Zambezi River was completed and one of the largest man-made lakes in the world was formed. The massive project was undertaken to provide hydroelectric power for the growing industries of Zimbabwe and Zambia. Two power stations, one on the Zambian bank and the other on the Zimbabwean side are in full operation. Covering an area of nearly 6,000 km², the lake has become a year-round source of water for an abundance of animal and bird life, and a sunny playground for both local and foreign tourists.

From the urban area of Kariba Township, near the dam wall, the lake extends westwards for 290 km with a width of 32 km.

The story of the creation of the lake and the building of Kariba Dam is an exciting account of modern engineering. But it is also the tale of the tragic but necessary removal of the Ba Tonga people, who held that the river god Nyaminyami would destroy the dam and allow the Zambezi to run free again. As well, it is the story of one of the most impressive wildlife rescue operations ever carried out in Africa. Over 5,000 animals were rescued, including 35 different mammal species and 44 black rhino. Frightened creatures ranging from elephant to snakes were captured for release into areas that now form Matusadona National Park and Chete Safari Area (1, 8).

C. PHYSICAL DIMENSIONS (2, 3, 4)

Surface area [km²]	5,400
Volume [$10^9 m^3$]	160
Maximum depth [m]	78
Mean depth [m]	31
Normal range of annual water level fluctuation (regulated) [m]	2-3
Length of shoreline [km]	2,164
Residence time [yr]	3
Catchment area [km²]	663,000

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHYCAL (2)

§ Sketch map (Fig. AFR-4-1).
§ Main islands (name and area): Chete (26.4 km^2).
§ Outflowing rivers and channels (number and names): 1 (Zambezi R.).

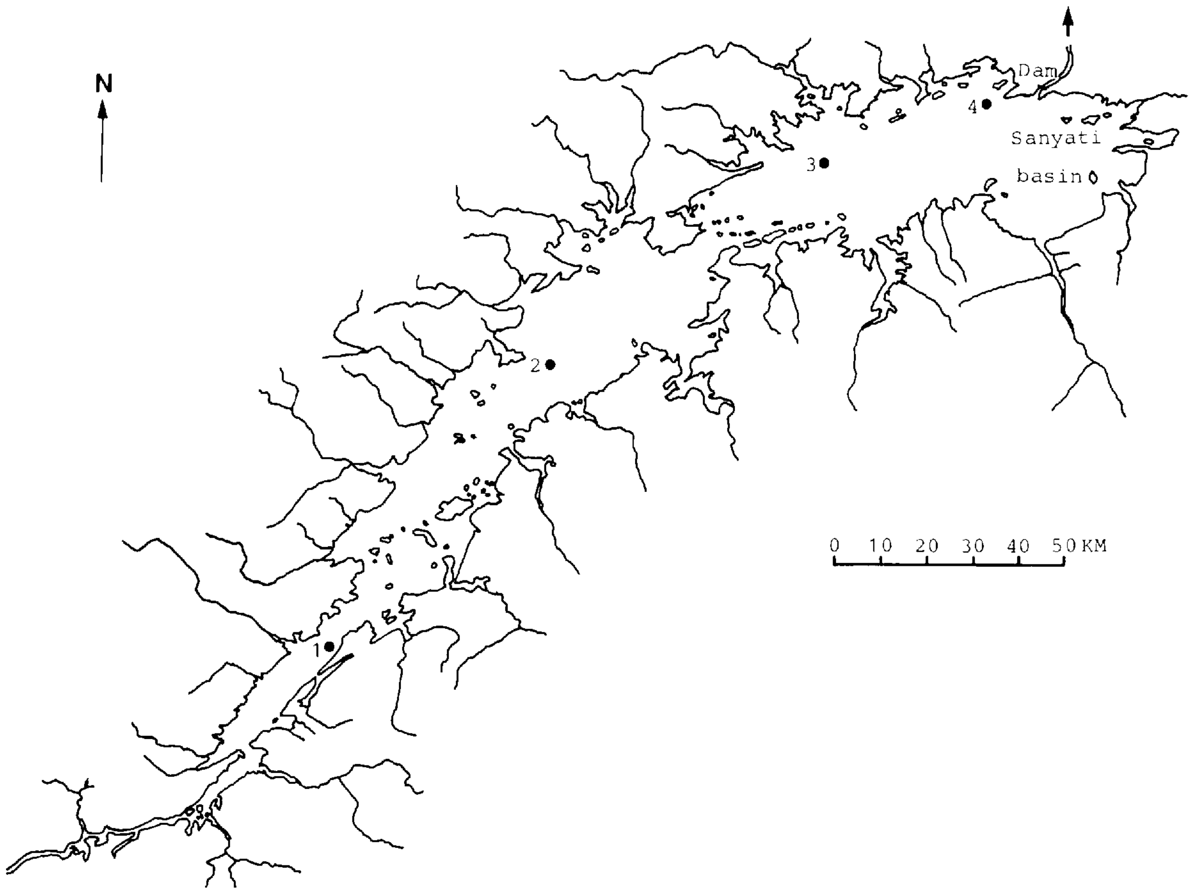
D2 CLIMATIC

§ Climatic data at Binga, 1960-1970 (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	25.8	25.4	25.7	24.7	22.7	20.2	24.7	20.0	22.6	26.2	29.2	27.7	24.7
Precipitation [mm]	149.6	126.0	90.7	14.2	4.6	0	0	0	0	10.9	42.3	157.0	608

§ Number of hours of bright sunshine (Binga, 1960-1970): 2,920.0 hr yr^{-1} (2).
§ Solar radiation (Binga, 1960-1970): 23.9 MJ $m^{-2}day^{-1}$ (2).

Fig. AFR-4-1 Sketch map of the reservoir (2).



§ Surface water temperature [°C] (4)
Sanyati basin, 1983

Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30	29	30	29	26	24	23	23	25	26	28	29

§ Mixing type: Monomictic (2).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (4)

Sanyati basin, 1983

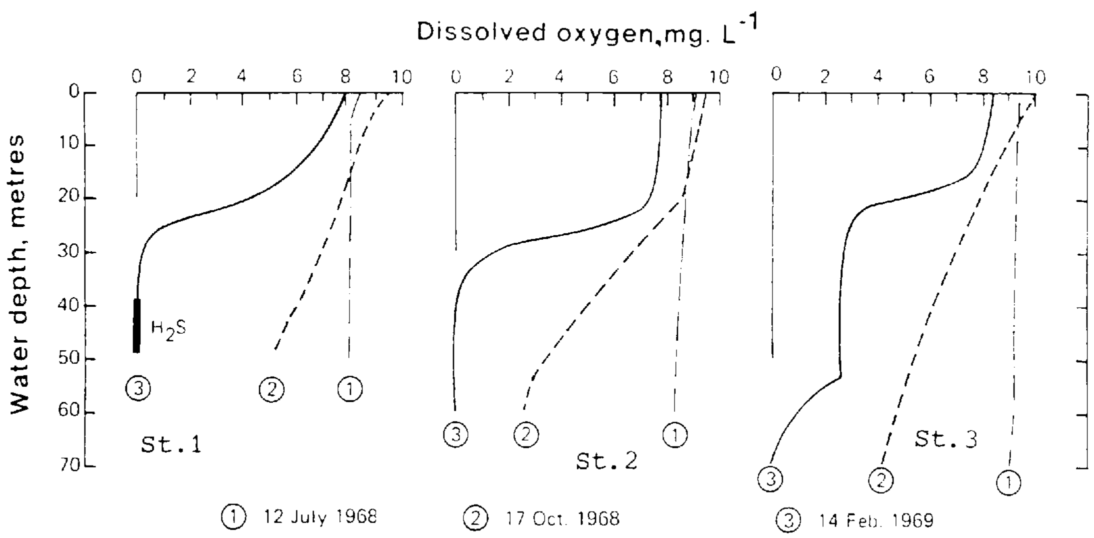
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.5	4.5	6.0	4.5	6.0	5.5	3.0	6.0	6.5	6.0	5.0	4.8

E2 pH

§ Surface water pH range : 7.5-8.5 (2).

E4 DO

Fig. AFR-4-2 DO [mg l^{-1}] distribution throughout the annual cycle (2).



E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$] (4)

§ Yearly mean chlorophyll concentration : 2.2.

E7 NITROGEN CONCENTRATION (2)

§ NO_3-N [$\mu g\ l^{-1}$]

Station 2, 1964-1965

Depth [m]	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Surface	45	34	30	36	12	12	18	20	–	14	87	39
ca. 50	123	106	34	134	107	121			–	15	26	–

Station 3, 1964-1965

Depth [z]	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Surface	28	38	13	27	32	17	23	18	21	30	–	18

Station 4, 1964-1965

Depth [m]	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Surface	13	21	13	15	21	22	45	15	13	20	14	10
ca. 50	91	86	92	112	180	133	111	74	117	71	21	49

E8 PHOSPHORUS CONCENTRATION (2)

§ PO_4-P [$\mu g\ l^{-1}$]

Station 2, 1964-1965

Depth [m]	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Surface	0	12	10	6	14	27	27		—	72	—	15
ca. 50	11	21	15	19	26	36	—	—	—	57	42	—

Station 3, 1964-1965

Depth [m]	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Surface	15	20	8	32	6	8	15	11	—	7	—	70

Station 4, 1964-1965

Depth [m]	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Surface	6	61	14	6	36	18	29	29	7	—	30	0
ca. 50	18	66	16	19	62	18	29	25	35	—	8	25

F. BIOLOGICAL FEATURES

F1 FLORA

§ Floating macrophytes : *Salvinia auriculata* (2).

§ Submerged macrophytes : *Ceratophyllum demersum, Potamogeton pusillus, Lagarosiphon ilicifolius, Vallisneria aethiopica, Najas* sp. (2).

§ Phytoplankton : *Cylindrospermopsis raciborskii, Anabaena* sp., *Lyngbya* sp., *Synedra acus, Melosira granulata, Peridinopsis cunningtonii, Chrysochromulina parva, Tetraedron minimum* (4).

F2 FAUNA

§ Zooplankton : *Brachionus falcatus, Bosmina longirostris, Tropodiaptomus kraepelini, Limnocnida rhodesiae* (2).

§ Fish : *Sargochromis codringtoni, Synodontis zambezensis, Tilapia rendalli, Clarias gariepinus, Synodontis nebulosus, Schilbe mystus, Heterobranchus longifilis, Malapterurus electricus, Eutopius depressirostris, Sarotherodon mossambicus* (2).

F4 BIOMASS

Fig. AFR-4-3 The phytoplankton biomass [mg m^{-3}] in the Sanyati basin, October 1982 -March 1984 (4).

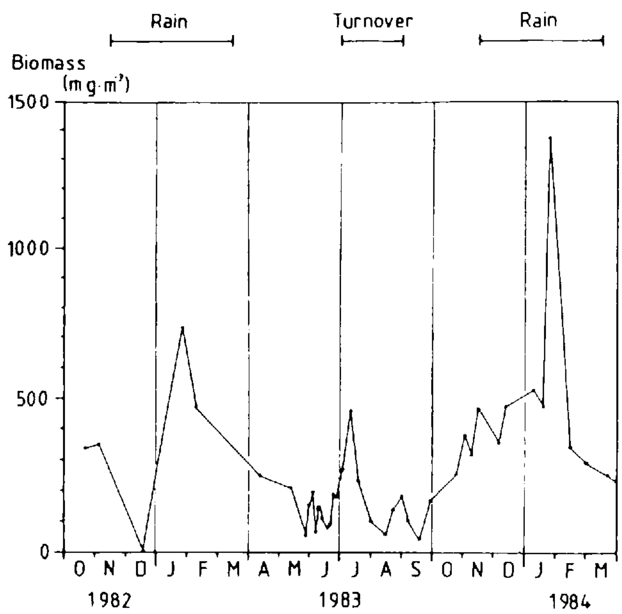
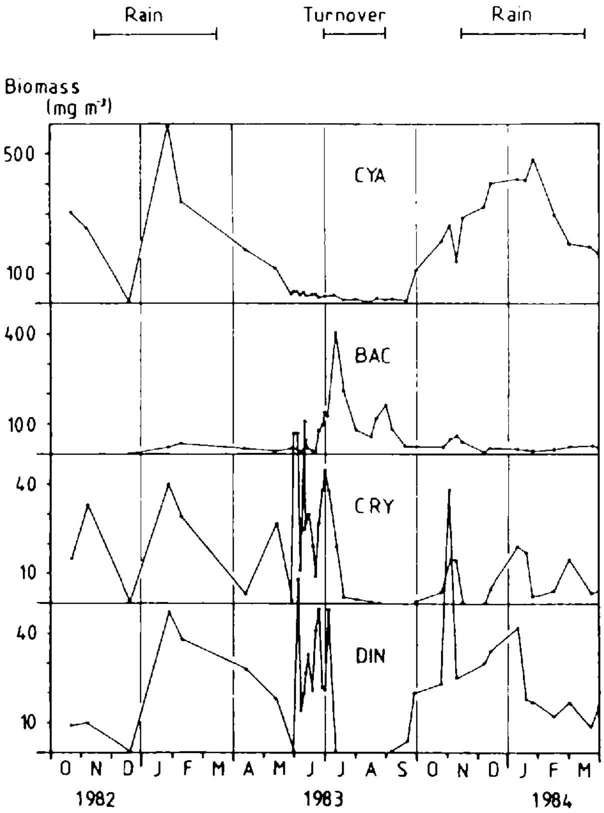


Fig. AFR-4-4 The biomass of dominating phytoplankton classes [mg m^{-3}] in the Sanyati basin, October 1982-March 1984 (4). CYA : Cyanophyceae. BAC : Bacillariophyceae. CRY : Cryptophyceae. DIN : Dinophyceae.



F5 FISHERY PRODUCTS

§ Annual fish catch in 1986 : 11,000 [metric tons] (6).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (8)

The story of Lake Kariba is often vividly linked with the explosion of *Salvinia molesta* (= *auriculata*), a South American aquatic pteridophyte introduced into the newly created lake from the upper Zambezi catchment. During the eutrophic filling phase of the lake the weed showed remarkable growth rates with no apparent predators. At the maximum storage capacity (1962) the weed covered about 25% of the entire lake surface area, i. e. in excess of 1000 km^2. Attempts to control the weed by herbicides had neglegible effect. In 1969, a grasshopper from South America, *Paulinia*, was introduced as part of a biological control strategy. At that time a number of events happened which contributed to the decline of *Salvinia*. After the attainment of maximun storage capacity the lake rapidly became oligotrophic due to net loss of nutrients in the outflow stream. It is also claimed that the harvesting of *Limnothrissa miodon*, a clupeid introduced into the lake from Lake Tanganyika, contributed to nutrient losses from the lake. Our recent data indicate that currently as much as 50 tons of P are harvested from the lake in this manner annually.

H. LAKE UTILIZATION (2, 5)

H1 LAKE UTILIZATION

Source of water, generation of electricity, fisheries, recreation (water skiing, scuba diving, sport-fishing and yachting) and bird-watching.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (7)

§ Extent of damage : Serious.

§ Supplementary notes : Predicted 80 t ha^{-1} from cultivated lands.

I2 TOXIC CONTAMINATION

§ Present status : DDT application for the control of both mosquito vectors and the tsetse fly.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (8)

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Lake Kariba Research Station, University of Zimbabwe

N. SOURCES OF DATA

(1) Africa Calls (1985) Around Zimbabwe, No. 2, 8 pp. Mardon Printers, Harare.

(2) Coche, A. G. (1974) Limnological study of a tropical reservoir. "Lake Kariba" (ed. Balon, E. K. & Coche, A. G.), pp. 11-247. Dr. W. Junk Publishers, The Hague.

(3) Thornton, J. A. (1987) GeoJournal, 14(3) : 339-352.

(4) Ramberg, L. (1987) Hydrobiologia, 153 : 193-202.

(5) Temple, P. H. (1981) Energy. "The Cambridge Encyclopedia of Africa" (ed. Oliver, R. & Crowder, M.), pp. 270-277. Cambridge University Press, London.

(6) Magadza, C. H. D. (1986) Nature and Resources, 22 (4) : 2-12.

(7) Elwell, H. A. (1976) Zimbabwe Rhodesia Agr. J., 75 (5) : 203-210.

(8) Magadza, C. H. D. (1988) The status of Lake Kariba. Report to the UNCRD/ILEC/UNEP Expert Group Workshop on River/Lake Basin Approach to Environmentally Sound Management of Water Resources, Otsu and Nagoya, February 1988. 5 pp.

LAKE VICTORIA

Fishing boats on the lakeshore

Photo: M. Nakashima

A. LOCATION

§ Mara, Muwanza and West Lake, Tanzania ; North Buganda, South Buganda and Busoga, Uganda ; and Nyanza and Western, Kenya.
§ 0°21′N-3°00′S, 31°39′-34°53′E ; 1,134 m above sea level.

B. DESCRIPTION

Lake Victoria, the largest of all African Lakes, is also the second widest freshwater body in the world. Its extensive surface belongs to the three countries ; the northern half to Uganda, the southern half to Tanzania, and part of the northeastern sector to Kenya. The lake occupies a wide depression near the equator, between the East and West Great Rift Valleys, but its drainage basin is relatively small, being slightly less than three times the lake's surface in area. The lake water is drained at a rate of about 600 m^3/sec. at Jinja on the northern shore, into the Victoria Nile which flows northward via L. Albert and the White Nile forming the uppermost reaches of the Nile River.

The lake shore is highly indented, and there are many isles in the lake, some of which, especially the Sesse Group, are known for their beautiful landscape, health resorts and sightseeing places. Abundant prehistoric remains found around the lake indicate the early development of agriculture. There are a number of coastal towns such as Kismu (Kenya), Entebe (Uganda), Bukoba, Muwanza and Musoma (Tanzania), connected with each other by ship routes and also to the cities of the Indian Ocean coast by railways. The dam constructed in 1954 at Owen Falls on the Victoria Nile supplies electricity and water for various uses in Uganda and Kenya.

C. PHYSICAL DIMENSIONS (Q1, 1)

Surface area [km^2]	68,800
Volume [10^9m^3]	2,750
Maximum depth [m]	84
Mean depth [m]	40
Water level	Regulated
Length of shoreline [km]	3,440
Residence time [yr]	23
Catchment area [km^2]	184,000

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. AFR-5-1).

§ Main slands : Ukerewe, Sesse, Ukara, Kome, Lolui and Mfanganu (3).

§ Outflowing rivers and channels (number and names) : 1 (Victoria Nile R.) (Q1).

D2 CLIMATIC

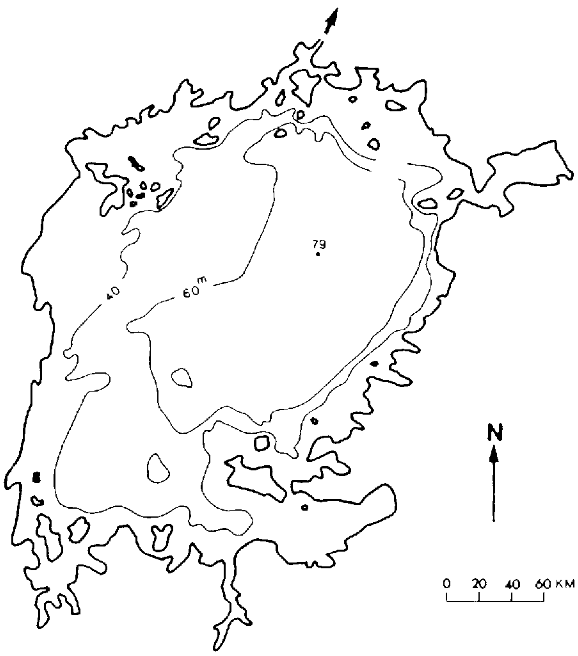
§ Climatic data at Kisumu (Q1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]*	24.0	23.6	23.9	23.2	23.1	23.3	21.8	22.1	22.8	23.4	23.3	23.3	23.1
Precipitation [mm]**	57	70	160	195	177	101	68	96	79	64	106	105	1,278

* 1976-1982. ** 1938-1962.

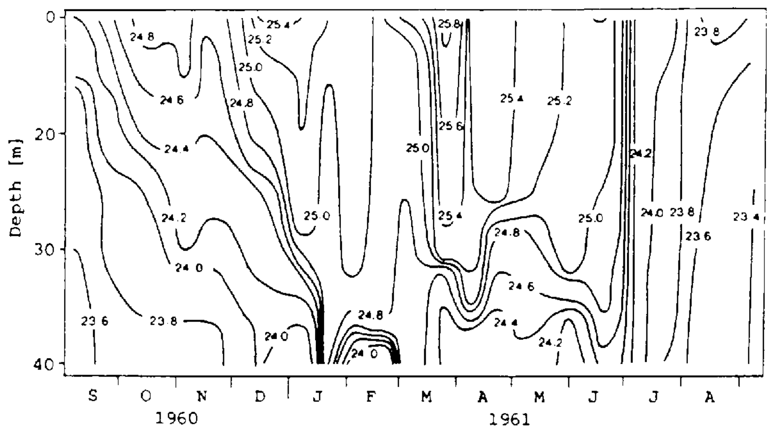
§ Solar radiation : 17.63 MJ $m^{-2}day^{-1}$ (Q1).

Fig. AFR-5-I Bathymetric map (2).



§ Water temperature

Fig. AFR-5-2 Seasonal and vertical change of water temperature [°C] (2).



§ Freezing period : None (2).
§ Mixing type : Monomictic (2).
§ Notes on water mixing and thermocline formation : Lake Victoria does have a season of deep vertical mixing when in fact the lake becomes isothermal. During June and July the established thermocline breaks down under the seasonal onset of the south-east trade winds and for a brief period at the end of July the main body of the lake becomes isothermal with respect to depth (Talling, 1966). The depth and stability of the thermocline depends upon the duration of the calm, warming period and the frequency and magnitude of mixing events. In Lake Victoria where the thermocline most often occurs at 30-40 m depth, complete mixing of this enomous water body occurs once a year and partial mixing occurs at other times (4).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (5)

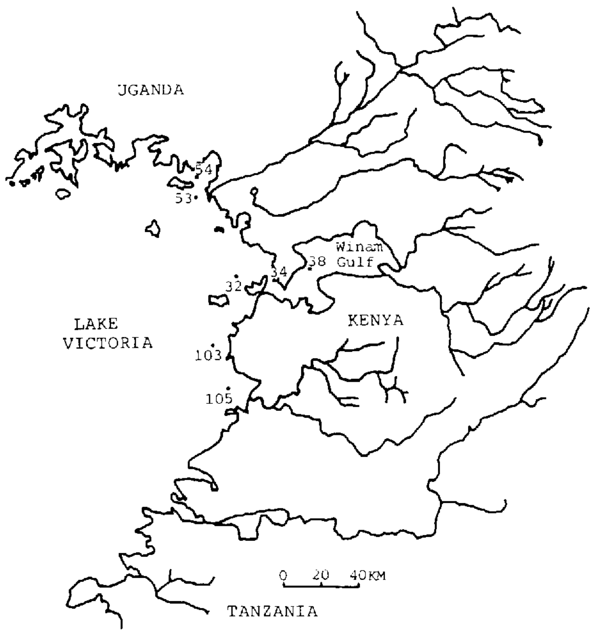
1985

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
34	—	—	—	—	—	—	—	—	1.5	1.3	—	—
32	—	—	—	—	—	—	—	—	1.9	1.3	—	—
103	—	—	—	—	—	—	—	—	2.5	1.6	—	—
105	—	—	—	—	—	—	—	—	1.2	0.9	—	—
53	—	—	—	—	—		—	—	0.85	0.5	—	—
51	—	—	—	—	—	—	—	—	1.1	0.8	—	—

1986

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
34	—	0.2	—	—	1.4	—	—	—	—	—	—	—
32	—	0.6	—	—	—	—	—	—	—	—	—	—
103	—	1.1	—	—	1.7	—	—	—	—	—	—	—
105	—	0.6	—	—	—	—	—	—	—	—	—	—
53	—	0.3	—	—	0.5	—	—		—	—	—	—
51	—	0.4	—	—	0.8	—	—	—	—	—	—	—

Fig. AFR-5-3 Map of sampling stations in northeastern part of Lake Victoria.



E2 pH (Q2)
Winam Gulf : 8.4 (Dec. 1976) ; 8.1 (Feb. 1977).

E3 TURBIDITY [NTU] (5)

1985

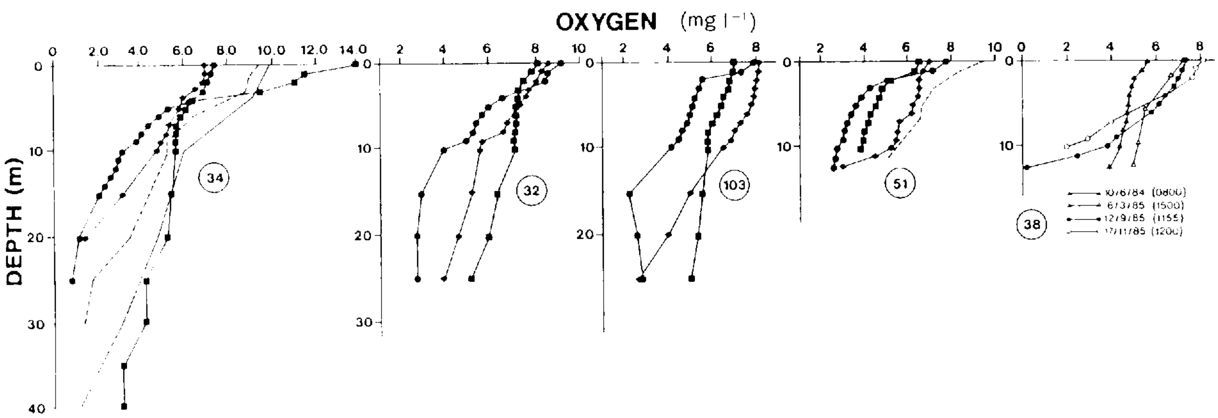
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
34	–	–	–	–	–	–	–	–	3.6	4.1	–	–
32	–	–	–	–	–	–	–	–	2.6	3.2	–	–
103		–	–	–	–	–		–	1.5	1.7	–	–
105	–	–	–	–		–	–	–	8.8	–	–	–
53	–	–	–	–		–	–	–	10.4	33.7	–	
51	–	–	–	–	–	–	–	–	14.7		–	–

1986

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
34	–	21.7	–	–	4.1	–	–	–	–	-	–	–
32	–	6.5	–	–	–		–	–	–	–	–	–
103	–	3.2	–	–	2.5	–	–	–	–	-	–	–
105	–	–	–	–	9.7	–		–	–	–	–	–
53	–	12.3	–	–	4.7	–		–	–	–	–	–
51	–	–		–	19.0	–	–	–	–	–	-	–

E4 DO

Fig. AFR-5-4 Oxygen depth profiles from several sampling stations [mg l^{-1}] (5).



E5 BOD [mg l^{-1}] (Q2)
Winam Gulf : 16-86.

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$] (Q2)

Winam Gulf, Sep. 1985

Depth [m]	Station 6	31	32
0	20.3	15.9	17.5
0.5	15.9	12.9	13.6
1	22.3	10.4	13.3
2	20.1	15.9	10.7
3	23.5	18.5	7.8
4	19.0	21.4	5.0
10	10.4		4.7
15	15.5		4.7
20	7.3		2.9
25	9.6		2.6
30			1.8

E7 NITROGEN CONCENTRATION (Q2)

§ NH_4-N [$mg\ l^{-1}$]

Winam Gulf, Sep. 1985

Depth [m]	Station 6	31	32	103
0	0.2	0.35	0.7	0.35
0.5	—	—	—	0.15
1	—	0.40	—	0.15
2	—	—		
3	—	N.D.	—	
4	—	—	—	
10	—		—	
15	0.35		0.4	
20	0.30		—	
25	—		—	
30	—		0.35	

§ NO_3-N [$mg\ l^{-1}$] (Q2)

Winam Gulf, Sep. 1985

Depth [m]	Station 6	31	32	103
0	0.1 *	0.1 *	0.1 *	0.1 *
0.5	—	—	—	0.1 *
1	—	0.1 *	—	0.1
2	—	—	—	
3	—	0.1 *	—	
4	—	—	—	
10	—		—	
15	0.1		0.1 *	
20	0.1		—	
25	—		—	
30			0.2	

* Less than given figure.

E8 PHOSPHORUS CONCENTRATION (Q2)

§ PO_4-P [mg l^{-1}]

Winam Gulf, Sep. 1985

Depth [m]	Station			
	6	31	32	103
0	N.D.	0.002 *	0.002 *	0.002
0.5	–	–	–	0.002
1	–	0.002 *	–	0.006
2	–	0.002 *	–	
3	–	0.002 *	–	
4	–	–	–	
10	–		–	
15	0.003		0.002 *	
20	0.003		–	
25	–		–	
30			0.01	

* Less than given figure.

E9 CHLORIDE CONCENTRATION [mg l^{-1}] (Q2)

Winam Gulf : 21 (Dec. 1976) ; 9.5 (Feb. 1977).

F. BIOLOGICAL FEATURES

F1 FLORA (Q1)

§ Emerged macrophytes : *Typha* spp., *Phragmites* spp., *Cyperus papyrus*, *Potamogeton* spp.

§ Floating macrophytes : *Vossia*.

§ Submerged macrophytes : *Ceratophyllum demersum*, *Hydrilla verticillata*, *Polygonum* spp.

§ Phytoplankton : *Melosira nyassensis*, *Lyngbya contorta*, *Spirulina* spp., *Anabaena* spp., *Oscillatoria* spp., *Pediastrum clathratum*, *Fragillaria* spp., *Cyclotella* spp., *Scenedesmus* spp., *Glenodinium* spp.

F2 FAUNA (Q1)

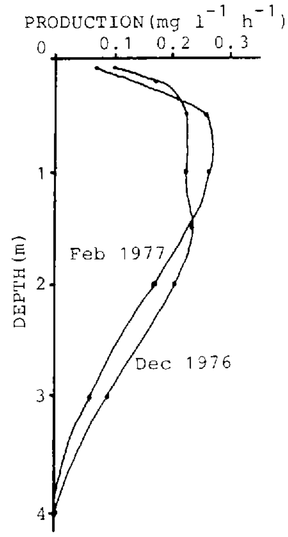
§ Zooplankton : *Daphnia* spp., *Chydorus* sp., *Leptodora* sp., *Cyclops* sp., *Diaptomus*, *Caridina nilotica*, *Philodina* spp., *Keratella* sp., *Asplanchna brightwelli*, *Limnocnida victoriae*.

§ Benthos : *Melania tuberculata*, *Bellamysa* sp., *Corbicula* sp., *Caelatura* sp., *Chaoborus* sp., *Chironomus* sp.

§ Fish : *Lates niloticus*, *Tilapia* spp.*, *Haplochromis* spp., *Labeo victorianus*, *Alestes baremose**, *Clarias* spp., *Bagrus docmac*, *Protopterus aethiopicus*, *Barbus**, *Scibe** (*economically important).

F3 PRIMARY PRODUCTION RATE

Fig. AFR-5-5 Production rate (9).



F4 BIOMASS

§ Fish biomass [kg ha^{-1}] (fresh wt., 1974) : 80 (6).

F5 FISHERY PRODUCTS

§ Annual fish catch in 1980 : 120,000 [metric tons] (Q1).

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (Q1)

An introduced species, Nile perch (*Lates niloticus*), dominates fishery products within the Kenyan portion of the lake. Traditional fishery have overfished tilapias and riverine species.

G. SOCIO-ECONOMIC CONDITIONS (Q2)

G1 LAND USE IN KENYAN PART OF THE CATCHMENT AREA (1985)

	Area [km^2]	[%]
Natural landscape	29,500	62
Woody vegetation	7,000	15
Herbaceous vegetation	22,500	47
Agricultural land	15,500	32
Crop field	11,000	23
Pasture land and fallow land	4,500	9
Residential area and others	2,700	6
Total	47,700*	100

* 26% of the whole catchment area.

§ Main types of woody vegetation : Savanna woodland (*Acacia*, *Albizzia* and *Butyrospermum*).

§ Main species of herbaceous vegetation : *Cymbopogon*, *Hyparrhenia*, *Londetia* and *Cyperus papyrus*.

§ Main kinds of crops : Maize, cotton, sisal, tabacco, beans, sugar cane, coffee, sorghum, millet, wheat and root crops (cassava, etc.).

§ Levels of fertilizer application on crop fields : Light.

§ Trends of change in land use : Decrease of forest areas due to very high population pressure and resultant excessive cultivation.

G2 INDUSTRIES IN KENYAN PARTS OF THE CATCHEMENT AREA AND THE LAKE (1985)

	Gross product per year [10^6 K£]**		Main products or major industries
Primary industry			
Cash crops	89	Value added	Coffee, tea, cotton, sugarcane
Animal husbandry	97	Value added	Milk, meat
Fisheries*	10	Value added	Nile perch, tilapia
Staple crops	181	Value added	
Secondary industry	400	Gross	Coffee & tea processing, sugar, pulp, dairy product, foods, leather, textile

* Kenyan side of the lake only, particularly Winam Gulf (water surface area 1,400 km²).
**0.75 k£ = 1.00 US $.

G3 POPULATION IN KENYAN PART OF THE CATCHMENT AREA (1985)

	Population	Population density [km^{-2}]	Main cities
Urban	630,000		
Rural	7,480,000		Kisumu, Eldoret
Total	8,110,000	170	

H. LAKE UTILIZATION (Q2)

H1 LAKE UTILIZATION

Source of water, navigation and transportation, recreation (yachting), and fisheries.

H2 THE LAKE AS WATER RESOURCE (1986)

	Use rate
Domestic water [$m^3 day^{-1}$]	15,000 (for Kisumu)
Irrigation [$m^3 sec^{-1}$]	1.7 (near Kisumu)

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : Not serious (Q2).
§ Supplementary notes : 4×10^6 ton yr^{-1} from 47,000 km² of catchment (an estimate) ; 0.5-1.0 mm yr^{-1} as lake sediment (7).

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious (Q2).

§ Main contaminants, their concentrations and sources (1984) (7)

Kisumu Bay of Winam Gulf

Name of contaminants	Concentrations [ppb] Fish*	Main Sources
DDE	4.3	Pesticide

* *Lates niloticus* (Nile perch) on wet weight basis.

§ Environmental quality standards for contaminants in the lake : Now follow WHO ambient standards (Q2).

§ Supplementary notes

Nzoia River draining into the lake is contaminated with pesticide residues ; DDT 0.3 ppm, DDE 0.3 ppm, BHC 0.2 ppm, Toxaphene 0.2 ppm in 1982 (8).

I3 EUTROPHICATION

§ Nuisance caused by eutrophication in Winam Gulf

Unusual algal bloom : *Microcystis aeruginosa, Anabaena circinalis* (7).

§ Supplementary notes

Mesotrophic in the main body of the lake. Although nutrient loads to the lake are not known, 400 kg $m^{-2}yr^{-1}$ of T-N and 20 kg $km^{-2}yr^{-1}$ of T-P are measured as averages of 24 points in the watershed of Nzoia River, a major tributary of the lake (8).

J. WASTEWATER TREATMENTS (Q2)

J1 GENERATION OF POLLUTANTS IN KENYAN PART OF THE CATCHMENT AREA : (d)

Measurable pollution with limited wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems : 4 (trickling filter plants, oxidation ponds).

§ Industrial wastewater treatment systems : Anaerobic ponds and aerobic oxidation ponds are used by very many factories (suger, texile, dairy and paper factories).

K. IMPROVEMENT WORKS IN THE LAKE (Q2)

None.

L. DEVELOPMENT PLANS (Q2)

An integrated regional development master plan for 1987-2005 is being drawn up by the Lake Basin Development Authority (Kenya) for agricultural, industrial, livestock, fishery and infrastructure developments.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q2)

M1 NATIONAL AND LOCAL LAWS CONCERNED (Kenya only)

§ Names of the laws

(1) The Water Act
(2) The Public Health Act
(3) The Poisonous Substance Act (indirect)
(4) The Pesticides Control Act (indirect)

§ Responsible authorities

(1) Ministry of Water Development
(2) Ministry of Health

§ Main items of control

(1) Sewage effluent and industrial effluent

M2 INSTITUTIONAL MEASURES (Kenya only)
(1) Ministry of Water Development, Nairobi, Kenya
(2) Marine Fishery Development, Kisumu, Kenya
(3) Lake Basin Development Authority, Kisumu, Kenya

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES
(1) Kenya Marine Fisheries Research Institute, Kisumu
(2) Tanzania Freshwater Fisheries Research
(3) Uganda Freshwater Fisheries Research Organization, Jinja
(4) Lake Basin Development Authority, Kisumu

N. SOURCES OF DATA

* Printed in Japanese. The title is tentatively translated into English with the original title in romanized Japanese in parentheses.

(Q1) Questionnaire filled by Dr. P. B. O. Ochumba, Kisumu Laboratory, Kisumu.

(Q2) Questionnaire filled by Dr. M. Nakashima, International Development Center, Tokyo.

(1) Serruya, C. & Pollinger, U. (1983) Lakes of the Warm Belt. 569 pp. Cambridge University Press, Cambridge.

(2) Talling, J. F. (1957) Comparative problems of phytoplankton production and photosynthetic productivity in a tropical and temperate lake. Mem. Ist. Idrobiol., 18, Suppl.: 339-424.

(3) Shimonaka, K. (ed.) (1984) Grand World Atlas (Sekai Dai Chizu-chô). 273 pp. Heibon-sha, Tokyo.*

(4) Payne, A. I. (1986) The Ecology of Tropical Lakes and Rivers. John Wiley and Sons Ltd., New York.

(5) Ochumba, P. B. O. (1987) Water Quality Bulletin, 12(3): 119-122.

(6) Ssentongo, G. W., Durand, J. R. & Harbott, B. (1981) The rational exploitation of African aquatic ecosystems. The Ecology and Utilization of African Inland Waters (ed. Symoens, J. J., Burgis, M. & Gaudet, J. J.), pp. 167-175. United Nations Environment Programme, Nairobi.

(7) Lake Basin Development Authority (1985) The Technical Annex to the Final Report on the Current and Future Implications of Development to the Aquatic Environment of Lake Victoria.

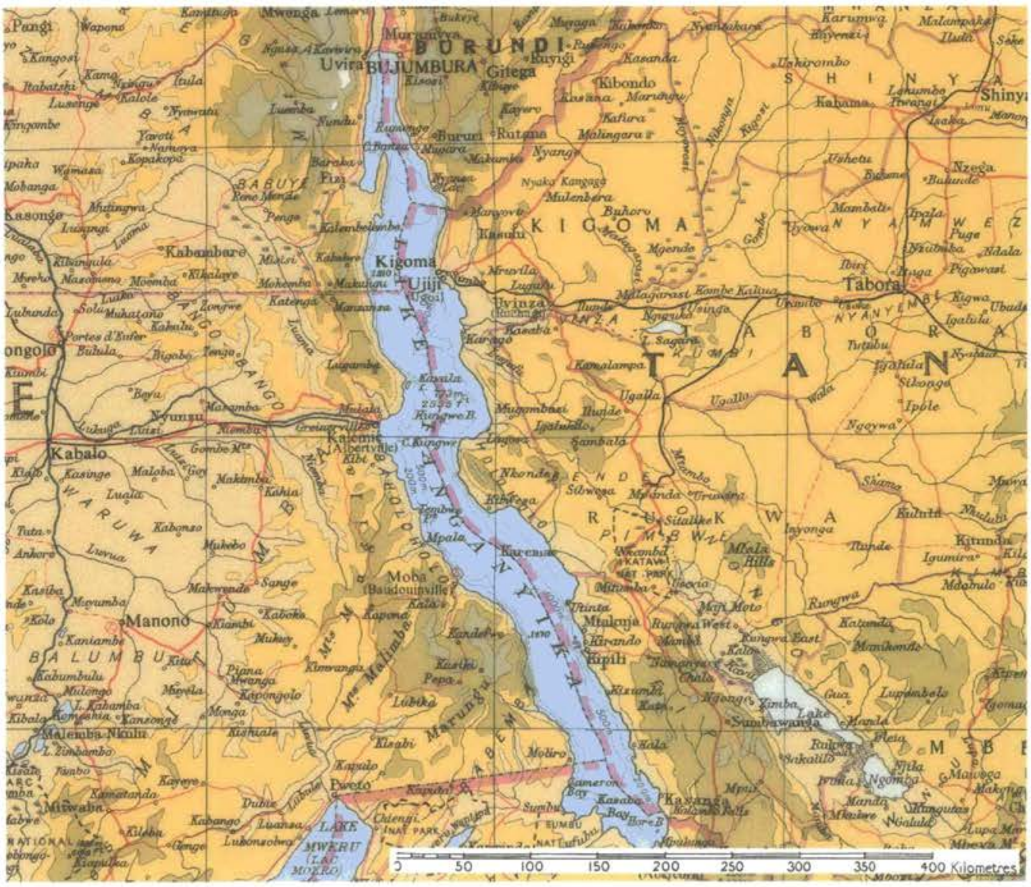
(8) Chabeda, P. I. M. (1983) A Survey of Eutrophication and Water Pollution Load in Four Rivers of the Northern Half of the Lake Basin Development Authority.

(9) Water Quality and Pollution Control Section (1978) Limnological Investigation of Lakes in Kenya 1976-1977. Technical Report No. 6. Resource Section, Water Department of Kenya, Nairobi.

LAKE TANGANYIKA

From the beach of a fishing village near Uvira, Zaire

Photo: S. Yamagishi



A. LOCATION

§ Kigoma and Rukwa, Tanzania ; Shaba and Kivu, Zaire ; Northern, Zambia ; and Burundi.
§ 3°25′-8°45′S, 29°10′-31°10′E ; 773 m above sea level.

B. DESCRIPTION

Among the chain of lakes on the bottom of the Western Great Rift Valley, Lake Tanganyika is outstanding for its extraordinary north-south extension (670 km) and depth (1,470 m). It is the second largest of African lakes, the second deepest (next to L. Baikal) and the longest lake of the world. Its very ancient origin, only rivalled by such old lakes as Baikal, and a long period of isolation resulted in the evolution of a great number of indigenous organisms, including brilliantly colored cichlid fishes, well-known gastropods with the appearance of marine snails, and so on. Of the 214 species of native fishes in the lake, 176 are endemic ; the number of endemic genera amounts to 30 in cichlids and 8 in non-cichlid fishes.

The surrounding areas are mostly mountainous with poorly developed coastal plains except on part of the east side. Especially on the western coast, steep side-walls of the Great Rift Valley reaching 2,000 m in relative height form the shoreline. The sole effluent river, the Lukuga, starts from the middle part of western coast and flows westward to join the Zaire River draining into the Atlantic.

Agriculture, livestock raising and the processing of these products as well as the mining (tin, copper, coal, etc.) are the main industries in the drainage basin of L. Tanganyika. Fishery products, the "Tanganyika sardine" (*Stolothrissa tanganikae*, Herring Family) in particular, are also important for local economy. Well-developed regular ship lines connect Kigoma (Tanzania), Kalémié (Zaire) and other coastal towns as essential part of the inland traffic system of east Africa.

C. PHYSICAL DIMENSIONS (7)

Surface area [km^2]	32,000
Volume [10^{12}m^3]	17.8
Maximum depth [m]	1,471
Mean depth [m]	572
Water level	Unregulated
Length of shoreline [km]	1,900
Catchment area [km^2]	263,000

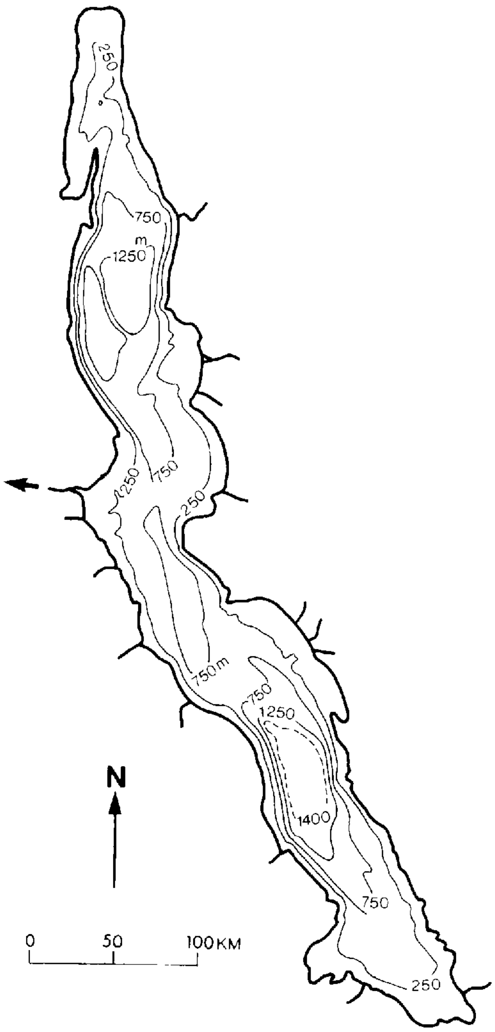
D. PHYSIOGRPHIC FEATURES (1)

D1 GEOGAPHICAL

§ Bathymetric map (Fig. AFR-6-1).

§ Outflowing rivers and channels (number and names): 1 (Lukuga R.).

Fig. AFR-6-1 Bathymetric map (1).



D2 CLIMATIC

§ Climatic Data at Bujumbura (3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]*	23.4	23.1	23.3	23.4	23.3	23.0	22.9	23.9	24.8	24.7	23.3	23.0	23.5
Precipitation [mm]**	94	109	121	125	57	11	5	11	37	64	100	114	848

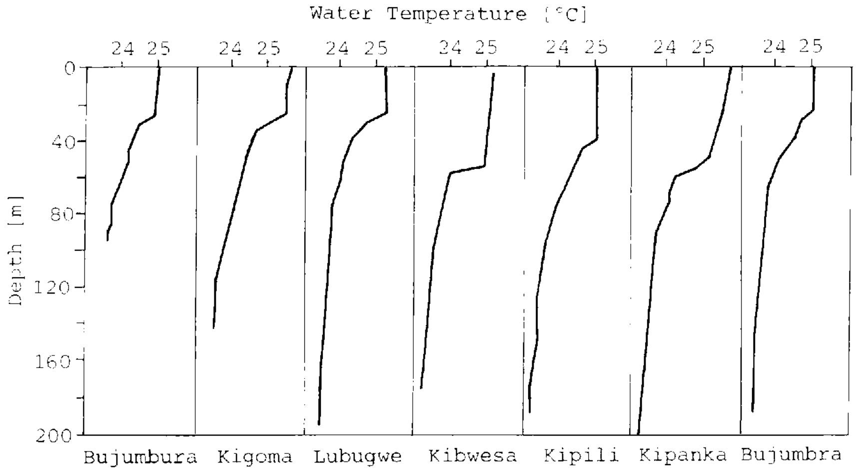
* 10-year average. ** 1931-1960.

§ Number of hours of bright sunshine (9-year average): 2,242 hr yr^{-1}.

§ Average solar radiation (2-year average): 18.31 MJ $m^{-2}day^{-1}$.

§ Water temperature

Fig. ASI-6-2 Vertical distribution of water temperature [°C] at 7 stations around the lake, Oct.-Nov. 1975 (place names refer to the nearest port) (4).



§ Notes on water mixing and thermocline formation : A more or less stable thermocline is formed at about 50 m depth. Seasonal variation of water temperature is limited to the surface 80 m layer, while the temperature remains stable in the underlying hypolimnion at 23.3-23.5 °C (1).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], means for the whole lake with ranges of fluctuation, 1975 (4)
Apr.-May (39 stations) : 14.5 (4.8-19.0).
Sep.-Nov. (44 stations) : 12.2 (5.5-16.0).

E2 pH : 8.6-9.2.

E5 COD
§ DOC (Oct.-Nov. 1975) : South Lake (10 stations) 323, Central Lake (12 stations) 245, North Lake (4 stations) 189 moles l^{-1} (4).

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]
§ Chlorophyll-a (Oct.-Nov. 1975) : South Lake 0.7, central Lake 4.6, North Lake 1.5 (4).

E7 NITROGEN CONCENTRATION [$\mu g\ l^{-1}$]
§ TDN (Oct.-Nov. 1975) : South Lake 85, Central Lake 72, North Lake 50 (4).

E8 PHOSPHORUS CONCENTRATION [$\mu g\ l^{-1}$]
§ TDP (Oct.-Nov. 1975) : South Lake 10, Central Lake 4, North Lake 7 (4).

F. BIOLOGICAL FEATURES

F1 FLORA
§ Emerged macrophytes : *Cyperus papyrus, Typha, Carex* (5).
§ Floating macrophytes : *Nymphaea, Trapa, Azolla, Pistia* (5).
§ Submerged macrophytes : *Potamogeton, Ceratophyllum, Utricularia* (5).
§ Phytoplankton : *Kirchneriella, Treubaria, Chroococcus limneticus, Chrysochromulina parva, Chromulina* sp., *Nitzschia, Anabaena, Stephanodiscus* sp., *Strombidium* (1).

F2 FAUNA
§ Zooplankton : *Cyclops, Diaptomus simplex, Limnochida tanganika* (1).

§ Benthos : Mollusca (*Grandideria burtoni, Brazzaea anceyi, Tiphobia horei, Bythoceras iridescens, Paramelania domoni*), Crustacea (*Platytelphusa armata*) (5).

§ Fish : *Stolothrissa tanganikae, Limnothrissa miodon, Lamprichthys tanganicus, Engraulicypris minutus, Bathybates minor, Bolengorochromis microlepis, Lates mariae, L. angustifrons, L. stappersi* (5).

F3 PRIMARY PRODUCTION RATE [mg C $m^{-2}day^{-1}$] (1, 4)

Apr.-May : 600, Oct. Nov. : 1,400, Annual mean : 1,000.

F4 BIOMASS

§ Phytoplankton and protozoan biomass (1975) (1, 4)

Station		Biomass [mg m^{-3}]		Percent composition of phytoplankton biomass*					
		Phyto-plankton	Protozoa	Cy	Chl	Chr	Pyr	Bac	Cry
Kipanga (south station)	Apr-May	169	89	37	27	18	6	10	3
Kilipi (SE shore)	Apr-May	138	144	35	16	25	15	7	2
	Oct-Nov	105	24	8	66	15	—	10	—
Malagarasi (NE river)	Apr-May	362	143	9	15	32	3	5	36
	Oct-Nov	105	38	53	30	1	10	5	0
Rumonge (north station)	Apr-May	108	72	22	38	25	—	13	2
	Oct-Nov	110	27	18	34	11	28	1	

* Cy = Cyanophyta, Chl = Chlorophyta, Chr = Chrysophyta, Bac = Bacillariophyta, Cry = Cryptophyta, Pyr = Pyrrophyta.

§ Fish biomass (fresh wt.) : Pelagic zone 40-875, average 162 kg ha^{-1} (6).

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA

§ Levels of fertilizer application on crop fields : Light.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

§ Main products and main kinds of industry.

Agriculture : Maize, cotton, tabacco, rice, sugar-cane, sisal, coffee, beans, groundnut, cassava, cattle and goat.

Manufacturing : Textile, leather, brewing, food and cement industry.

Mining : Tin, copper and coal.

G3 POPULATION IN THE CATCHMENT AREA

§ Total population : N. A.

§ Main cities (population) : Bujumbura (157,000), Kalemie, Kigoma (20,000), Mbala.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Fisheries and navigation.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION

§ Extent of damage : No information.

I2 TOXIC CONTAMINATION : No information.

I4 ACIDIFICATION : No information.

J. WASTEWATER TREATMENT

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Tanzania Fisheries Research Institute, Kigoma Centre, Tanzania.
(2) Centre of Uvira, S. R. I. (Scientific Research Institute), Uvira, Zaire.

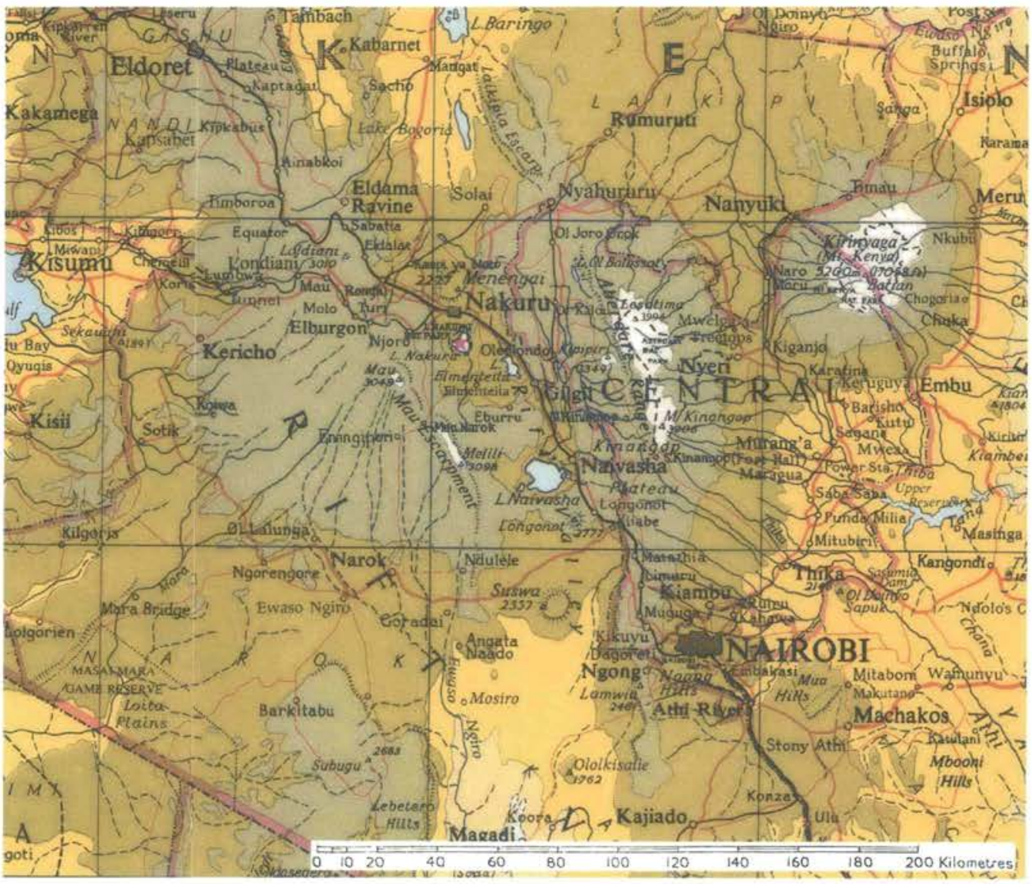
N. SOURCES OF DATA

(1) Serruya, C. & Pollinger, U. (1983) Lakes of the Warm Belt. 569 pp. Cambridge University Press, Cambridge.
(2) Hutchinson, G. E. (1975) A Treatise on Limnology, Vol. 1. Part 1, Geography and Physics of Lakes. 540 pp. Wiley-Interscience, New York.
(3) Müller M. J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306 pp. Dr. W. Junk Publishers, The Hague.
(4) Hecky, R. E., Fee, E. J., Kling, H. & Rudd J. W. M. (1978) Studies on the Planktonic Ecology of Lake Tanganyika. 51 pp. Western Region Fisheries and Marine Service, Department of Fisheries and the Environment, Winnipeg.
(5) Beadle, L. C. (1981) The Inland Waters of Tropical Africa (2nd ed.). 468 pp. Longman Inc., New York.
(6) Ssentongo, G. W., Durand, J. R. & Harbott, B. (1981) The rational exploitation of African aquatic ecosystems. The Ecology and Utilization of African Inland Waters (ed. Symoens, J. J., Burgis, M. & Gaudet, J. J.), pp. 167-175. United Nations Environment Programme, Nairobi.
(7) Herdendorf, C. E. (1982) Large lakes of the world. J. Great Lakes Res., 8(3) : 379-412.

LAKE NAKURU

Flamingos on the lakeshore

Photo: T. Kira



A. LOCATION

§ Rift Valley Province, Kenya.
§ 00°22′S, 36°05′E ; 1,759 m above sea level.

B. DESCRIPTION

Lake Nakuru is a small, shallow, alkaline-saline lake located in a closed basin without outlets in the Eastern Rift Valley of equatorial East Africa. It is the center of a most familiar national park of Kenya known for its spectacular bird fauna (495 species), particularly the vast flock of lesser flamingo (*Phoeniconaias minor*).

Being in the Rift Valley where tectonic and volcanic activities as well as climatic changes have been very remarkable, the lake underwent drastic changes during the recent geological ages. About 10,000 years ago, Nakuru and its two neighbor lakes, Elmenteita and Naivasha (60 km south of Nakuru), formed a single deep freshwater lake, which however dried owing to the later dessication of climate leaving the three separate lakes as remnants. The present maximum depth is about three meters, but the lake water level is still quite variable ; the whole lake had been almost dried up several times during the past 50 years (Fig. AFR-7-2) due to unknown reasons.

The lake is a soda-lake with a water pH value of 10.5 and an alkalinity of 122 meq l^{-1}. Main ions are sodium and bicarbonate-carbonate. The biota in the lake is very simple as in other saline lakes, consisting of phytoplankters dominated by blue-green algae and very poor planktonic and benthic fauna originally lacking fish. However, the lake is highly eutrophic owing to the vigorous growth of a planktonic blue-green alga, *Spirulina platensis*, which supports an immense number of alga-grazing lesser flamingo and an increasing population of the introduced fish, *Sarotherodon alcalicum grahami*, though, in the last several years since 1974, the planktonic productivity and the flamingo population decreased abruptly.

The lake's catchment area amounts to some 1,800 km^2 and is extensively utilized for agriculture and livestock raising. The city of Nakuru on the northernmost shore of the lake is a rapidly growing local center of industry and agriculture. Effluents from the city's two sewage treatment plants are discharged into the lake. The potential danger of pollution is suspected, but it is not yet clear whether the pollution is responsible for the recent changes of the lake ecosystem (1-8).

C. PHYSICAL DIMENSIONS (2, 5, 8)

Surface area [km^2]	40
Volume [10^6 m^3]	92.0
Maximum depth [m]	2.8
Mean depth [m]	2.3
Water level	Unregulated
Length of shoreline [km]	27
Catchment area [km^2]*	1,800

* Including the lake area.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. AFR-7-1).
§ Outflowing rivers and channels : None.
§ Main islands : None.

Fig. AFR-7-1 Bathymetric map (Dec. 1979) (8).
Depth in meters. Solid isopleths are actual shorelines at different lake water levels; from outer to inner, Dec. 1979, Jan. 1969, Jan. 1967 and Jan. 1961. Dashed isopleths are based on soundings in Feb. 1971. Two sewage plants are marked by a and b. Stippled areas indicate fringing forests dominated by *Acacia xanthophloea*.

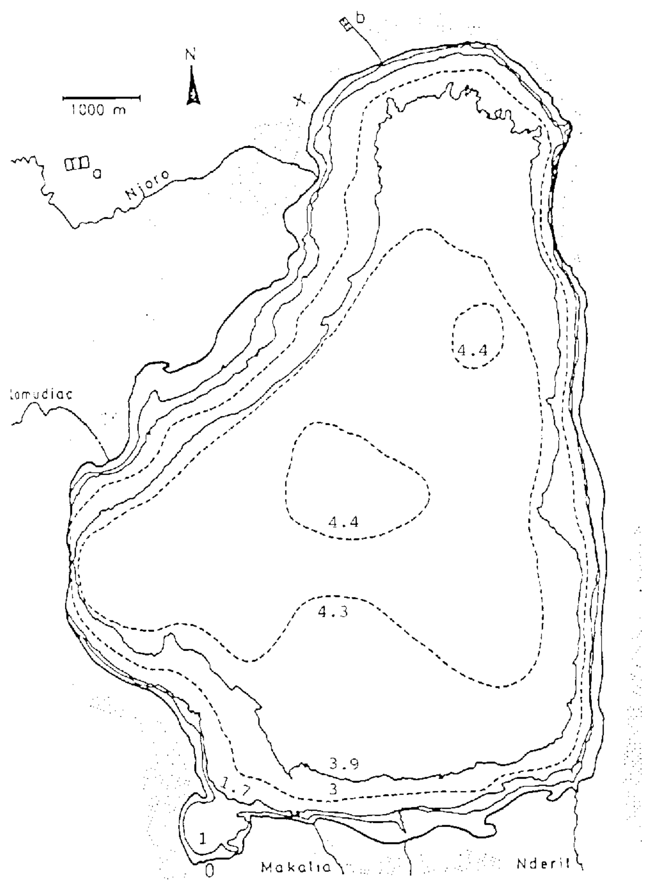
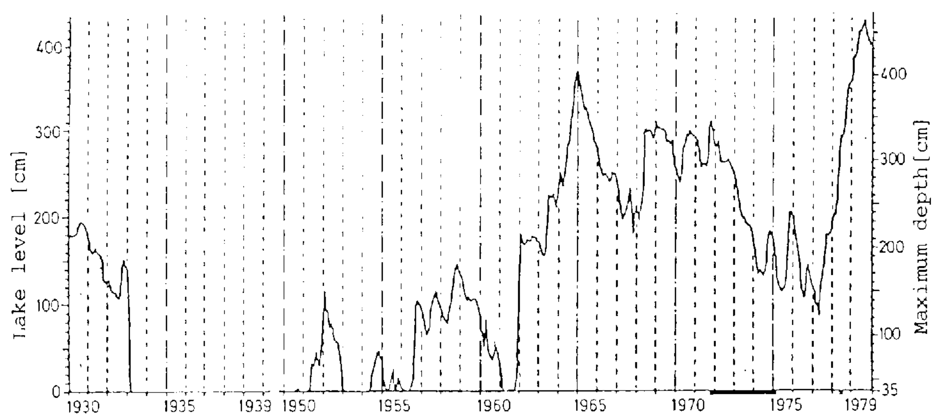


Fig. AFR-7-2 Lake water level fluctuation, 1930–1979 (8).



D2 CLIMATIC

§ Climatic data near the shore (8)

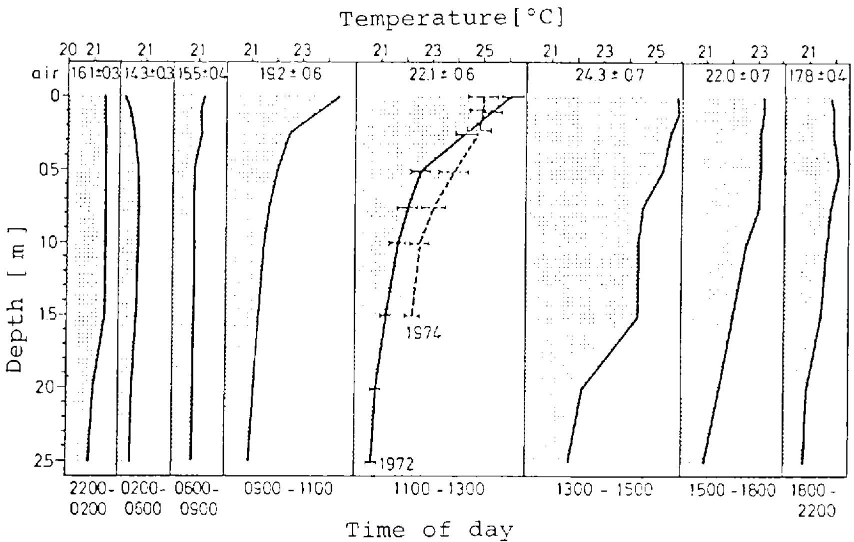
Annual mean temperature (1931-1955): 18.18±0.8 °C; monthly mean temperature fairly constant throughout the year.

Mean annual precipitation (1947-1977): 876±143 mm yr^{-1}; driest month (January) 24.5 mm $month^{-1}$; wettest months 128.2 mm $month^{-1}$ (April) and 114.9 mm $month^{-1}$ (August).

§ Solar radiation on the lake surface (average for 1968-1972): 486 J $m^{-2}sec^{-1}$, with little seasonal variation (8).

§ Water temperature

Fig. AFR-7-3 Mean water temperature profiles (1972-1973) at different times of day. A midday profile in 1974 is also given. Horizontal bars indicate standard errors (8).



§ Freezing period: None.

§ Mixing type: Polymictic.

§ Notes on water mixing and thermocline formation: Remarkable daily thermocline is formed at 0.5-1.5 m depth on clear days, but disappears in the afternoon due to wind mixing (8).

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m]

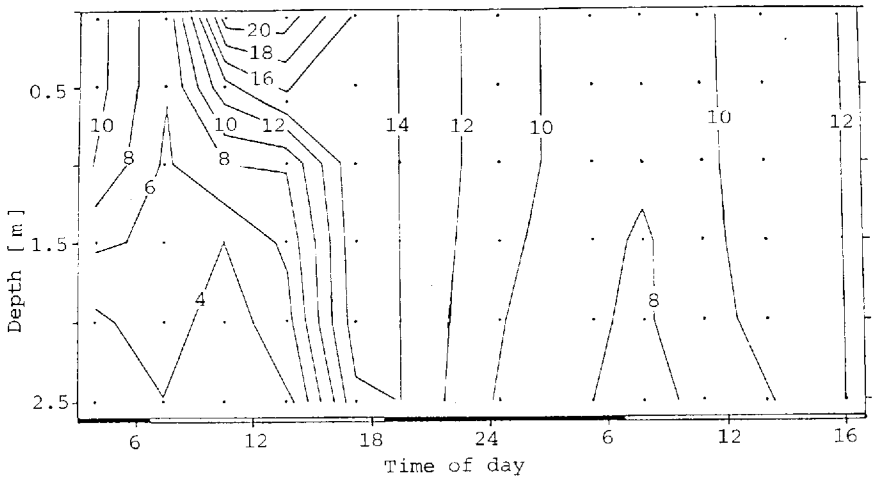
0.08 (1977) (3); 0.15 (1971) (2); 0.10 or less (1971-1973) (8); 0.40-0.50 (1974) (8).

E2 pH

Fairly constant at 10.5 and largely unsusceptible to changes in alkalinity and conductivity (2, 8).

E4 DO (Fig. AFR-7-4)

Fig. AFR-7-4 Time-depth distribution of DO [mg l^{-1}] 13-14 June 1971 (2).



Supplementary note : Dissolved oxygen concentration near the bottom was less than 1.0 mg l^{-1} for at least 6 hours during daytime in 1972-1973, while it remained >2.0 mg l^{-1} in 1974 (8).

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}] (8)

	1972	1973	1974	1978
Chlorophyll-a concentration	1,160±80	920±50	164±20	155

E8 PHOSPHORUS CONCENTRATION [mg l^{-1}]

§ Total P : 9.850±1.100 (1972-1973) (8).

§ PO_4-P : 4.4 (1971) (2) ; 0.149-0.202 (1972-1973) (8).

E9 CHLORIDE CONCENTRATION [mg l^{-1}] (8)

1,390±0.3 (1973).

§ Supplementary notes : Alkalinity ($HCO_3^- + CO_3^{--}$) 5,000-90,000 mg l^{-1} ; conductivity 8,500-165,500 μS (20°C).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Cyperus papyrifera*, etc. only at the mouth of inflows (5).

§ Floating macrophytes : None.

§ Submerged macrophytes : None.

§ Phytoplankton : Cyanobacteria (*Spirulina platensis, Spirulina* spp., *Synechococcus* spp., *Chroococcus minutus, Anabaenopsis arnoldii, A. elenkinii*) ; diatoms (*Navicula elkab, Nitschia frustulum*) (2, 5, 8).

F2 FAUNA

§ Zooplankton : Copepoda (*Lovenula africana*) ; Rotifera (*Brachionus dimidiatus, B. plicatilis Hexartha jenkinae*) (5, 8).

§ Benthos : Insecta (*Leptochironomus* sp., *Tanytarsus* sp., *Sigara hieroglyphica kilimandjaronis, Micronecta scutellaris, M. jenkinae*) (1, 5).

§ Fish : *Sarotherodon alcalicum grahami* (introduced ; only species) (7).

F3 PRIMARY PRODUCTION RATE

Year (Source no.)	1971(2)	1972-73(8)	1974(8)	1978(8)
Mean integrated rate of net photosynthesis [g $O_2m^{-3}hr^{-1}$]	—	0.64	0.40	0.34
Mean maximum rate of net photosynthesis at depth of highest production [g $O_2m^{-3}hr^{-1}$]	1.1-2.3	12.4	2.6	0.82
Mean daily rate of net photosynthesis [g O_2 $m^{-2}day^{-1}$]	5.4-8.6 * 31-36 **	7.6	1.3	5.0
Mean respiration rate [g $O_2m^{-3}hr^{-1}$]	—	3.5	0.98	2.6

* Light and dark bottle method. ** Diurnal free water method.

F4 BIOMASS

§ Biomass of phytoplankton [g m^{-3}, dry weight] (8)

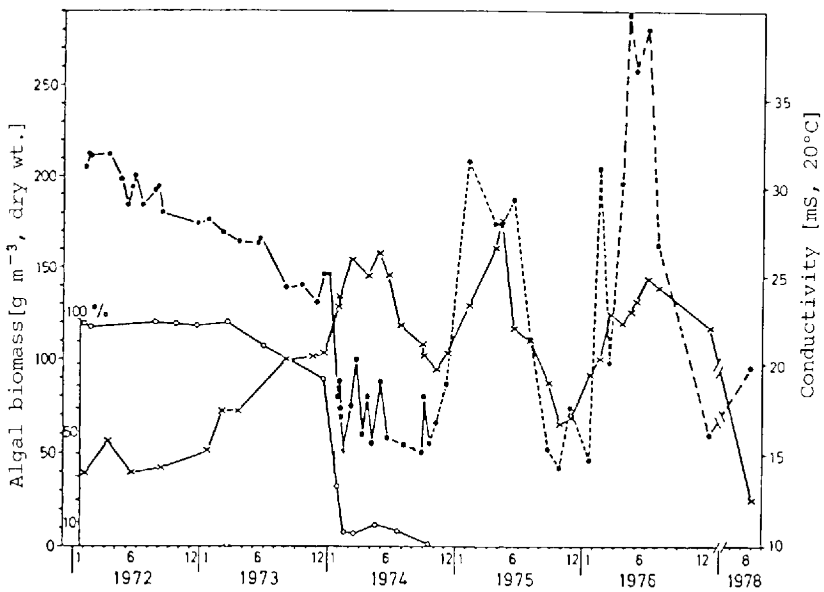
	1972	1973	1974	1978
Mean	194±4.3	157+5	71±4	58
Surface	270±22	246±40	137+20	65

§ Biomass of benthic animals [g m^{-2}]
Mean benthic biomass : 0.4 (dry weight) (4).
Mean biomass of *Leptochironomus* larvae : 60 (wet weight) (3).

§ Biomass of fish (*Sarotherodon alcalicum grahami*) : 2.1 g m^{-2}(90 metric tons per lake, dry weight) in 1972 ; 10.2 g m^{-2}(400 metric tons per lake) in 1973.

F6 PAST TRENDS

Fig. AFR-7-5 Trends of algal biomass (●) and conductivity of lake water (×) during 1972-1978. The percent contribution of *Spirulina platensis* to the total algal biomass is also shown (8).



F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS

The fauna of L. Nakuru originally contained no fish species, but a salt-tolerant species of Tilapia (*Sarotherodon alcalicum grahami* = *Tilapia grahami*) was introduced into the lake from its home Lake Magadi in 1953, 1959 and 1962 to combat mosquito breeding. The Tilapia has since been established its population in the lake, maintaining a biomass range of 2-13 g m^{-2}(dry wt.) in 1972-1976, and become one of the main primary consumers of algae, which had so far been mostly grazed by lesser flamingos. The introduction of Tiliapia also resulted in the increase of fish-eating birds such as Great White Pelican (*Pelecanus onocrotalus roseus*) (7).

The blue-green alga (cyanobacterium) *Spirulina platensis* was in a lasting bloom in 1971-1973, accounting for 80-100% of the large phytoplankton biomass (up to 200 g m^{-3}(dry wt.)). In 1974, however, it almost disappeared from the lake for unknown reasons and was replaced by such coccoid cyanobacteria as *Anabaenopsis* and diatoms. This change was also associated with the serious reduction in algal biomass, primary productivity and flamingo population (from 1 million to several thousands) (2, 6, 8).

No scientific information was available on the state of the lake's ecosystem during the last decade, though the recovery of lesser flamingo population has been reported.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (6, 8)

About two-thirds of the lake's drainage basin (ca. 1,800 km^2 including the lake area) are used for agricultural purposes, mainly as rangelands. Forest areas are found only along watershed ridges of Mau Escarpment to the west of the lake. An extensive industrial area is rapidly growing around Nakuru City.

The vegetation surrounding the lake consists of a narrow belt of fringing forest dominated by *Acacia xanthophloea* (Fig. AFR-7-1), scrub communities on steep cliff encircling the southern part of the lake (in some places dominated by tall euphorbia, *Euphorbia ingens*) and grasslands with scattered shrubs used for cattle grazing.

G3 POPULATION IN THE CATCHMENT AREA

Data unavailable ; the largest town is Nakuru with a population of 60,000 in 1977(6).

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Sightseeing and tourism. A portion of the lake was declared a National Park in 1961. The park area was later extended to the present 160 km^2 that cover the whole lake and surrounding areas (6).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION : Not very serious.

I2 TOXIC CONTAMINATION : Suspected but no information.

I3 EUTROPHICATION : No evidence of progressive eutrophication.

I4 ACIDIFICATION : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems : two treatment plants in Nakuru City ; treatment system unknown (8).

N. SOURCES OF DATA

(1) Hammer, U. T. (1986) Saline Lake Ecosystems of the World. Dr. W. Junk Publishers, The Hague. 616 pp.
(2) Melack, J. M. & Kilham, P. (1974) Photosynthetic rates of phytoplankton in East African alkaline, saline lakes. Limnol. & Oceanogr., 19(5) : 743-755.
(3) Millbrink, G. (1977) On the limnology of two alkaline lakes (Nakuru and Naivasha) in the East Rift Valley system in Kenya. Int. Rev. ges. Hydrobiol., 62 : 1-17.
(4) Payne, A. I. (1986) The Ecology of Tropical Lakes and Rivers. John Wiley & Sons, New York.
(5) Serruya, C. & Pollingher, U. (1983) Lakes of the Warm Belt. Cambridge Univ. Press, Cambridge. 569 pp.
(6) Vareschi, E. (1978) The ecology of Lake Nakuru (Kenya). I. Abundance and feeding of the lesser flamingo. Oecologia (Berl.), 32 : 11-35.
(7) Vareschi, E. (1979) The ecology of Lake Nakuru (Kenya). II. Biomass and spatial distribution of fish. Ibid., 37 : 321-325.
(8) Vareschi, E. (1982) The ecology of Lake Nakuru (Kenya). III. Abiotic factors and primary production. Ibid., 55 : 81-101.

LAKE MENDOTA

A view from the campus of the University of Wisconsin

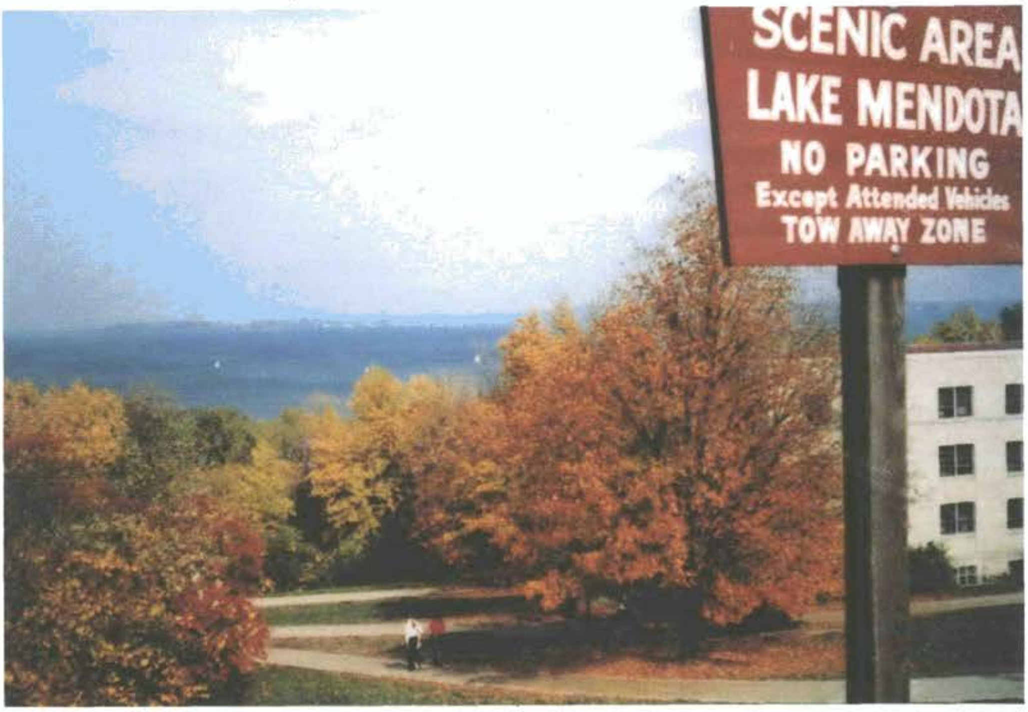
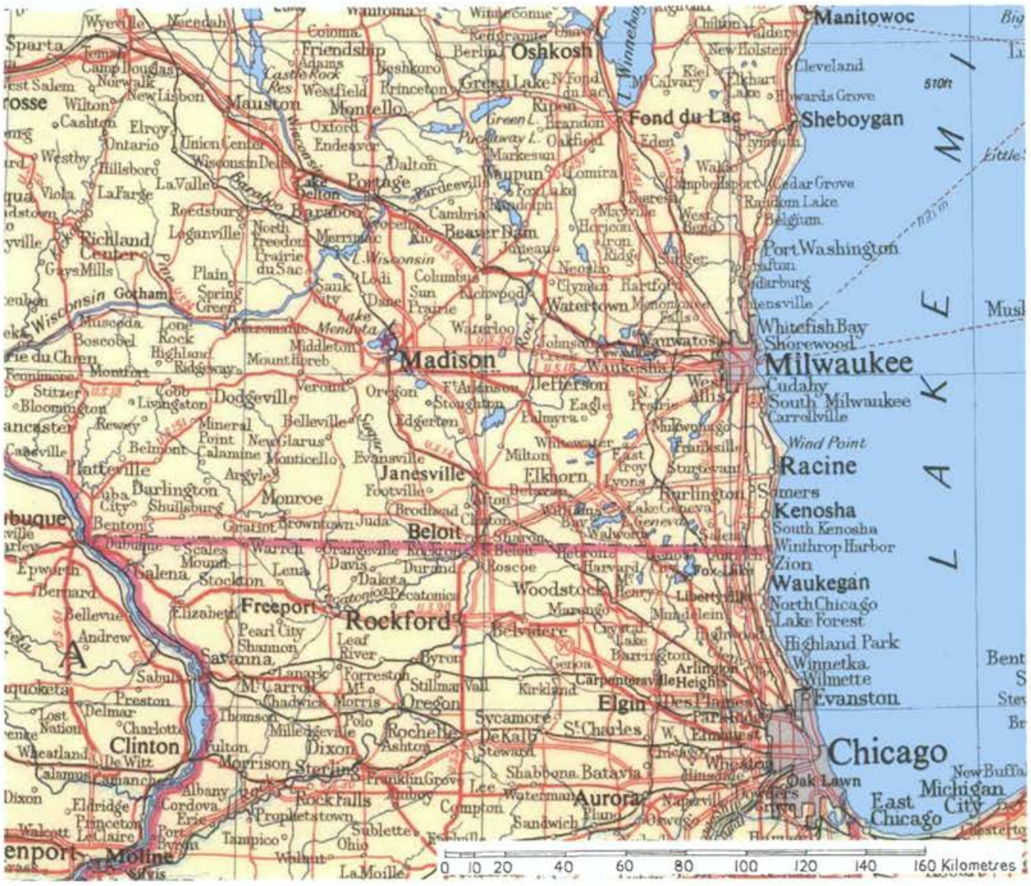


Photo: Y. Kada



A. LOCATION

§ Dane County, Wisconsin, U.S.A.
§ 43°06′ N, 89°25′ W ; 850 m above sea level.

B. DESCRIPTION

Lake Mendota is located approximately 120 km west from Milwaukee, a city on the western shore of Lake Michigan. Although the lake is comparatively small (surface area 40 km^2) and shallow (mean depth 12.2 m), it is significant as a birthplace of modern limnology and an early instance of artificially accelerated eutrophication.

The lake has a freezing period of about three and a half months annually, and the concentration of dissolved oxygen in the water is generally high in the epiliminion throughout the year, though it falls to 1-2 mg/l in the bottom water during the summer.

Owing to the influx of domestic wastewater, the lake has suffered from eutrophication since the beginning of this century. From 1912 to 1958, copper sulphate was applied over the lake to reduce the overgrowth of algae. The algal bloom was effectively suppressed but the lake became polluted with copper, which still remains accumulated in the bottom sediments as insoluble copper carbonate.

The diversion project for wastewater is particularly noteworthy in the lake's water treatment plan. When the main lake became heavily eutrophicated, inflowing wastewater was diverted to the three small lakes downstream, but these also became eutrophicated over time. Therefore, the wastewater flowing into the four lakes was collectively diverted to the Yahara River to cope with the situation. The history of wastewater treatment in L. Mendota and the nearby city of Madison tells of a bitter struggle for an effective control of eutrophication (Q).

C. PHYSICAL DIMENSIONS (1, 2)

Surface area [km^2]	39.4
Volume [$10^6 m^3$]	481
Maximum depth [m]	25
Mean depth [m]	12.2
Length of shoreline [km]	35.3
Residence time [yr]	3.1-8.8
Catchment area [km^2]	522

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-1-1) (8).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Yahara R.)

D2 CLIMATIC (3, 4)

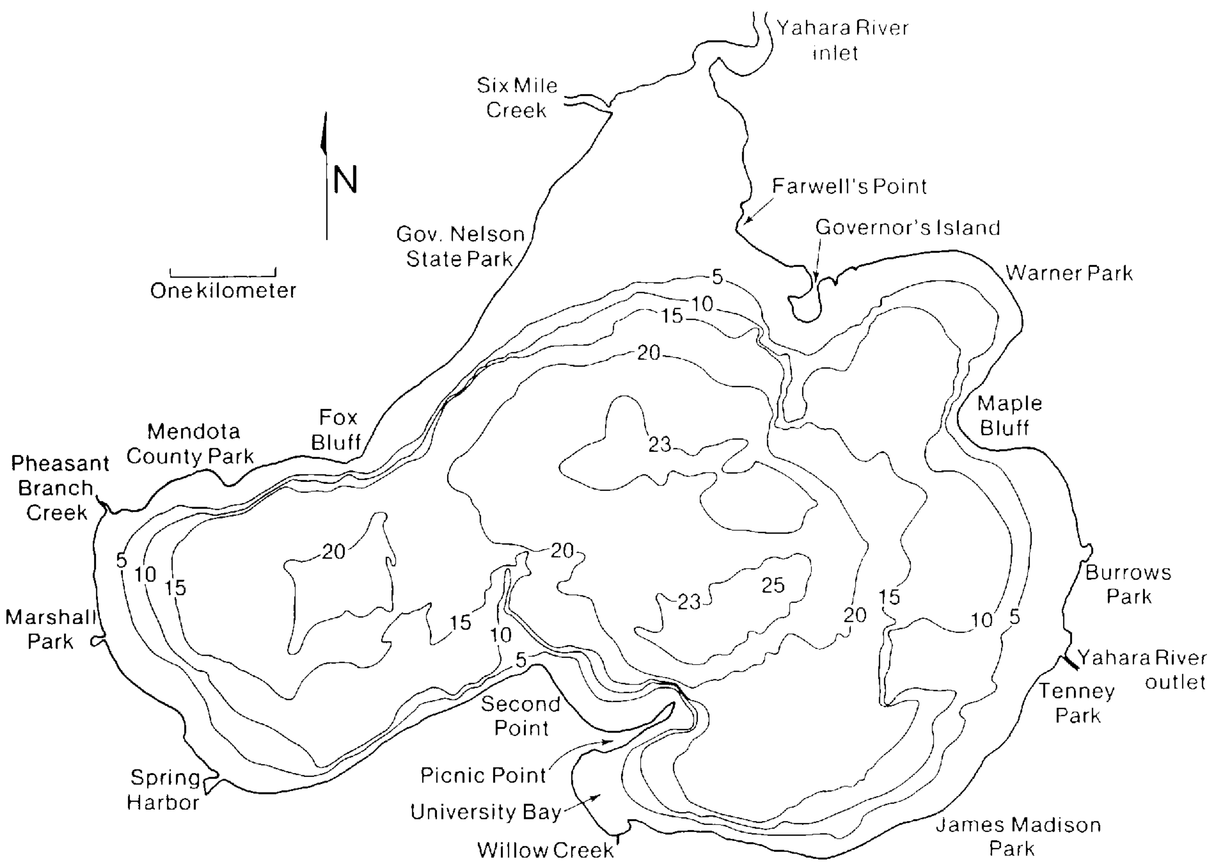
§ Climatic data at Dane County Regional Airport*, 1943-1982

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp.[°C]	-8.6	-6.2	-0.1	7.8	14.0	19.3	21.9	20.8	15.9	10.2	1.9	-5.2	7.7
Precipitation [mm]	31	26	52	74	84	104	95	91	80	53	50	39	779

* Approximately 9 km east of the lake center.

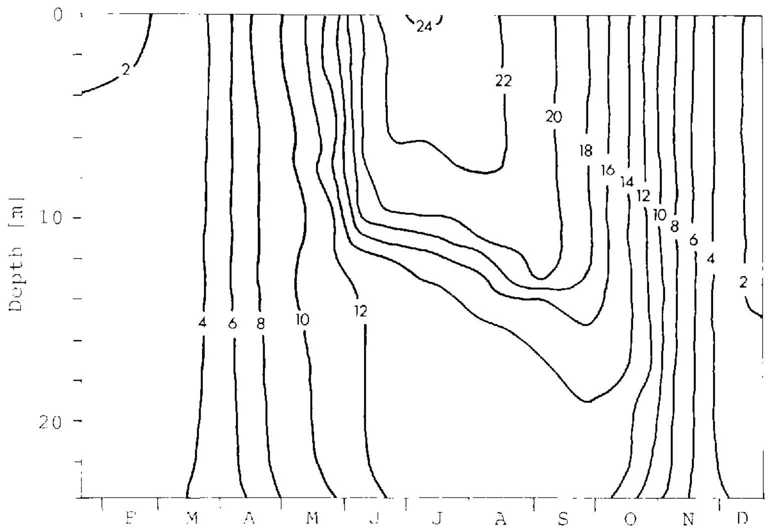
§ Number of hours of bright sunshine (1947-1982) : 2,500 hr yr^{-1}.
§ Solar radiation (1951-1975) : 13.5 MJ m^{-2} day^{-1}.

Fig. NAM-1-1 Bathymetric map (8).



§ Water temperature

Fig. NAM-1-2 Seasonal and vertical distribution of water temperature [°C], 1976 (1).

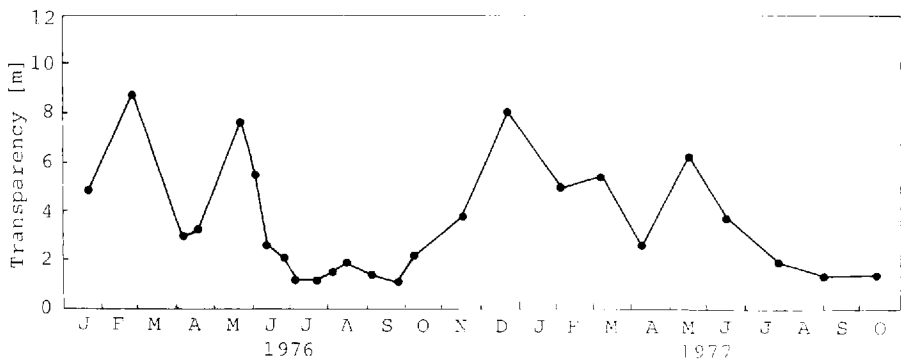


§ Freezing period (1852-1983) : From 20 Dec. to 15 Apr.
§ Mixing type : Dimictic.

E. LAKE WATER QUALITY

E1 TRANSPARENCY

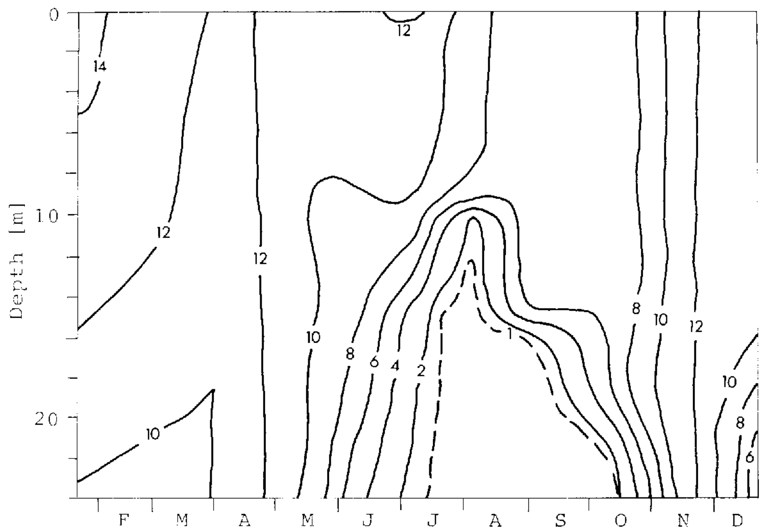
Fig. NAM-1-3 Seasonal changes of transparency (1).



E3 SS [mg l^{-1}], the outlet on southeast side, 1976-1977 : 1.9 (range 0.5-6.8) (5).

E4 DO

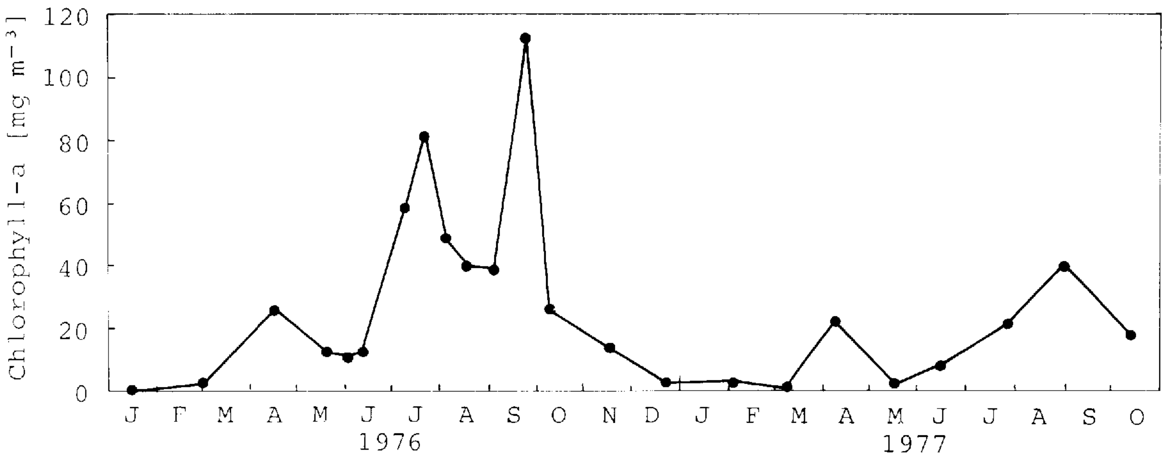
Fig. NAM-I-4 Seasonal and vertical distribution of DO [mg l^{-1}], 1976 (1).



E5 COD [mg l^{-1}], the outlet on southeast side, 1976-1977 : 21 (range 1-43) (5).

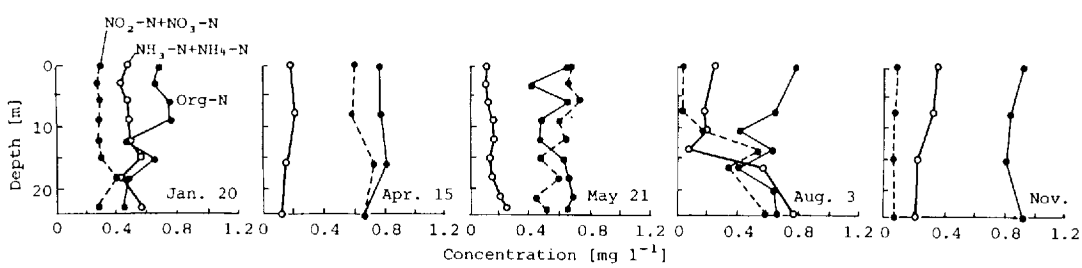
E6 CHLOROPHYLL CONCENTRATION

Fig. NAM-I-5 Seasonal change of chlorophyll-a [μg l^{-1}], 0-2 m (1).



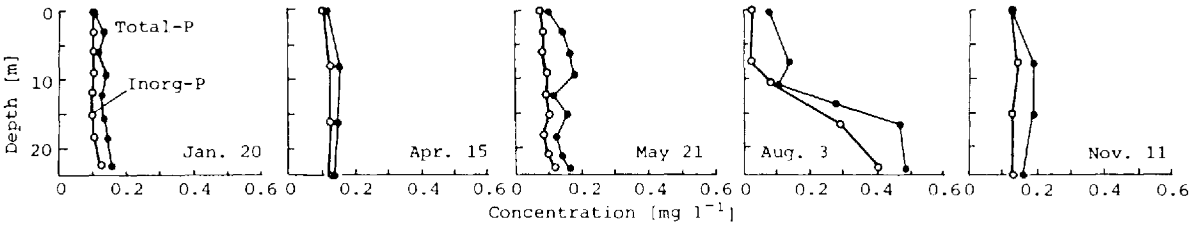
E7 NITROGEN CONCENTRATION

Fig. NAM-I-6 Seasonal change of nitrogen concentration [mg l^{-1}], 1976 (1).



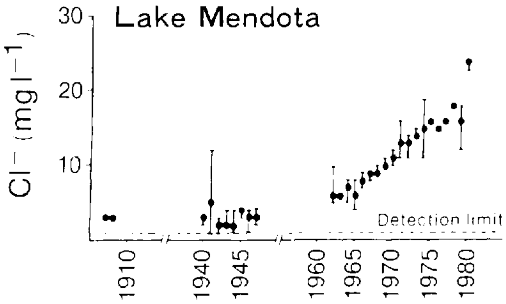
E8 PHOSPHORUS CONCENTRATION

Fig. NAM-I-7 Seasonal change of total and inorganic phosphorus concentration [mg l^{-1}], 1976 (1).



E9 CHLORINE ION CONCENTRATION

Fig. NAM-I-8 Past trends of chloride concentration [mg l^{-1}] (9).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Phytoplankton : *Aphanizomenon, Stephanodiscus, Cryptomonas, Fragilaria, Anabaena, Microcystis* (1, 6, 7).

F2 FAUNA

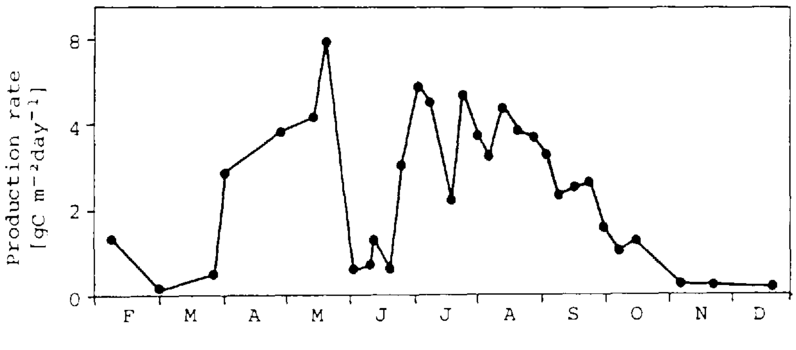
§ Zooplankton : *Asplanchna* sp., *Bosmina longirostris, Brachyonus* sp., *Ceriodaphnia* sp., *Chydorus sphaericus, Daphnia galeata mendotae, D. parvula, D. pulex, D. retrocurva, Diacyclops bicuspidatus thomasii, Diaphanosoma leuchtenbergianum, Filinia* sp., *Keratella cochlearis, K. quadrata, Polyarthra* sp., *Trichocerca* sp. (1).

§ Benthos : *Limnodrilus, Tubifex, Pisidium, Chironomus, Corethera punctipennis, Protenthes* (8).

§ Fish : *Roccus chrysops, Lepomis macrochirus, Perca flavescens, Esox luis, Amoloplites rupestris, Micropterus colomieui, M. salmoides, Pomoxis nigromaculatus* (1).

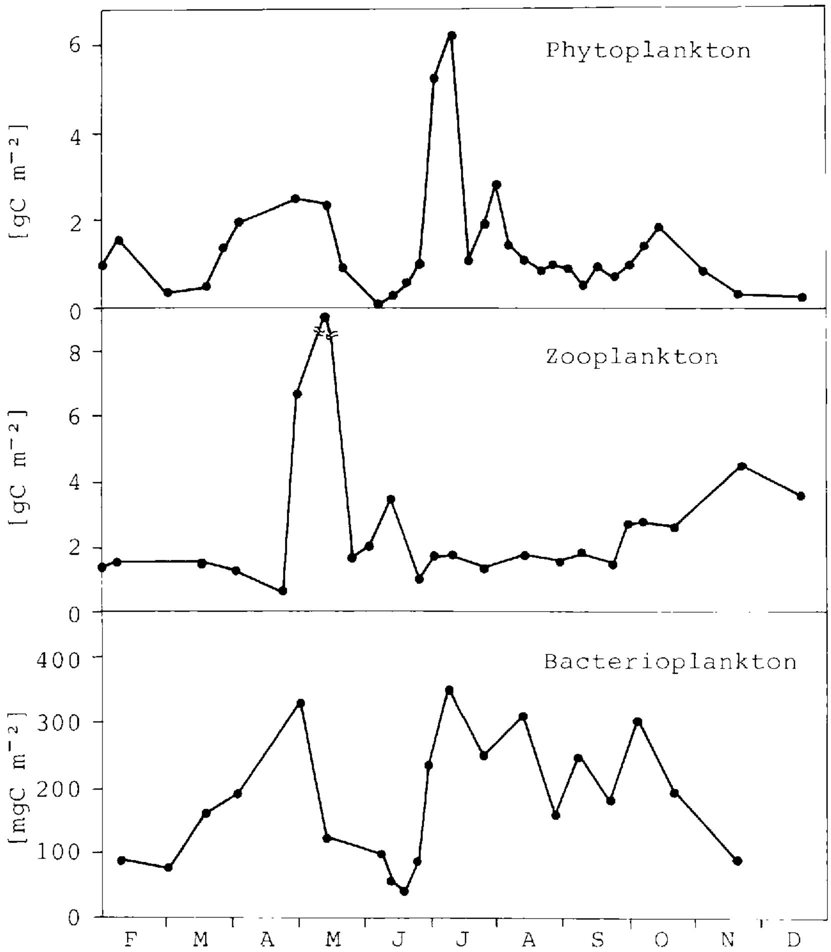
F3 PRIMARY PRODUCTION RATE

Fig. NAM-I-9 Algal primary production rate [gC $m^{-2}day^{-1}$], 1980 (7).



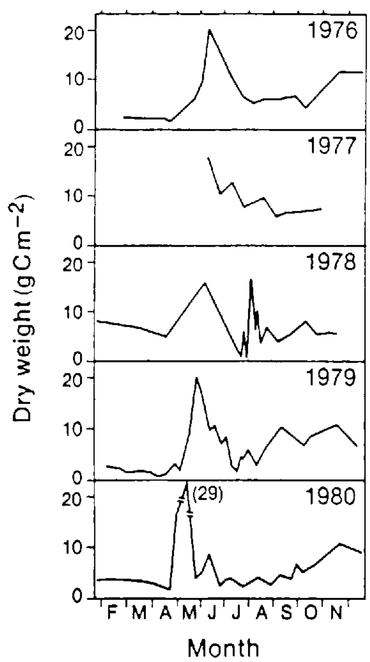
F4 BIOMASS

Fig. NAM-I-10 Biomass of phytoplankton, zooplankton and bacterioplankton, 1980 (7).



F6 PAST TRENDS

Fig. NAM-I-11 Past trend of total zooplankton biomass (10).



§ Past trend of the size of *Perca flavescens* (11)

Year	1916	1931	1932	1939	1943	1946	1948
Number of fish in sample	169	261	51	25	297	375	210
Average total length [mm]	162	198	180	188	214	220	243
Average weight [g]	50	84	76	86	128	137	180

G. SOCIO-ECONOMIC CONDITIONS (Q)

G1 LAND USE IN THE CATCHMENT AREA (1975)

	Area [km²]	[%]
Natural landscape		
Woody vegetation	40	7.2
Swamp	24	4.3
Agricultural land	430	76.9
Residential area	65	11.6
Total	559	100.0

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE

§ Main products and main kinds of industry

Agriculture: Dairy farming. Manufacturing: Electrical machinery, agricultural machinery, fertilizer and foods (dairy products).

G3 POPULATION IN THE CATCHMENT AREA

§ Population in the catchment area: N.A.

§ Main cities: Madison (population 170,600 in 1980); not all the city area is included in the catchment area.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Sightseeing, tourism and recreation (swimming, sport-fishing) (Q).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I3 EUTROPHICATION

§ Nitrogen and phosphorus loading to the lake, 1976-1977

Phosphorus [kg yr^{-1}] (12)

Source	1976 Total P	1976 Soluble P	1977 Total P	1977 Soluble P
Baseflow	4,500	2,600	3,700	2,300
Precipitation	700	550	1,000	790
Dry fallout	2,400	1,000	2,400	1,000
Groundwater seepage	120	120	160	160
Rural runoff				
Monitored (397 km^2)	24,200	11,700	8,200	4,900
Unmonitored (113 km^2)	6,900	3,300	2,300	1,400
Urban (38.6 km^2)	4,200	2,100	5,100	2,500
Total				
kg	43,000	21,000	23,000	13,000
g/m^2 of lake surface/yr	1.1	0.53	0.58	0.33
g/m^3 of lake volume/yr	0.090	0.043	0.048	0.027

Values are in kilograms for the whole lake. The urban loading does not include about 21.5 km^2 of developed area in villages and cities in the monitored rural area.

Nitrogen [kg yr^{-1}] (12, 13)

Source	1976 Total Nitrogen	1976 Inorganic Nitrogen	1977 Total Nitrogen	1977 Inorganic Nitrogen
Baseflow	180,000	150,000	140,000	120,000
Rural runoff	160,000	86,000	48,000	23,000
Urban runoff	20,000	5,000	26,000	6,000
(Others)*	(210,000)	(130,000)	(210,000)	(130,000)
Total	(570,000)	(370,000)	(420,000)	(280,000)

* Includes precipitation, dry fallout, groundwater and nitrogen fixation estimates. Values in parentheses are estimates.

N. SOURCES OF DATA

(Q) Questionnaire filled by Prof. M. S. Adams, Institute of Environmental Studies, University of Wisconsin, based on the data obtained from the following sources.

(1) Lathrop, R. C. & Johnson, C. D. (1979) Water quality conditions. Dane County Water Quality, Appendix B. Dane County Regional Planning Commission, Madison, Wisconsin.

(2) Wessley, J., Nyenhuis, G. & Eaton, E. (1981) Lake Survey Map of Lake Mendota, Dane County. Wisconsin Department of Natural Resources, Madison, Wisconsin.

(3) National Climatic Center (1982) Local Climatological Data, Annual Summary with Comparative Data, 1982, Madison, Wisconsin. National Oceanic and Atmospheric Administration, Environmental Data and Information Service, National Climatic Center, Ashville, N. Carolina.

(4) Knapp, C. L. et. al. (1980) Insolation Data Manual. Solar Energy Research Institute.

(5) Dane County Regional Planning Commission (1979) Dane County Water Quality. Dane County Regional Planning Commission, Madison, Wisconsin.

(6) Fallon, R. D. & Brock, T. D. (1980) Planktonic blue-green algae: production, sedimentation and decomposition in Lake Mendota, Wisconsin. Limnol. & Oceanogr., 25: 72-88.

(7) Pedrós-Alió, C. & Brock, T. D. (1982) Assessing biomass and production of bacteria in eutrophic Lake Mendota, Wisconsin. Appl. Environ. Microbiol., 44: 203-218.

(8) Brock, T. D. (1985) A Eutrophic Lake: Lake Mendota, Wisconsin. Ecological Studies 55. Springer-Verlag, New York, 308pp.

(9) *Lillie, R. A. & Mason, J. W. (1983) Limnological Characteristics of Wisconsin Lakes.

Technical Bulletin No. 183. Department of Natural Resources, Madison, Wisconsin.

(10) *Pedrós-Alió C., Woolsey, E. & Brock, T. D. (1985) Zooplankton dynamics in Lake Mendota : abundance and biomass of the metazooplankton from 1976 to 1980. Transactions of the Wisconsin Academy of Sciences.

(11) *Bardach, J. E. (1951) Changes in the yellow perch population of Lake Mendota, Wisconsin, between 1916 and 1948. Ecology, 32 : 719-728.

(12) *Lathrop, R. C. (1979) Dane County Water Quality Plan. Appendix B : Water Quality Conditions ; Appendix H : Lake Management. Dane County Regional Planning Commision, Madison, Wisconsin.

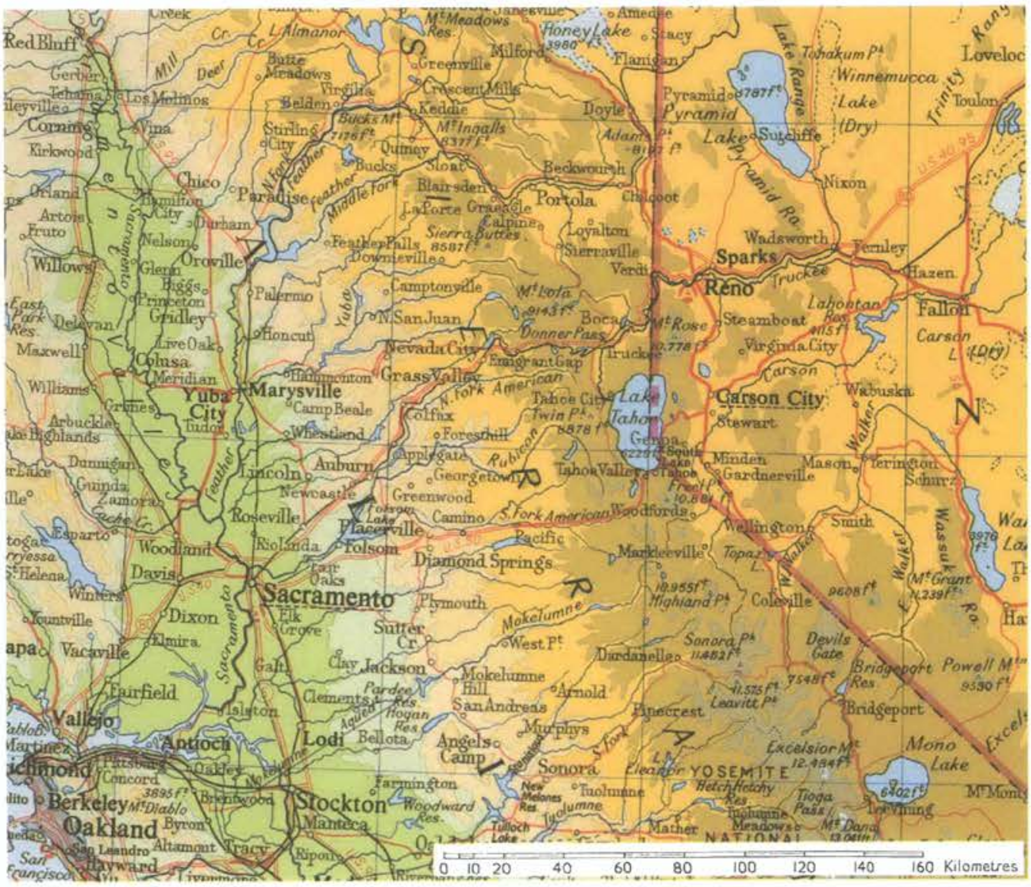
(13) *Sonzogni, W. C. & Lee, G. F. (1975) Phosphorus sources for the lower Madison lakes. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters, 63 : 162-175.

*Cited from (8).

LAKE TAHOE

A view from the lakeside hill

Photo: Y. Watanabe



A. LOCATION

§ California and Nevada, U.S.A.
§ 39°05'N, 120°03'W ; 1,897 m above sea level.

B. DESCRIPTION

Lake Tahoe is located on the California-Nevada border in the Sierra Nevada Mountain Range at about 1,900 m above sea level, and is surrounded by spectacular mountain peaks. The lake water is extremely clear. The climate of the lake basin is characterized by long but rather mild winters and short, dry summers. The splendid scenery around the lake attracts many visitors.

The drainage basin is comparatively small as compared with other lakes, with the result that the residence time of lake water is very long. Tahoe soils are derived from volcanic or granitic parent material, and are easily eroded during heavy rain. Thus surface flows from the lake's watershed carry a continuous load of nutrients and sediments to the lake. In addition, the recent and rapid increase of visitors and residents has caused some eutrophication, though the nutrient level of the lake is still quite oligotrophic. In order to avoid further environmental disruption, the bi-state Tahoe Regional Planning Agency was established in 1970, and has worked out a plan for land use, transportation, conservation, recreational development and public services. It is well known as one of the most successful environmental management and conservation efforts in the United States.

C. PHYSICAL DIMENSIONS (1-4)

Surface area [km^2]	499
Volume [$10^9 m^3$]	375
Maximum depth [m]	505
Mean depth [m]	313
Length of shoreline [km]	120
Residence time [yr]	700
Catchment area [km^2]	841

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

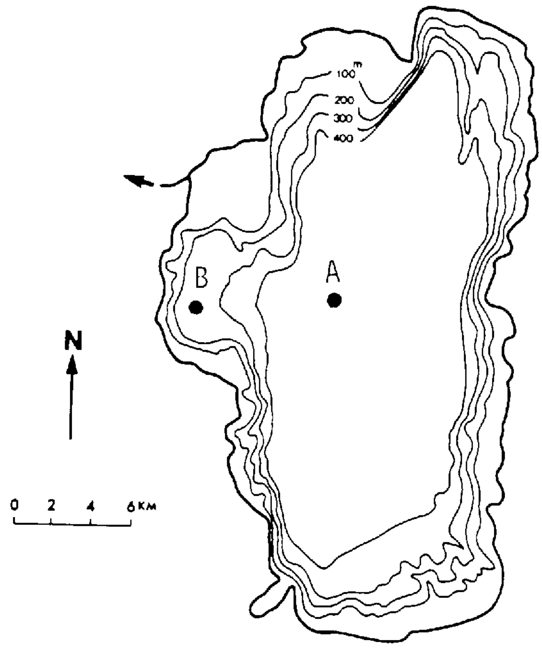
§ Bathymetric map (Fig. NAM-2-1).
§ Outflowing rivers and channels (number and names) : 1 (Truckee R.).

D2 CLIMATIC (2)

§ Climatic data at Tahoe City (2)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-2.6	-1.9	0.1	3.3	7.5	11.4	15.8	15.4	11.8	7.2	2.2	-1.1	5.8
Precipitation [mm]	157	137	97	56	25	13	6	5	13	41	79	133	762

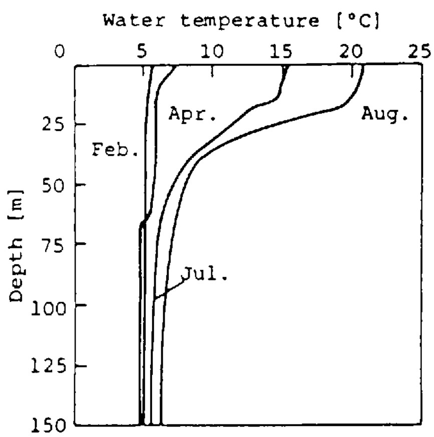
Fig. NAM-2-1 Bathymetric map (5).



A : Lake center. B : Index station.

§ Water temperature

Fig. NAM-2-2 Vertical and seasonal distribution of water temperature, Lake center, Apr. 1969-Feb. 1970 (4).



§ Freezing period : None.
§ Mixing type : Monomictic.

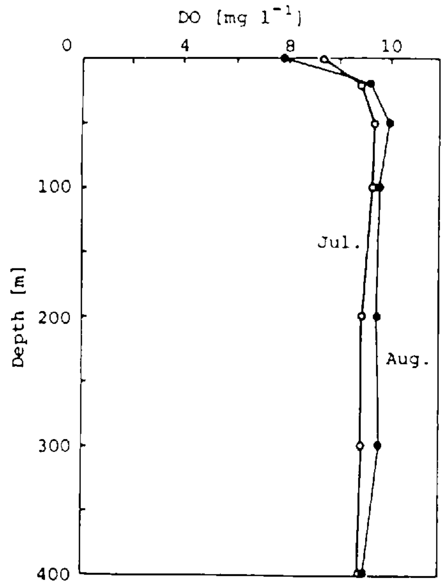
E. LAKE WATER QUALITY

§ Average water quality (surface water, average for 1981) (1, 3)

Transparency	27.6	[m]
pH	7.1-8.2	
DO	7 11	[mg l^{-1}]
DO percent saturation	90-105	[%]
T-N	21.1	[μg l^{-1}]
T-P	5.8	[μg l^{-1}]
Chlorophyll	0.07-0.41	[mg l^{-1}]

E4 DO

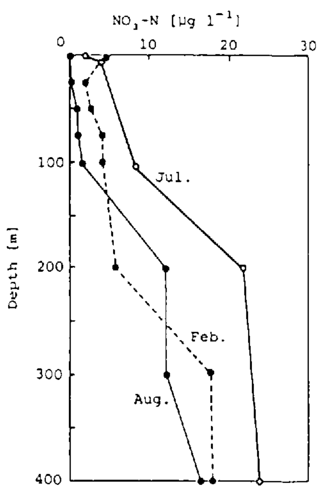
Fig. NAM-2-3 Vertical distribution of DO, Lake center, 1969 (4).



E7 NITROGEN AND PHOSPHORUS CONCENTRATION

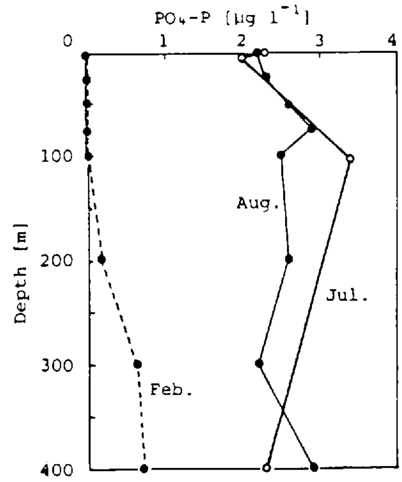
§ NO_3-N

Fig. NAM-2-4 Vertical distribution of NO_3-N, Lake center, Jul. 1969 Feb. 1970 (4).



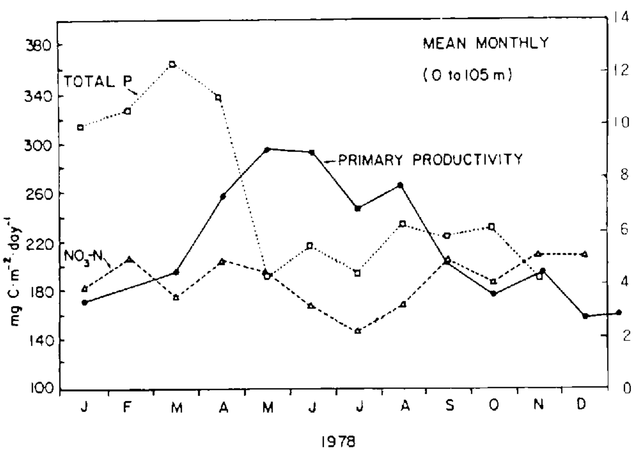
§ PO_4-P

Fig. NAM-2-5 Vertical distribution of PO_4-P, Lake center, Jul. 1969-Feb. 1970 (4).



§ Total-P and nitrate-N

Fig. NAM-2-6 Total-P and nitrate-N, Tahoe Index Station, 1978 (6).



E9 PAST TRENDS

Nitrate-N (values are in tons) (6)

Year	Mixing interval	Depth of mixing [m]	Euphotic zone (0-105m)	Aphotic zone (105-450m)
1973	9 Mar. -19 Mar.	450	5.71	14.32
1974	2 Feb. - 4 Mar.	450	6.20	14.12
1975	17 Feb. -31 Mar.	450	5.81	13.76
1976	23 Mar. - 4 Apr.	200-250	4.29	19.94
1977	11 Mar. -27 May	175	3.41	29.34
1978	15 Mar. -27 Mar.	125-250	1.87	25.67
1979	28 Feb. - 2 Apr.	275	4.64	24.26
1980	22 Jan. -29 May	275	1.6	12.9

F. BIOLOGICAL FEATURES

F1 FLORA

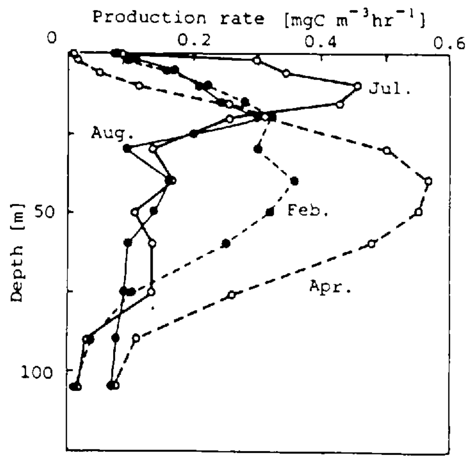
§ Emerged macrophytes : *Typha latifolia, Carex rostrata, C. vesicaria, Glyceria borealis, G. elata* (7).
§ Floating macrophytes : *Nymphaea polysepala* (7).
§ Submerged macrophytes : *Isoetes bolanderi, I. muricata* var. *hesperia, Potamogeton richardsonii, Elodea canadensis* (7).
§ Phytoplankton : *Melosira crenulata, Cyclotella bodanica, Navicula aurora, Fragilaria crotonensis, Asterionella formosa, Synedra ulna, Nitzschia amphibia, Staurastrum natator, Dinobryon sociale* (4).

F2 FAUNA

§ Zooplankton : *Kellicottia longispina, Epischura nevadensis, Diaptomus tyrelli, Bosmina longirostris, Mysis relicta* (8, 9).
§ Fish : *Oncorhynchus nerka, Salmo clarki* (1).

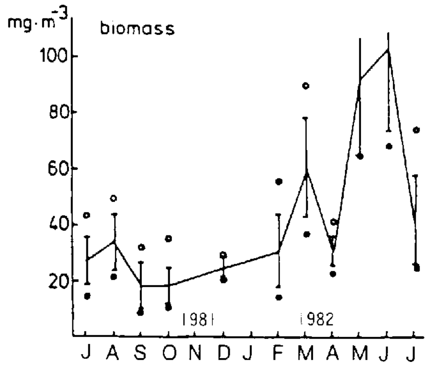
F3 PRIMARY PRODUCTION RATE

Fig. NAM-2-7 Vertical and seasonal distribution of primary production rate. Lake center, Apr. 1969 Feb. 1970 (4).



F4 BIOMASS

Fig. NAM-2-8 Seasonal change of phytoplankton biomass (nine stations in the littoral zone) (10).



(Vertical lines=S.D., O=monthly maximum, •=monthly minimum)

F6 PAST TRENDS

Fig. NAM-2-9 Trend of the population of kokanee salmon (*Oncorhynchus nerka*) (1).

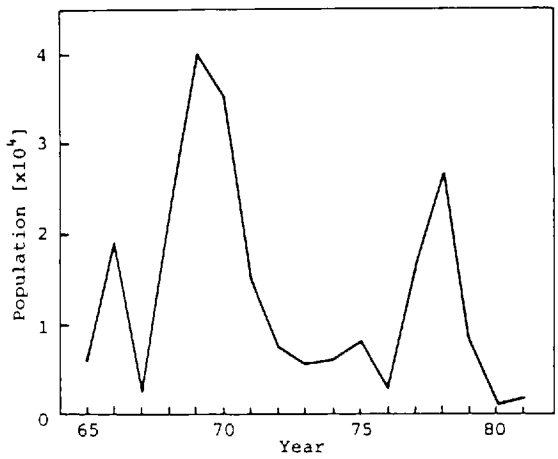
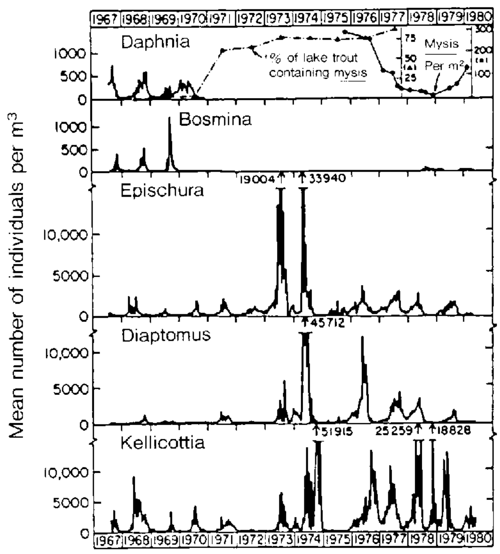


Fig. NAM-2-10 Trend of the populations of zooplankton (6).



G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1977) (1)

	Area	
	[km²]	[%]
Woody vegetation	706.4	88.1
Agricultural land	10.1	1.3
Residential area	64.8	8.1
Commercial area	8.7	1.1
Public service	11.9	1.5
Total	801.9	100.0

§ Main types of woody vegetation: Lodgepole pine plantation (*Pinus contorta* var. *murryana*);

subalpine red fir forest (*Abies magnifica*); jeffrey pine forest (*Pinus jeffreyi*); mixed conifer forest; deciduous broadleaf forest (*Populus tremuloides*) (6).

§ Main types of herbaceous vegetation: Meadow, sagebrush and alpine communities (6).

G3 POPULATION IN THE CATCHMENT AREA (1980) (1)

	Population	Population density [km^{-2}]	Main cities (population)
Total	124,300	93	South Lake Tahoe (50, 700)

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, navigation and transportation, sightseeing and tourism, recreation and fisheries.

H2 THE LAKE AS WATER RESOURCE (1981) (1)

	Use rate [m^3 sec^{-1}]
Domestic water	115
Irrigation	N.A.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION

§ Present status: None.

I3 EUTROPHICATION

§ Nuisance caused by eutrophication: None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (c) Limited pollution with wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

Secondary and tertiary treatment systems: by activated sludge, ammonia stripping and charcoal adsoption.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Tahoe Regional Planning Compact (1969, as amended in 1980)

§ Responsible authorities

(1) Tahoe Regional Planning Agency and State Governments of California and Nevada

§ Main items of control

(1) Water quality, air quality and land use

N. SOURCES OF DATA

(1) Tahoe Regional Planning Agency (1982) Environmental Impact Statement for the Establish-

ment of Environmental Threshold Carrying Capacities. 140pp. South Lake Tahoe.
(2) Tahoe Regional Planning Agency & Forest Service, U. S. Department of Agriculture (1971) Climate and Air Quality of the Lake Tahoe Region ; A Guide for Planning. 30pp. South Lake Tahoe.
(3) Tahoe Regional Planning Agency & Forest Service, U. S. Department of Agriculture (1971) Limnology and Water Quality of the Lake Tahoe Region ; A Guide for Planning. 13pp. South Lake Tahoe.
(4) Holm-Hansen, O., Goldman, C. R., Richards, R. & Williams, P. M. (1976) Chemical and biological characteristics of water column in Lake Tahoe. Limnol. & Oceanogr., 21(4) : 548-562.
(5) Loeb, S. L. & Goldman, C. R. (1979) Water and nutrient transport via groundwater from Ward Valley into Lake Tahoe. Ibid., 24(6) : 1146-1154.
(6) Goldman C. R. (1981) Lake Tahoe : two decades of changes in a nitrogen deficient oligotrophic lake. Verh. Internat. Verein Limnol., 21 : 45-70.
(7) Tahoe Regional Planning Agency & Forest Service, U. S. Department of Agriculture (1971) Vegetation of the Lake Tahoe Region ; A Guide for Planning. 43pp. South Lake Tahoe.
(8) Goldman, C. R., Morgan, M. D., Threlkeld, S. T. & Angeli, N. (1979) A population dynamics analysis of the cladoceran disappearance from Lake Tahoe, California-Nevada. Limnol. & Oceanogr., 24(2) : 289-297.
(9) Threlkeld, S. T. (1981) The recolonization of Lake Tahoe by *Bosmina longirostris* : evaluating the importance of reduced *Mysis relicta* populations. Ibid., 26(3) : 433-444.
(10) Eloranta, P. V. & Loeb, S. L. (1984) Near-shore littoral phytoplankton communities in Lake Tahoe, California-Nevada. Verh. Internat. Verein Limnol., 22 : 600-604.

LAKE MICHIGAN

Northernmost part of the lake from Fort Mackinac

Photo: A. Kurata

A. LOCATION

§ Michigan, Indiana, Illinois and Wisconsin, U.S.A.
§ 41°40′-46°08′N, 84°44′-87°44′W ; 176.7 m above sea level.

B. DESCRIPTION

Lake Michigan is the third largest of North America's Great Lakes, and is the only one entirely within the United States, while Canada shares sovereignty over the other four lakes. The lake is therefore the largest freshwater lake in the United States. It extends about 520 km from north to south, and measures about 100 km in its maximum width, with long stretches of scenic shoreline, beaches, bays and inlets. The lake water flows out to L. Huron through Mackinac Straights.

Since the middle of the last century, urbanization and industrialization have progressed rapidly along the lake's southern shore, which is now one of the most highly industrialized areas in the United States. The lake water along the southern coast has been seriously eutrophicated since the early 1970's. To counter this trend, a number of laws have been legislated and wastewater treatment plants constructed. The use of synthetic detergents containing phosphorus was thereby prohibited in the lake's watershed. The wastewater, that had once entered the lake, was diverted to the Mississippi River. As the result, the quality of the lake water is now recovering gradually.

C. PHYSICAL DIMENSIONS (1-3)

Surface area [km^2]	58,016
Volume [$10^9 m^3$]	4,871
Maximum depth [m]	281
Mean depth [m]	84
Normal range of annual water level fluctuation (unregulated) [m]*	0.3
Length of shoreline [km]	2,656
Residence time [yr]	99.1
Catchment area [km^2]	117,845

* During the period of recorded history (130 yrs) the lake level has fluctuated ±2m.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q, 1-5)

§ Bathymetric map (Fig. NAM-3-1).

§ Main islands (name and area): Beaver (200 km^2), Washington (55 km^2), North Manitou (48 km^2), South Manitou (21 km^2), Garden (17 km^2), South Fox (14 km^2), High (13 km^2), Hog (9 km^2).

§ Outflowing rivers and channels (number and names): 2 (Straits of Mackinac and Chicago Diversion).

D2 CLIMATIC (1, 2, 4-8)

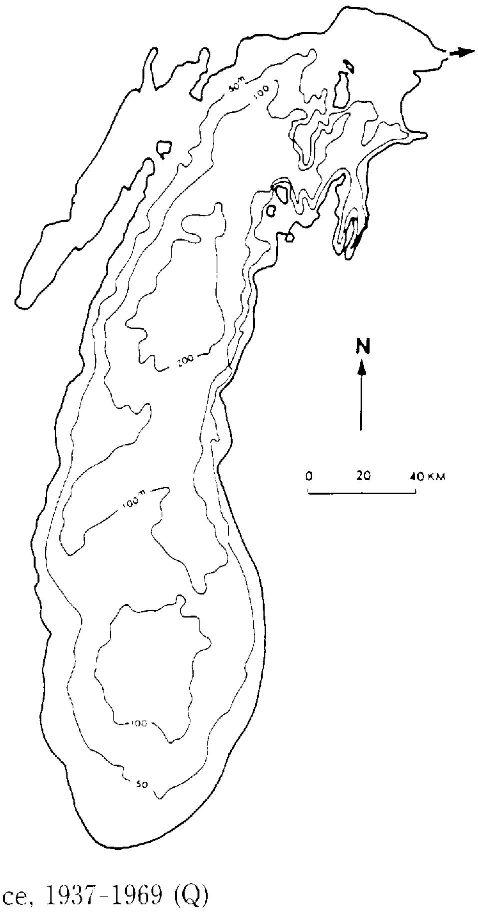
§ Climatic data at Muskegon (1943-1980)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-4.8	-4.4	0.2	7.2	13.2	18.4	21.1	20.4	16.3	10.6	3.9	-1.8	8.3
Precipitation [mm]	60	43	64	79	69	69	61	77	79	67	75	67	808

§ Number of hours of bright sunshine: 2,406 hr yr^{-1}.

§ Solar radiation: 35.30 MJ m^{-2}day^{-1}.

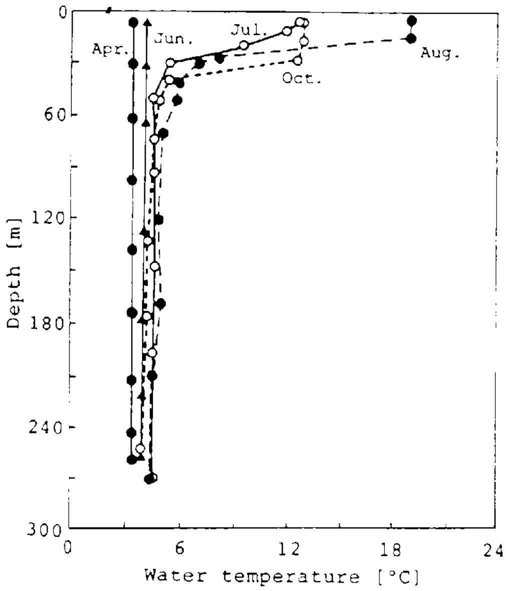
Fig. NAM-3-1 Bathymetric map (Q).



§ Water temperature [°C], surface, 1937-1969 (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	1	3	5	10	16	21	17	12	7	4

Fig. NAM-3-2 Seasonal change in water temperature (northern part), 1976 (Q).



§ Freezing period : From Dec./Jan. to mid-Mar.

§ Mixing type : Dimictic.

§ Notes on water mixing and thermocline formation : Thermocline generally develops during Jan. -Mar. and Jul. Nov.

§ Supplementary notes

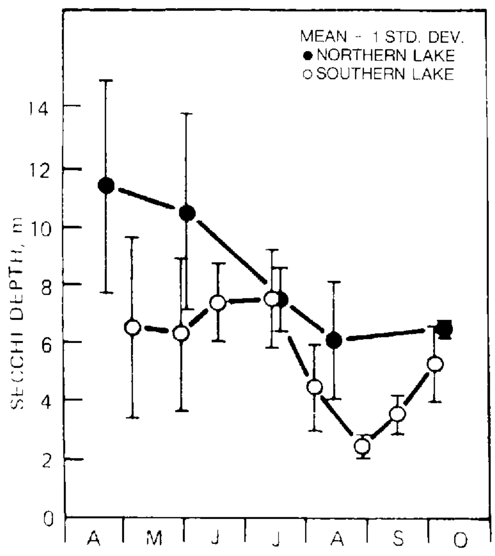
Thermal cycle is similar throughout the lake but with variations resulting from differences in latitude and depth. While the water temperature in the lake is nearly homothermous from Nov. to late May, slight inverse stratification often occurs in mid-winter. Thermal stratification of Lake Michigan begins in early to mid-June.

In the lower latitudes of Lake Michigan, the ice forms in December or January and lasts until mid-March. In the northern latitudes, ice formation may begin about 30 days earlier. In either case, the lake never freezes shore to shore.

E. LAKE WATER QUALITY (Q, 1-5, 9-13)

E1 TRANSPARENCY

Fig. NAM-3-3 Seasonal variation in Secchi depth [m] in 1976 (Bartone & Schleske, 1982).

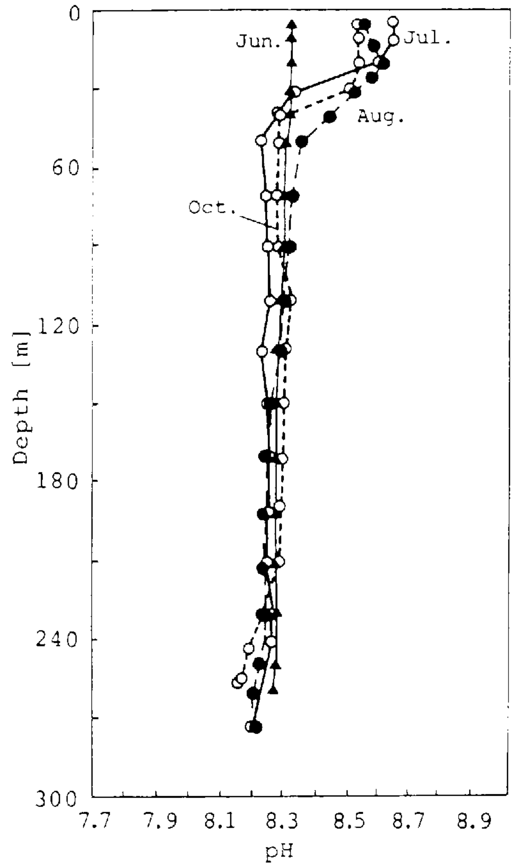


§ Supplementary notes

The Michigan Department of Natural Resources (MDNR) (1984) found that secchi depth transparency ranged from 0.4m to 9.8m with increasing transparency from south to north, excluding Green Bay. Northern locations generally averaged 2 to 4 times greater transparency than southern lake locations.

E2 pH

Fig. NAM-3-4 pH profiles in the northern part, 1976 (Q).



E3 SS [mg l^{-1}], 1976

Depth [m]	Average
1	1 9
1 off the bottom	1-9

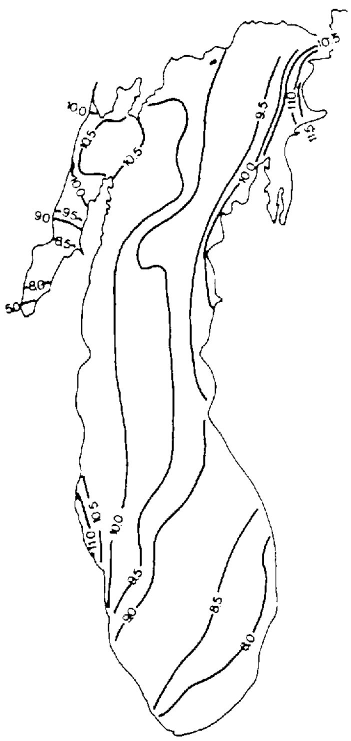
Municipal loadings [kg day^{-1}]

Basin	1978	1981
Indiana	39,491	19,335
Michigan	36,490	20,522
Wisconsin	46,662	21,354

E4 DO [mg l^{-1}]

Lake wide survey, 1964 : 8.0-10.5.

Fig. NAM-3-5 Distribution of DO in surface water, 1964 (Beeton & Moffet, 1964).



E5 COD [mg l^{-1}], 1969-1973

Determined by K_2CrO_4 method.

Station	Range	Average
Illinois	2-16	6.5
Indiana Harbor	2 21	9.1
Milwaukee	5-40	8.2

E6 CHLOROPHYLL CONCENTRATION [μg l^{-1}]

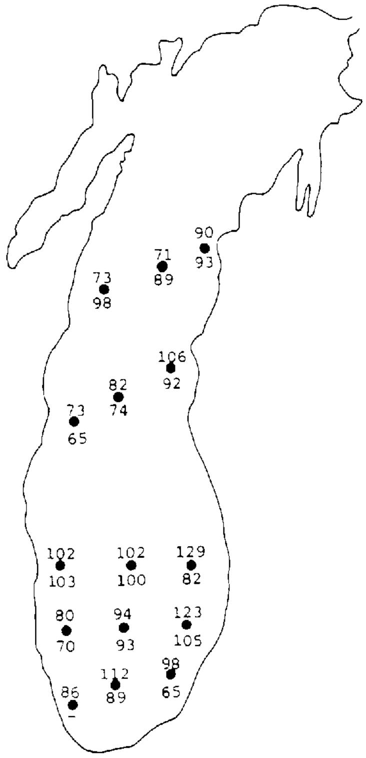
Inshore, 1970-1971 : 1.1-10.3.

Offshore, 1970-1971 : 0.6-3.7.

Mean of all stations, 1974-1975 : 1.34.

E7 NITROGEN CONCENTRATION

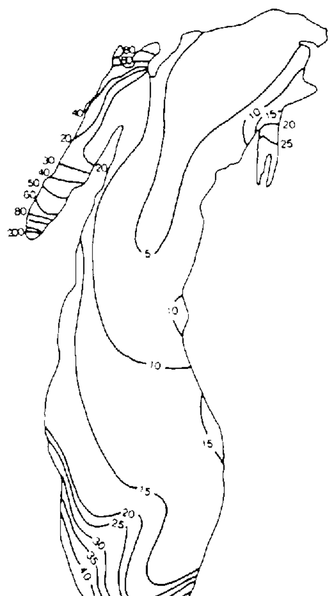
Fig. NAM-3-6 Average concentration of organic nitrogen [$\mu g\ l^{-1}$] (Robertson & Powers, 1968). Upper number : in the upper 20 m. Lower number : below a depth of 20 m.



E8 PHOSPHORUS CONCENTRATION [$\mu g\ l^{-1}$], 1964

§ PO_4-P, open waters : 5-20.

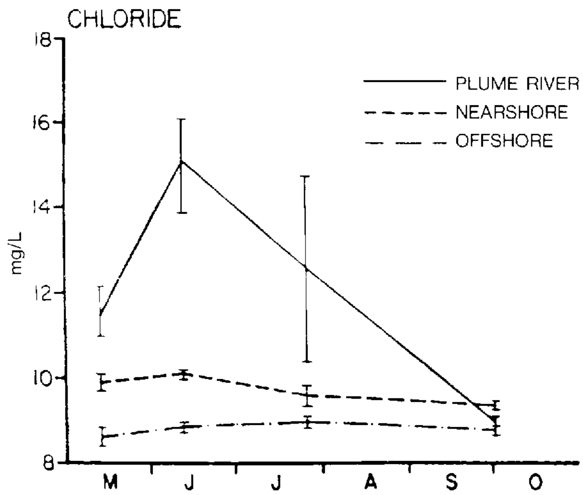
Fig. NAM-3-7 Distribution of PO_4-P [$\mu g\ l^{-1}$] in surface water (Beeton & Moffet, 1964).



E9 CHLORINE ION CONCENTRATION [mg l^{-1}]

Year	Area	Range	Average
1962-1965	Inshore	–	7.1
	Offshore	–	6.5
	Southern end		8.0
1984	Nearshore and Offshore	7.6-9.1	8.3

Fig. NAM-3-8 Seasonal and spatial distribution of chloride, 1980 (Moll & Brahce, 1986). Means and standard errors are plotted.



E10 PAST TRENDS

Loading of total dissolved solids to all of the Great Lakes, with the exception of Lake Superior, has increased significantly over the past 50 years. This has resulted in increased concentration of nutrients, chlorides, sulphates and numerous other ions and compounds in Lakes Michigan, Huron, Erie and Ontario.

F. BIOLOGICAL FEATURES

F1 FLORA (1-5, 11, 13-15)

§ Emerged macrophytes : *Scirpus acutus*, *S. americanus*, *Sparganium* sp., *Phragmites* sp., *Eleocharis* sp.

§ Floating macrophytes : No dominant species.

§ Submerged macrophytes : *Nitella flexilis*, *Chara globularis*, *Isoetes riparia*.

§ Phytoplankton : *Cyclotella comensis*, *C. comita*, *C. glomerata*, *Coelastrum reticulatum*, *Tabellaria fenestrata*, *Asterionella formosa*.

F2 FAUNA (1-5, 11, 13-15)

§ Zooplankton : Protozoa (*Difflugia globulosa*), Cladocera (*Bosmina longispina*, *Daphnia retrocurva*), Rotifera (*Polyarthra vulgaris*, *Notholca longispira*), Copepoda (*Diaptomus ashlandi*, *Limnocalanus macrurus*).

§ Benthos : Amphipoda (*Pontoporeia affinis*), Oligochaeta (*Limnodrilus* sp., *Tubifex* sp., *Stylodrilus* sp.), Mollusca (*Pisidium* sp.).

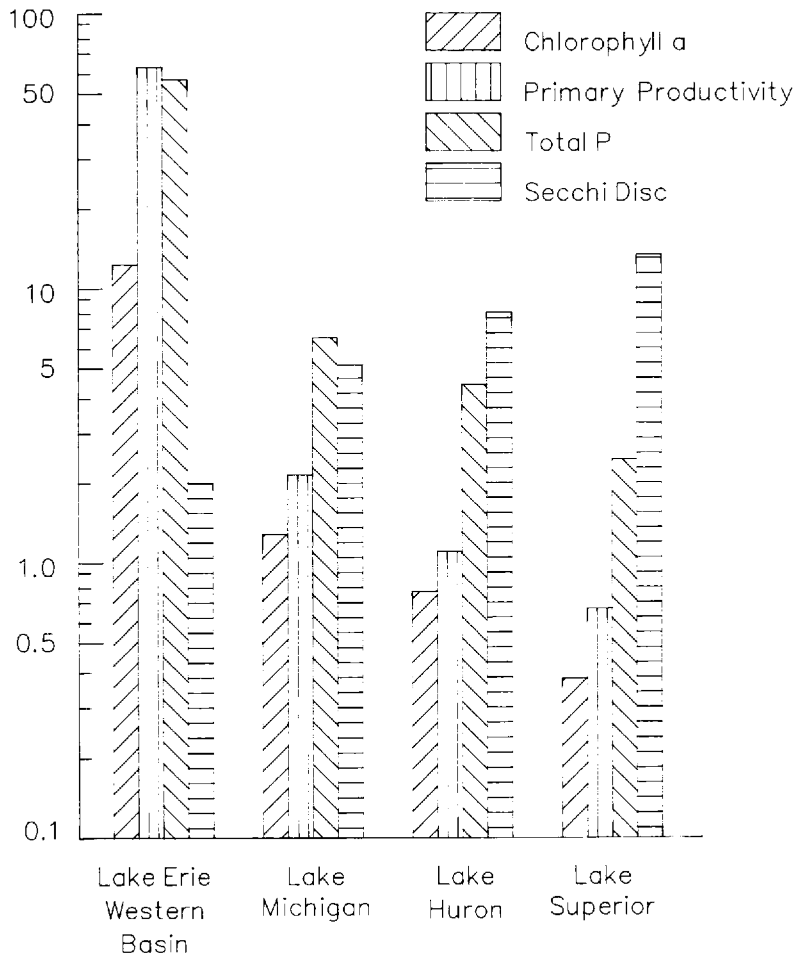
§ Fish : *Alosa pseudoharengus*, *Cyprinus carpio*, *Oncorhynchus kisutch*, *O. tschawytscha*, *Perca flavescens*, *Osmerus* sp., *Salvelinus namaycush*, *Coregonus clupeaformis*.

F3 PRIMARY PRODUCTION RATE (Q)

§ Carbon-fixation rate [mg C m^{-3} day^{-1}] : 2.40±0.82.

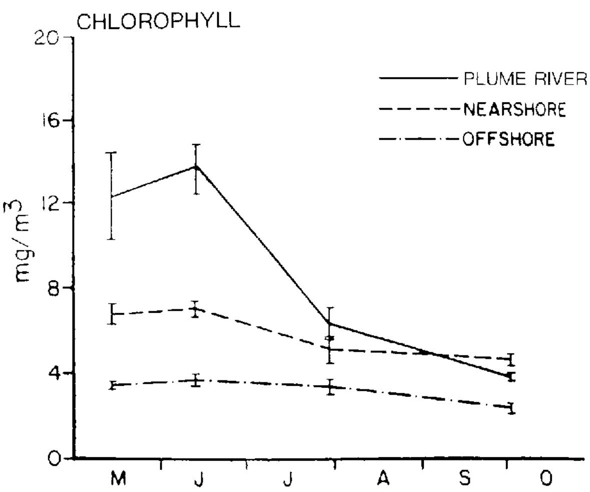
§ Photosynthetic assimilation ratio [mg C hr^{-1} mg $(Chl\text{-}a)^{-1}$] : 0.74.

Fig. NAM-3-9 Chlorophyll-a [mg m^{-3}], primary productivity [mg C m^{-3} hr^{-1}], total phosphorus [mg PO_4-P m^{-3}] and Secchi disc transparency [m] in the Great Lakes (Schelske, 1974).



F4 BIOMASS (Q)

Fig. NAM-3-10 Seasonal and spatial distribution of chlorophyll, 1980 (Mohr & Brahce, 1986). Means and standard errors are plotted.



F5 FISHERY PRODUCTS (Q)

§ Annual fish catch in 1980 : 11,432 [metric tons].

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE

The phytoplankton of Lake Michigan were originally dominated by oligotrophic diatoms. With increased nutrient loading to the lake, the more eutrophic species of diatoms became more prevalent. Recently, an additional shift has occurred from diatoms to phytoplankton assemblages with increasing proportions of both green and blue-green algae. These shifts are most evident in eutrophic areas of Green Bay and localized areas at the southern shore (16).

Major upheaval has occurred during the past 40 years. By 1946, sea lamprey has invaded all the Great Lakes and decimated the native fish populations. The decline of native fish populations created conditions favorable for the explosive increase of alewife (*Alosa pseudoharengus*) which, in turn, greatly reduced the populations of yellow perch (*Perca flavescens*), cisco (*Coregonus* sp.) and lake herring (*Coregonus artedii*). Salmon species were introduced in 1964 and have effectively utilized the alewife as a food source. This has served to both reduce the alewife population and create a vital sport-fishing industry. The predominance of alewife also resulted in a shift toward smaller size zooplankton as the larger species were selectively harvested (Wells, L., 1969 : U. S. Fish Wildlife Service, Fish. Bull., 60 : 343-369).

G. SOCIO-ECONOMIC CONDITIONS (Q, 3-5, 10, 17-24)

G1 LAND USE IN THE CATCHMENT AREA (1978)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	58,645	49.8
Herbaceous vegetation	27,515	23.3
Agricultural land	27,595	23.4
Settlement area	4,090	3.5
Total	117,845	100.0

§ Supplementary notes : The land use patterns within the Lake Michigan watershed are somewhat equally divided between nonagricultural areas such as forest, scrub, swamps and bogs in the upper peninsula of Michigan and agricultural areas supporting dairying, livestock, grain and fruit crops in the Wisconsin and Michigan lower peninsula watershed. A small (about 2%) portion of the watershed, especially in the Green Bay, Wisconsin and Milwaukee-Chicago-Gary-Michigan City strip along lower Lake Michigan, is heavily urbanized and industrialized.

§ Main types of woody vegetation : Aspen-birch forest, maple-beech forest, oak-hickory forest, spruce-fir forest, pine forest.

§ Main types of herbaceous vegitation : Bracken (*Pteridium aquilinum*), along with farm crops such as maize, dry beans, sugar beets, barley, mixed grains, greenhouse and nursery products, hay, oats, potatoes, wheat, various fruits, flax seed.

§ Main kinds of crops : Silage, hay, oats, fruits, vegetables, maize.

§ Levels of fertilizer application on crop fields : Heavy-moderate.

§ Trends of change in land use : In the past several decades, there has been an increase in the number and size of urban centers in the lower quarter of the lake, and shoreline recreational use has increased everywhere.

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (1970)

	Gross product per year [10^6\$]	No. of persons engaged	No. of establishments	Main products and main kinds of industry
Primary industry				
Agriculture	2,869.42	118,350	110,215	1)
Fisheries	N.A.	N.A.	N.A.	
Others	N.A.	N.A.	N.A.	
Secondary industry				
Manufacturing	27,599.80	1,808,395	N.A.	2)
Mining	286.00	8,392	N.A.	3)
Others	N.A.	3,436,022	N.A.	

1) Grains, dairy products, forest products, vegetables, hay, silage.
2) Machinery, metal fabrication, primary metal industries, electrical machinery.
3) Sand, gravel, crushed stones, cement, petroleum.

§ Numbers of domestic animals in the catchment area : Cattle 328,100, sheep 38,000, swine 410,000, poultry 2,750,000.

G3 POPULATION IN THE CATCHMENT AREA (1970)

Population	Population density [km^{-2}]	Main cities (population)
13,517,000	114.7	Chicago* (3,063,000), Milwaukee, Grand Rapids, Green Bay.

* Not all the city area is included in the drainage basin.

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, navigation, tourism, recreation (swimming, sport-fishing and yachting) and fisheries.

H2 THE LAKE AS WATER RESOURCE (1975) (U.S. only)

	Use rate [m^3 sec^{-1}]
Domestic water	77.4
Irrigation	5.4
Industrial water	290.7
Power plant	472.0
Mining	6.5
Livestock	2.0

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS (Q)

I1 ENHANCED SILTATION

§ Extent of damage : Not serious.

§ Supplementary notes : The siltation is only serious at its confluence (i.e., about 0.6 km) with rivers draining agricultural areas. Presently, the problem is not serious overall ; however, it could become a serious problem if not controlled.

As of 1987, Lake Michigan was at a record high level, leading to greatly increased shoreline erosion and temporary shoreline siltation.

I2 TOXIC CONTAMINATION

§ Present status : Detected but not serious.

§ Generalized distribution of contaminants in the lake sediments [ppb, dry weight basis]

Names of contaminants	Range	Average
DDT	< 10-40 <	12
PCB	< 2-20 <	10
Dieldrin	<0.1-1.0<	0.25
Hg	< 50-500<	–
Pb	<50,000, 100,000-150,000	–

§ Distribution of contaminants in the lake sediments [ppm, dry weight basis]

Parts of Lake	Parameters[1]	Concentrations in sediments						
		Sample numbers	HEOD[2]	Chlordane	Heptachlor Epoxide	Total Cyclodienes	Sample numbers	PCB
Whole Lake	Mean	286	0.25	0.37	0.67	1.29	279	9.7
	SD		0.43	0.88	1.03	1.90		15.7
Non-Depositional Zones	Mean	194	0.17	0.19	0.50	0.86	193	6.3
	SD		0.38	0.55	0.83	1.50		8.1
Depositional Basins	Mean	92	0.41	0.73	1.05	2.19	86	17.3
	SD		0.49	1.26	1.29	2.29		23.9
Algoma Basin	Mean	40	0.36	0.53	0.56	1.45	37	10.1
	SD		0.36	0.93	0.62	1.33		10.6
Fox Basin	Mean	4	0.21	0.05	2.70	2.96	4	73.5
	SD		0.21		1.08	1.17		78.9
Grand Haven Basin	Mean	9	0.52	1.47	1.18	3.17	8	17.1
	SD		0.71	2.05	1.90	4.40		23.1
Milwaukee Basin	Mean	6	0.38	0.56	2.52	3.46	6	29.2
	SD		0.31	1.25	2.06	2.42		23.1
Sarian Basin	Mean	2	0.06	1.33	0.58	1.97	2	7.9
	SD		0.06	1.80	0.74	2.48		2.0
Southern Basin	Mean	19	0.36	1.04	0.92	2.32	17	17.1
	SD		0.47	1.61	1.17	2.64		11.1
Traverse Basin	Mean	2	0.46	0.28	0.05	0.79	2	2.5
	SD		0.26	0.32		0.58		
Waukegan	Mean	10	0.77	0.66	1.95	3.38	10	19.5
	SD		0.80	0.72	1.18	1.69		13.2

*1 For purposes of calculating the mean and SD, trace amounts of HEOD were assigned 0.1 ng/g, Heptachlor Epoxide 0.3 ng/g, Chlordane 0.5 ng/g, and PCB 2.5 ng/g, and for non-detectable levels 0.01 ng/g for HEOD, 0.05 ng/g for Heptachlor Epoxide and Chlordane, and 1.0 ng/g for PCB.

*2 HEOD : Dieldrin.

§ Past trends of decrease of contaminants in fish muscles [ppm, wet weight basis] : Fig. NAM-3-11-14.

Fig. NAM-3-11 Past trend of total DDT residues in Lake Michigan fish (D'Itri, 1987). Lake Trout : *Salvelinus namaycush*. Bloater Chub : *Coregonus chupeaformis*.

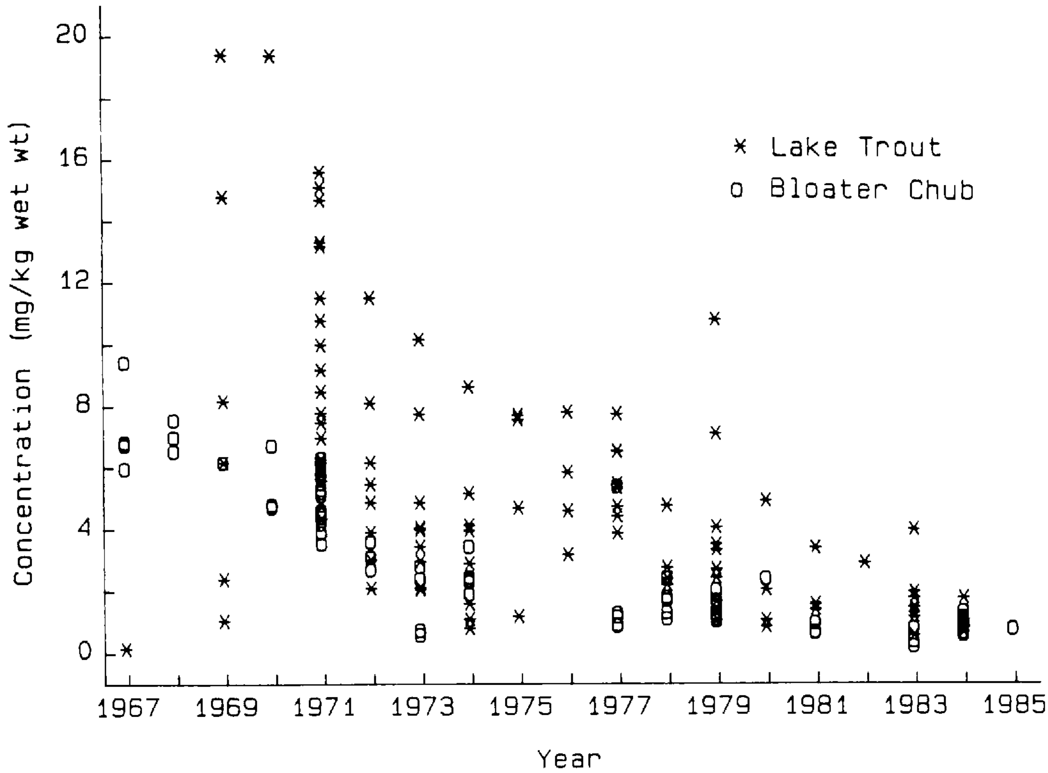


Fig. NAM-3-12 Past trend of total PCB residues in Lake Michigan fish (D'Itri, 1987).

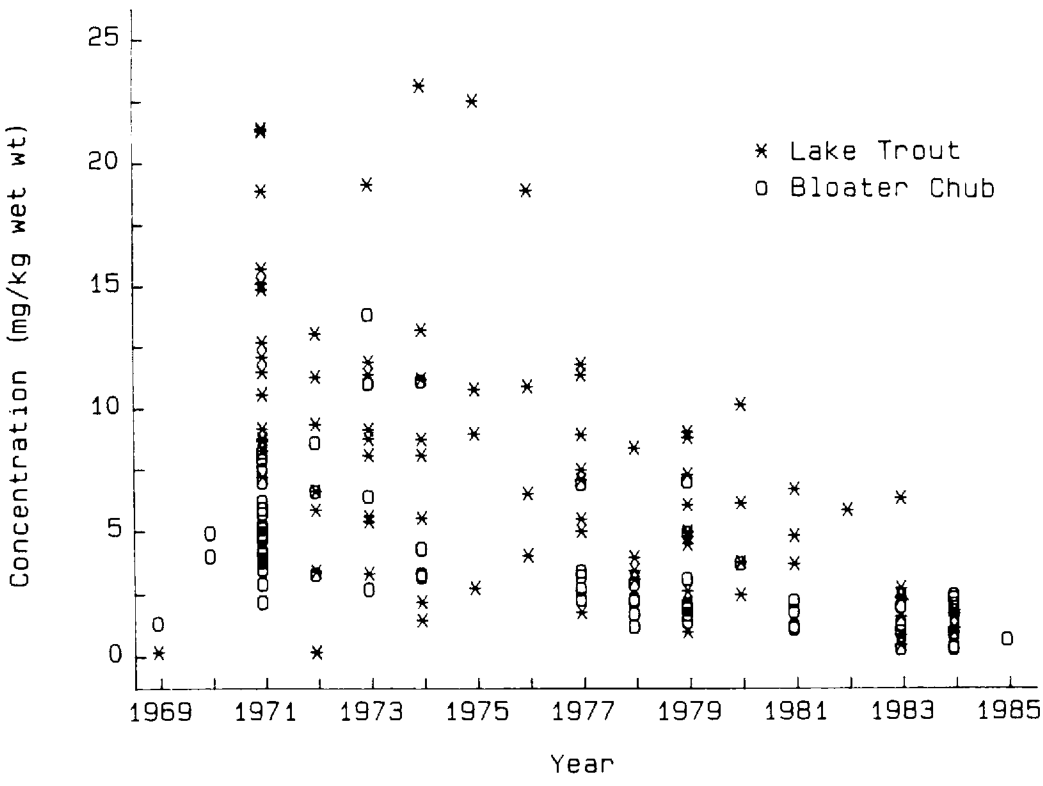


Fig. NAM-3-13 Past trend of dieldrin residues in Lake Michigan fish (D'Itri, 1987).

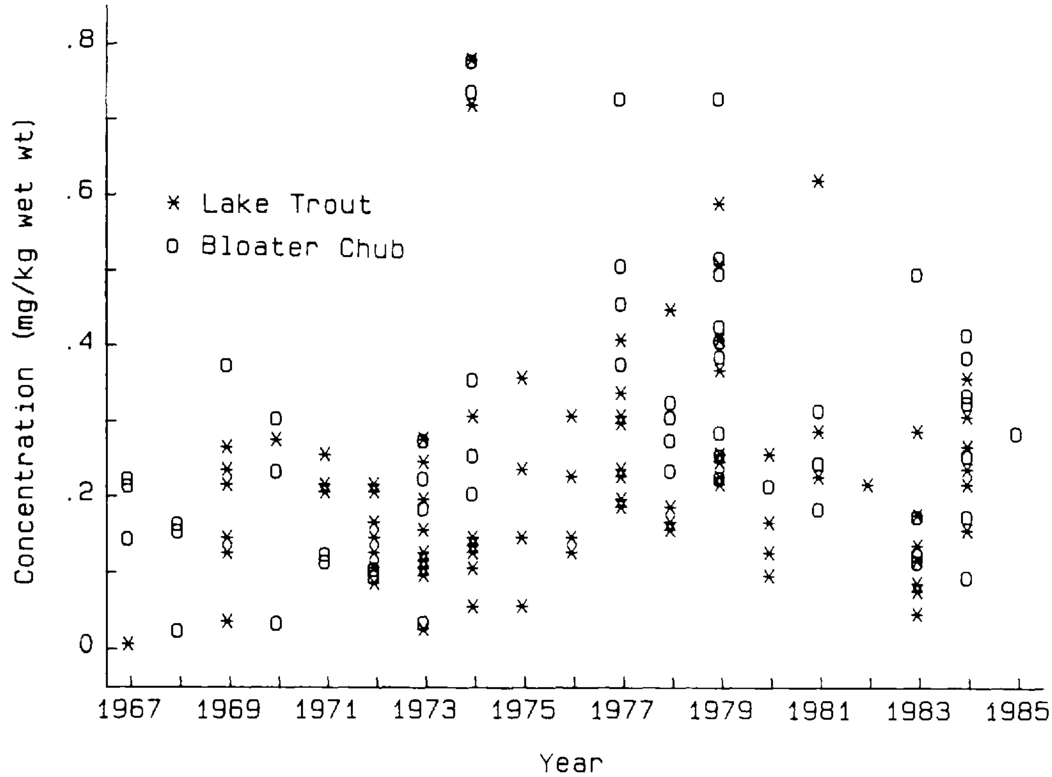


Fig. NAM-3-14 Past trend of mercury residues in Lake Michigan fish (D'Itri, 1987). Yellow perch : *Perca flavescens.*

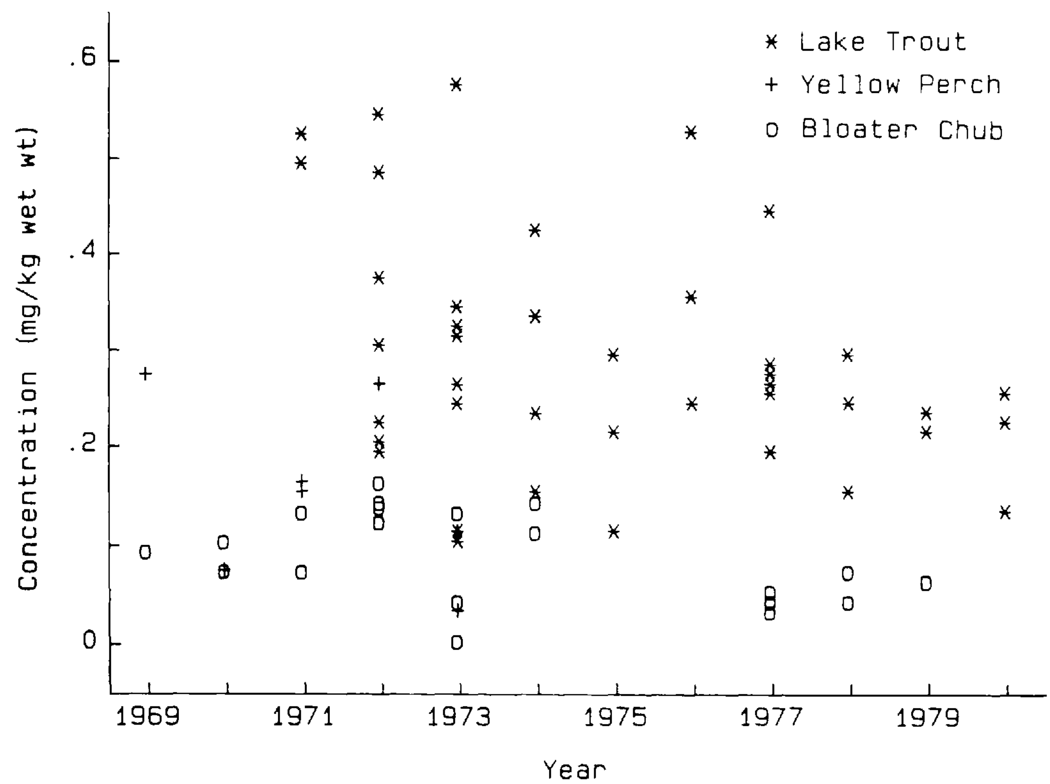
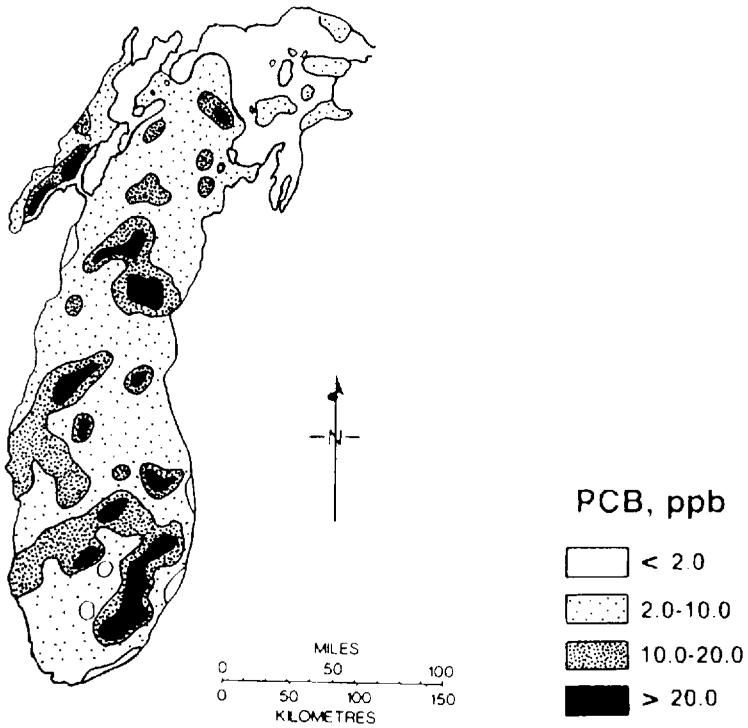


Fig. NAM-3-15 PCB concentrations in surface sediments (25).



§ Environmental quality standards for contaminants in the lake

IJC* 1978 Agreement objectives are "no-effect levels, for the protection of aquatic life, human consumers of fish, or fish-consuming aquatic birds." Objectives have been recommended for approximately 40 organic and inorganic chemicals, including persistent toxic substances, non-persistent toxic substances, physical materials, microbiological and radiological contaminants. Examples of specific objectives include: Dieldrin, less than 0.001 μg/l in water and less than 0.3 mg/kg in edible portions of fish. DDT and metabolites, less than 0.003 μg/l in water and 1.0 mg/kg in fish. PCB should not exceed 0.1 mg/kg in fish while the mercury content of filtered water should be less than 0.2 μg/l and 0.5 mg/kg in fish flesh.

* IJC: International Joint Commission.

§ Supplementary notes

Critical pollutants in the Great Lakes ecosystem include: PCB, 2, 3, 7, 8-TCDD, mirex, 2, 3, 7, 8-TCDF, hexachlorobenzene, benzo-a-pyrene, dieldrin, alkylated lead, DDT and metabolites, toxaphene, and mercury. The worst problems associated with contaminated sediments occurs in bays, harbor mouths and connecting channels. For example, the sediments in some of the drainage ditches emptying into Waukegan Harbor near Chicago contain as much as 500,000 mg/kg PCB (Villeneue, 1986). Heavy urban and industrial development and use of connecting channels as a transportation corridor have contributed to the degradation of the water quality of the St. Mary's River connecting Lake Superior and Lake Michigan.

Past experience with persistent toxic chemicals such as PCB, DDT, mercury, dieldrin and mirex show that once they are introduced into an aquatic ecosystem, they are extremely difficult to remove, especially in sediments which become a source for their remobilization into the water column. Therefore, the emphasis of regulatory officials has been directed toward preventing their release and the development of effective and efficient responses to identified problems.

§ Food safety standards or tolerance limits for toxic contaminant residue

Regulatory limitations are set by the U. S. Food and Drug Administration and Canada Dept. of National Health and Welfare and are advisories only with regard to human consumption of fish. the U.S. standards are: PCB 2 mg kg^{-1}, DDT 5 mg kg^{-1}, Dieldrin 0.3 mg kg^{-1} and mercury 1 mg kg^{-1} (Federal limit) and 0.5 mg kg^{-1} (State limit).

	Restrict consumption (important)[2]	Do not eat
Lake Michigan*[1] (applies to Michigan, Illinois, Indiana and Wisconsin waters)	Lake Trout 20-23", Coho Salmon over 26", Chinook Salmon 21-32", and Brown Trout up to 23"	Lake Trout over 23", Chinook over 32", Brown Trout over 23", Carp and Catfish
Green Bay[1] (Wisconsin waters South of Marinette/ Menominee)	Splake up to 16"	Rainbow Trout over 22", Chinook over 25", Brown Trout over 12", Brook Trout over 15", Splake over 16", Northern Pike over 28", Walleye over 20", White Suckers, White Bass and Carp

*[1] Also applies to tributaries into which migratory species enter.

*[2] Nursing mothers, pregnant women, women who anticipate bearing children, and children age 1 and under should not eat the fish listed in any of the categories listed above.

I4 ACIDFICATION

§ Extent of damage : No information. Evidence of damage to Lake Michigan from acidic deposition is not discernible at this time.

§ Supplementary notes

Data relating the amount of airborne acid deposition and stream effect are highly variable depending on the total stream alkalinity. For very soft water streams in the Upper Peninsula of Michigan (i.e., alkalinity less than 10 mg/l as $CaCO_3$), pH decreases of 1-2 units (from stream pH values of 7-8 to 6-7) have been observed in the headwaters area. To date, no studies have demonstrated detectable ecosystem trends which can be totally ascribed to acidification. The effects of increased acidic deposition, especially over terrestrial watershed with little alkaline character, may be more discernible.

Because of its size, Lake Michigan possesses a large buffering capacity and apparently is able to neutralize the airborne acid deposition it receives. Consequently, Lake Michigan doesn't appear to be directly affected. This is not true for many of the streams and tributaries and smaller lakes that surround and feed Lake Michigan and the other Great Lakes.

Both the United States and Canada monitor atmospheric depotition for a range of organic chemicals and heavy metals of concern to the Great Lakes ecosystem. An estimated 20 % to 25 % of the pollutants into the Great Lakes come from atmospheric fallout.

No effective countermeasures have been implemented to date.

§ Total deposition of airborne trace metals to Lake Michigan [metric tons yr^{-1}]

Metal	Total deposition
Zn	*
Pb	1,730
Cu	575
Cd	58
Ni	575
Fe	*
Al	28,800
Mn	1,150

* Estimate not possible from available data.

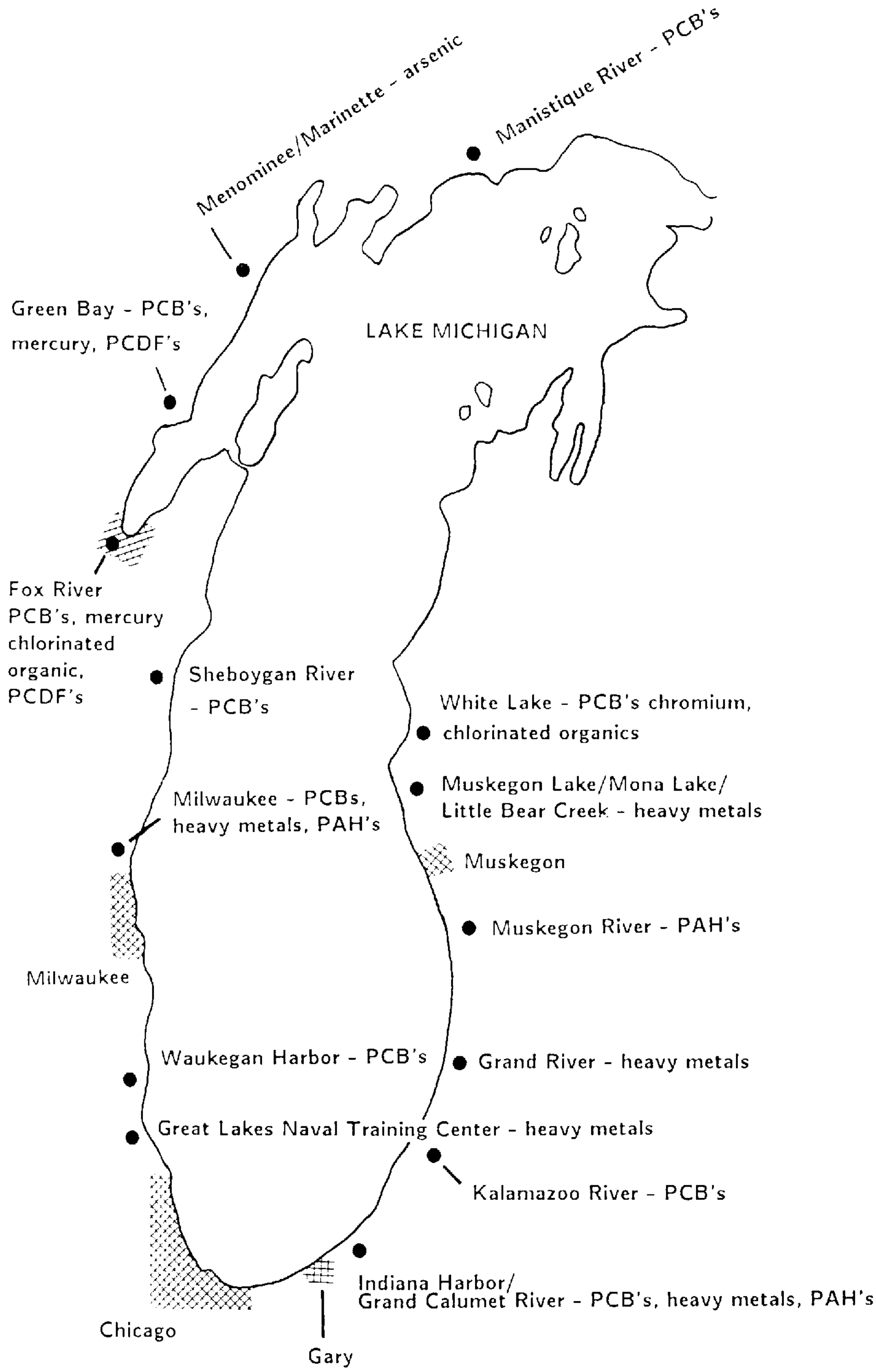
§ Total deposition of airborne trace organic substances to Lake Michigan [metric tons yr^{-1}]

Substance	Total deposition
Total PCB	6.9
Total DDT	.40
α-BHC	2.3
γ-BHC	11.2
Dieldrin	.38
HCB	1.2
p, p'-methoxychlor	5.9
α-endosulfan	5.6
β-endosulfan	5.6
Total PAH	114
Anthracene	3.4
Phenanthrene	3.4
Pyrene	5.9
Benzo(a)anthracene	2.9
Perylene	3.3
Benzo(a)pyrene	5.6
DBP	11
DEHP	11
Total organic carbon	1.4×10^5

I5 OTHER HAZARDS

Other hazards included the input of toxic inorganic and organic chemicals from municipal point sources, combined sewer overflows, rural and urban nonpoint sources and leachates from municipal and hazardous waste landfill disposal sites. Problems from these sources are most apparent in highly industrialized harbors and embayments and nearby areas.

Fig. NAM-3-16 Areas of concern in Lake Michigan. The IJC areas of concern include locales where environmental degradation and impairment of beneficial uses is severe and those where some environmental degradation is obvious and where uses may be impaired.



J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastwater treatment. (d) Measurable pollution with limited wastwater treatment. (f) Others.

J2 APPROXIMATE PERCENTAGE DISTRUBUTION OF NUTRIENT AND POLLUTANT LOADS

§ Summary of total phosphorus loads to the Great Lakes, 1976 (IJC, 1978)

Source	P [metric tons yr^{-1}]			
	Canada	U.S.	Total	[%]
Direct municipal sewage treatment plants	–	1,040	1,040	16
Tributary municipal sewage treatment plants		1,458	1,458	23
Direct industrial	–	32	32	<1
Tributary industial	–	247	247	4
Urban nonpoint direct	–	*	*	
Tributary diffuse	–	1,891	1,891	30
(Tributary total)	–	(3,596)	(3,596)	
Sub-total	–	4,668	4,668	74
Atmospheric	–	–	1,682	26
Load from upstream lake	–	–	–	
Total			6,350	100
Shoreline erosion (not included in total)	–	3,711	3,711	

J3 SANITARY FACILITIES AND SEWERAGE (data for Michigan only)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment systems) and public sewerage : 71 %.

§ Municipal wastewater treatment systems

Number of tertiary treatment systems : 7.
Number of secondary treatment systems : 66.
Number of primary treatment systems : 2.

K. IMPROVEMENT WORKS IN THE LAKE (Q)

K1 RESTORATION

Green Bay Nutrient Mass Balance Study as basis for remedial action plan. St. Louis River-IJC area of concern for remedial action plan.

K2 AERATION : N.A.

K3 OTHERS : N.A.

L. DEVELOPMENT PLANS (Q)

Generally, 3 areas of development planning have been or are significant : 1) the planning that has occurred for the conversion of most of the small commercial port facilities to recreational facilities beginning about 1980, 2) the county by county planning for recreational second home development along and near the lake front beginning about 1960, and 3) the recent planning that has occurred with the high water levels (1987). The urban areas are at risk and will be fortifying their water fronts. The state's Sea Grant Programs and the Coastal Management Program of NOAA have had primary responsibility.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Rivers and Harbors Acts (1899 and 1909)

(2) Flood Control Acts (1917, 1936 and 1944)
(3) Safe Drinking Water Act
(4) State legislation implementing and augmenting federal laws
(5) Federal Water Pollution Control (Clean Water) Act (1972, amendments 1977 and 1987)

§ Responsible authorities
(1) Corps of Engineers of the U.S. Army
(2) Corps of Engineers of the U.S. Army
(3) State Agencies for Environment and Natural Resources
(4) U.S. Environmental Protection Agency
(5) U.S. Environmental Protection Agency

§ Main items of control
(1) Discharges, dredging and filling
(2) Flood control
(3) Drinking water-including standards
(4) The entire range of water related problems
(5) Water pollution

§ Supplementary notes

Other U.S. laws which indirectly relate to preserving the water quality of the Great Lakes include the 1976 Resource Conservation and Recovery Acts (RCRA), the 1976 Toxic Substances Control Act (TSCA) and the Comprehensive Environmental Response, Compensation and Liability Act of 1980 as amended 1987 (CERCLA or Superfund).

M2 INSTITUTIONAL MEASURES

(1) Great Lakes Fishery Commission (International); established in 1960 to formulate, coordinate and implement fisheries research programs related to the Great Lakes; Ann Arbor, MI
(2) International Joint Commission (International); established in 1909 to investigate pollution in the boundary waters of the United States and Canada; Windsor, Ontario.
(3) U.S. Environmental Protection Agency; established in 1972 to protect the nation's atmospheric, terrestrial and aquatic environments and enforce legislation enacted to protect them; Chicago, IL
(4) The U.S. Army Corps of Engineers (U.S., Federal); concerned with all aspects of water resources as they relate to present and future needs of navigation, flood control, power, water supply, irrigation, beach erosion, dredging and recreational activities; Chicago, IL
(5) The U.S. Bureau of Commercial Fisheries (Federal); concerned with maintaining viable and expanding fisheries in the Great Lakes; in this regard, it conducts a broad research program on parasite (lamprey) control, effects of exploitation on the Great Lakes fishery and establishing the relationship between limnological conditions and the general biology of commercial fish species
(6) The U.S. Public Health Service (Federal); concerned with monitoring food and water supplies as they relate to human health; one of their primary functions is to develop and maintain an inventory of the sources and nature of pollutants entering each lake relative to the population and industry of the region; Washington, DC
(7) U.S. Department of Agriculture (Federal); concerned with developing programs and research to minimize nonpoint pollution from agriculture (pesticides, nutrients, and erosion) as it relates to protecting the water quality of the Great Lakes
(8) U.S. Department of Commerce (Federal); Great Lakes research and monitoring programs administered under its National Oceanic and Atmospheric Adminstration (NOAA)
(9) U.S. Department of the Interior (Federal); under its U.S. Geological Survey, sponsors research and education programs through the State Water Resources Institute program
(10) Great Lakes Commission (an interstate compact commission); established in 1955 by the eight states bordering the Great Lakes to provide communication, coordination and advocacy on Lakes issues; the Commission deals with environmental quality, resources management, transportation and economic development; Ann Arbor, MI
(11) The State Departments of Natural Resources (State); Each state in the United States has a Department of Natural Resources or equivalent department which is responsible for monitoring the state's natural resources and enforcing legislation enacted to protect them
(12) The State Departments of Public Health (State); each state in the United States has a

Department of Public Health or equivalent department, which is responsible for monitoring food and water supplies as they relate to human health

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Great Lakes Research Division, University of Michigan
(2) University of Minnesota Limnological Research Center, University of Minnesota

§ Supplementary notes

Private organizations concerned with the well-being of the Great Lakes.

(1) Center for the Great Lakes, Chicago, IL
(2) Great Lakes Tomorrow, Toronto, Ontario
(3) Great Lakes United, Buffalo, NY
(4) Operation Clean Niagara, Niagara-on-the-Lake, Ontario
(5) Pollution Probe, Toronto, Ontario

N. SOURCES OF DATA

(Q) Questionnaire filled by Prof. F. M. D'Itri, Institute of Water Research, Michigan State University based on the following sources.
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(2) Pincus, H. J. (1962) Great Lakes Basin. American Association for the Advancement of Science, Washington, D. C.
(3) Great Lakes Basin Commission Public Information Office (1974) Great Lakes Basin Framework Study. Ann Arbor, Michigan.
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(11) United States Environmental Protection Agency. Limnological Conditions in Southern Lake Huron, 1974 and 1975. Publication No. EPA-600/3-80-074. Duluth, Minnesota.
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(15) Interagency Committee on Marine Science and Engineering, Federal Council for Science and Technology, Argonne National Laboratory (1975) Proceedings of the Second Federal Conference on the Great Lakes.
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Resources, Video Census Series No. 2.
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(19) International Great Lakes Diversions and Consumptive Uses Study Board (1981) Great Lakes Diversions and Consumptive Uses, Annex F: Consumptive Water Uses.
(20) International Joint Commission (1978) Inventory of Land Use and Land Use Practices. 1, Canadian Great Lakes Basin Summary.
(21) Ontario Ministry of Agriculture and Food, Statistics Section (1982) Agricultural Statistics for Ontario, 1981.
(22) Ontario Ministry of Treasury and Economics. Ontario Statistics, 1982.
(23) Ontario Ministry of Natural Resources, Fisheries Branch. Employment and Investment in the Commerciai Fishery, 1982 and Commercial Fish Industry.
(24) Pollution in the Great Lakes Basin from Land Use Activities, 1980. International Joint Commission; United States and Canada Great Lakes Regional Office, Windsor, Ontario.
(25) Allan, R.J. (1986) The Role of Particulate Matter in the Fate of Contaminants in Aquatic Ecosystems. Inland Waters Directorate, National Water Research Institute, Canada Centre for Inland Waters. Scientific Series No. 142, p.60.

LAKE SUPERIOR

A view from the lakeside hill at Duluth

Photo : A. Kurata

A. LOCATION

§ Michigan, Wisconsin and Minnesota, U.S.A.; and Ontario, Canada.
§ 46°25′-48°40′N, 84°30′-92°05′N; 183 m above sea level.

B. DESCRIPTION

Lake Superior is the second largest lake in the world next to the Caspian Sea, and has more surface area than any other freshwater lake. Its surface area (82,367 km^2) is larger than the State of Maine. The lake was formed approximately 14,000 years ago by the retreat of continental ice-sheet together with the other Great Lakes. It is surrounded by hills and cliffs which offer the most spectacular landscape of any of the Great Lakes. The largest island, Isle Royale, is a United States National Park. The Apostle Islands of Wisconsin are now a National Lakeshore, with beautiful scenery and geological features. The long, hooked arm of the beautiful Keweenaw Peninsula is also a National Lakeshore of Michigan. The lake water flows out to L. Huron through the St. Mary's River from the eastern end.

There are no large cities along the Canadian northern shore of this lake except for Thunder Bay, Ontario. Twin cities, Duluth and Superior, are situated at the western end of the lake. A large amount of ore and grain is loaded for transport abroad in the harbors of these cities. The 1,900 km journey from Duluth, Minnesota, to Kingston, Ontario, is the longest inland water transportation route in the world. The lake water is still oligotrophic and transparency at the lake center is generally around 9 m.

C. PHYSICAL DIMENSIONS (1-3)

Surface area [km^2]	82,367
Volume [10^9m^3]	12,221
Maximum depth [m]	406
Mean depth [m]	148
Normal range of annual water level fluctuation (regulated) [m]	0.3*
Length of shoreline [km]	4,768
Residence time [yr]	191
Catchment area [km^2]	124,838

*During the period of recorded history (130 yrs) the lake has fluctuated ±2 m.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q. 1-5, 6, 9)

§ Bathymetric map (Fig. NAM-4-1).
§ Main islands (name and area): Royale (544 km^2) and Grand (36.4 km^2).
§ Outflowing rivers and channels (number and names): 1 (St. Mary's R.).

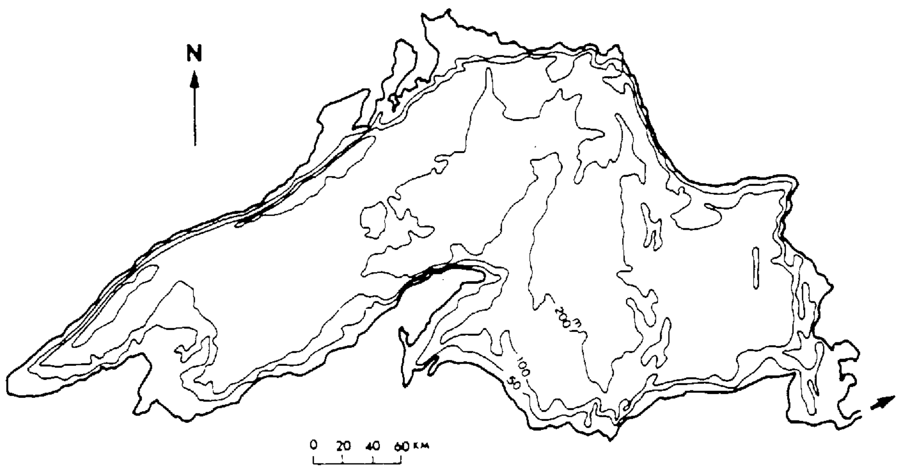
D2 CLIMATIC (Q. 4-8)

§ Climatic data at Marquette (1943-1980)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-8.3	-7.9	-3.3	3.7	9.6	15.2	18.8	18.0	14.0	8.4	0.8	-0.5	5.3
Precipitation [mm]	52	43	52	62	74	87	77	71	89	70	72	58	808

§ Number of hours of bright sunshine: 2,104 hr yr^{-1}.
§ Solar radiation: 31.22 MJ m^{-2}day^{-1}.

Fig. NAM-4-1 Bathymetric map (Q).



§ Surface water temperature [°C]
Marquette, 1937-1969

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	1	1	2	4	7	12	12	9	6	3

§ Freezing period: From Nov. to Apr. (Ice formation in Lake Superior begins in November; however, it never freezes shore to shore. The ice normally begins to break up in April but may not be completely melted until May).
§ Mixing type: Dimictic.
§ Notes on water mixing and thermocline formation: Thermocline generally develops January-March and July-September. Mixing efficiency to lake bottom is fairy low due to great depth.

Thermal cycle is similar throughout the lake but with variations resulting from differences in latitude and depth. While the water temperature in the lake is nearly homothermous from November to late May, slight inverse stratification often occurs in mid-winter. Thermal stratification in Lake Superior begins to occur in early/mid July.

E. LAKE WATER QUALITY (Q, 3-5, 12, 13-15, 23, 30)

E1 TRANSPARENCY [m]

Location	Range	Average
Nearshore*	0.5-15	8.5
Back Bay	—	2.3

*Summer and fall, 1973.

Fig. NAM-4-2 Areal distribution of Secchi disc readings in nearshore waters.

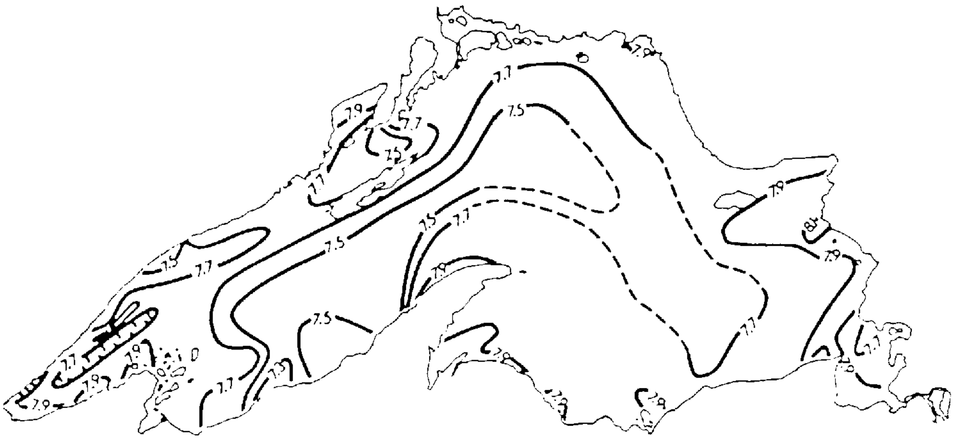
E2 pH

Surface water

Season	Range
Spring*	7.4-8.0
Fall*	7.6-7.9
	7.6-7.8**

*1974. **1975.

Fig. NAM-4-3 pH of surface water (1969).



E3 SS

Suspended solids were virtually absent in Lake Superior waters, except in the harbor areas. The lower transparency in Black Bay and Batchawana Bay was attributed to the natural resuspenion of bottom sediments by wave action and the low transparency in Thunder Bay and Nipigon Bay was to urban and industrial sources of suspended solids.

E4 DO [mg l^{-1}]

Surface water

Season	Range	Average
Spring*	10.1-13.2	
Fall*	8.5-10.9	–
Annual**	11.2-13.2	12.4±0.6

*1974. **1975.

Fig. NAM-4-4 DO [% saturation] in bottom water (1971).

E6 CHLOROPHYLL CONCENTRATION

Location	Range	Average
Nearshore	(2 <)*	0.8
Embayment areas	0.4-3.8	–

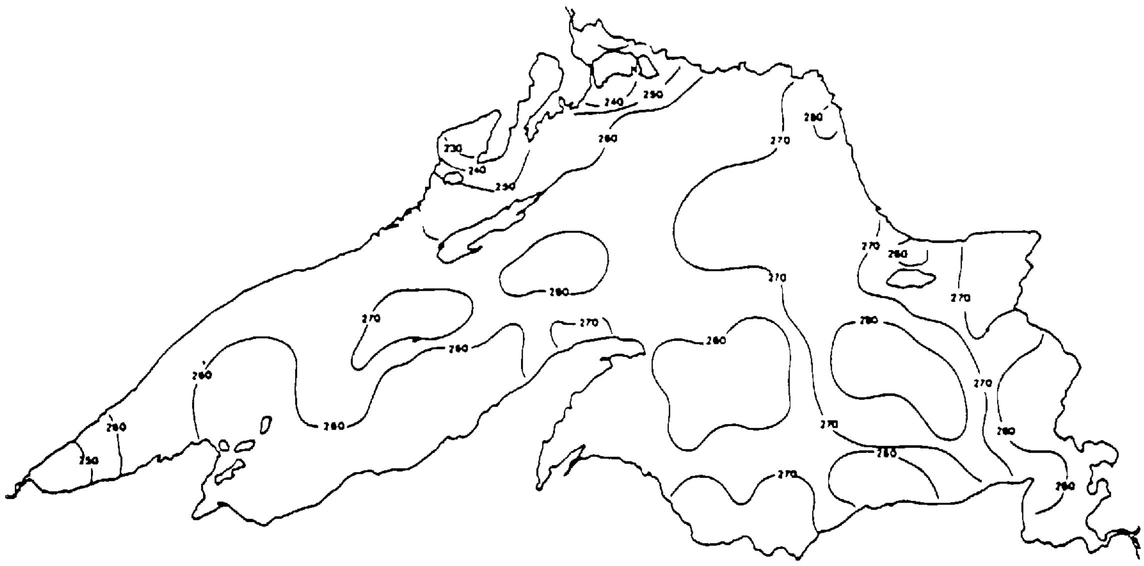
*Rarely exceeded.

Fig. NAM-4-5 Mean concentrations of chlorophyll-a [$\mu g\ l^{-1}$] (1970-1971).

E7 NITROGEN CONCENTRATION

§ Inorganic-N

Fig. NAM-4-6 Mean concentrations of inorganic-N [$\mu g\ l^{-1}$] at 5 m depth (1971).



E8 PHOSPHORUS CONCENTRATION

§ Total-P

Fig. NAM-4-7 Mean concentrations of total-P [$\mu g\ l^{-1}$] at 5 m depth (1971).

E9 CHLORIDE ION CONCENTRATION [$mg\ l^{-1}$]

	Range	Average
1963	—	1.9
1974	0.9-1.4	
1975	1.1-2.3	—

F. BIOLOGICAL FEATURES (Q, 3-5, 12, 13-15, 24, 30, 41, 32-36)

F1 FLORA

§ Emerged macrophytes : *Scirpus acutus*, *S. americanus*, *Sparganium* sp., *Phragmites* sp., *Eleocharis* sp.

§ Submerged macrophytes : *Nitella flexilis*, *Chara globularis*, *Isoetes riparia*.

§ Phytoplankton : *Cyclotella comensis*, *C. comita*, *C. glomerata*, *Coelastrum reticulatum*, *Tabellaria fenestrata*, *Asterionella formosa*.

F2 FAUNA

§ Zooplankton : Protozoa (*Difflugia globulosa*, *Codonella* sp.), Cladocera (*Bosmina longispina*, *Daphnia retrocurva*), Rotifera (*Polyarthra vulgaris*, *Notholca longispira*), Copepoda (*Diaptomus ashlandi*, *Limnocalanus macrurus*).

§ Benthos : Amphipoda (*Pontopooreia affinis*), Oligochaeta (*Limnodrilus* sp., *Tubifex* sp., *Stylodrilus* sp.), Mollusca (*Pisidium* sp.).

§ Fish : *Alosa pseudoharengus*, *Oncorhynchus kisutch*, *O. tschawytscha*, *Perca flavescens*, *Osmerus* sp., *Stizostedion vitreum*, *Salvelinus namayucush*, *Coregonus clupeaformis*.

§ Supplementary notes on the biota

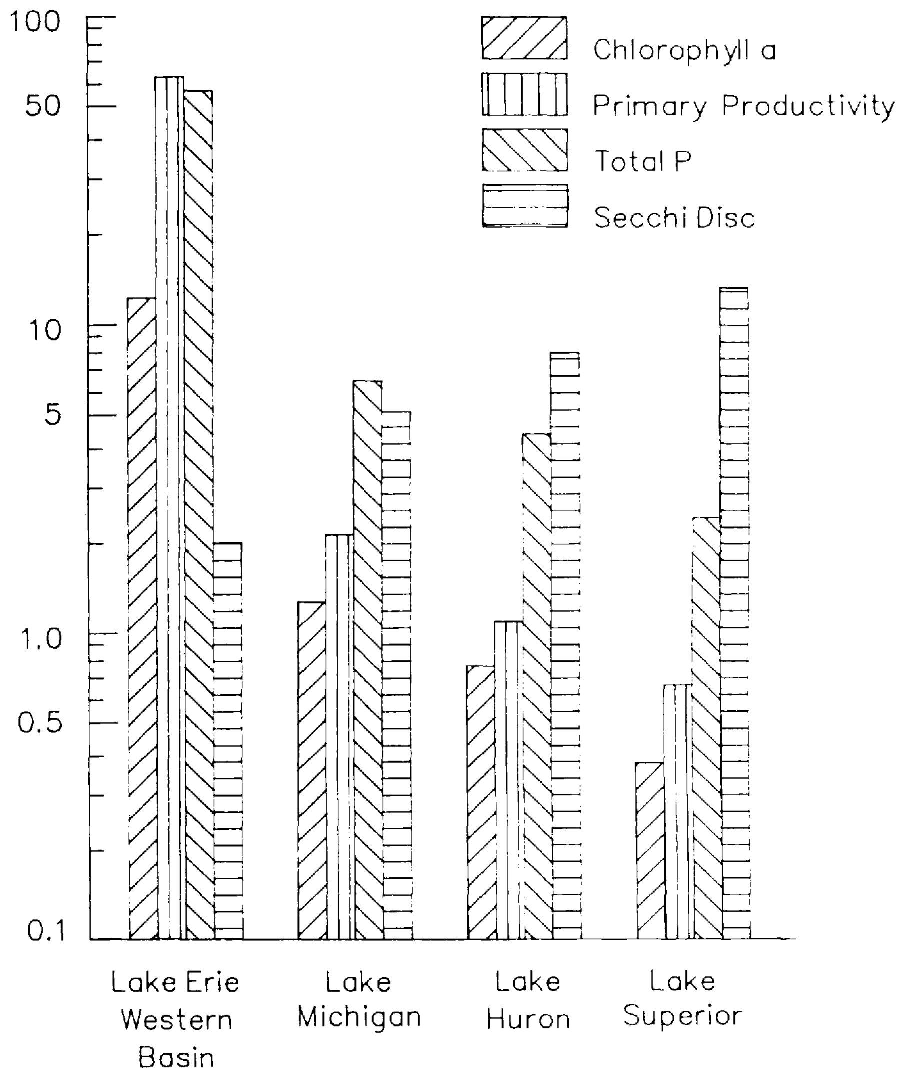
Phytoplankton assemblages originally dominated by diatoms have been altered dramatically, first from oligotrophic diatoms to more eutrophic diatoms and more recently, from diatom dominated assemblages to phytoplankton assemblages with increasing proportions of blue-green and green algae has occurred (Conway et al., 1977 ; Schelske et al., 1976 ; Stoermer et al., 1974 ; Schelske and Stoermer, 1971). Phytoplankton growth is phosphorus limited and increased inputs of this nutrient have stimulated growth of diatoms to the extent that, in summer, silica becomes the limiting nutrient. The result is that the phytoplankton assemblages are shifting from diatoms to physiological forms of phytoplankton which do not require silica (Schelske and Stoermer, 1972).

F3 PRIMARY PRODUCTION RATE

§ Carbon fixation rates [mg C m^{-3} day^{-1}], 1973
Open water : 0.37±0.18.
Bays : 0.59±0.14.

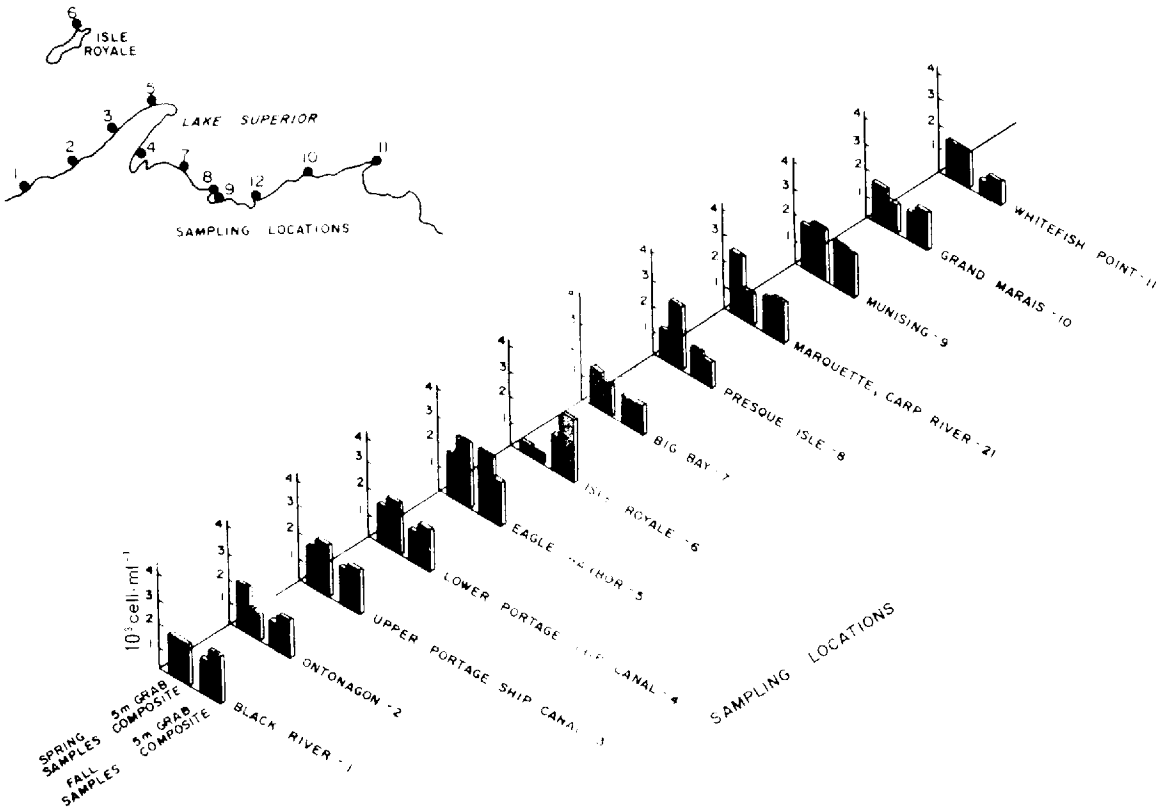
§ Photosynthetic assimilation ratios [mg C hr^{-1} mg chl-a]
Open water : 0.82±0.45.

Fig. NAM-4-8 Chlorophyll a [mg m^{-3}], primary productivity [mg C m^{-3} hr^{-1}], total phosphorus [mg PO_4-P m^{-3}] and Secchi disc transparency [m] in the Great Lakes.



F4 BIOMASS

Fig. NAM-4-9 Nearshore phytoplankton standing crop (1974).



F5 FISHERY PRODUCTS

§ Annual fish catch in 1977 : 4,184 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS (Q, 3, 5, 10, 11, 16-22, 27)

G1 LAND USE IN THE CATCHMENT AREA

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	117,970	95.0
Herbaceous vegetation	4,963	4.0
Agricultural land	1,740	1.0
Residential area	165	1.0
Total	124,838	100.0

§ Main types of woody vegetation : Aspen-birch forest, beech-maple forest, spruce-fir forest, pine forest.

§ Main types of herbaceous vegetation : *Pteridium aquilinum*.

§ Main kinds of crops : Hay and potato.

§ Levels of fertilizer application on crop fields : Light.

§ Trends of change in land use : No significant changes in the last 20 years.

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (U. S. only)

	Gross product per year [10^6 $]	No. of persons engaged	No. of establishments	Main products and main kinds of industry
Primary industry				
Agriculture	32.40	10,900	7,194	Livestock, hay, forest products
Fisheries	2.06	173	N. A.	Lake herring
Others	2,321.55	6,660	203	Paper produts
Secondary industry				
Manufacturing	982.50	25,485	N. A.	Machinary, paper products, printing, publishing
Mining	624.73	17,044	N. A.	
Others	254.40	125,488	N. A.	

§ Numbers of domestic animals in the catchment area : Cattle 26,000, sheep 5,200, swine 2,800, poultry 68,500.

G3 POPULATION IN THE CATCHMENT AREA (1970, U.S. only)

Population	Population density [km^{-2}]	Main cities
533,500	4.3	Duluth, Marquette, Superior

H. LAKE UTILIZATION (Q)

H1 LAKE UTILIZATION

Source of water, fisheries, tourism, recreation (swimming, yachting, sport-fishing) and navigation.

H2 THE LAKE AS WATER RESOURCE (1975, U.S. only)

	Use rate [m^3 day^{-1}]
Domestic water	1.5×10^5
Irrigation	8.7×10^3
Industrial water	10.8×10^5
Power plant	21.1×10^5
Mining	8.3×10^5

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : Not serious.

§ Supplementary notes : Local siltation in Duluth/Superior harbor and in Thunder Bay from mining. High water levels (1987) have led to increased siltation in some shoreline areas due to shore erosion. Presently, the problem is not serious, because the area is very lightly farmed and there is little open area ; however, it could become serious if not controlled.

12 TOXIC CONTAMINATION

§ Present status : Detected but not serious (Q).

§ Past trends of decrease of contaminants in various fish [ppm, wet weight basis] (25).

Names of contaminants	Fish*	Degree of decrease [ppm]
DDT	Lake trout*	1.2(1977) → <0.4(1982)
PCB	Lake trout	1.8(1980) → 0.4(1982)
Dieldrin	Lake trout	0.5

**Salvelinus namaycush* muscle samples tested.

Fig. NAM-4-10 Total DDT residues in Lake Superior lake trout.

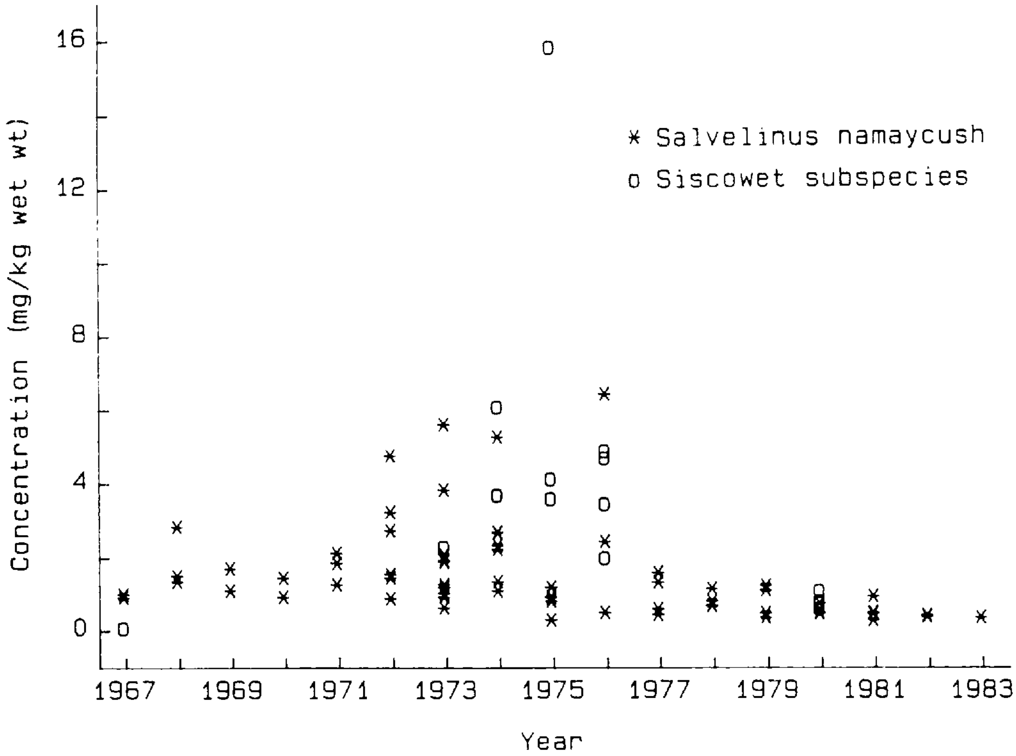


Fig. NAM-4-11 Total PCB residues in Lake Superior lake trout.

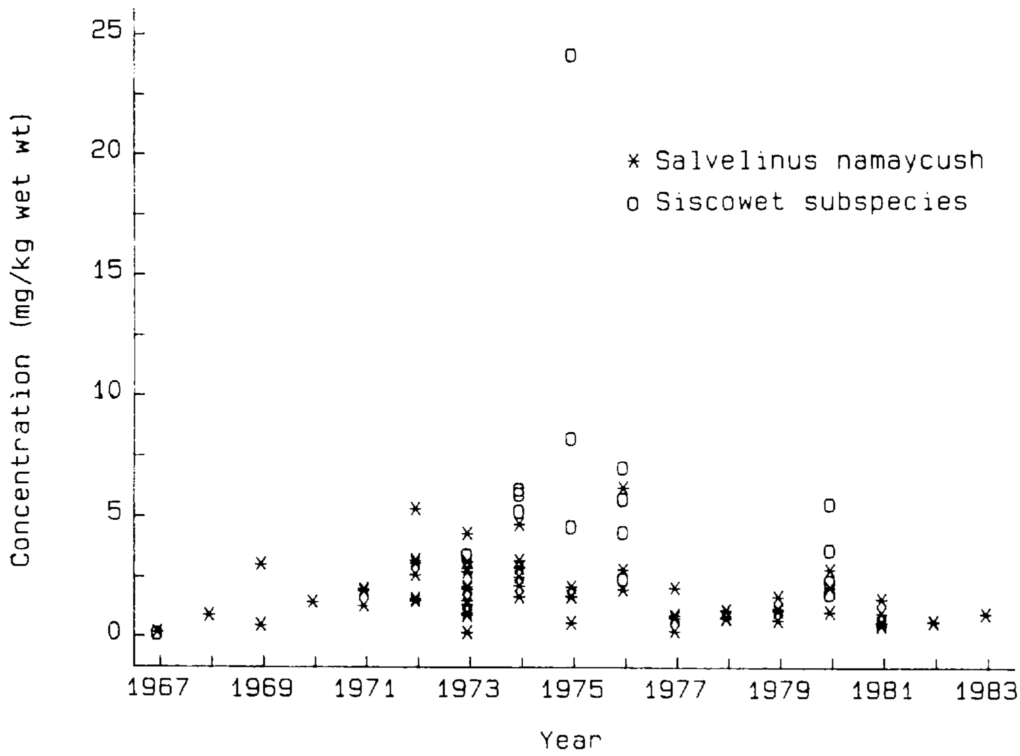


Fig. NAM-4-12 Dieldrin residues in Lake Superior lake trout.

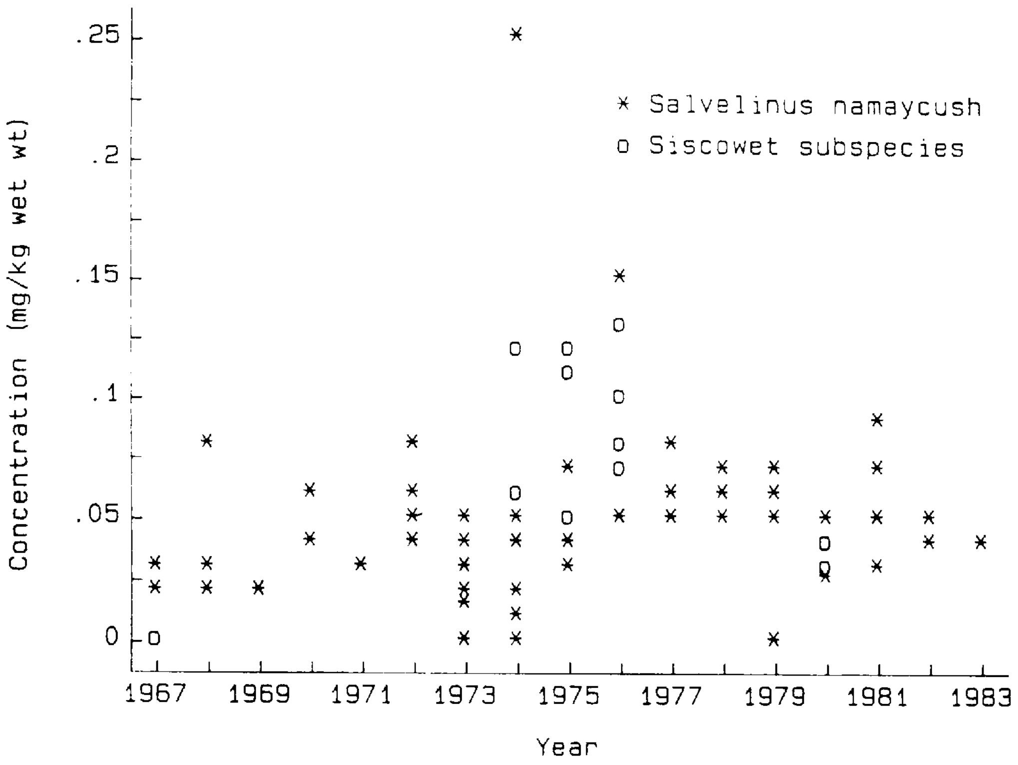
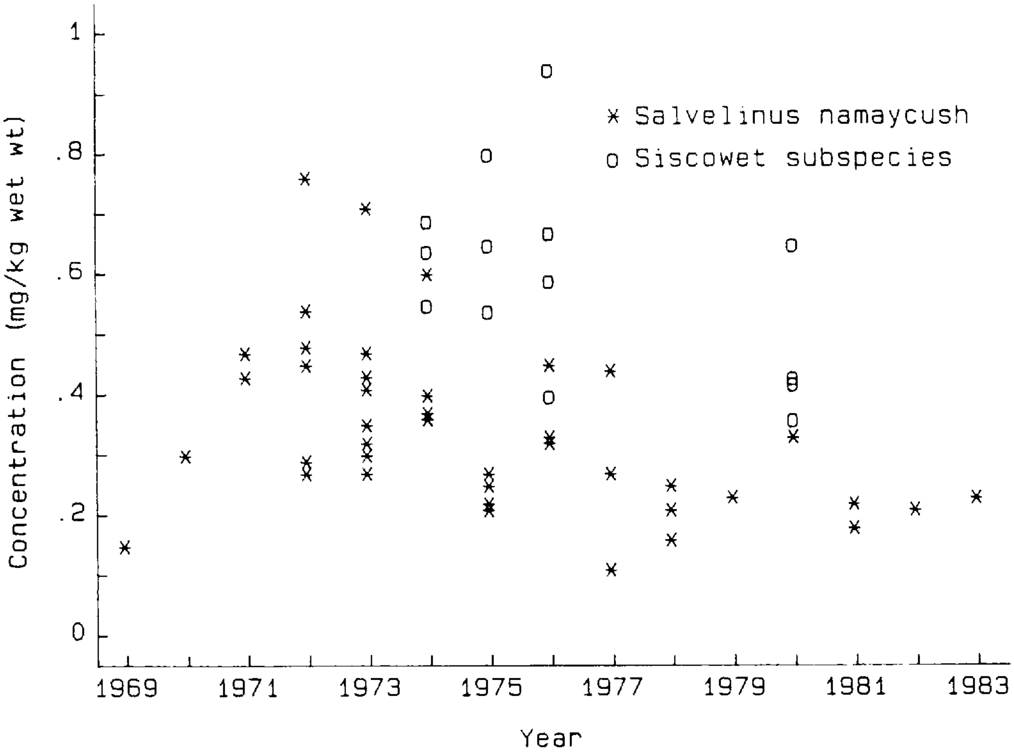


Fig. NAM-4-13 Mercury residues in Lake Superior lake trout.



§ Distribution of contaminants in the lake sediments
[ppb, dry weight basis] (26, 27)

Names of contaminants	Range	Average
DDT	<1.0-3.0<	0.71
PCB	< 5 -10<	3.3
Dieldrin	—	<0.25
Hg	<50-500	—
Pb	<50,000, 100,000-150,000	—

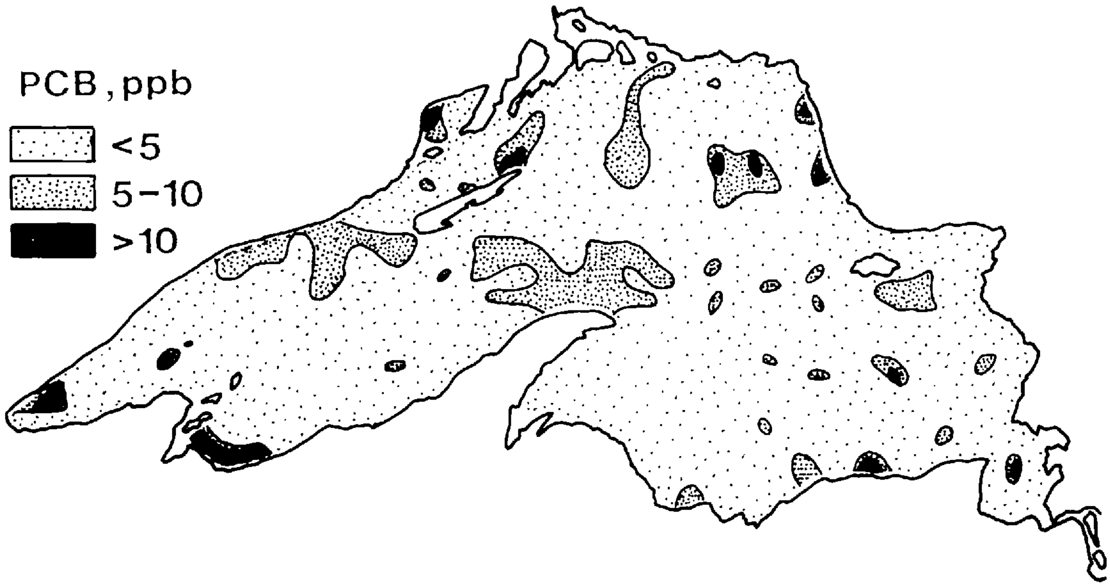
§ Distribution of contaminants in the lake sediments
[ppm, dry weight basis] (1973) (Q)

Locations	Number	Content in dry sediments (ng/g)*					
		p,p′-DDE		HEOD**		PCB	
		Mean	SD	Mean	SD	Mean	SD
All basins	216	1.1	1.9	0.25	0.18	4.8	5.5
Non-depositional zone	189	0.4	0.6	<0.25	—	3.9	2.1
Duluth sub-basin	27	1.9	1.6	<0.25	—	8.6	13.7
Chefswet sub-basin	27	0.7	0.8	<0.25	—	3.3	1.3
Apostle sub-basin	13	0.6	0.7	0.25	0.19	5.0	2.2
Thunder Bay Trough	17	2.7	5.5	0.27	0.17	5.5	2.9
Isle Royale sub-basin	50	0.8	0.7	0.25	0.15	4.5	2.2
Thunder Bay	5	1.2	1.3	0.26	0.13	5.7	3.6
Marathon basin	6	0.7	0.3	0.32	0.18	6.4	7.3
Keweenaw basin	4	0.8	0.7	<0.25	—	3.1	1.3
Caribou sub-basin	49	0.8	1.0	0.27	0.28	3.7	1.6
Whitefish sub-basin	18	0.9	1.2	0.28	0.16	4.4	3.0

* For purposes of calculating the Mean and SD, trace amounts (0.25–0.50 ng/g) of DDE and HEOD were assigned 0.4 ng/g and non-detectable amounts (<0.25 ng/g) assigned 0.1 ng/g, and for PCB trace amounts (2.5–5.0 ng/g) were assigned 4.0 ng/g and non-detectable amounts (<2.5 ng/g) assigned 1.0 ng/g.

**HEOD : Dieldrin.

Fig. NAM-4-14 PCB concentrations in surface sediments (3 cm) (38).



§ Food safety standards or tolerance limits for toxic contaminant residue (Q)

Regulatory limitations are set by the U.S. Food and Drug Administration and Canada Dept. of National Health and Welfare and are advisories only with regard to human consumption of fish. The U.S. standards are : PCB 2 mg kg^{-1}, DDT 5 mg kg^{-1}, Dieldrin 3 mg kg^{-1} and mercury 1 mg kg^{-1} (Federal limit) and 0.5 mg kg^{-1} (State limit).

	Restrict consumption Important*	Do not eat
Lake Superior (applies to Michigan, Wisconsin and Minnesota waters)	Lake Trout up to 30″	Lake Trout over 30″

* Nursing mothers, pregnant women, women who anticipate bearing children, and children age 1 and under should not eat the fish listed in any of the categories listed above.

§ Environmental quality standards for contaminants in the lake (Q)

IJC 1978 Agreement objectives are "no-effect levels, for the protection of aquatic life, human consumers of fish, or fish-consuming aquatic birds." Objectives have been recommended for approximately 40 organic and inorganic chemicals, including persistent toxic substances, non-persistent toxic substances, physical materials, microbiological and radiological contaminants. Examples of specific objectives include : Dieldrin, less than 0.001 $\mu g/l$ in water and less than 0.3 mg/kg in edible portions of fish ; DDT and metabolites, less than 0.003 $\mu g/l$ in water and 1.0 mg/kg in fish ; PCB should not exceed 0.1 mg/kg in fish, while the mercury content of filtered water should be less than 0.2 $\mu g/l$ and 0.5 mg/kg in fish flesh.

§ Supplementary notes (Q, 37)

Critical pollutants in the Great Lakes ecosystem include : PCB, 2, 3, 7, 8-TCDD, mirex, 2, 3, 7, 8-TCDF, hexachlorobenzene, benzo-a-pyrene, dieldrin, alkylated lead, DDT and metabolites, toxaphene, and mercury. The worst problems associated with contaminated sediments occurs in bays, harbor mouths and connecting channels. For example, the sediments in some of the drainage ditches emptying into Waukegan Harbor near Chicago contain as much as 500,000 mg/kg PCB. Heavy urban and industrial development and use of connecting channels as a transportation corridor have contributed to the degradation of the water quality of the St. Mary's River connecting Lake Superior and Lake Michigan.

Past experience with persistent toxic chemicals such as PCB, DDT, mercury, dieldrin and mirex show that once they are introduced into an aquatic ecosystem, they are extremely difficult to remove, especially in sediments which become a source for their remobilization into the water column. Therefore, the emphasis of regulatory officials has been directed toward preventing their release and the development of effective and efficient responses to identified problems.

Both the United States and Canada monitor atmospheric deposition for a range of organic chemicals and heavy metals of concern to the Great Lakes Ecosystem. An estimated 20% to 25% of the pollutants into the Great Lakes come from atmospheric fallout. The latest data relative to the total deposition of airborne trace metals and organics are attached. No effective countermeasures have been implemented to date.

Total deposition of airborne trace substances to Lake Superior [metric tons $year^{-1}$] (28).

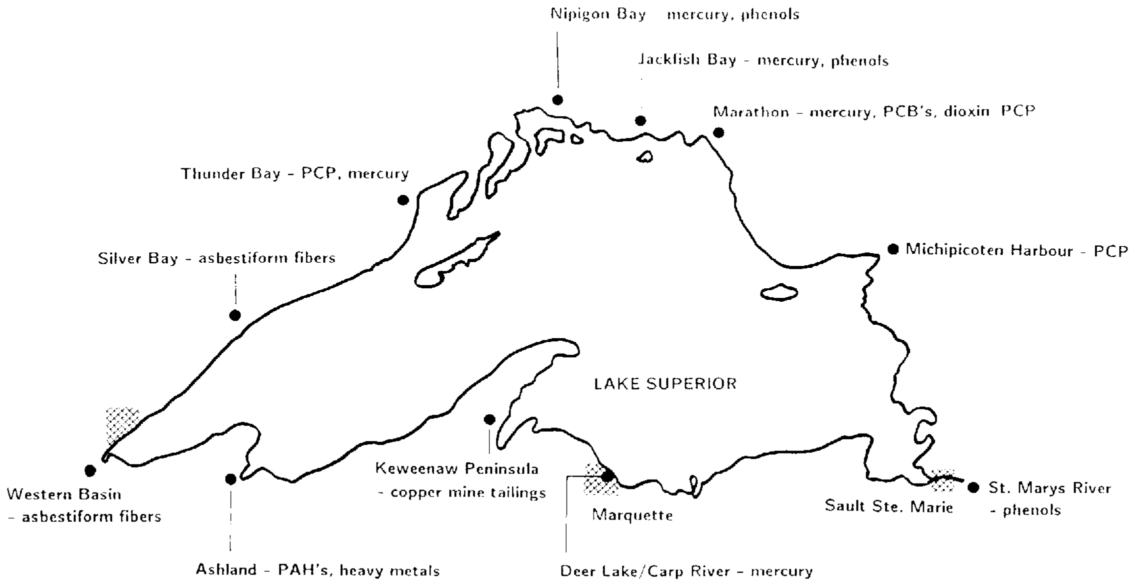
Metal	Total deposition
Zn	8,210
Pb	1,230
Cu	821
Cd	82
Ni	328
Fe	8,210
Al	14,000
Mn	1,640

Substance	Total deposition
Total PCB	9.8
Total DDT	.58
α-BHC	3.3
γ-BHC	15.9
Dieldrin	.54
HCB	1.7
p,p'-methoxychlor	8.3
α-endosulfan	7.9
β-endosulfan	8.0
Total PAH	163
Anthracene	4.8
Phenanthrene	4.8
Pyrene	8.3
Benzo (a) anthracene	4.1
Perylene	4.8
Benzo (a) pyrene	7.9
DBP	16
DEHP	16
Total organic carbon	2×10^5

Other hazards include the input of toxic inorganic and organic chemicals from municipal point sources, combined sewer overflows, rural and urban nonpoint sources and leachates from municipal and hazardous waste landfill disposal sites. Problems from these sources are most apparent in highly industrialized harbors and embayments and nearby areas.

The IJC areas of concern include locales where environmental degradation and impairment of beneficial uses is severe and those where some environmental degradation is obvious and where uses may be impaired. The Lake Superior areas of concern are attached.

Fig. NAM-4-15 Areas of concern in Lake Superior.



I3 EUTROPHICATION

§ Nuisance caused by eutrophication (Q)

Others : Not a significant problem except in urban areas, bays and river mouth.

I4 ACIDIFICATION

§ Extent of damage : No information (Q).

§ Kinds of damage : Evidence of damage to Lake Superior from acidic deposition is not discernable at this time (Q).

§ Supplemtary notes (Q)

Data relating the amount of airborne acid deposition and stream effect are highly variable depending on the total stream alkalinity. For very soft water streams in the Upper Peninsula of Michigan (i.e., alkalinity less than 10 mg/l as $CaCO_3$), pH decreases of 1 to 2 units (from stream pH values of 7 or 8 to 6 or 7) have been observed in the headwaters area. To date, no studies have demonstrated detectable ecosystem trends which can be totally ascribed to acidification. The effects of increased acidic deposition, especially over terrestrial watershed with little alkaline character, may be more discernable.

Mean monthly value of pH (Washington Creek, Isle Royale National Park, 1967-1980) (58).

Month							
O	F	M	M	J	J	A	S
7.28	7.47	7.41	7.20	7.33	7.57	7.38	7.19

Because of its size, Lake Superior possesses a large buffering capacity and apparently is able to neutralize the airborne acid deposition it receives. Consequently, Lake Superior doesn't appear to be directly affected. This is not true for many of the streams and tributaries and smaller lakes that surround and feed Lake Superior and the other Great Lakes.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment, and (d) Measurable pollution with limited wastewater treatment. Situafion differs lecally.

J2 APPROXIMATE PERCENTAGE DISTRUBUTION OF POLLUTANT LOADS

§ Summary of total phosphorus loads, 1976 (27)

Sources	P [metric tons year^{-1}]			
	Canada	U.S.	Total	[Percent]
Direct municipal sewage treatment plants	29	39	68	[2]
Tributary municipal sewage treatment Plants	38	162	200	[5]
Direct industrial	102	0	102	[2]
Tributary industrial	0	33	33	[<1]
Urban nonpoint direct	16		16	[<1]
Tributary diffuse	1,453	769	2,222	[53]
(Tributary total)	(1,491)	(964)	(2,455)	
Sub-total	1,638	1,003	2,641	[63]
Atmospheric	-	—	1,566	[37]
Load from upstream lake	—	—	—	
Total			4,207	[100]
Shoreline erosion (not included in total)	0	3,781	3,781	

J3 SANITARY FACILITIES AND SEWERAGE (Q)

§ Municipal wastewater treatment systems (data for Michigan only)

Number of tertiary treatment systems: 3.

Number of secondary treatment systems: 38.

Number of primary treatment systems: 9.

K. IMPROVEMENT WORKS IN THE LAKE (Q)

None.

L. DEVELOPMENT PLANS (Q)

On the southern shore of Lake Superior, some limited development planning has occurred with respect to increased recreational use (second homes, tourism) by the states' Sea Grant Programs and the Coastal Management Program of NOAA. The Coastal Management Program has been especially concerned since 1982 with high water levels.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

(1) Rivers and Harbors Acts of 1899 and 1909 (33 USC 401 et seq.)
(2) Flood Control Acts of 1917, 1936 and 1944
(3) Safe Drinking Water Act
(4) State legislation implementing and augmenting federal laws
(5) Federal Water Pollution Control (Clean Water) Act of 1972 (PL 92-500) and Amend-

ments of 1977 and 1987 (33 USC 125 et seq.)
(6) Boundary Water Treaty of 1909 between United State and Canada
(7) 1972 and 1978 United States-Canada Agreements on Great Lakes Water Quality
(8) Canada Shipping Act (Section XX)
(9) Canada Navigable Water Protection Act
(10) Canada Waters Act
(11) Canada Environmental Contaminants Act
(12) Canada Fisheries Act (Section XXXIII)
(13) Canada Pesticide Registration Act
(14) Ontario Water Resources Act (1982)
(15) Ontario Environmental Protection Act (amended 1983)
(16) Ontario Pesticide Act (1974 as amended)

§ Responsible authorities
(1) Corps of Engineers of the U.S. Army
(2) Corps of Engineers of the U.S. Army
(3) State Agencies for Environment and Natural Resources
(4) U.S. Environmental Protection Agency
(5) U.S. Environmental Protection Agency
(6) International Joint Commission
(7) International Joint Commission
(8) Canadian Ministry of Transport
(9) Canadian Ministry of Transport
(10) Environment Canada
(11) Environment Canada
(12) Environment Canada
(13) Environment Canada and Agriculture Canada
(14) Ontario Ministry of the Environment
(15) Ontario Ministry of the Environment
(16) Ontario Ministry of the Environment

§ Main items of control
(1) Discharges, dredging and filling
(2) Flood control
(3) Drinking water-including standards
(4) The entire range of water related problems
(5) Water pollution
(6) Quality of Great Lakes water relative to nutrients
(7) Quality of Great Lakes water relative to toxic chemicals
(8) All contaminants
(9) All contaminants
(10) Nutrients
(11) Toxic organic and inorganic chemicals
(12) Substances injurious to fish
(13) Pesticides
(14) All contaminants
(15) All contaminants
(16) Pesticides, herbicides and slimicides

§ Supplementary notes

Other U.S. laws which indirectly relate to preserving the water quality of the Great Lakes include the 1976 Resource Conservation and Recovery Acts (RCRA), the 1976 Toxic Substances Control Act (TSCA) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 as amended 1987 (CERCLA or Superfund).

M2 INSTITUTIONAL MEASURES

(1) Great Lakes Fishery Commission (International) was established in 1960 to formulate, coordinate and implement fisheries research programs related to the Great Lakes. MI.
(2) International Joint Commission (International) was established in 1909 to investigate pollution in the boundary waters of the United States and Canada. Windsor, Ontario.

(3) United States Environmental Protection Agency was established in 1972 to protect the nation's atmospheric, terrestrial and aquatic environments and enforce legislation enacted to protect them. Chicago, IL.
(4) The United States Army Corps of Engineers (U.S., Federal) is concerned with all aspects of water resources as they relate to present and future needs of navigation, flood control, power, water supply, irrigation, beach erosion, dredging and recreational activities. Chicago, IL.
(5) The United States Bureau of Commercial Fisheries (U.S., Federal) is concerned with maintaining viable and expanding fisheries in the Great Lakes. In this regard, it conducts a broad research program on parasite (lamprey) control, effects of exploitation on the Great Lakes Fishery and establishing the relationship between limnological conditions and the general biology of commercial fish species.
(6) The United States Public Health Service (U.S., Federal) is concerned with monitoring food and water supplies as they relate to human health. One of their primary functions is to develop and maintain an inventory of the sources and nature of pollutants entering each lake relative to the population and industry of the region. Washington, DC.
(7) U.S. Department of Agriculture (U.S., Federal) is concerned with developing programs and research to minimize nonpoint pollution from agriculture (pesticides, nutrients, and erosion) as it relates to protecting the water quality of the Great Lakes.
(8) U.S. Department of Commerce (U.S., Federal) has Great Lakes research and monitoring programs administered under its National Oceanic and Atmospheric Adminstration (NOAA).
(9) U.S. Department of the Interior (U.S., Federal) under its U.S. Geological Survey, sponsors research and education programs through the State Water Resources Institute program.
(10) Great Lakes Commission (an interstate Compact Commission) was established in 1955 by the eight states bordering the Great Lakes to provide communication, coordination and advocacy on Lakes issues. The Commission deals with environmental quality, resources management, transportation and economic development. Ann Arbor, MI.
(11) The State Departments of Natural Resources (U.S., State). Each state in the United States has a Department of Natural Resources or equivalent department which is responsible for monitoring the state's natural resources and enforcing legislation enacted to protect them.
(12) The State Departments of Public Health (U.S., State). Each state in the United States has a Department of Public Health or equivalent department, which is responsible for monitoring food and water supplies as they relate to human health.
(13) Environment Canada (Canada, Federal). Primary concerns are related to the protection of the atmospheric, terrestrial and aquatic environments. Toronto, Ontario.
(14) Department of Fisheries and Oceans (Canada, Federal). Primary function is to protect the water quality of freshwater and marine environments as fish habitats. Burlington, Ontario.
(15) Health and Welfare Canada (Canada, Federal). Primary function is to monitor food (fish) taken from the Great Lakes as it relates to human health. Ottawa, Ontario.
(16) Agriculture Canada (Canada, Federal) is responsible for developing programs and research to minimize nonpoint pollution from agriculture (pesticides, nutrients and erosion) as it relates to protecting the water quality of the Great Lakes. Ottawa, Ontario.
(17) Ministry of Agriculture and Food (Canada, Provincial). Primary function is to monitor food (fish) taken from the Great Lakes as it relates to human health. Toronto, Ontario.
(18) The Ontario Ministry of the Environment (Canada, Provincial) is responsible for monitoring the water quality of lakes, streams, groundwater and drinking water and to enforce abatement activities around industrial and municipal facilities. Toront, Ontario.
(19) Ontario Ministry of Natural Resources (Canada, Provincial). Primary function is to protect the environmental quality of forests and lakes as related to fisheries and wildlife habitat. Toronto, Ontario.

M3 RESEARCH INSTITUTE ENGAGED IN THE LAKE ENVIRONMENT STUDIES

(1) Institute of Environmental Studies, University of Toronto, Toronto, Ontario ; Emphasis : monitoring and research
(2) Lakehead University, Thunder Bay, Ontario ; Emphasis : fish toxicity studies as related to Lake Superior
(3) Great Lakes Institute, University of Windsor, Windsor, Canada ; Emphasis : Great Lakes monitoring and research

(4) Great Lakes Research Division, University of Michigan, Ann Arbor, Michigan ; Emphasis : monitoring and research
(5) University of Minnesota Limnological Research Center, University of Minnesota, St. Paul, Minnesota ; Emphasis : monitoring and research

§ Supplementary notes

Private orgainzations concerned with the well being of the Great Lakes :

(1) Center for the Great Lakes, Chicago, IL
(2) Great Lakes Tomorrow, Toronto, Ontario
(3) Great Lakes United, Buffalo, NY
(4) Operation Clean Niagara, Niagara-on-the-Lake, Ontario
(5) Pollution Probe, Toronto, Ontario

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LAKE HURON

A view from Fort Mackinac

Photo: A. Kurata

A. LOCATION

§ Michigan, U. S. A. ; and Ontario, Canada.
§ 43°00′-46°21′N, 79°50′-84°45′W ; 176 m above sea level.

B. DESCRIPTION

Lake Huron is the second largest of the Great Lakes and the fifth largest in the world, with the most irregular shape of any of the Great Lakes. Even its largest island, Manitoulin, is wider than the State of Rhode Island, and has five small lakes of its own. The lake is connected with its neighbor, nearly same-sized L. Michigan, only by a narrow straight called the Straights of Mackinac, which is spanned by a 8 km-long bridge, the Mighty Mac. The shores around Mackinac offer spectacular landscape.

The water quality of the lake is still excellent and oligotrophic. Transparency is generally recorded at 8 m, and chlorophyll-a concentration at the lake center is less than 2 mg m^{-3}. However, the water in Saginaw Bay in the southern part has become considerably worse due to the nutrient loading from surrounding areas.

Many long freighters and other seafacing vessels come and go on this "inland sea". In summer, recreational boating and yacht-racing are supported by many local clubs almost every day.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	59,570
Volume [$10^9 m^3$]	3,535
Maximum depth [m]	228
Mean depth [m]	53
Water level	Unregulated
Length of shoreline [km]	5,088
Residence time [yr]	22.6
Catchment area [km^2]*	128,164

* Not including the catchments of the two upstream Great Lakes.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (1-5)

§ Bathymetric map (Fig. NAM-5-1).

§ Main islands : Manitoulin, Dummond, st. Joseph, Cockburn.

§ Outflowing rivers and channels (number and names) : 1 (St. Claire R.).

D2 CLIMATIC (4-8)

§ Climatic data at Alpena, 1943-1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-7.1	-7.5	-2.9	4.2	10.4	16.0	19.0	18.2	13.9	8.5	1.9	3.9	5.9
Precipitation [mm]	46	38	49	58	73	78	69	75	79	64	60	49	739

§ Number of hours of bright sunshine (Alpena, 1943-1980) : 2,324 hr yr^{-1}.

§ Solar rediation (Alpena, 1943-1980) : 11.10 MJ $m^{-2}day^{-1}$.

§ Period of snowfall : 120 day yr^{-1} (mid Nov.-mid Mar.).

§ Amount of total snowfall : 2.46 m yr^{-1}.

Fig. NAM-5-1 Bathymetric map (Q).

§ Water temperature [°C]

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	0	1	3	6	14	20	20	18	11	7	3

§ Freezing period : 80 days with ca. 60 % ice coverage.

§ Mixing type : Dimictic.

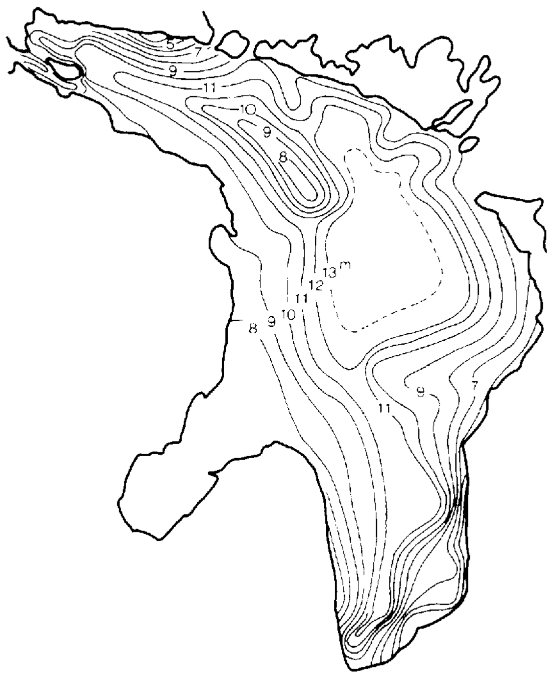
§ Notes on thermocline formation : Generally from July to November and from January to March.

E. LAKE WATER QUALITY (3-5, 9-13)

E1 TRANSPARENCY

Lake center, 1954 : 12 m (Jun.), 14 m (Jul.), 13 m (Aug.).

Fig. NAM-5-2 Distribution of transparency [m] (Aug. 1954) (Ayers, 1956).



E2 pH

Off Harbor Beach, 1974

Depth	May	Jun	Jul	Aug	Sep	Oct	Nov
Surface	8.40	8.45	8.30	8.55	–	–	8.3

E4 DO

Fig. NAM-5-3 Percent saturation of DO [%] of bottom water (1971).

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$]

Off Harbor Beach, 1974

Depth	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Surface	2	2	2	0.4	0.6		1.5	0.6

E7 NITROGEN CONCENTRATION

Fig. NAM-5-4 Distribution of inorganic nitrogen. Isopleths refer to mean concentrations [$\mu g\ l^{-1}$] at 1 m depth (1971).

E8 PHOSPHORUS CONCENTRATION

Fig. NAM-5-5 Distribution of total phosphorus. Isopleths refer to mean concentrations [$\mu g\ l^{-1}$] at 1 m depth (1971).

E9 PAST TRENDS

The water quality of open Lake Huron and that of Saginaw Bay should be considered separately because they are distinct limnologically. The open waters of Lake Huron exhibit low concentrations of dissolved ions with a general increase occurring from north to south. Although the levels indicate a general absence of contamination, the transparency data indicate a decrease from 10 m to 7 m during the 1957–1971 period (Dobson, H. H. (1971): Nutrients in Lake Huron, Canada Centre for Inland Waters).

A review of Saginaw Bay water quality data (12) indicates that high levels of nutrient loading have continued from 1956 to 1971. Concentrations of all parameters are higher than those found in the open waters of Lake Huron and are a substantial cause for the north to south increasing concentration gradient.

Loadings of total dissolved solids to all of the Great Lakes, with the exception of Lake Superior, have increased significantly over the past 50 years. This has resulted in increased concentrations of nutrients, chlorides, sulphates, and numerous other ions and compounds in Lakes Michigan, Huron, Erie and Ontario.

F. BIOLOGICAL FEATURES (3–5, 11, 13–16)

F1 FLORA

§ Emerged macrophytes: *Scirpus acutus, S. americanus, Sparganium* sp., *Phragmites* sp., *Eleocharis* sp.

§ Submerged macrophytes: *Nitella flexilis, Chara globularis, Isoetes riparia.*

§ Phytoplankton: *Cyclotella comensis, C. comita, C. glomerata, Coelastrum reticulatum, Tabellaria fenestrata, Asterionella formosa.*

F2 FAUNA

§ Zooplankton: Protozoa (*Difflugia globulosa, Codonella* sp.), Cladocera (*Bosmina longispina, Daphnia retrocurva*), Rotifera (*Polyarthra vulgarlis, Notholca longispira*); Copepoda (*Diaptomus ashlandi, Limnocalanus macrurus*).

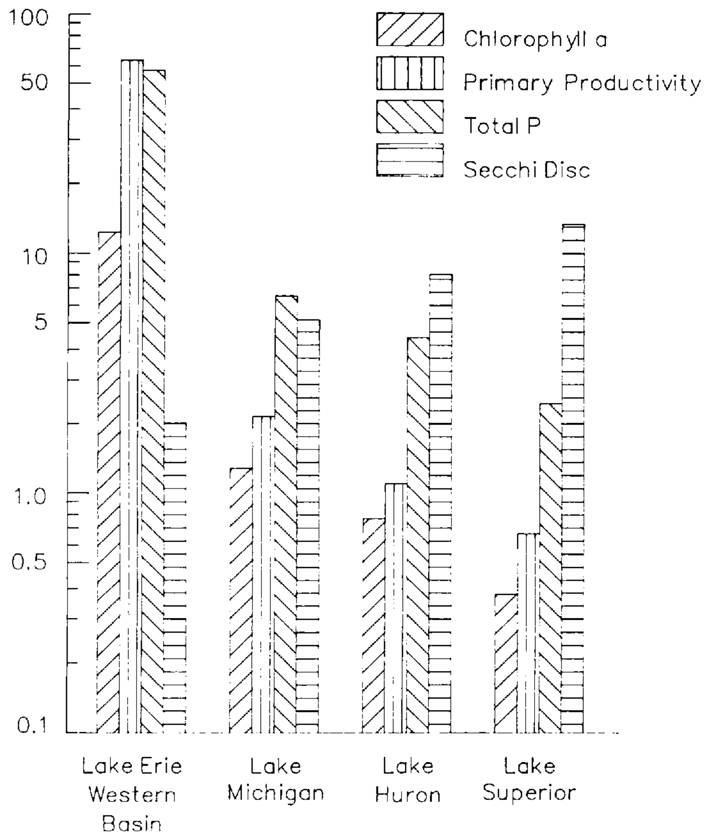
§ Benthos: Amphipod (*Pontoporeia affinis*), Oligochaeta (*Limnodrilus* sp., *Tubifex* sp., *Stylodrilus* sp.), Mullusca (*Pisidium* sp.).

§ Fish: *Alosa pseudoharengus, Oncorhynchus kisutch, O. tschawytscha, Perca flavescens, Osmerus* sp., *Stizostedion vitreum, Salvelinus namaycush, Coregonus clupeaformis.*

F3 PRIMARY PRODUCTION RATE [mg C m^{-3} hr^{-1}] (1969-1970)

Open water 0.77 1.69, Saginaw Bay 28.

Fig. NAM-5-6 Chlorophyll-a [mg m^{-3}], primary productivity [mg C m^{-3} hr^{-1}], total phosphorus [mg PO_4-P m^{-3}] and Secchi disc transparency [m] in Great Lakes (16).



F5 FISHERY PRODUCTS

§ Annual fish catch (commercial) in 1977 : 2,977 [metric tons].

F7 NOTES ON THE REMERKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (Q)

During the past 40 years major upheavals have occurred. By 1946 sea lamprey had invaded all the Great Lakes and decimated the native fish population, especially lake trout (*Salvelinus namaycush*). The decline of native fish populations created conditions favorable for the explosive increase of alewife (*Alosa pseudoharengus*) which, in turn, greatly reduced the populations of yellow perch (*Perca flavescens*), cisco (*Coregonus* sp.) and lake herring (*Coregonus artedii*). Salmon species were introduced in 1964 and have effectively utilized the alewife as a food source. This has served to both reduce the alewife populations and create a vital sport-fishing industry. The predominance of alewife also resulted in a shift toward smaller size zooplankton as the larger species were selectively harvested (Wells, L. (1969) : U. S. Fish Wildlife Service, Fish. Bull., 60 : 343-369).

G. SOCIO-ECONOMIC CONDITIONS (3-5, 17-24)

G1 LAND USE IN THE CATCHMENT AREA (1978)

Natural landscape		
Woody vegetation	84,447	66.0
Herbaceous vegetation	12,841	10.0
Agricultural land	28,840	22.0
Residential area	2,336	2.0
Total	128,464	100.0

§ Main types of woody vegetation : Aspen-birch forest, oak-hickory forest, maple-beech forest and pine forest.
§ Main kinds of crops : Dry field bean, sugar beet, hay, potato, corn and soybean.

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (1970)

	Gross product during the year [10^6 \$]	No. of persons engaged	No. of establishments	Main products and main kinds of industry
Primary industry				
Agriculture	1,090.09	42,000	23,977	Dry field beans, livestock, sugar beet, hay, grains
Fisheries	8.72	325	N. A.	Whitefish
Others	541.69	1,554	48	Paper products
Secondary industry				
Manufacturing	5,336.70	165,433	1,186	Transportation equipment, machinery, metal fabrication
Mining	2,427.25	1,696	N. A.	Sand, cement, gravel, crushed stone
Others	1,472.85	243,524	N. A.	Building, construction engineering

G3 POPULATION IN THE CATCHMENT AREA (U. S. only) (1970)

	Population	Population density [km^{-2}]	Main cities
Total	1,236,300	9.6	Flint, Midland Alpena, Saginaw

H. LAKE UTILIZATION

H1 LAKE UTILIZATION

Source of water, fisheries, navigation, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (U. S. only) (1975)

	Use rate [$m^3 day^{-1}$]
Domestic	3.5×10^5
Irrigation	0.4×10^5
Industrial	30.8×10^5
Power plant	27.1×10^5
Mining	2.7×10^5

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION

§ Mean contaminant concentrations in whole fish samples of Lake Huron rainbow smelt, 1979–1983 [mg kg^{-1}, wet weight] (25)

Year	PCB	pp′DDE	ΣDDT	Ag	As	Se
1979	0.19	0.05	0.07	0.06	0.27	0.64
1980	0.11	0.05	0.07	0.07	0.26	0.69
1981	0.13	0.07	0.10	0.06	0.31	0.68
1982	0.29	0.08	0.12	0.05	0.36	0.54
1983	0.18	0.07	0.10	–	–	–

§ Mean contaminant concentrations in whole fish samples of Lake Huron lake trout, 1979–1983 [mg km^{-1}, wet weight] (25)

Year	PCB	pp′DDE	ΣDDT	Ag	As	Se
1979	0.78	0.15	0.20	0.16	0.15	0.70
1980	0.42	0.22	0.25	0.18	0.18	0.75
1981	2.26	0.60	1.06	0.24	0.43	0.48
1982	2.44	0.48	0.73	0.19	0.43	0.62
1983	1.24	0.39	0.68	–	–	–

Fig. NAM-5-7 Distribution of cadmium concentrations in surface bottom sediments (26).

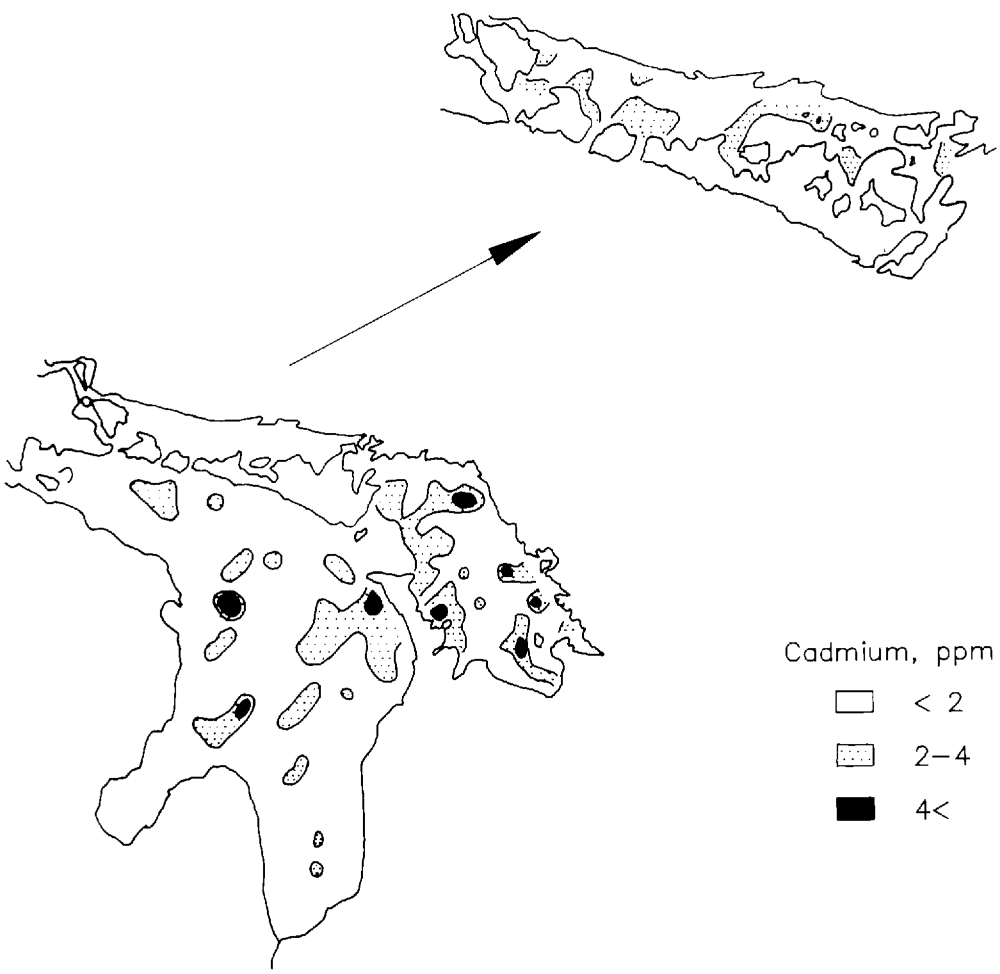
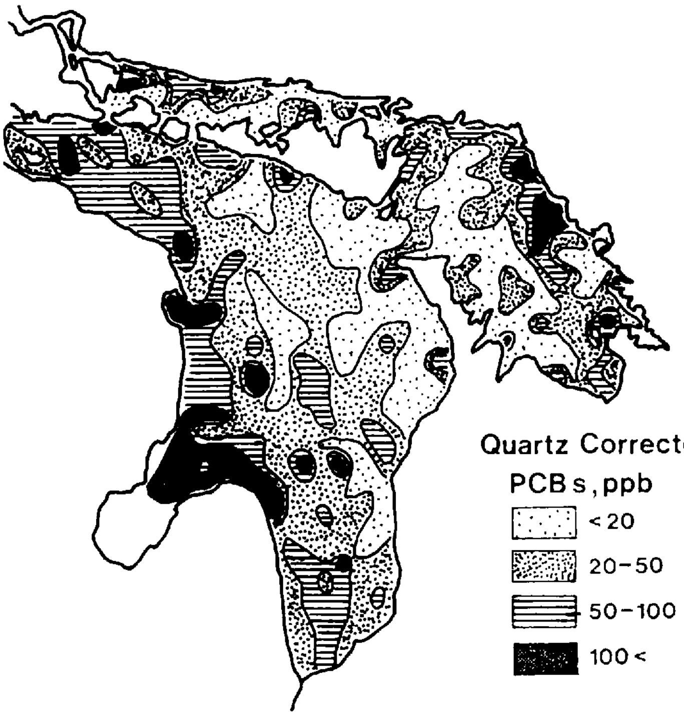


Fig. NAM-5-8 Distribution of quartz-corrected PCBs in surface bottom sediments (27).



§ Supplementary notes (Q)

Toxic contamination hazards included the input of toxic inorganic and organic chemicals from municipal point sources, combined sewer overflows, rural and urban nonpoint sources and leachates from municipal and hazardous waste landfill disposal sites. Problems from these sources are most apparent in highly industrialized harbors and embayments and nearby areas.

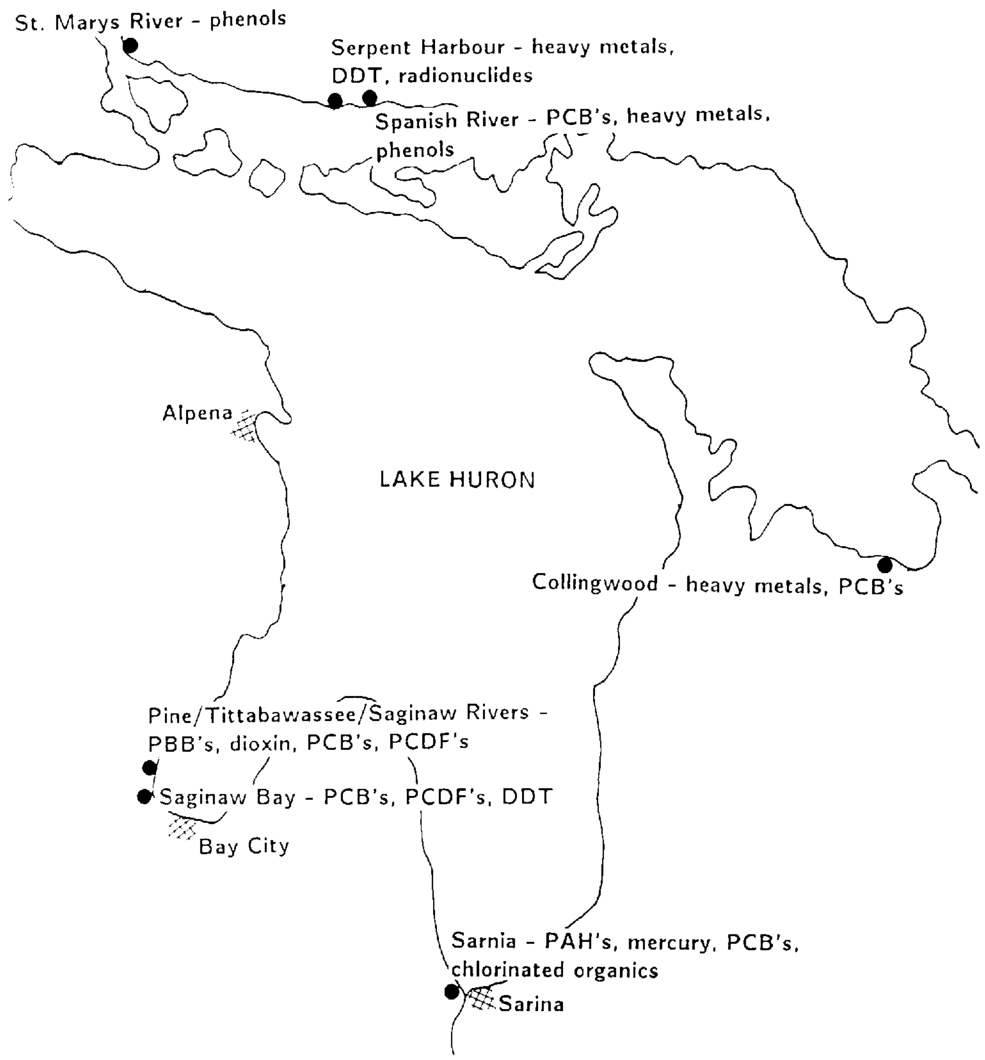
I3 EUTROPHICATION (Q)

§ Nitrogen and phosphorus loadings to the lake (1976) [t yr^{-1}]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	N. A.	N. A.	N. A.	N. A.	24,700
T-P	122	515	2,442	1,129	4,857 *

* Including 657 t from upstream lakes.

Fig. NAM-5-9 Areas of concern in Lake Huron. The International Joint Commission areas of concern include locales where environmental degradation and impairment of beneficial uses is severe and those where some environmental degradation is obvious and where uses may be impaired.



J. WASTEWATER TREATMENTS (Q)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (f) Measurable pollution with well-developed wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

Number of secondary and tertiary treatment (activated sludge, trickling filter and oxidation pond) systems: 81 (rate of treatment 420,000 m^3 day^{-1}) (1978).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS (Q)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws (the year of legislation)

A large number of Federal and State Laws, Policies and Industrial Agreements (see Lake

Erie).

§ Responsible authorities

United States and Canadian Federal Governments, State of Michigan and Province of Ontario, local governments

§ Main items of control

(1) Water quality and waste disposal, water use and withdrawal, fishing rights, navigation, flood and erosion control

K. IMPROVEMENT WORKS IN THE LAKE (Q)

Beginning in 1970, a multi-billion dollar remedial program was undertaken by the United States and Canada under the supervision of the International Joint Commission.

N. SOURCES OF DATA

(Q) Questionnaire was filled by Prof. F. M. D'Itri, Institute of Water Research, Michigan State University, Lansing, based on the data obtained from the following sources (1-27).

(1) Hough, J. L. (1958) Geology of the Great Lakes. University of Illinois Press, Urbana, Illinois.

(2) Pincus, H. J. (1962) Great Lakes Basin. American Association for the Advancement of Science, Washington, D. C.

(3) Great Lakes Basin Commission Public Information Office (1974) Great Lakes Basin Framework Study. Ann Arbor, Michigan.

(4) Great Lakes Fishery Commission (1980) Annual Report. Ann Arbor, Michigan.

(5) Great Lakes Fisheries Commission (1978) Commercial Fish Production in the Great Lakes, 1967-1977. Technical Report 3. Ann Arbor, Michigan.

(6) National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, National Climatic Data Center. Department of Commerce, Asheville, North Carolina.

(7) Solar Energy Research Institute. Solar Energy Information Data Book, Insolation Data Manual. Golden, Colorado.

(8) National Oceanic and Atmospheric Administration Environmental Data Service. U. S. Department of Commerce, Local Climatological Data.

(9) Great Lakes Water Quality Board, International Joint Commission; United States and Canada Great Lakes Regional Office (1973) Great Lakes Water Quality Annual Report to the International Joint Commission. Windsor, Ontario.

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(11) United States Environmental Protection Agency. Limnological Conditions in Southern Lake Huron, 1974 and 1975. Publication No. EPA-600/3-80-074. Duluth, Minnesota.

(12) Great Lakes Research Division, Institute of Science and Technology, University of Michigan (1973) Limnological Survey of Lakes Michigan, Superior, Huron and Erie. Publication No. 17. The University of Michigan, Ann Arbor, Michigan.

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(14) Sommers, L. M. (1982) Fish in Lake Michigan. Michigan Sea Grant, University of Michigan, Ann Arbor, Michigan.

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(16) Weathesen, G. L. (1983) Ontario Mineral Score, 1982. Ontario Ministry of Natural Resources, Video Census Series No. 2.

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(18) International Great Lakes Diversions and Consumptive Uses Study Board (1981) Great Lakes Diversions and Consumptive Uses, Annex F: Consumptive Water Uses.

(19) International Joint Commission (1978) Inventory of Land Use and Land Use Practices, 1, Canadian Great Lakes Basin Summary.
(20) Ontario Ministry of Agriculture and Food, Statistics Section (1982) Agricultural Statistics for Ontario, 1981.
(21) Ontario Ministry of Treasury and Econcmics. Ontario Statistics, 1982.
(22) Ontario Ministry of Natural Resources, Fisheries Branch. Employment and Investment in the Commercial Fishery, 1982 and Commercial Fish Industry.
(23) International Joint Commission ; United States and Canada Great Lakes Regional Office (1980) Pollution in the Great Lakes Basin from Land Use Activities. Windsor, Ontario.
(24) International Joint Commission ; United States and Canada Great Lakes Regional Office (1978) Great Lakes Water Quality Agreement. Windsor, Ontario.
(25) Great Lakes Water Quality Board (1985) 1985 Report on Great Lakes Water Quality.
(26) Thomas. R. L. & Mudroch, A. (1979) Report to Small Craft Harbours, Ontario Region, December 1979. 149. pp.
(27) Frank, R., Thomas, R. L., Kemp, A. W. L., Broun, H. E. & Dawson, R. (1979) J. Great Lakes Res., 5 : 131-138.

LAKE ERIE

On the northwestern end of Canadian lakeshore

Photo: H. Kurata

A. LOCATION

§ Michigan, Ohio, Pennsylvania and New York, U. S. A.; and Ontario, Canada.
§ 41°21′-42°07′N, 78°48′-83°28′W; 174 m above sea level.

B. DESCRIPTION

Lake Erie is the fourth largest and shallowest of the five Great Lakes, and is the only one with its floor above sea level. Generally the eastern portion of the lake is deep, while the western part is shallow and has many islands. The northern shore of the lake is in the Province of Ontario, Canada, and the southern shore is shared by four states of the United States. The lake water comes from L. Huron through the St. Clair River and the Detroit River (via L. St. Clair) at the west end. The only natural flow-out is at the northeast end through the Niagara River; besides, the Welland Canal bypasses Niagara Falls leading to L. Ontario.

Extensive commerce is carried out between the harbors on the lake as well as to and from the other Great Lakes. L. Erie is thus quite important to the St. Lawrence seaway system. The western shore side is one of the most highly industrialized and densely populated areas in the United States. The lake reached a fairly high level of eutrophication similar to that of L. Ontario before the 1970's. On the other hand, L. Erie is known, together with L. Michigan, for abundant fish catch which is much greater than that in other Great Lakes.

C. PHYSICAL DIMENSIONS

Surface area [km^2]	25,821
Volume [$10^9 m^3$]	458
Maximum depth [m]	64
Mean depth [m]	17.7
Water level	Unregulated
Length of shoreline [km]	1,369
Residence time [yr]	2.6
Catchment area [km^2]*	78,769

* Not including the catchments of the three upstream Great Lakes.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q1)

§ Bathymetric map (Fig. NAM-6-1).
§ Main islands : Pelee.
§ Outflowing rivers and channels (number and names) : 2 (Niagara R. and Welland Canal).

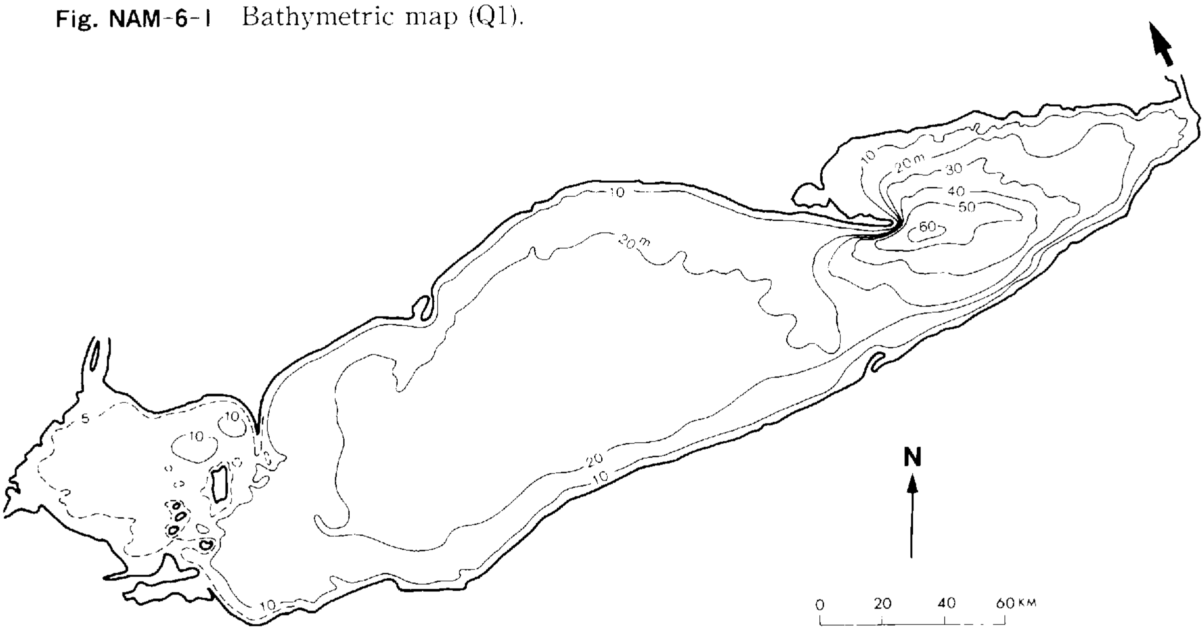
D2 CLIMATIC

§ Climatic data at Cleveland (Q1)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-2.8	2.3	2.3	9.0	14.6	19.9	21.9	21.1	17.7	12.1	5.3	-0.9	9.8
Precipitation [mm]	63	58	71	71	79	84	86	74	79	66	66	61	864

§ Number of hours of bright sunshine (Cleveland) : 2,352 hr yr^{-1}.
§ Solar radiation (Cleveland) : 12.38 MJ $m^{-2}day^{-1}$.
§ Average depth of maximum snow accumulation : ca. 0.3 m.

Fig. NAM-6-1 Bathymetric map (Q1).



§ Water temperature [°C] (Q1)
Whole lake, 1968-1983

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	1	1	1	4	9	17	21	22	19	15	9	3

§ Freezing period : 80 days ; 95-100 % ice coverage often present.
§ Thermocline formation
Western basin : Isothermal throughout the year. Central basin : Early June to early September. Eastern basin : Early June to mid October.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (Q1)

Lake-wide surveys. 1962-1972

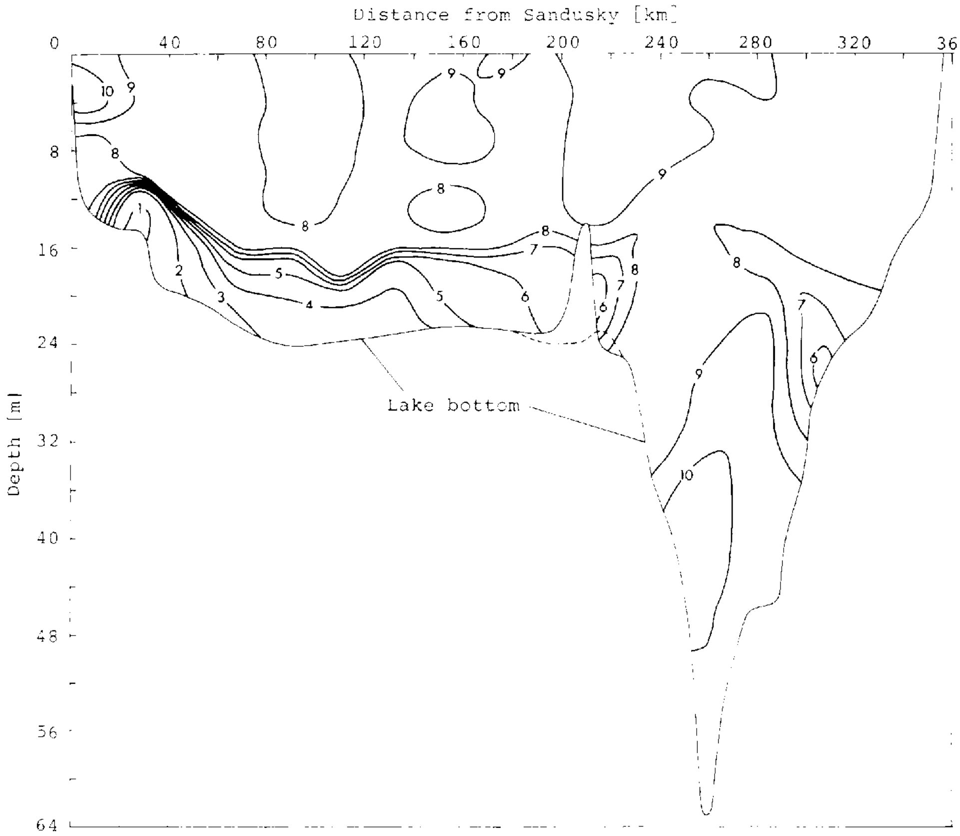
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
–	2.7	1.4	2.1	2.5	2.8	4.2	4.2	3.2	2.4	1.8	1.5

E2 pH

Surface water (1968 1983): 7.8-8.6 (mostly 8.0-8.5) (Q1).

E4 DO

Fig. NAM-6-2 Vertical distribution of DO (east-west profile from Sandusky to Buffalo, 29 Jul. 2 Aug., 1968) [mg l^{-1}] (Q1).



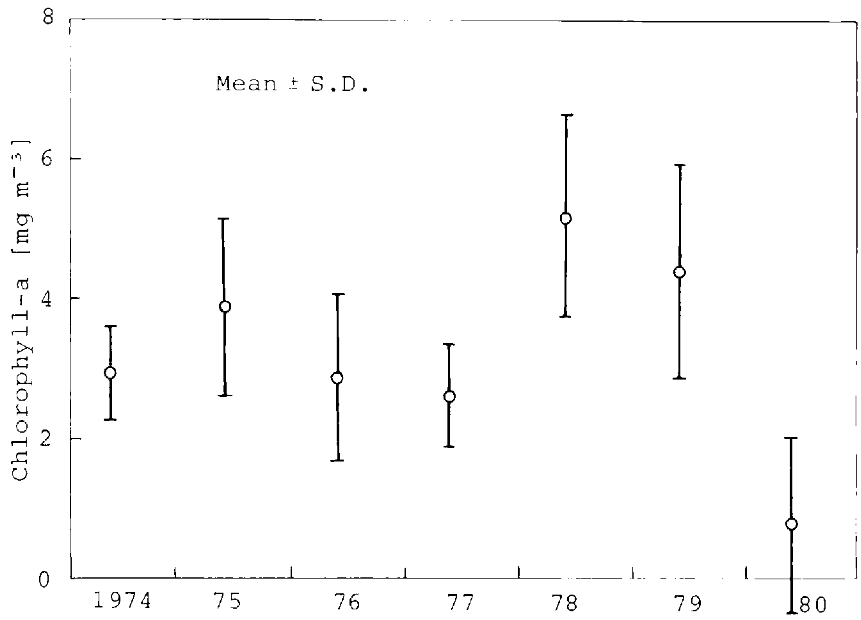
E5 COD [mg l^{-1}] (1)

1963-1968

	Average	Maximum	Minimum
Western basin	10.1	19.0	1.1
Central basin	7.8	16.0	3.1
Eastern basin	7.8	27.0	4.7

E6 CHLOROPHYLL CONCENTRATION

Fig. NAM-6-3 Chlorophyll-a concentration [$\mu g\ l^{-1}$] (East Central Basin, Apr. -Jun.) (2).



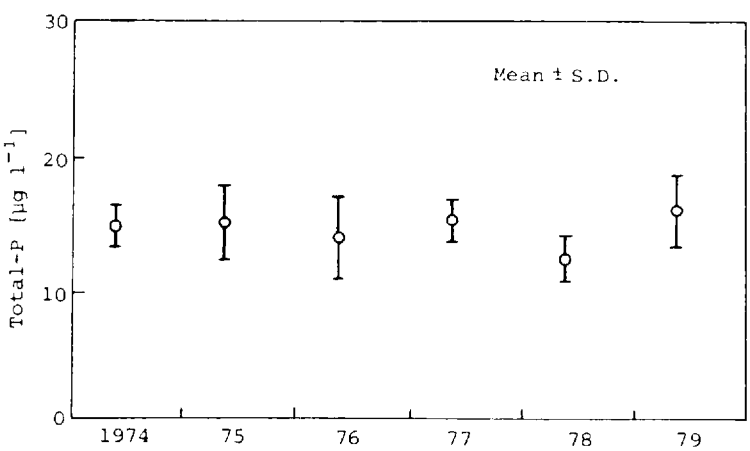
E7 NITROGEN CONCENTRATION

§ Inorganic-N (lake-wide surveys, 1968-1980) : 100-1,020 [$\mu g\ l^{-1}$] (Q1).

E8 PHOSPHORUS CONCENTRATION

§ Total-P

Fig. NAM-6-4 Total-P concentration [$\mu g\ l^{-1}$] (East Central Basin, Apr.-Jun.) (2).



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Typha* sp., *Scirpus acutus*, *S. americanus*, *Sparganium* sp., *Phragmites* sp., *Eleocharis* sp. (Q1).

§ Submerged macrophytes : *Myriophyllum* spp., *Potamogeton* spp., *Vallisneria americana*, *Nitella flexilis*, *Chara globularis*, *Isoetes riparia* (Q1).

§ Phytoplankton : *Coscinodiscus rotbii*, *Fragilaria capucina*, *F. crotonensis*, *Melosira binderana*, *M.*

islandica, Stephanodiscus tenuis, Cryptomonas erosa, Rhodomonas minuta, Ceratium hirundinella, Aphanizomenon flos-aquae, Chroococcus dispersus var. *minor, Chlorella* sp., *Cosmarium* sp., *Oedogonium* sp. (3).

F2 FAUNA (Q1)

§ Zooplankton : Protozoa (*Difflugia globulosa, Codonella cratera*) ; Cladocera (*Bosmina longispina, Daphnia retrocurva*) ; Rotifera (*Polyarthra vulgaris, Notholca longispira*) ; Copepoda (*Diaptomus ashlandi, Limnocalanus macrurus*).

§ Benthos : Western basin (*Chironomus plumosus, Limnodrilus* spp., *Pisidium, Sphaerium*) ; Central basin (*Chironomus plumosus, Potamothrix spherox*) ; Eastern basin (*Procladius* cf. *denticulatus, Chironomus plumosus, Tubifex* spp.)

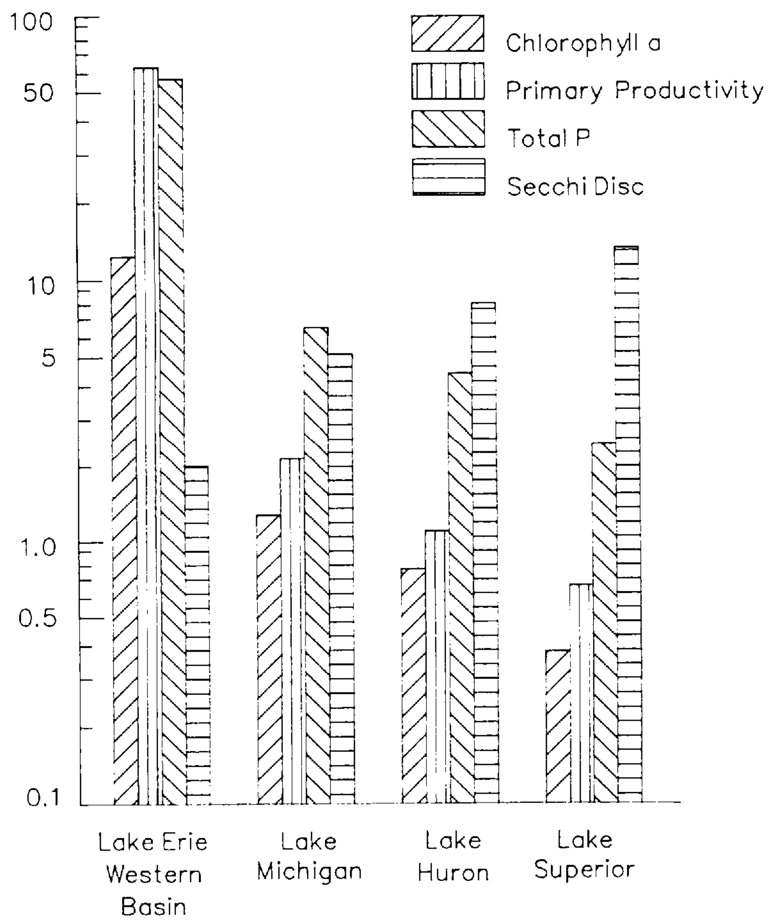
§ Fish : *Stizostedion vitreum, Osmorus mordox, Perca flavescens, Dorosoma cepedianum, Aplodinotus grunniens, Notropis atherinoides, N. hudsonius.*

F3 PRIMARY PRODUCTION RATE (4, Q2)

§ Net primary production rate [mg C $m^{-2}day^{-1}$] (Jan.-Dec., 1970)

Western basin (3 stations) 30-4,760, Central basin (14 stations) 120-1,690, Eastern basin (8 stations) 140-1,440, Whole lake average 250.

Fig. NAM-6-5 Chlorophyll-a [mg m^{-3}], primary productivity [mg C $m^{-3}hr^{-1}$], total phosphorus [mg PO_4-P m^{-3}] and Secchi disc transparency [m] in the Great Lakes (Schelske, 1974).



F4 BIOMASS

§ Phytoplankton biomass [mg l^{-1}] (Apr.-Dec., 1970) (Q1).
Western basin 0.8-13.2, Central basin 0.6-6.0, Eastern basin 1.0-4.2.

F5 FISHERY PRODUCTS

§ Annual fish catch in 1915-1980 (commercial, Canada & U. S.): 13,000 33,000 [metric tons].

F7 NOTES ON THE REMERKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (Q1)

Primary production since the 1930's has experienced shifts both in species dominance and standing crop. Generally the diatoms are becoming less dominant, while green and blue-green algae are becoming more important. A program of phosphorus control (removal from detergents and sewage treatment plants) was initiated in 1972 in both Canada and the United States. This has curtailed the rate of increase of phytoplankton.

There was a dramatic decline in walleye (*Stizostedion vitreum*) fishery in the late 1940's; dramatic recovery in the late 1970's following closure of the commercial walleye fishery because of high levels of mercury.

The mayfly, *Hexagenia*, which was an important component of the bottom fauna in the Central and Western basins, virtually disappeared in the 1950's and 1960's apparently from periods of low oxygen in bottom waters.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1978) (2, 5-10)

	Area [km²]			Total
	U. S.	Canada	Total	[%]
Forest/woodland	10,057	3,422	11,479	17.1
Barren/brush/wetland	11,148	344	11,492	14.6
Cropland	19,233	11,822	31,055	39.4
Pasture	8,823	6,700	15,523	19.7
Residential	5,531	659	6,190	7.9
Commercial	797	233	1,030	1.3
Total	55,589	23,180	78,769	100.0

§ Main types of woody vegetation: *Carpinus caroliniana, Acer* spp., *Juglans nigra, Carya ovata, Quercus* spp., *Liriodendron tulipifera, Magnolia acuminata, Asimina triloba, Lindera benzoin, Rosa setigera, Cercis canadensis, Cornus florida.*

§ Main kinds of crops: Maize, wheat, soybean, vegetables, fruit trees and tobacco.

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (U. S. 1970, Canada 1980-1982) (2, 5-8)

	Gross product during the year [10^6 $]*	No. of persons engaged	No. of establishments	Main products and main kinds of industry
Primary industry				
Agriculture				
U. S.	1,731.58	144,900	72,533	1)
Canada	2,200.23	N. A.	26,256	
Fisheries				
U. S.	10.55 **	N. A.	N. A.	2)
Canada	26.26	N. A.	N. A.	
Others				
U. S.	N. A.	N. A.	N. A.	3)
Canada	185.92	133	4	
Secondary industry				
Manufacturing				
U. S.	19,347.30	1,597,426	N. A.	4)
Canada	21,954.00	210,963	2,701	
Mining				
U. S.	297,602.43	8,662	N. A.	5)
Canada	187,069.93	N. A.	N. A.	
Others				
U. S.	N. A.	2,731.336	N. A.	6)
Canada	3,628.57	56,097	N. A.	
Tertiary industry	N. A.	N. A.	N. A.	

* U. S. and Canada data in U. S. dollars and Canadian dollars, respectively. U. S. $1= Canad. $1.24 in 1982.
** Data for 1977.
1) Grains, vegetables, dairy products and fruits.
2) Smelt and yellow perch.
3) Saw and planning mills.
4) Transportation equipment, metal fabrication, machinery and primary metal industries.
5) Salt, cement, sand, gravel and crushed stone.
6) Building, engineering and construction.

G3 POPULATION IN THE CATCHMENT AREA (U. S. 1970, Canada 1981) (2, 5-10)

Total	Population	Population density [km^{-2}]	Main cities (population)
U. S.	11,513,900	N. A.	Detroit* (1,290,000),
Canada	2,335,200	N. A.	Buffalo, Toledo,
Total	13,849,100	175.8	Cleveland, Erie

* Not all the city area is included in the catchment area.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q1)

Source of water, fisheries, navigation, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1983) (2, 5-7)

	Use rate [$m^3 day^{-1}$]	
	U. S.	Canada
Domestic	4,556	465
Irrigation	100	196
Rural-stock	–	73
Industrial	24,205	3,718
Mining	748	–
Power plant	30,829	2,470

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION

§ Toxic metals in suspended particles and surficial sediments (11)

Sample type	Element	Lake Erie*1 Basin [$\mu g\ g^{-1}$]	Typical upper*2 Niagara River [$\mu g\ g^{-1}$]	Typical lower*3 Niagara River [$\mu g\ g^{-1}$]
Suspended particles	As	–	9.8	16
	Cd	6.6	8.2	3
	Cr	53	160	80
	Cu	170	290	100
	Pb	79	170	100
	Hg	0.14	0.73	0.69
	Ni	91	75	53
	Zn	160	870	330
Surficial sediments	As	3.2	1.9	2.5
	Cd	2.5	0.50	0.72
	Cr	53	11	15
	Cu	39	8.5	8.8
	Pb	81	11	13
	Hg	0.48	0.09	0.19
	Ni	49	6	7.2
	Zn	177	100	63

*1 Station in Thunder Bay and represents eastern Lake Erie.
*2 Station in Tonawanda Channel some 8 km above Niagara Falls.
*3 Station below Niagara Falls some 8 km above Lake Ontario.

§ Organic chemicals in suspended particles and surficial sediments (11)

Sample type	Chemical	Lake Erie*[1] Basin [10^{-3} $\mu g\ g^{-1}$]	Typical upper*[2] Niagara River [10^{-3} $\mu g\ g^{-1}$]	Typical lower*[3] Niagara River [10^{-3} $\mu g\ g^{-1}$]
Suspended particles	Total PCBs	450	660	230
	Lindane	ND	ND	8
	Total DDT + metabolites	30	43	9
	HCB	ND	30	97
	Mirex	20	15	130
Surficial sediments	Total PCBs	86	960	2,700
	Lindane	–	ND	ND
	Total DDT + metabolites	30	2	179
	HCB		ND	250
	Mirex	ND	ND	640

§ Mean levels of selected contaminants in herring gull eggs from the Niagara River and nearby monitor colonies [$\mu g\ g^{-1}$, wet weight] (11)

Colony	Contaminants	1979	1981	1982
Lake Erie	pp′ DDE	3.4	4.7	7.5
	PCBs	38	44	60
	Mirex	0.25	0.42	0.60
Niagara River	pp′ DDE	4.1	5.7	3.7
	PCBs	50	50	46
	Mirex	0.49	0.74	0.98

§ Mean contaminant concentrations in whole fish samples of Lake Erie walleye, 1977–1983 [mg kg^{-1}, wet weight] (12)

Year	PCB	pp′ DDE	ΣDDT	Dieldrin	Hg	Zn	As	Se
1977	1.61	0.36	0.50	0.07	0.20	12.93	–	0.26
1978	1.47	0.14	0.26	0.05	0.15	12.34	0.22	0.35
1979	3.05	0.21	0.49	0.10	0.15	12.99	0.32	0.37
1980	1.40	0.19	0.45	0.04	0.13	13.76	0.33	0.33
1981	1.16	0.04	0.10	0.02	0.10	11.03	0.38	0.44
1982	1.62	0.10	0.24	0.04	0.12	13.58	0.31	0.36
1983	1.54	0.13	0.26	0.05	–	–	–	–

§ Mean contaminant concentrations in whole fish samples of Lake Erie rainbow smelt, 1977–1983 [mg kg^{-1}, wet weight] (12)

Year	PCB	pp′ DDE	ΣDDT	Hg	Pb	As	Se
1977	0.18	0.04	0.06	0.05	tr*	–	0.29
1978	0.27	0.04	0.06	0.05	tr	0.15	0.36
1979	0.38	0.05	0.10	0.04	tr	0.23	0.31
1980	0.26	0.06	0.12	tr	0.21	0.16	0.37
1981	0.23	0.03	0.06	0.04	tr	0.23	0.35
1982	0.30	0.03	0.07	0.03	tr	0.26	0.35
1983	0.32	0.02	0.04	–		–	–

* >50% of results below detection limit.

Fig. NAM-6-6 Comparative mean values for whole body contaminant burdens [$\mu g\ g^{-1}$ wet weight] for 3^+ aged Coho salmon (*Onchorhynchus kisutch*) from Lake Erie and Lake Ontario (13).

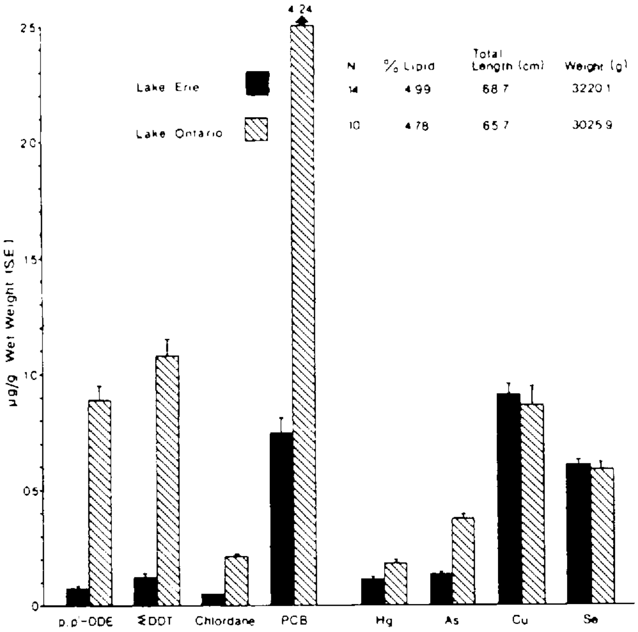
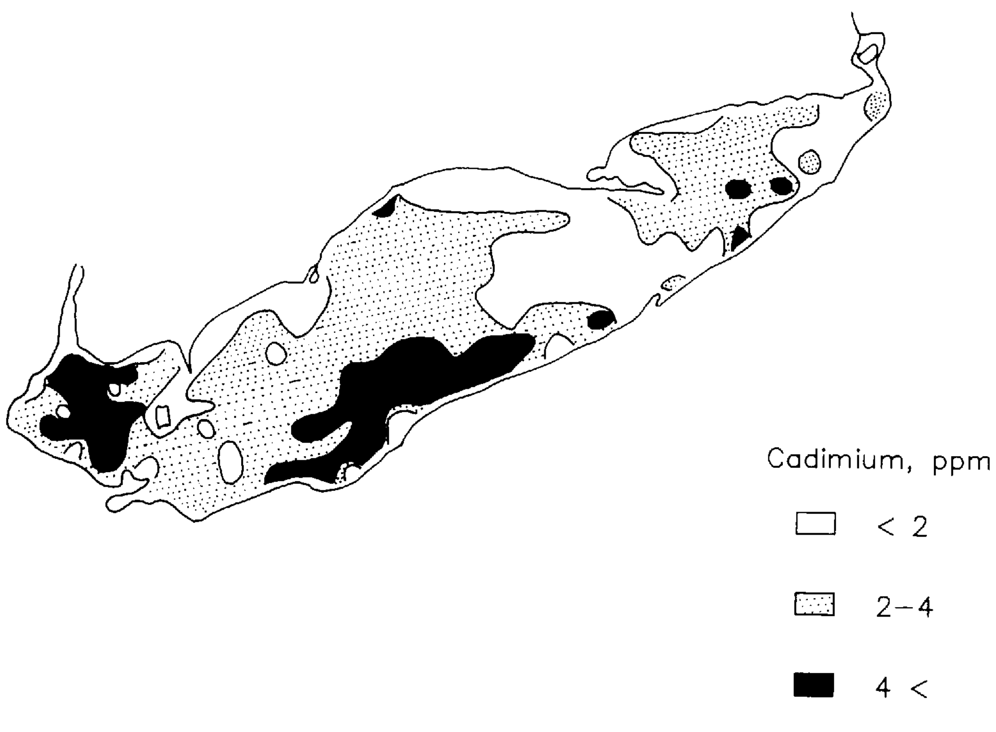


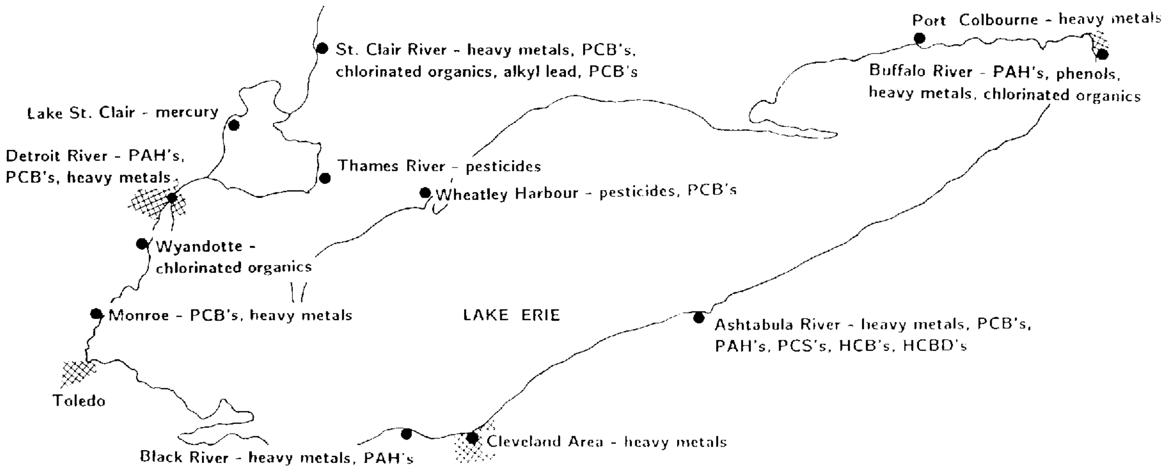
Fig. NAM-6-7 Cadmium concentrations in surface bottom sediments (14).



§ Supplementary notes

Toxic contamination hazards included the input of toxic inorganic and organic chemicals from municipal point sources, combined sewer overflows, rural and urban nonpoint sources and leachates from municipal and hazardous waste landfill disposal sites. Problems from these sources are most apparent in highly industrialized harbors and embayments and nearby areas.

Fig. NAM-6-8 Areas of concern in Lake Erie. The International Joint Commission areas of concern include locales where environmental degradation and impairment of beneficial uses is severe and those where some environmental degradation is obvious and where uses may be impaired.



I3 EUTROPHICATION

§ Nuisance caused by eutrophication

Unusual bloom of blue-green algae (*Aphanizomenon, Anabaena*) (Q1)

§ Nitrogen and phosphorus loadings to the lake: T-N 1967-1976, T-P 1976 [t yr^{-1}] (9, 10)

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N	N. A.	N. A.	N. A.	N. A.	193,000-292,000
T-P	347	6,828	8,445	774	17,474*

* Including 1,070 t from upstream lakes. The T P load declined to ca. 11,000 t yr^{-1} by 1983.

J. WASTEWATER TREATMENTS (Q1)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (f) Severe pollution with well-developed wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal and industrial wastewater treatment systems

Number of secondary and tertiary treatment (activated sludge, trickling filter, oxidation pond) systems: 135 (U. S. 102, Canada 33; rate of treatment 10,370,000 m^3 day^{-1}).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRANDING LAKE ENVIRONMENTS (Q1)

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Names of the laws concerned (the year of legislation).

(1) Canada: Canada Water Act, Fisheries Act; Ontario Water Resources Commission Act, Ontario Environment Protection Act; Environmental Contaminants Act.

(2) U. S.: National Environmental Policy Act. Clean Water Act, Clean Air Act; Water Resources Planning Act, Federal Water Pollution Control Act, Toxic Substances Control Act.

(3) Canada/U. S.: Boundary Waters Treaty (1909); Great Lakes Water Quality Agreement (1972 and 1978).

§ Responsible authorities.

(1) Canada: Governments of Canada and the Province of Ontario.

(2) U. S.: Governments of U. S. A. and the States of Michigan, Ohio, Pennsylvania and

New York.

(3) Canada/U. S. : International Joint Commission ; Great Lakes Fishery Commission.

§ Main items of control.

(1) Canada : Waste disposal, water quality, air quality and water use.

(2) U. S. : Waste disposal, water quality, air quality and water use.

(3) Canada/U. S. : Water withdrawals ; advisory roles in water quality, air quality and fisheries.

N. SOURCES OF DATA

(Q1) Questionnaire filled by Drs. J. R. Vallentyne and K. Subock, Canada Centre for Inland Waters, Burlington.

(Q2) Questionnaire filled by Prof. F. M. D'Itri, Institute of Water Research, Michigan State University, Lansing.

(1) Data supplied to Drs. Vallentyne and Subock by Prof. F. D'Itri, Institute of Water Research, Michigan State University.

(2) International Joint Commission (1983) International Joint Commission Great Lakes Water Quality Board Report for 1983.

(3) Munawar, M. & I. F. (1981) A general comparison of the taxonomic composition and size analyses of the phytoplankton of the North American Great Lakes. Verh. Intern. Verein Limnol., 21 : 1695-1716.

(4) Vollenweider, R. A., Munawar, M. & Stadelman, P. (1974) A comparative review of phytoplankton and primary production in the Laurentian Great Lakes. J. Fish. Res. Bd. Can., 31(5) : 739-792.

(5) Weatheson, G. L. (1983) Ontario Mineral Score, 1982. Ontario Statistics 1982. Ministry of Natural Resources, Video Census Series No. 2.

(6) Ontario Ministry of Treasury and Economics (1983) Ontario Statistics 1982.

(7) International Great Lakes Diversions and Consumptive Uses Study Board (1981) Great Lakes Diversions and Consumptive Uses, Annex F, Consumptive Water Uses.

(8) Ontario Ministry of Natural Resources, Fisheries Branch (1983) Employment and Investment in the Commercial Fishery-1982 and Commercial Fish Industry.

(9) International Joint Commission. Inventory of Land Use Practices, Vol. 1.

(10) Ontario Ministry of Agriculture and Food, Statistics Section (1982) Agricultural Statistics for Ontario, 1981.

(11) Allan, R. J. (1986) The Role of Particulate Matter in the Fate of Contaminants in Aquatic Ecosystems. Scientific Series No. 142, 128. pp. Inland Waters Directorate, National Water Research Institute, Canada Centre for Inland Waters, Burlington.

(12) Great Lakes Water Quality Board (1985) 1985 Report on Great Lakes Water Quality.

(13) Whittle, D. M. & Fitzsimons, J. D. (1983) J. Great Lakes Res. 9 : 295-302.

(14) Thomas, R. L. & Mudroch, A. (1979) Report to Small Craft Harbours, Ontario Region, December 1979. 149 pp.

LAKE ONTARIO

On the lakeshore at Burlington

Photo: A. Kurata

A. LOCATION

§ Ontario, Canada ; and New York, U.S.A.
§ 43°12′-44°13′N, 76°15′-79°49′W ; 75 m above sea level.

B. DESCRIPTION

Lake Ontario is the smallest and easternmost of the Great Lakes, covering only 19,099 km^2, but is still nearly 30 times the area of L. Biwa. The Lake forms part of the international boundary between Canada and the United States ; the whole northern shore belongs to the Canadian Province of Ontario and its southern shore is in the State of New York. Water flows into the lake from L. Erie through the Niagara River with the famous Niagara Falls, and flows out at the northeast end into the St. Lawrence River. There are no large islands in the lake, apart from the far east corner at the entrance to the St. Lawrence River. The most densely populated and industrialized area of Ontario Province is located on the west side of the lake, but there are only a few cities of significant size on the American side.

The eutrophication of the lake started with the increase of population in the lake's drainage basin at the beginning of this century, and continued to advance until around 1973. It has been shown by scientists that the eutrophication of Lakes Ontario, Erie and Michigan is due to the increase in phosphorus loading, of which the main source is sewage effluents and in particular the domestic use of detergents containing phosphorus. After the Canada-U.S. international treaty was signed in 1972 for preventing eutrophication of the Great Lakes, however, the concentration of phosphorus in the lake water is decreasing owing to the prohibition on detergent use and the required treatment of sewage discharged into the drainage basin.

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	19,009
Volume [10^9m^3]	1,638
Maximum depth [m]	224
Mean depth [m]	86
Water level	Unregulated
Length of shoreline [km]	1,161
Residence time [yr]	7.9
Catchment area [km^2]	75,272

* Not including the catchments of the four upstream Great Lakes.

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-7-1).

§ Outflowing rivers and channels (number and names): 1 (St. Lawrence R.) (Q).

D2 CLIMATIC

§ Climatic data at Rochester, 1941-1970 (Q)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-4.4	-4.0	0.6	7.8	13.6	19.4	21.8	20.7	16.8	11.3	4.7	-2.1	8.8
Precipitation [mm]	63	61	66	66	74	76	79	71	69	71	69	66	828

§ Number of hours of bright sunshine (Rochester, 1978): 2,392 hr yr^{-1}.

§ Solar radiation (Rochester, 1978): 11.84 MJ $m^{-2}day^{-1}$.

§ Average depth of maximum snow accumulation: ca. 0.2 m.

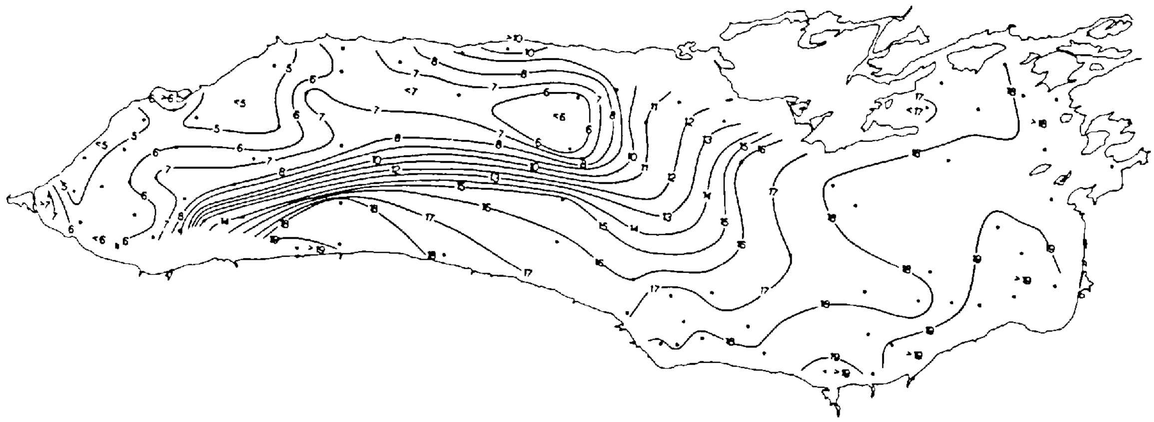
§ Period of snowfall (Rochester, 1978): 120 day yr^{-1}.

Fig. NAM-7-1 Bathymetric map (1).

§ Water temperature [°C] (Q1, 2)
1904-1968

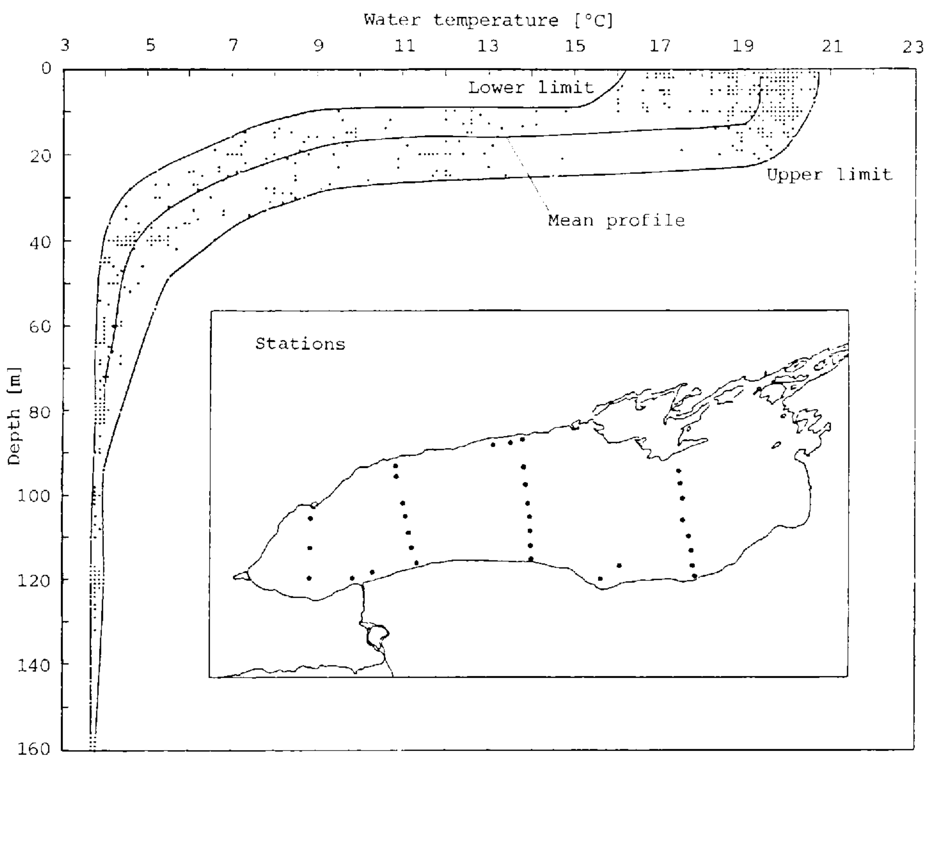
Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	2	2	2	4	7	12	19	20	18	13	7	3

Fig. NAM-7-2 Temperature (°C) at a depth of 20 m, September 7-11, 1976 (after Dobson, 1984).



§ Freezing period: Mid January-early April; 15 % ice coverage normal; rarely freezes over.
§ Notes on thermocline formation: Early June-mid October; a thermal bar forms in mid April-mid June, isolating nearshore from offshore waters.

Fig. NAM-7-3 Temperature profile (32 stations distributed over the lake, 5-11 September, 1972) (3).



E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (Q1)

Lake-wide surveys for 15-176 stations, 1979

Apr	May	Jun	Jul	Aug	Sep	Oct
1.8	3.4	4.2	6.2	5.3	4.9	2.9

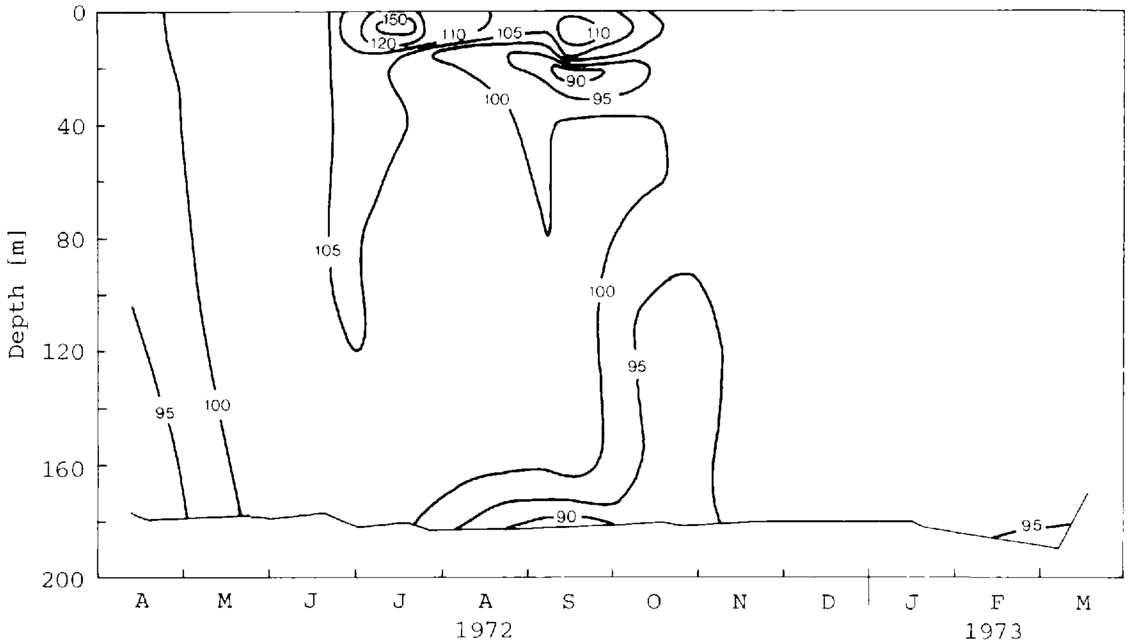
E2 pH (Q1)

Lake-wide surveys for 15-176 stations, 1979

Apr	May	Jun	Jul	Aug	Sep	Oct
7.76	8.25	8.36	7.97	8.20	8.35	8.14

E4 DO

Fig. NAM-7-4 Depth / season distribution of DO percent staturation [%] (4).



E6 CHLOROPHYLL CONCENTRATION [mg m^{-3}] (5)

Lake-wide surveys, 1974

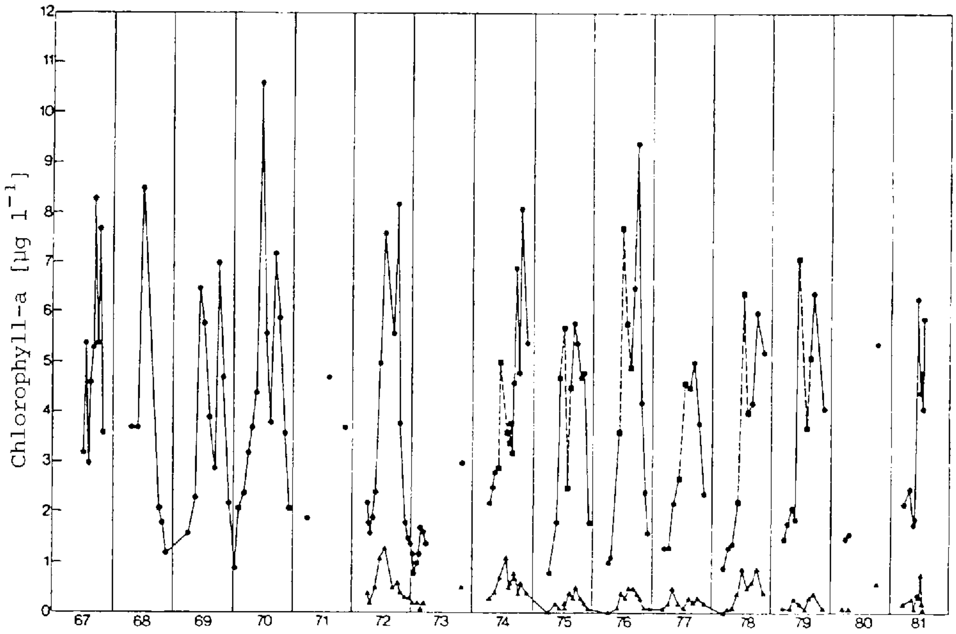
Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
5.7	6.3	5.0	4.8	4.2	5.5	8.8	5.9

Fig. NAM-7-5 Seasonal and annual variation of chlorophyll-a and phaeopigments concentrations [$\mu g\ l^{-1}$] in offshore, near-surface waters (cruise-mean values for 1967-1981) (6).

●———● Total chlorophyll-a (active chlorophyll-a + phaeopigments).

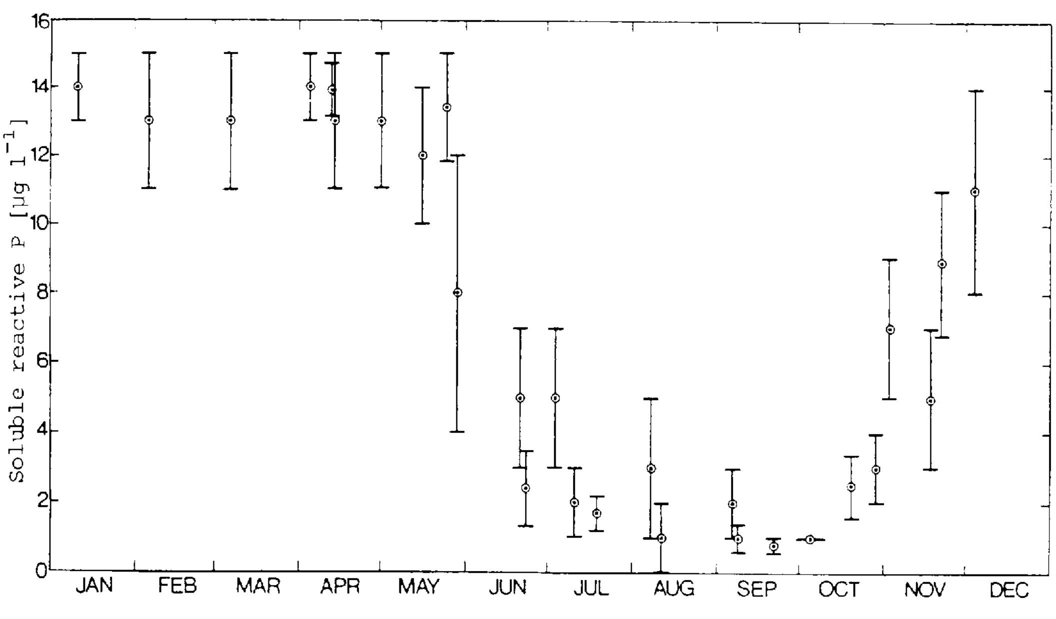
■———■ Total chlorophyll-a, integrated samples in June, July, August ; integrated to 20 m when epilimnion is <10 m thick.

▲———▲ Phaeopigments, inactive chlorophyll, perhaps indicative of zooplankton grazing.



E8 PHOSPHORUS CONCENTRATION

Fig. NAM-7-6 Seansonal change of soluble reactive P concentration [$\mu g\ l^{-1}$] in offshore surface water (mean with S. D., 1968-1972) (7).



E9 PAST TRENDS

Fig. NAM-7-7 Trend of NO_3-N concentration in offhsore, near-surface water during March and April (8).

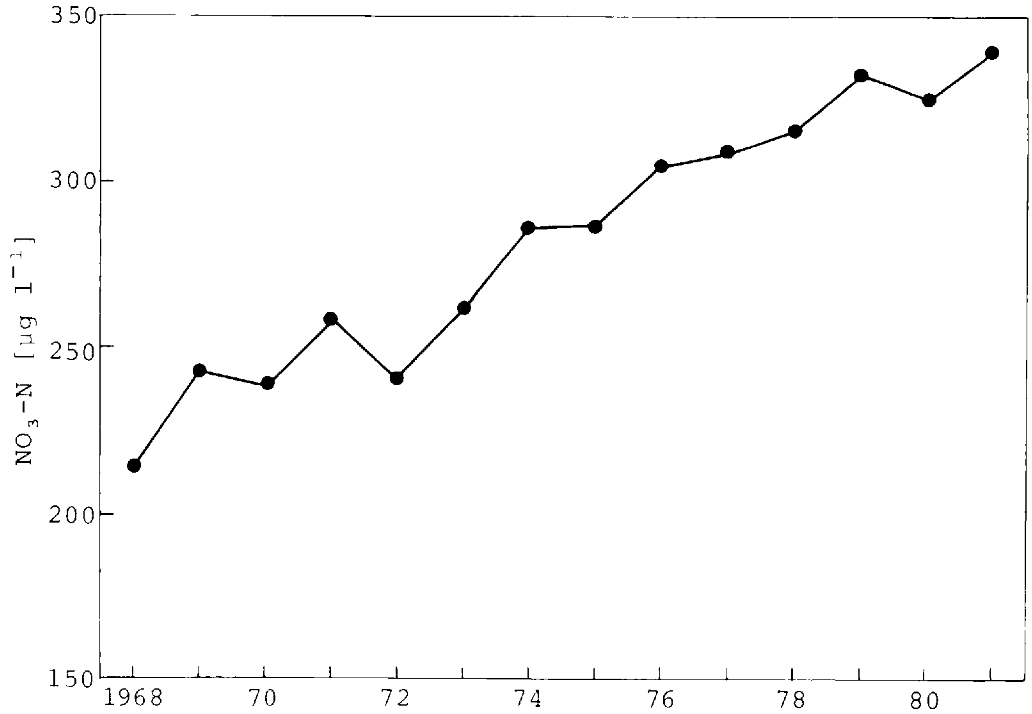
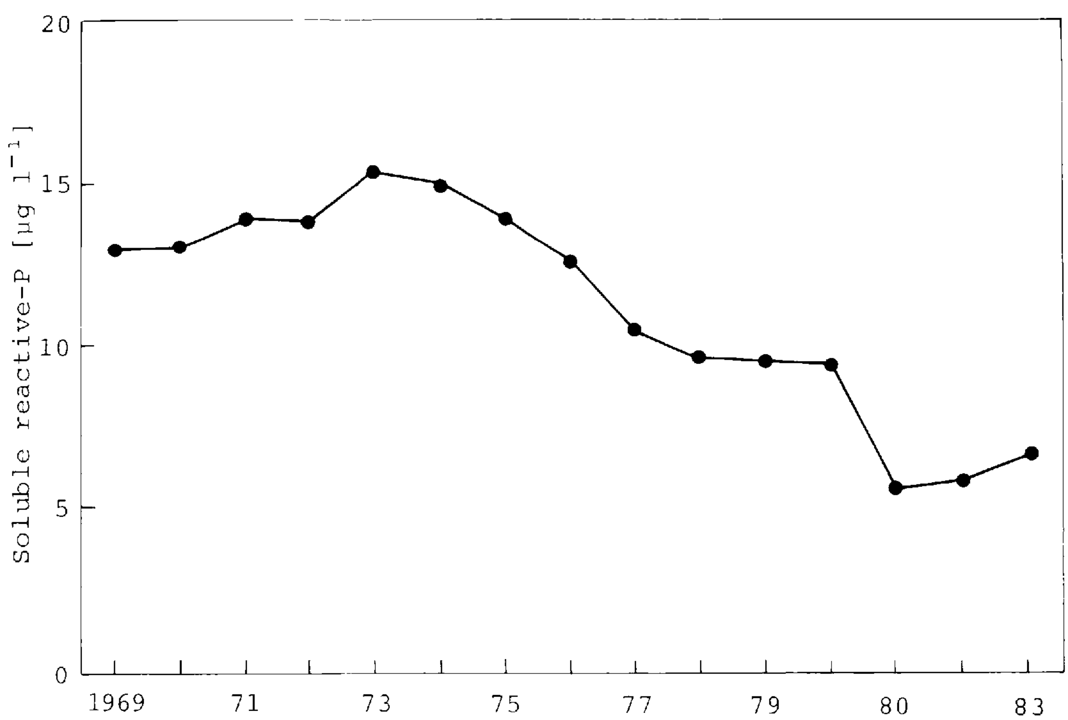


Fig. NAM-7-8 Trend of soluble reactive P concentration in offshore, near-surface waters during March and April ; the goal is 6.0 μg l^{-1}.



F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Typha* spp. (Q1).

§ Submerged macrophytes : *Potamogeton* spp., *Myriophyllum* spp. (Q1).

§ Phytoplankton : *Asterionella formosa, Fragilaria crotonesis, Melosira binderana, Navicula* sp., *Nitzchia palea, Stephanodiscus astrea, Tabellaria fenestrata, Cryptomonas erosa, Ceratium hirundinella, Glenodinium pulvisculus, Aphanizomenon flos-aquae, Oscillatoria limnetica, Ankistrodesmus borgei, Pediastrum simplex, Staurastrum paradoxum, Wothrix sublilissima* (10).

F2 FAUNA (Q1)

§ Zooplankton : *Cyclops bicuspidatus thomasi, Daphnia retrocurva, Bosmina longirostris, Tropocyclops prasinus mexicanus, Ceriodaphnia lacustris, Keratella cochlearis, Polyarthra* sp.

§ Benthos : *Pontoporeia affinis, Heterotrissocladius oliveri, Procladius* sp., *Stylodrilus heringianus, Mysis relicta.*

§ Fish : *Coregonus cupeaformis, Alosa pseudoharengus, Osmerus mordax, Stigostedion vitreum, Morone americana, Perca flavescens, Micropterus dolemieui, Lepomis gibbosus, L. macrochirus, Ictalus nebulosus, Catostomus commersoni.*

F3 PRIMARY PRODUCTION RATE

§ Net primary production rate (whole lake surveys, Jan.-Dec. 1970) : 120-1,080 mgC $m^{-2}day^{-1}$ (11).

F5 FISHERY PRODUCTS (Q1)

§ Annual fish catch (commercial, 1975-1981) : 1,100-3,500 [metric tons].

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE IN RECENT YEARS (Q1)

Between 1923 and 1954 the standing crop of phytoplankton approximately doubled in the waters near Toronto. The dominant algae in the spring pulse changed from *Asterionella* to *Cyclotella* and *Melosira* during this period.

Dramatic decline of lake trout (*Salvelinus namaycush*) and *Coregonus* spp. to very low levels took place during 1930-1950.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1978) (Q1)

	Area [km²]			[%]
	U. S. A.	Canada	Total	
Natural landscape				
Woody vegetation	29,422	12,546	41,968	55.8
Herbaceous vegetation Swamp	5,387	848	6,235	8.3
Agricultural land				
Crop field	4,079	3,877	7,956	10.6
Pasture land	5,262	10,565	15,827	21.0
Settlement area	1,553	1,102	2,655	3.5
Others	67	564	631	0.8
Total	45,770	29,502	75,272	100.0

§ Main types of woody vegetation : Maple-beech, elm, ash, aspen-birch, spruce-fir (U. S. A.) ; red pine (*Pinus resinosa*), white pine (*P. strobus*), *Acer* spp., *Quercus* spp., basswood (*Tilia americana*) (Canada) ; northern limit of many deciduous broadleaf species (Q1).

§ Types of important scrub vegetation : Staghorn sumach (*Rhus typhina*), raspberries and blackberries (*Rubus*), spice bush (*Lindera benzoin*), climbing rose (*Rosa setigera*) (Canada) (Q1).

§ Main kinds of crops : Vegetables, fruits, grains (U. S. A.) ; maize, winter wheat, spring grain, peach, cherry, plum, apple (Canada) (Q1).

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (U. S. A. 1970, Canada 1980 -1981)

	Gross product per year [10^6 $]*	No. of persons engaged	No. of establishments	Main products and main kinds of industry
Primary industry				
Agriculture				
U. S. A.	1,003.35	31,677	29,151	1)
Canada	952.44	N.A.	22,374	
Fisheries				
U. S. A.	N.A.	N.A.	N.A.	2)
Canada	1.90	294	N.A.	
Others				
U. S. A.	N.A.	N.A.	N.A.	3)
Canada	185.72	533	17	
Secondary industry				
Manufacturing				
U. S. A.	8,255.30	308,787	N.A.	4)
Canada	44,720.70	514,620	7,665	
Mining				
U. S. A.	116.40	3,206	N.A.	5)
Canada	398.06	N.A.	N.A.	
Others				
U. S. A.	N.A.	620,696	N.A.	6)
Canada	7,150.02	110,538	N.A.	

* U. S. A. data in U. S. $; Canada data in Canada $ (in 1982 $1 U. S.=1.24 Canadian).
1) Vegetables, dairy products, poultry, fruits and cattle.
2) White perch and yellow perch.
3) Saw and planning mill.
4) Machinery, motor vehicles, metal fabrication and primary metal industries (salt, stone, zinc).
5) Cement and stone.
6) Building, engineering and construction.

G3 POPULATION IN THE DRAINAGE BASIN (U. S. A. 1970, Canada 1981) (Q1)

	Population	Population density [km^{-2}]	Main cities (population)
U. S. A.	2,531,700	94.8	Toronto (633,000),
Canada	4,604,100	N.A.	Hamilton, Rochester,
Total	7,135,800	N.A.	St. Catherines

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q1)

Source of water, navigation, fisheries, tourism and recreation (swimming, sport-fishing, yachting).

H2 THE LAKE AS WATER RESOURCE (1975)

	Use rate [$m^3 sec^{-1}$]	
	U. S. A.	Canada
Domestic	8.4	17.6
Irrigation	0.6	1.1
Industrial	18.0	56.3
Mining	2.6	0.3
Rural-stock	N.A.	0.6
Power plant	101.7	129.4

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I2 TOXIC CONTAMINATION

§ Summary and range of concentrations of organic contaminants in Lake Ontario media [ppt]*[1] (12)

Chemical	Raw water	Bottom sediment	Benthos	"Suspended" sediments	Plankton	Fishes	Herring gull eggs
Total DDT	0.3-57	25,000-218,000	440,000-1,088,000	40,000	63,000-72,000	620,000-7,700,000	7,700,000-34,000,000
PCBs	5-60	110,000-1,600,000	470,000-9,000,000	600,000-6,000,000	110,000-6,100,000	1,378,000-17,000,000	41,000,000-204,000,000
Mirex	0.1	144,000	41,000-228,000	15,000	ND*[2] 12,000	50,000-340,000	1,800,000-6,350,000
CBs	1-54	11,000-4,500,000	NA*[3]	574,000	27,000	6,000-370,000	300,000
Dioxins	0.01-0.03	8,000	NA	NA	NA	5-107	44-1,200
Lindane	0.4-11	46,000	NA	1,000-12,000	12,000	2,000-360,000	78,000

*[1] These values are only of the crudest nature and are not statistical means. Where only one reference existed, the numbers are means, often of widely ranging values. Where a range is given, several sources of data were involved.
*[2] Not detected.
*[3] Not analyzed.

§ Toxic metals in surficial sediments [$\mu g\ g^{-1}$] (12)

Element	Concentration
As	3.3
Cd	2.5
Cr	48
Cu	50
Pb	106
Hg	0.65
Hi	52
Zn	192

§ Mean levels of selected contaminants in herring gull eggs [$\mu g\ g^{-1}$, wet weight] (12)

Contaminants	1979	1981	1982
DDE	9.0	10	12
PCBs	76	72	64
Mirex	1.8	2.5	3.6

Fig. NAM-7-9 Comparative mean values for whole body contaminant burdens [$\mu g\ g^{-1}$ wet weight] for 3^+ aged Coho salmon (*Onchorhynchus kisutch*) from Lake Erie and Lake Ontario (after Whittle & Fitzimons, 1983).

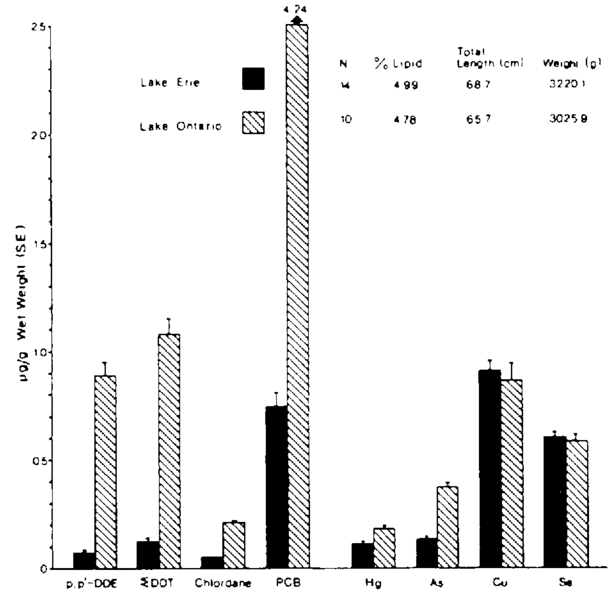


Fig. NAM-7-10 Distribution of cadmium in surficial bottom sediments (after Thomas and Mudroch, 1979).

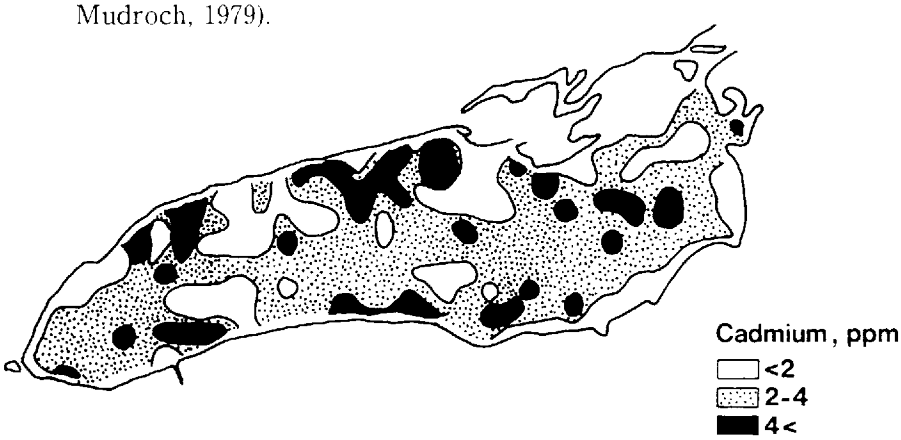
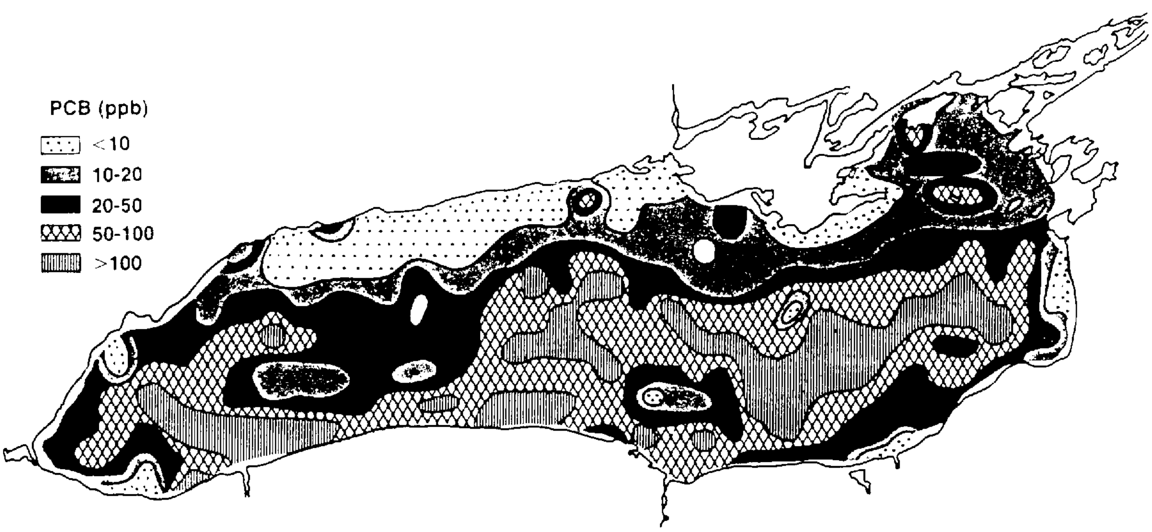


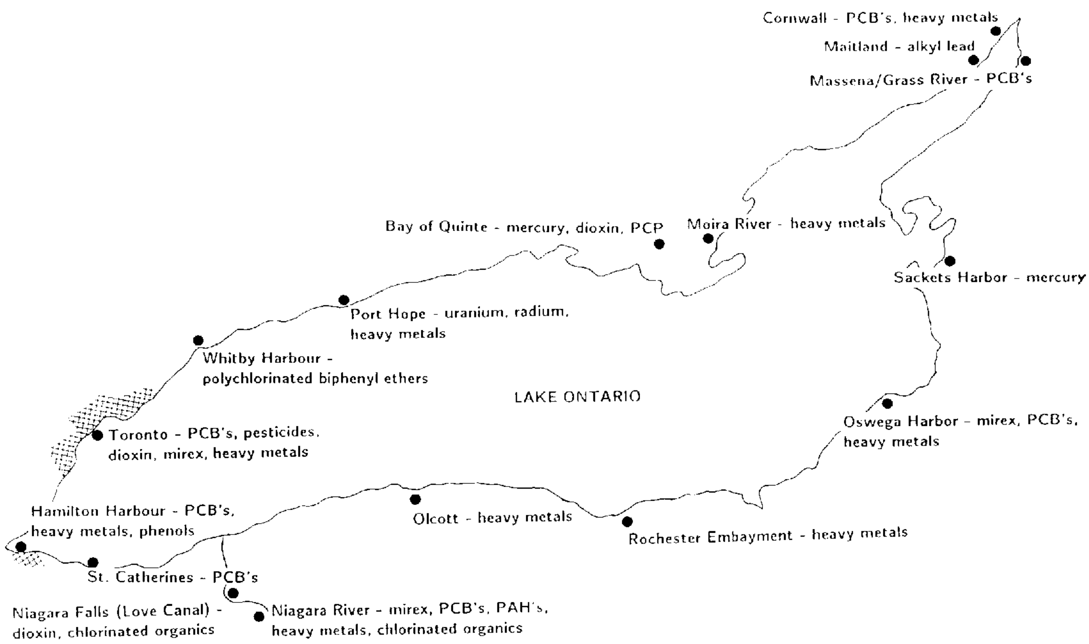
Fig. NAM-7-11 Distribution of total PCBs in surface bottom sediments (after Thomas, 1983).



§ Supplementary notes (Q2)

Toxic contamination hazards included the input of toxic inorganic and organic chemicals from municipal point sources, combined sewer overflows, rural and urban nonpoint sources and leachates from municipal and hazardous waste landfill disposal sites. Problems from these sources are most apparent in highly industrialized harbors and embayments and nearby areas.

Fig. NAM-7-12 Areas of concern in Lake Ontario. The International Joint Commission areas of concern include locales where environmental degradation and impairment of beneficial uses is severe and those where some environmental degradation is obvious and where uses may be impaired.



I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication

Disturbed filtration in cleaning bed. While eutrophication problems are not evident in the open waters, there are local problems near major tributaries.

§ Nitrogen and phosphorus loadings to the lake [t yr^{-1}]

Sources	Industrial	Domestic	Agricultural	Natural	Total
T-N 1967	N.A.	N.A.	N.A.	N.A.	176,000
T-P 1967	N.A.	N.A.	N.A.	N.A.	27,300
1976	102	2,815	3,581	488	11,755 *

* Including 4,769 t from upstream lakes.

J. WASTE WATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA: (f) Severe pollution with well-developed wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE

§ Municipal wastewater treatment systems

Number of secondary and tertiary treatment systems: 95 (U. S. A. 51, Canada 44; rate of treatment 6,846,000 m^3 day^{-1}).

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION

Multi-billion dollar remedial programs (capital operating) to improve sewage treatment for removal of BOD and phosphorus (to 1 mg l^{-1}) were inaugurated in Canada and the U. S. A. in 1970, following a report on pollution in Lake Erie and Ontario undertaken by the International Joint Commission. A regional (Great Lakes) Office of the International Joint Commission was established under the Canada-United States Great Lakes Water Quality Agreement of 1972 in Windsor, Ontario.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

See L. Erie.

N. SOURCES OF DATA

(Q1) Questionnaire filled by Drs. J. R. Vallentyne and K. Suboch, Canada Centre for Inland Waters, Burlington.

(Q2) Questionnaire filled by Prof. F. M. D'Itri, Institute of Water Research, Michigan State University, Lansing.

(1) International Joint Commission (1969) Report on Pollution of Lakes Ontario and Erie.

(2) Dobson, H. F. H. (1984) National Water Research Institute, Contribution No. 15, 157 pp.

(3) Dobson, H. F. H. (1972) Unpublished atlas.

(4) Dobson, H. F. H. Unpublished atlas.

(5) Dobson, H. F. H. (1981) Trophic conditions and trends in the Laurentian Great Lakes. Water Quality Bulletin, 6(4) : 146-151, 158.

(6) Dobson, H. F. H. (1967-1981) Unpublished atlas.

(7) Dobson, H. F. H. (1968-1981) Unpublished atlas.

(8) Dobson, H. F. H. (1968-1981) Unpublished atlas.

(9) Dobson, H. F. H. (1969-1983) Unpublished atlas.

(10) Munawar, M. & I. F. (1981) A general composition of the taxonomic composition and size analyses of the phytoplankton of the North American Great Lakes. Verh. Internat. Verein. Limnol., 21 : 1695-1716.

(11) Vollenweider, R. A., Munawar, M. & Stadelmann, P. (1974) A comparative review of phytoplankton and primary production in the Laurentian Great lakes. J. Fish. Res. Bd. Can., 31(5) : 739-762.

(12) Allan, R. J. (1986) The Role of Particulate Matter in the Fate of Contaminants in Aquatic Ecosystems. Scientific Series No. 142, 128. pp. Inland Waters Directorate, National Water Research Institute, Canada Centre for Inland Waters.

(13) Whittle, D. M. & J. D. Fitzsimons (1983) J. Great Lakes Res., 9 : 295-302.

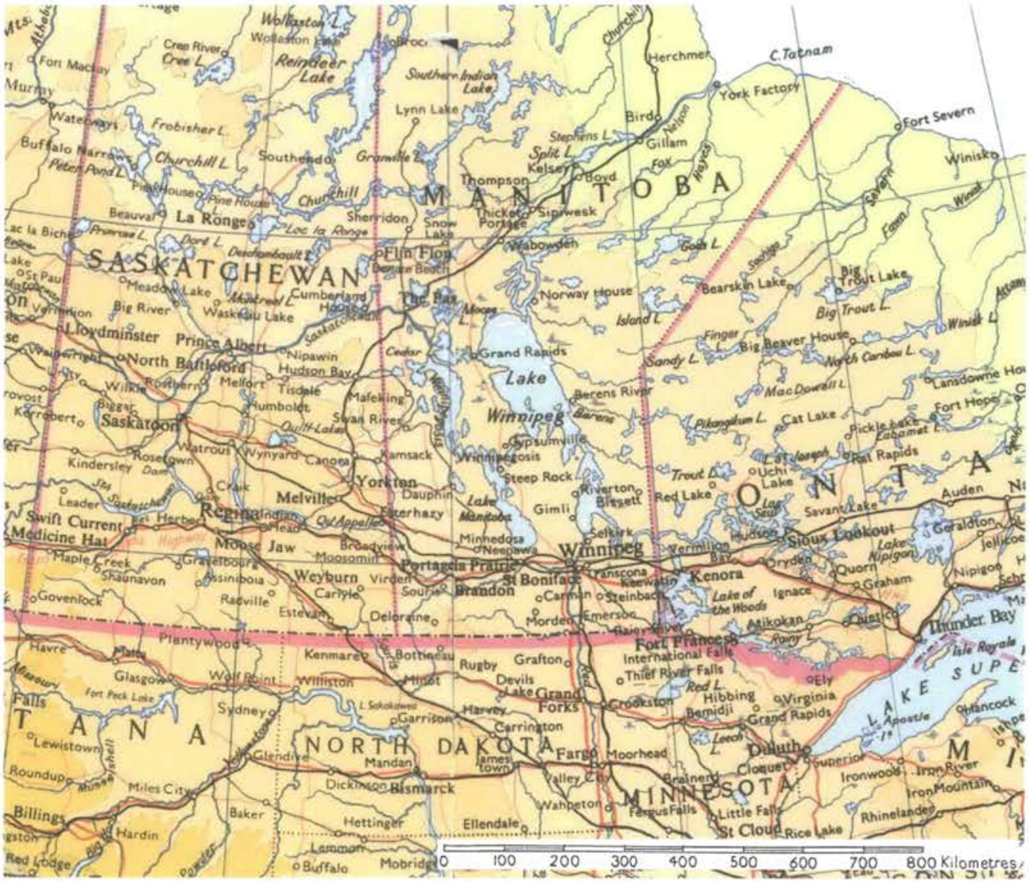
(14) Thomas, R. L. & A. Mudroch (1979) Report to Small Craft Harbours, Ontario Region, December 1979. 149 pp.

(15) Thomas, R. L. (1983) J. Great Lakes Res., 9 : 118-124.

LAKE WINNIPEG

Swimming beach in the provincial park in the south basin

Photo : A. Kurata



A. LOCATION

§ Manitoba, Canada.
§ 50°23′-53°50′N, 96°22′-99°11′W ; 217 m above sea level.

B. DESCRIPTION

Lake Winnipeg is located on the northern fringe of the Canadian prairie where endless wheat fields and grasslands dotted with grazing cattle are characteristic of the landscape. The lake itself is surrounded by dense stands of elm, ash, basswood, maple and aspen, which bring, fleetingly, their gorgeous rich autumn color to the scenery.

The lake is composed of two basins ; a wide north basin and a narrow south basin. The Nelson River, the only outflow of this lake, proceeds northward from the north basin to Hudson Bay. On the other hand, the Red River flows into the south basin with abundant loads of mud and nutrients washed out from the prairie. The city of Winnipeg is situated in the upper reaches of the Red River in the heart of Manitoba. The lake is so shallow in spite of its extensive area that the water remains always muddy due to wave and turbulent mixing by strong winds. The population density in the drainage basin is still very low, but the lake has been fairly eutrophicated by nutrient loading of the Red and other inflowing rivers.

C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	23,750
Volume [10^9m^3]	284
Maximum depth [m]	36.0
Mean depth [m]	12.0
Water level	Unregulated
Length of shoreline [km]	1,750
Residence time [yr]	2.9-4.3
Catchment area [km^2]	953,250

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-8-1).
§ Main islands : Reindeer, Berens, Black and Helca (2).
§ Outflowing rivers and channels (number and names) : 1 (Nelson R.).

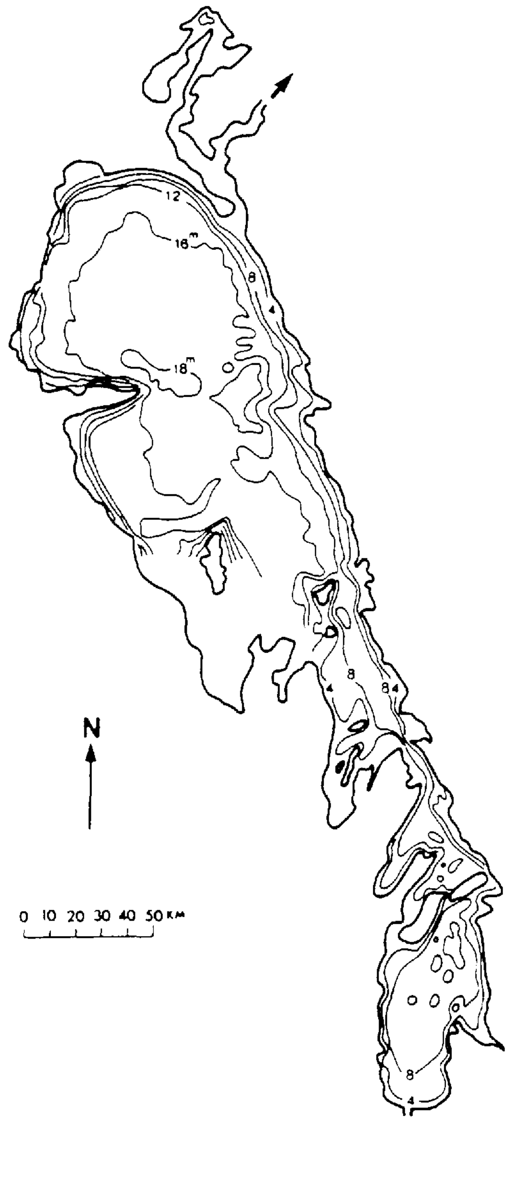
D2 CLIMATIC

§ Climatic data at Winnipeg, 1931-1960 (3)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	-17.7	-15.5	-7.9	3.3	11.3	16.5	20.2	18.9	12.8	6.2	-4.8	-12.9	2.5
Precipitation [mm]	26	21	27	30	50	81	69	70	55	37	29	22	517

§ Number of hours of bright sunshine : 2,177 hr yr^{-1} (3).

Fig. NAM-8-1 Bathymetric map (1).



§ Water temperature [°C] (4)

Center of North Basin, 1969

Depth [m]	Apr	May	Jun	Jul	Aug	Sep	Oct
1	–	–	5.9	15.8	–	17.5	10.0
2	0.1	–	–	–	–	–	–
5	–	–	–	–	–	–	10.0
8	0.3	–	–	–	–	–	–
15-17	2.3		–	11.0	–	–	10.0

§ Freezing period : Nov.-Mar.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m] (1)

§ Transparency at the mouths of 5 rivers (mid-summer, 1979) : 0.35-2.0m.

E2 pH (4)

Center of North Basin, surface water, 1969

Apr	May	Jun	Jul	Aug	Sep	Oct
8.1	–	8.1	8.2	–	8.4	8.4

F. BIOLOGICAL FEATURES

F1 FLORA (5)

§ Phytoplankton : *Pediastrum duplex, Closterium acutum, Staurastrum apidulatum, Melosira granulata, Cyclotella meneghiniana, Stepahnodiscus astraea, Tabellaria fenestrata, Fragilaria crotonensis, Nitzschia dissipata, Rhodomonas minuta, Gymnodinium palustre.*

F2 FAUNA (6)

§ Zooplankton : *Ceriodaphnia quadrangula, Diaptomus siciloides, D. minutus, D. leptopus, Daphnia schoedleri, D. pulex, D. ambigua, D. parvula.*

§ Benthos : *Oecetis inconspicua, Molanna flavicornis, Phryganea cinerea.*

§ Fish : *Stizostedion canadense, Coregonus clupeaformis, Perca fluviatilis, Esox lucius, Hiodon alosoides, Acipenser fulvescens, Catostomus catostomus, Morone chrysops, Ambloplities rupestris.*

F3 PRIMARY PRODUCTION RATE (6)

16.44 mg C $m^{-2}day^{-1}$.

F5 FISHERY PRODUCTS (6)

§ Annual fish catch in 1982-1983 : 7,726 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (6)

	Area [km^2]	[%]
Natural landscape	476,000	50
Woody vegetation	381,000	40
Swamp	95,000	10
Agricultural land	477,000	50
Total	953,000	100

§ Main types of woody vegetation : *Pinus banksiana, Larix laricina, Picea mariana, P. canadensis,*

Carya cordiformis, Tilia americana, Populus deltoides, P. balsamifera, Quercus macrocarpa.
§ Main kinds of crops : Wheat, oats, barley, rye, flax, sugar beet.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1)

	No. of persons engaged [$\times 10^3$]	No. of establish-ments	Main products and main kinds of industry
Primary industry			
Agriculture	N.A.	N.A.	Wheat, oats, sunflower, apple, vegetables
Livestock-farming	N.A.	N.A.	Cattle, swine, sheep, poultry
Forestry	N.A.	N.A.	Saw-mill
Secondary industry			
Manufacturing	25-50	N.A.	Paper mill, refineries, pulp, steel, fabricated metals, machinery
Mining	5 10	N.A.	Petroleum, nickel, gold, silver, copper

G3 POPULATION IN THE CATCHMENT AREA (1970) (1)

Total population	Population density [km^{-2}]	Main cities (population)
3,859,000	4.0	Winnipeg (560,000), Calgary, Edmonton

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (6)
Tourism and recreation (swimming, sport-fishing, yachting).

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I3 EUTROPHICATION (1)
§ Nitrogen and phosphorus loadings (1969-1974)
Total-N : 47,020 108,280 t yr^{-1}.
Total-P : 2,980-10,570 t yr^{-1}.

J. WASTEWATER TREATMENTS (6)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatments.

J3 SANITARY FACILITIES AND SEWERAGE
§ Municipal and industrial wastewater treatment systems
Number of treatment systems : 3 (activated sludge) ; rate of treatment 260 $m^3 day^{-1}$.

N. SOURCES OF DATA

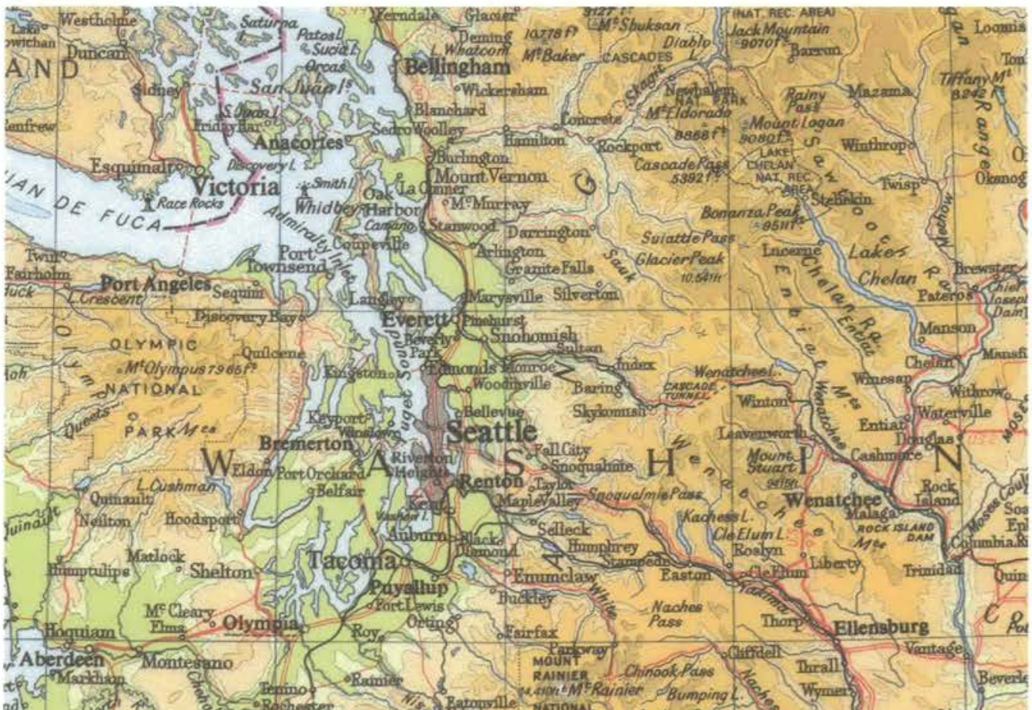
(1) Brunskill, G.J., Elliott, S.E.M. & Campbell, P. (1980) Morpphometry, Hydrology and Watershed Data Pertinent to the Limnology of Lake Winnipeg. Canadian Manuscript Report of Fisheries & Aquatic Sciences, No. 1556.
(2) John Bartholomew & Son Ltd. (1985) The Times Atlas of the World, Plate 100. Times

Books Ltd., London.
(3) Müller, M.J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306 pp. Dr. W. Junk Publishers, The Hague.
(4) Brunskill, G.J., Campbell P. & Elliott, S.E.M. (1979) Temperature, Oxygen, Conductance and Dissolved Major Elements in Lake Winnipeg. Fisheries & Marine Service Manuscript Report, No. 1526.
(5) Killing, H. & Holmgren, S.K. (1970) Data Based on the Lake Winnipeg Cruise 300, June 4-12, 1969. Manuscript Rerport, 1970.
(6) Hara, T., personal communication.

LAKE WASHINGTON

A view of the lake with Mt. Rainier in the background

Photo: Y. Kurata



A. LOCATION

§ Washington, U. S. A.
§ 47°30′-45′N, 122°10′-16′W ; Nearly 0 m above sea level.

B. DESCRIPTION

Lake Washington is a long, narrow lake located in an urbanized area close to Seattle. It covers an area of 88 km^2 and is crossed by two floating bridges. The lake shore affords a good view of the snow-covered cone of Mt. Rainier. The climate around the lake is mild throughout the year with only sporadic snowfall in winter.

In 1916, a canal with locks and a fish ladder was made connecting the lake with the open sea to the west for navigation. The lake had been still oligotrophic in the late 1930's, but an increasing influx of urban sewage from the surrounding area caused rapid progress of eutrophication, as indicated by the frequent bloom of blue-green algae in summer since 1955. However, the construction of sewage treatment plants and the diversion of treated water through a 180 km-long pipeline, carried out in the five years from 1963 to 1968, have improved the quality of the lake water until it recovered almost completely in 1975. The chemical parameters of the lake water have remained quite stable for the past ten years, and the citizens of Seattle and neighboring cities enjoy swimming, fishing and sailing in the lake again.

C. PHYSICAL DIMENSIONS

Surface area [km^2]	87.6
Volume [10^9m^3]	2.89
Maximum depth [m]	65.2
Mean depth [m]	32.9
Water level	Regulated
Residence time [yr]	3.1-1.7
Catchment area [km^2]	1,274

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Bathymetric map (Fig. NAM-9-1).

§ Main islands : Mercer.

§ Outflowing rivers and channels (number and names) : 1 (Lake Washington Ship Canal).

D2 CLIMATIC

§ Climatic data at Seattle (1931-1960) (1)

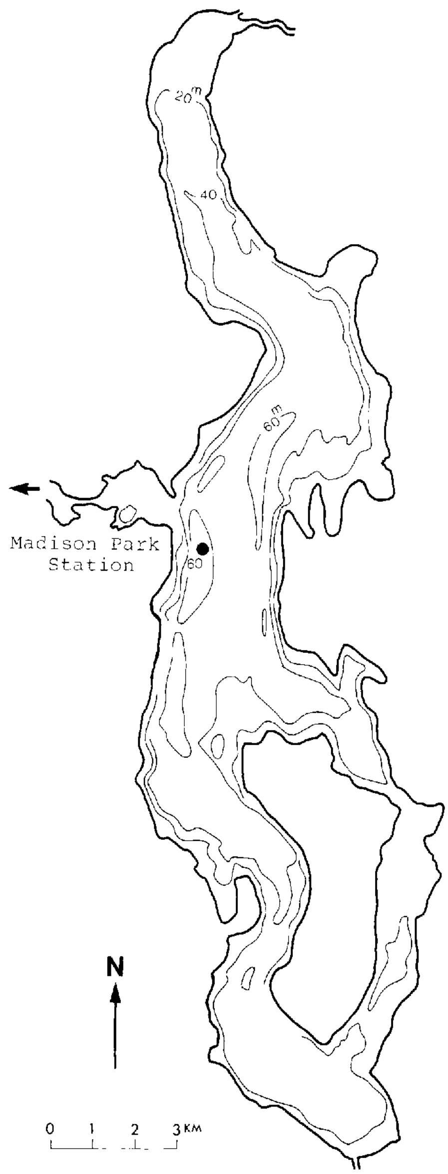
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	5.1	6.4	8.0	11.0	14.1	16.3	18.7	18.3	16.2	12.4	8.3	6.6	11.8
Precipitation [mm]	132	99	84	50	40	36	16	19	42	83	127	138	865

§ Number of hours of bright sunshine : 2,019 hr yr^{-1}.

§ Solar radiation : 11.77 MJ $m^{-2}day^{-1}$.

§ Snowfall : Intermittent (Q).

Fig. NAM-9-1 Bathymetric map (Q).

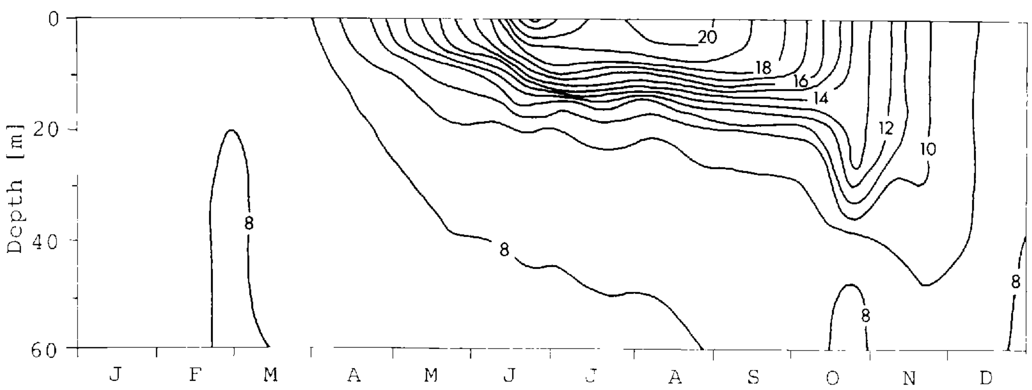


§ Water temperature [°C] (Q)

Surface (Madison Park Station), 1982

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.7	7.4	7.6	9.4	13.8	19.9	20.0	20.2	18.7	15.1	11.0	9.1

Fig. NAM-9-2 Seasonal and vertical distribution of water temprature (Madison Park Station), 1982 (Q).



§ Freezing period : None.

§ Mixing type : Monomictic.

§ Notes on water mixing and thermocline formation : Thermocline exists usually from late April or early May until early December.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY [m]

Madison Park Station, 1982

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.2	7.0	5.7	4.4	2.6	6.4	6.4	5.9	5.6	5.4	6.6	6.9

E2 pH

Surface water (Madison Park Station), 1982

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.20	7.26	6.25	8.19	9.02	8.75	8.38	8.22	8.18	7.71	7.42	7.27

E3 SS [mg l^{-1}]

Madison Park Station, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.19	1.35	1.52	3.99	5.52	–	1.27	1.92	2.98	1.81	1.64	1.86
5	–	–	–	4.32	5.50	–	1.30	–	2.03	2.16	1.69	–
10	1.47	1.51	1.58	3.61	2.79	–	1.38	2.01	1.99	2.03	1.54	1.50
15	–	–	–	2.72	1.28	–	1.39	0.81	0.80	1.69	–	–
20	–	–	–	–	0.86	–	0.69	0.71	0.78	0.65	1.56	–
30	–	–		–	–	–	0.58	0.59	0.87	0.58	0.90	1.58
40	–	–	–	–	–	–	0.30	0.56	0.62	0.76	0.90	1.40
50	–	–	–	–	–	–	0.40	0.56	0.64	0.93	1.52	1.47
60	1.23	1.79	1.95	3.15	1.84	–	1.38	1.90	0.96	1.92	1.62	1.91

E4 DO [mg l⁻¹]

Madison Park Station, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	10.17	11.14	11.52	12.96	12.76	10.14	9.51	9.78	9.42	9.66	9.55	9.51
5		–	–	12.84	12.72	10.99	9.51	9.88	9.38	9.64	9.55	–
10	10.12	11.10	11.58	12.06	11.53	10.19	9.24	9.31	9.12	9.54	9.49	9.51
15	–	–	–	11.44	11.09	9.79	8.56	7.51	9.06	6.77	–	–
20	–	–	–	–	10.97	9.93	8.84	8.17	7.45	6.83	9.45	–
30	–		–	–	–	10.42	9.72	9.11	8.48	7.67	6.70	9.55
40	–	–	–	–	–	–	9.86	9.05	8.37	7.87	6.42	9.55
50	–	–	–	–	–	9.84	9.61	8.57	8.19	6.99	5.99	9.35
60	10.05	11.05	11.13	10.92	9.43	7.69	7.64	6.11	5.98	5.50	5.54	6.15

E6 CHLOROPHYLL CONCENTRATION [μg l⁻¹]

Madison Park Station, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.40	0.61	3.08	11.61	19.96	2.40	3.22	2.53	3.03	5.64	4.00	3.18
5		–	–	11.37	24.34	3.46	2.92	4.40	3.44	6.17	5.28	–
10	0.57	0.61	3.52	8.61	11.47	3.44	2.79	3.87	2.61	7.32	4.18	3.32
15	–	–	–	7.37	4.77	2.97	1.96	2.54	1.12	6.33	–	–
20	–	–	–	–	2.38	1.34	1.48	1.52	0.90	0.83	4.66	–
30	–	–	–	–	–	0.75	0.71	0.49	0.43	0.60	0.97	3.59
40	–	–	–	–	–	–	0.87	0.37	0.40	0.59	0.98	3.51
50	–	–	–	–		0.61	0.70	0.31	0.28	0.74	1.09	3.30
60	0.66	0.56	1.87	2.91	2.71	1.03	1.20	0.99	0.21	1.27	1.32	2.94

§ Total-N

Total Kieldhal N [mg l⁻¹], Madison Park Station, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	.24	.244	.203	.249	.322	.248	.213	.294	.268	.277	.299	.216
5	–	–	–	.289	.327	.317	.219	.256	.223	.254	.446	–
10	.221	.266	.182	.249	.275	.311	.183	.256	.268	.277	.247	.171
15	–	–	–	.223	.236	.279	.195	.138	.189	.331	–	–
20	–	–	–	–	.178	.216	.207	.225	.242	.215	.247	–
30	–	–	–	–	–	.178	.178	.213	.175	.277	.194	.22
40	–	–	–	–	–	–	.178	.294	.182	.231	.262	.156
50	–	–	–	–	–	.19	.225	.256	.189	.277	.232	.182
60	.212	.216	.194	.151	.171	.197	.178	.313	.195	.277	.239	.192

E8 PHOSPHORUS CONCENTRATION

§ Total-P [$\mu g\ l^{-1}$]

Madison Park Station, 1982

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	.027	.030	–	.025	.029	.011	.009	.011	.012	.013	.012	.018
5	–	–	–	.026	.021	.015	.010	.012	.013	.010	.011	.015
10	.028	.030	–	.029	.013	.019	.009	.012	.012	.010	.011	–
15	–	–	–	.026	.010	.008	.009	.011	.007	.010	–	–
20	–	–	–	–	.016	.008	.009	.010	.006	.006	.012	–
30	–	–	–	–	–	.019	.017	.015	.014	.013	.023	.016
40	–	–	–	–	–	–	.019	.025	.023	.022	.028	.017
50	–	–	–	–	–	.024	.022	.030	.030	.032	.030	.022
60	.028	.032	–	.043	.031	.026	.031	.045	.034	.041	.037	.026

E10 PAST TRENDS

Secondarily treated sewage effluent had once been dumped into the lake from the city of Seattle and other small cities around the lake, until a diversion system was implemented in 1968. Certain chemical parameters were much different in the late 1950's and early to mid 1960's than they are today. Winter PO_4 and total-P routinely reached a level of 50 $\mu g\ l^{-1}$. There has also been a temporal shift in peak chlorophyll concentration. In 1963, maximum values occurred in the summer with the bloom of the blue-green filament, *Oscillatoria agardhii.* Since sewage diversion, however, maximum phytoplankton biomass has occured in spring when diatoms are in the greatest abundance, and so the maximum chlorophyll concentration tended to appear in late April through May. Oxygen depletion at the bottom during late summer continues to occur, but in a lesser degree since production has been reduced. When large summer blooms used to occur, surface pH became more alkaline than it does now, often reaching 9. The chemistry values for the lake have been fairly stable for the past ten years, and the year 1982 for which the data are given here is considered a typical year chemically.

F. BIOLOGICAL FEATURES

F1 FLORA

§ Floating macrophytes : *Nymphaea odorata.*

§ Submerged macrophytes : *Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton* spp., *Elodea canadensis, Zanichellia palustris.*

§ Phytoplankton : Spring (*Melosira italica, Fragilaria crotonensis, Stephanodiscus* spp., *Cyclotella pseudostelligera*) ; Summer and autumn (*Aphanizomenon flos-aquae, Microcystis aeruginosa, Coelosphaerium haegilianum, Tabellaria flocculosum, Ociptis gigas*).

F2 FAUNA

§ Zooplankton : *Daphnia pulicaria, D. thorata, Diaptomus ashlandi, Epischura* sp., *Neomysis mercedis.*

§ Benthos : Various species of chironomids (not identified).

§ Fish : *Oncorhynchus nerka, O. tshaorytscha, Salmo gairdneri, Micropterus salmoides, Perca flavescens, Lepomis gibbosus, Osmerus* sp.

F5 FISHERY PRODUCTS

§ Annual fish catch in 1984 : Not estimated ; sport fishing only.

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE

Change in phytoplankton from *Oscillatoria* dominance to diatom dominance since sewage diversion.

Appearance and domination of *Daphnia* spp. since 1976.

Appearance and spread of *Myriophyllum* in shallow water zones.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1984)

	Area	
	[km^2]	[%]
Woody and herbaceous vegetation	382	30
Agricultural land	127	10
Residential area	765	60
Total	1,274	100

§ Main types of woody vegetation : *Pseudotsuga menziesii* forest ; *Alnus rubra* forest.
§ Main types of herbaceous vegetation : Pasture and grasslands.
§ Main kinds of crops : Grasses for hay.

G2 INDUSTRIES IN THE CATCHEMENT AREA AND THE LAKE (1982)
Mainly residential and recreational use of the lake and shoreline.
Boeing Company at the south end of the lake.

G3 POPULATION IN THE CATCHMENT AREA (1982)

	Population	Population density [km^{-2}]	Main cities (population)
Total	1,500,000	1,180	Seattle (490,000), Bellevue

H. LAKE UTILIZATION

H1 LAKE UTILIZATION
Navigation, tourism and recreation (swimming, yachting and sport-fishing).

H2 THE LAKE AS WATER RESOURCE (1984)
Not used.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION
§ Extent of damage : Not serious.

I3 EUTROPHICATION
§ Nuisance caused by eutrophication : Unusual bloom of *Oscillatoria agardhii* in the late 1950's to 1974 ; since gone from the lake.
§ Nitrogen and phosphorus loadings : Nitrogen mainly from agricultural and natural sources, and phosphorus mainly from domestic and agricultural sources.

I4 ACIDIFICATION
§ Extent of damage : Not serious.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (c) Limited pollution with wastewater treatment.
§ Municipal wastewater treatment systems : Present (activated sludge ; for domestic wastewater and rainwater).

K. IMPROVEMENT WORKS IN THE LAKE

K1 RESTORATION

Diversion: All sewage effluent diverted from the lake in 1968 and disposed of elsewhere (Puget Sound).

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED

§ Responsible authorities

(1) Municipality of metropolitan Seattle

§ Main items of control

(1) Sewage treatment and disposal

N. SOURCES OF DATA

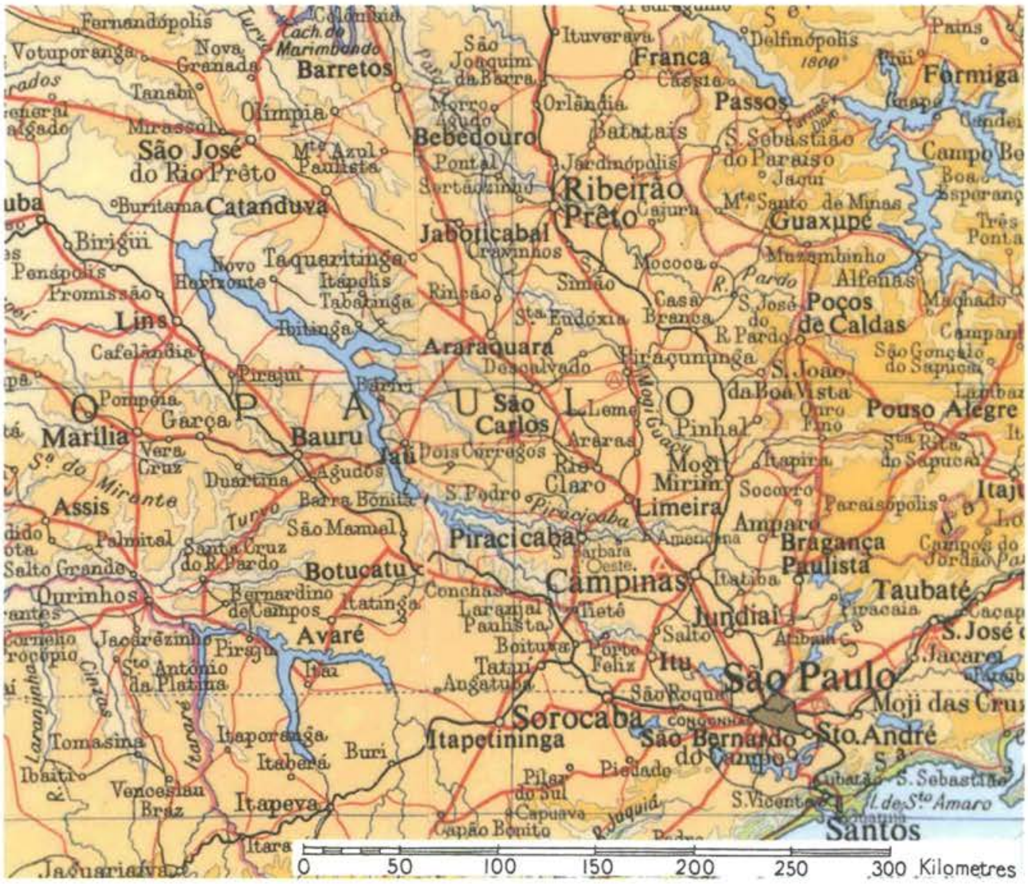
(Q) Questionnaire filled by Dr. S. Abella by recommendation of Dr. W. T. Edmondson, Department of Zoology, University of Washington.

(1) Müller, M. J. (1982) Selected Climatic Data for a Global Set of Standard Stations for Vegetation Science. 306 pp. Dr. W. Junk Publishers, The Hague.

RÊPRESA DO LOBO (BROA RESERVOIR)

A bird-eye view of the whole lake

Photo: J.G. Tundisi



A. LOCATION

§ São Paulo State, Brazil.
§ 22°12′S, 47°51′W ; 710 m above sea level.

B. DESCRIPTION (Q)

Broa Reservoir is a man-made lake at the center of São Paulo State of Brazil created in a tropical savanna (cerrado) region in 1936 by damming up the Itaqueri River, a small tributary of the Rio Parana. At present, however, the lake is turned into an area of environmental protection because of its importance as a recreation area of scenic beauty and of scientific activities in and around the lake. Large scientific and educational projects are now in progress.

The lake is 7.5 km long and has a very flat basin with a mean water depth of 3m. A maximum depth of 12m is observed near the dam site. The water level fluctuates within a range of 1.5m, being high in April at the end of rainy season and low in September at the end of dry season.

A large portion of its catchment area is covered by sandy soils, which are very aged and extremely infertile. The lake water is also oligotrophic and low in nitrogen level, and certain heavy metals often limit phytoplankton production.

Since the lake is located only 100 km apart from large reservoir systems of S. Paulo State and its water remains relatively free from eutrophication and pollution, it serves as an important standard system for comparison with the large eutrophied reservoirs. The limnology of this reservoir was opened by Brazilian scientists in 1971. Several climatological, hydrological, biological and water chemistry aspects were studied. The researches also cover the ecology, physiology and chemistry of almost all organisms present in the lake. The number of scientific papers so far published regarding this lake now amounts to approximately 200, including several masters and doctoral theses prepared at the University of S. Paulo and Federal University of S. Carlos. The Centre for Hydrological Researches and Applied Ecology, University of S. Paulo, is currently engaged in scientific projects including the modelling of Broa Reservoir system. Educational programs using the lake area as a natural laboratory have also started since 1985 (Q3, Q1, Q2).

C. PHYSICAL DIMENSIONS (1, 2)

Surface area [km^2]	6.8
Volume [10^{9}m^3]	0.22
Maximum depth [m]	12.0
Mean depth [m]	3.0
Normal range of annual water level fluctuation (regulated) [m]	1.5
Length of shoreline [km]	18.3
Residence time [yr]	0.14
Catchment area [km^2]	280

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q3)

§ Bathymetric map (Fig. SAM-1-1 and 2).
§ Main islands : None.
§ Outflowing rivers and channels (number and names) : 1 (Rio do Lobo-Rio Jacare Guacu).

D2 CLIMATIC (Q3, 17, 18)

§ Climatic data at Centre for Hydric Resources, University of S. Paulo, 1971 1986 (Fig. SAM-1-3).
§ Number of hours of bright sunshine (São Carlos) : 2,663 hr yr^{-1}.
§ Solar radiation (São Carlos) : 8.0 MJ m^{-2} day^{-1}.

Fig. SAM-1-1 Sketch map of Broa Reservoir, showing morphometry, sampling stations (1 -5), limit of macrophyte distribution and prevailing wind direction (W) (18).

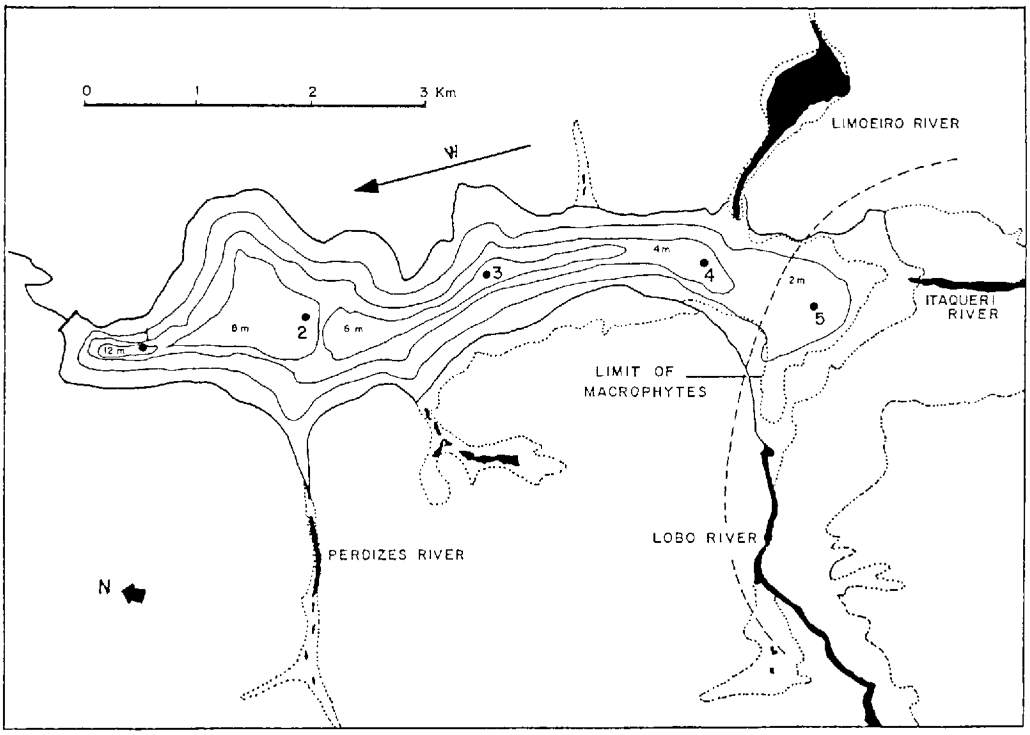


Fig. SAM-I-2 Map of Broa watershed, showing the main characteristics of its hydrographic network, in- and out-flowing rivers, and compartments of the lake (17).

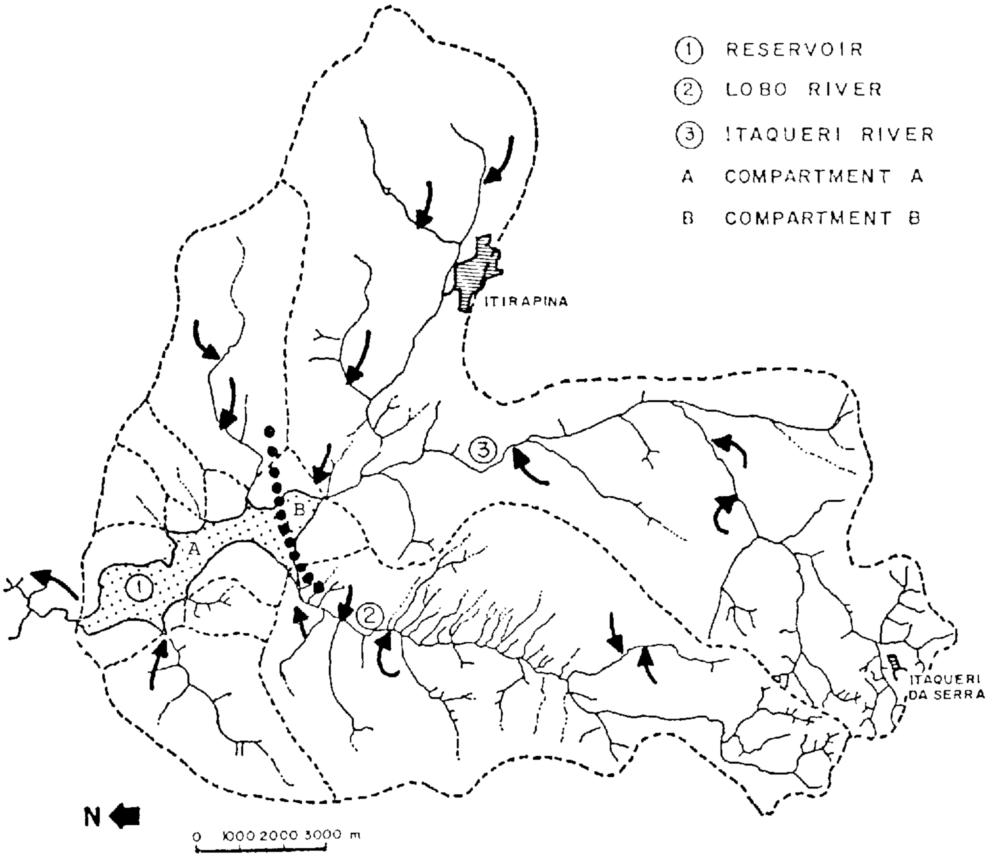
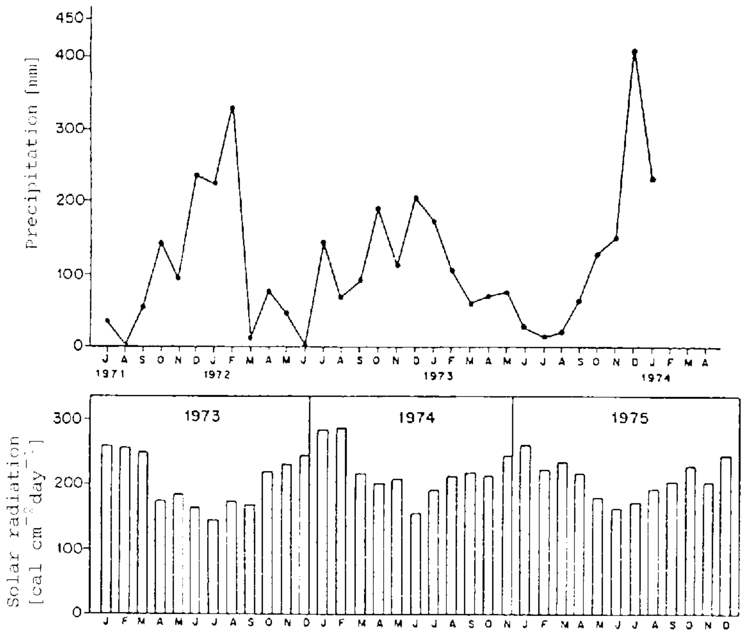
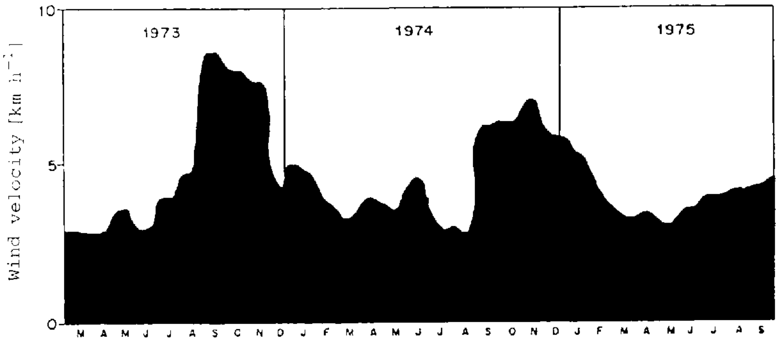
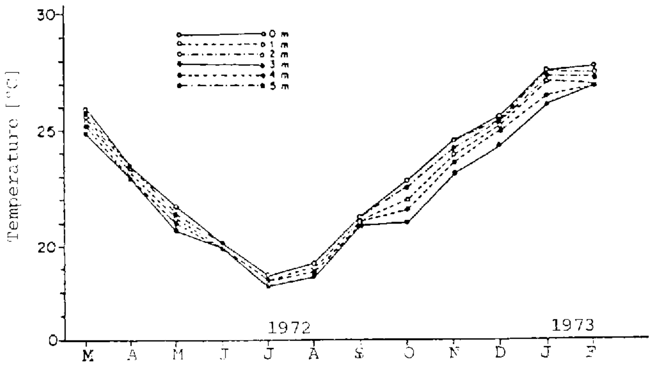


Fig. SAM-I-3 Seasonal trends of precipitation, solar radiation, wind velocity and water temperature (17).







§ Water temperature [°C] (3)

Station 1, Nov. 1974-Oct. 1975

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	25.7	26.1	26.8	23.6	20.9	18.5	17.4	19.8	21.8	23.0	24.5	24.5

§ Freezing period : None.

§ Notes on water mixing and thermocline formation : Prevailing strong wind prevents stratification.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], 1973-1975 (3)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.3	1.7	2.1	2.1	2.1	2.0	1.8	1.9	1.7	1.5	1.7	1.6

E2 pH, 1973-1974 (3)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	5.5	5.6	6.2	—	5.8	5.9	5.9	6.0	5.8	5.9	6.3	5.8

E3 SS [mg l⁻¹], 1973-1974 (3)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	7.9	5.8	5.1	7.1	4.8	5.3	2.4	5.6	6.5	8.1	9.4	4.6

E4 DO [mg l⁻¹], 1973-1974 (3)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	7.5	7.3	7.3	8.5	8.4	7.7	8.8	8.7	8.3	8.1	7.5	7.6

E6 CHLOROPHYLL CONCENTRATION [$\mu g\ l^{-1}$], 1975-1976 (4)

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surface	17	10	10	9	22	15	15	11	14	23	33	23

E7 NITROGEN CONCENTRATION (5)

§ NO_3-N [μgl^{-1}] : Summer (Jan.-Feb.), 0.6-2.6 ; winter (Jul.), 0.0-1.1.

E8 PHOSPHORUS CONCENTRATION [$\mu g\ l^{-1}$] (5)

	Summer(Jan-Feb)	Winter(Jul)
Dissolved-P	0.8-0.9	0.7-0.8
Total-P	12-16	11-14

F. BIOLOGICAL FEATURES

F1 FLORA (6, 7, 11, 12, 15, 16, 18 and 19)

§ Floating macrophytes : *Nymphoides indicum, Pontederia cordata.*

§ Submerged macrophytes : *Mayaca sellowiana, Utricularia inflata, U. vulgaris, Ludwigia* sp., *Eleocharis* sp.

§ Phytoplankton : *Anomoeoneis serians, Cymbella pusila, C. amphicephala, Frustulia rhomboides, Melosira italica, Navicula pupula.*

Dominant phytoplankton during winter (Jul.-Sep.) : *Melosira italica* (wind action on the bottom of the lake resuspends *Melosira*).

F2 FAUNA (Q, 8, 11, 12, 15 and 16)

§ Zooplankton : Rotifera (*Ptygura, Conochiloide, Filinia, Brachionus falcatus, B.mirabilis, Keratella, Lecane, Polyarthra*), Cladocera (*Bosmina coregoni, Bosminopsis deitersi, Diaphanosoma* sp., *Argyrodiaptomus furcatus, Thermoxyclops minutus*).

§ Benthos : Chironomidae, Chaoborinae, Tanypodinae.

§ Fish : *Geophagus brasiliensis,* **Hoplias malabaricus, Leporinus octofasciatus,* **Astyanax fasciatus,* **A. bimamlatus* (*economically important).

F3 PRIMARY PRODUCTION RATE [mg C $m^{-2}day^{-1}$] (10)

Station 1, 1973-1976

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gross production	350	280	300	250	180	150	130	160	220	230	350	400

(cf. Maximum production rate of *Argyrodiaptomus furcatus* in winter : 30 mgC $m^{-3}day^{-1}$)

F7 NOTES ON THE REMARKABLE CHANGES OF BIOTA IN THE LAKE (17)

No remarkable change. Occasional changes occurred due to the interaction of such hydrological processes as low water level, increase in flushing rate, etc., resulting in the shift of dominance from diatoms(e.g. *Melosira italica*) to flagellates(e.g. Chrysophyceae), from large-celled phytoplankton to small-celled species, and from copepods to rotifers.

G. SOCIO-ECONOMIC CONDITIONS

G1 LAND USE IN THE CATCHMENT AREA (1986) (16, Q3)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	56	20
Herbaceous vegetation	56	20
Swamp	28	10
Others	14	5
Agricultural land		
Crop field	56	20
Pasture land	28	10
Settlement area	28	10
Others	14	5
Total	280	100

§ Main types of woody vegetation : Gallery forest along the river.
§ Main types of herbaceous vegetation : Savanna (*cerrado* type).
§ Types of other important vegetation : Grass swamp.
§ Main kinds of crops : Maize and rice.
§ Levels of fertilizer application on crop fields : Moderate.
§ Trends of change in land use in recent years : Decrease of natural forest due to the progress of urbanization (recreation areas) and road construction.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1986) (14)

	Gross product	No. of persons engaged	No. of establishments	Main products and major industries
Primary industry				
Crop production	N.A.	N.A.	12	Maize, rice
Animal husbandry	N.A.	N.A.	N.A.	Cattle
Others	N.A.	N.A.	N.A.	Mining (sand)
Secondary industry			None	
Tertiary industry			None	

§ Number of domestic animals in the catchment area : Cattle 1,000, sheep 50.

G3 POPULATION IN THE CATCHMENT AREA (1986) (14)

	Population	Population density [km^{-2}]	Main cities
Urban	—	—	
Rural	27,000	—	None
Total	27,000	96.4	

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (14)

Tourism (number of visitors in 1986 : 150,000), recreation (swimming, sport fishing, yachting), scientific studies and education.

H2 THE LAKE AS WATER RESOURCE (1986) (14)

	Use rate
Domestic water	Negligible
Irrigation	Experimental, negligible
Industrial water	Negligible
Power plant	3 m^3 sec^{-1}

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q3)

§ Extent of damage : Not serious.

§ Supplementary notes : The deforestation and mining for sand are the causes of increased siltation. Rate of sedimentation : 1 mm yr^{-1}.

I2 TOXIC CONTAMINATION (Q3)

§ Present status : Detected but not serious.

§ Supplementary notes : Contamination with herbicides and pesticides was detected in the early 1980's, causing a slight increase in their accumulation in fish bodies through food chain. Countermeasures are related to the legislation of a government act to protect this area in 1983.

I3 EUTROPHICATION (Q3)

§ Nuisance caused by eutrophication : None.

§ Supplementary notes : No eutrophication processes were observed in the last ten years. Eutrophication is prevented by the long residence time of the lake and the growth of macrophytes in the main inflowing rivers. Measures taken to prevent eutrophication include the treatment of domestic sewage and the use of septic tanks in individual residences.

I4 ACIDIFICATION (Q3)

§ Extent of damage : Detected but not serious.

§ Supplementary notes : The mining operation caused only occasional, slight changes in acidity, but is expected to stop by 1987 by the legislation of the government act.

I5 OTHER HAZARDS (Q3)

Deforestation in the catchment area.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (a) Pristine lake environments (14).

J2 APPROXIMATE PERCENTAGE DISTRIBUTION OF NUTRIENT LOAD (13)

	Percentage
Non-point sources	60
Point sources	
Municipal	20
Industrial	10
Others (occasional non-point sources)	10
Total	100

J3 SANITARY FACILITIES AND SEWERAGE (14)

§ Percentage of municipal population in the catchment area provided with adequate sanitary facilities (on-site treatment system) or public sewerage : 80%.

§ Percentage of rural population with adequate sanitary facilities : 60%.

§ Municipal wastewater treatment systems

Number of tertiary treatment systems : None.
Number of secondary treatment systems : None.
Number of primary treatment systems : 2 (oxidation ponds).
Number of other types : Septic tanks for residences.

§ Industrial wastewater treatment systems : 1 (treatment tanks for mining).

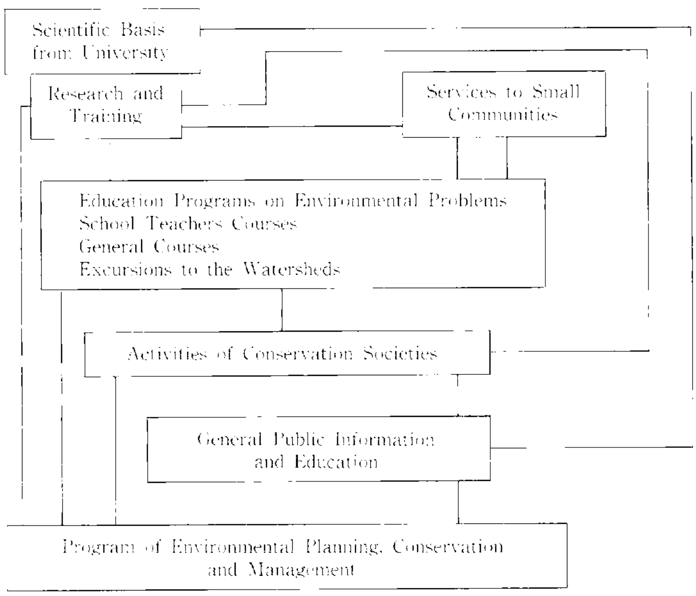
K. IMPROVEMENT WORKS IN THE LAKE

K3 OTHERS (17)

Solid waste collection system and reforestation of gallery forests.

L. DEVELOPMENT PLANS

The development of recreation areas and the plantation of non-native tree species (*Eucalyptus* sp.) for commercial purposes have been carried out in the catchment area by private companies. The development plan of Broa area for scientific/educational purposes is also in progress under the scheme shown below (17).



M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (17)

§ Names of the laws (the year of legislation)
(1) Law Declaring Broa Watershed Area of Environmental Protection (1983).

§ Responsible authorities
(1) State Government of S. Paulo and Municipalities.

§ Main items of control
Road construction ; deforestation ; impariment of wildlife, fish fauna and gallery forest.

§ Supplementary notes :
Broa Catchment area has been protected since 1983 by a special law of the State Government of S. Paulo for its landscape, wildlife, scientific studies and recreational activity.

M2 INSTITUTIONAL MEASURES (17)

(1) Legislative measures (see above)
(2) Association for Protection of Broa Watershed (authorized as a public utility organization in 1984)

M3 RESEARCH INSTITUTES ENGAGED IN THE LAKE ENVIRONMENT STUDIES (Q3)

(1) Center for Hydric Resources, School of Engineering, University of S. Paulo
(2) Institute of Physics, University of S. Paulo
(3) Federal University of S. Carlos

N. SOURCES OF DATA

(Q1) Questionnaire filled by Dr. N. Nakamoto, Shinshu University, Ueda, Japan.

(Q2) Questionnaire filled by Prof. T. Sunaga, Kagawa University, Takamatsu, Japan.

(Q3) Questionnaire filled by Prof. J. G. Tundisi, School of Engineering, University of São Paulo, São Carlos, Brazil.

(1) Tundisi, J. G. Strinxino, T., Marins, M., Tundisi, T. M., Strinxino, S., Moraes, E. M. & Santos, E. P. (1972) Ecological Studies in a Lacustrine Environment. I. Progress Report. Univ. Fed. S. Carlos, São Carlos.

(2) Nakamoto, N., Marins, M. & Tundisi, J. G. (1976) Oecologia (Berl.), 23 : 179-184.

(3) Godinho, M. J. L. (1976) Ciclo sazonal, standing stock e distribucão do bacterioplancton em ecosistema lacustre artificial, Represa do Lobo, São Carlos. Masters Thesis, Univ. S. Paulo.

(4) Rocha, O. (1978) Flutuacan sazonal e distribucão de populacão de *Diaptomus furcatus* Sars (Copepoda, Clanoida) na Represa do Lobo (Broa), São Carlos, S. P. Masters Thesis, Univ. S. Paulo.

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(7) Tundisi, J. G. & Hino, K. (1981) Rev. Brasil. Biol., 41 : 63-68.

(8) Matsumura-Tundisi, T. & Tundisi, J. G. (1976) Oecologia (Berl.), 25 : 265-270.

(9) Tundisi, J. G., Gentil, J. G. & Dirickson, M. C. (1978) Revta Brasil. Bot., 1 : 35-39.

(10) Tundisi, J. G. (1981) Verh. Intern. Verein Limnol., 21 : 1031-1039.

(11) Tundisi, J. G. (1986) Bol. Hidraulica e Saneamento, 11 : 1-46.

(12) Tundisi, J. G. (in press) The Lobo (Broa) ecosystem. "Ecosystem Dynamics in Wetland and Shallow Water Bodies ; Proceedings of a SCOPE Meeting". Tallin, USSR.

(13) Tundisi, J. G. & Matsumura-Tundisi, T. (1986) Eutrophication process and trophic state for 23 reservoirs in S. Paulo State, Southern Brazil. Paper presented at the 5th Brazil-Japan Symposium on Science and Technology, Tokyo, October 1986.

(14) Tundisi, J. G. & Schiel, D. (1986) Sistema de Atualizacão de Professores de Ciencias e Geografia com a Utilizacão do Conceito de Bacia Hidrografica como Unidade : Conceitos Basicos, Projeto e Perspectivas. 13pp. Publ. Especial CRHES/CDCC, IFQUSP.

(15) Tundisi, J. G., Matsumura-Tundisi, T., Strinxino, G., Marins, M., Mattos, M. A. & Santos, E. P. (1972) Ecological Studies at Broa Reservoir. I. Progress Report. 123pp.

(16) Tundisi, J. G. & Matsumura-Tundisi, T. (1972) Ibid. II. Progress Report. 165pp.

(17) Tundisi, J. G. (1986) Local community involvement in environmental planning and management—The Lobo-Broa Reservoir case study. UNCRD/ILEC/UNEP Expert Group Workshop on Environmental Planning and Managenent : Focus on Training Aspects Derived from Studies of Inland Water Management, Otsu and Nagoya, November 1986.

(18) Tundisi, J. G. (1977) Producão Primaria, "Standing stock", Fracionamento do Fitoplancton, e Factores Ecologicos em Ecosistema Lacustre Artificial. 409pp. DSC Thesis, Univ. S. Paulo (with English summary).

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LAGO NAHUEL HUAPI (LAKE NAHUEL HUAPI)

A bird-eye view of the lake

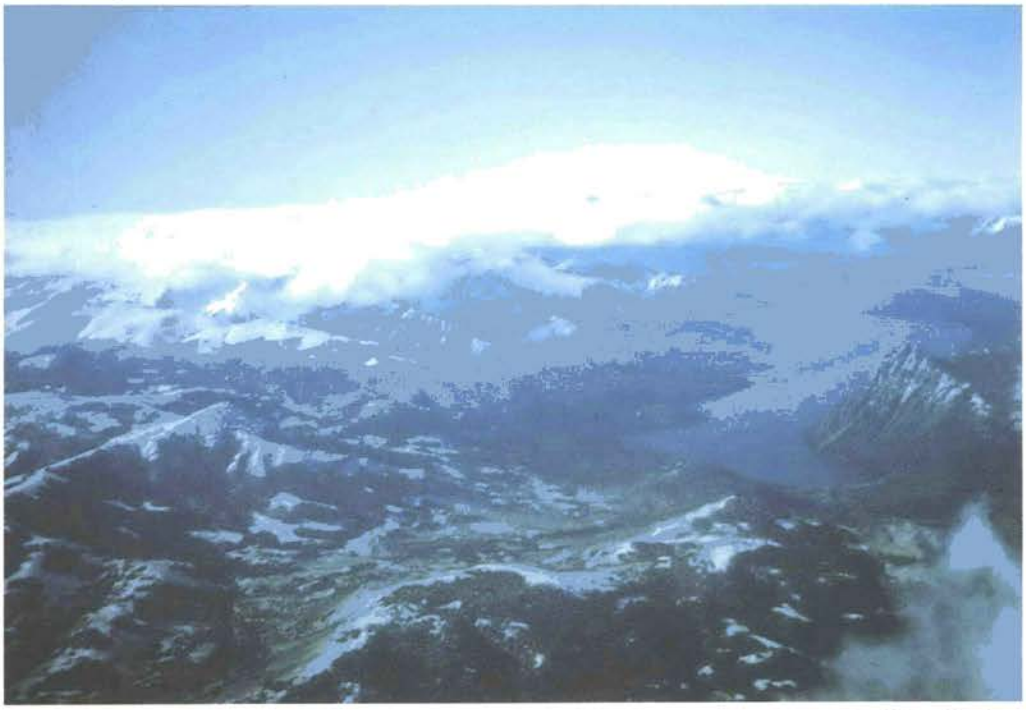
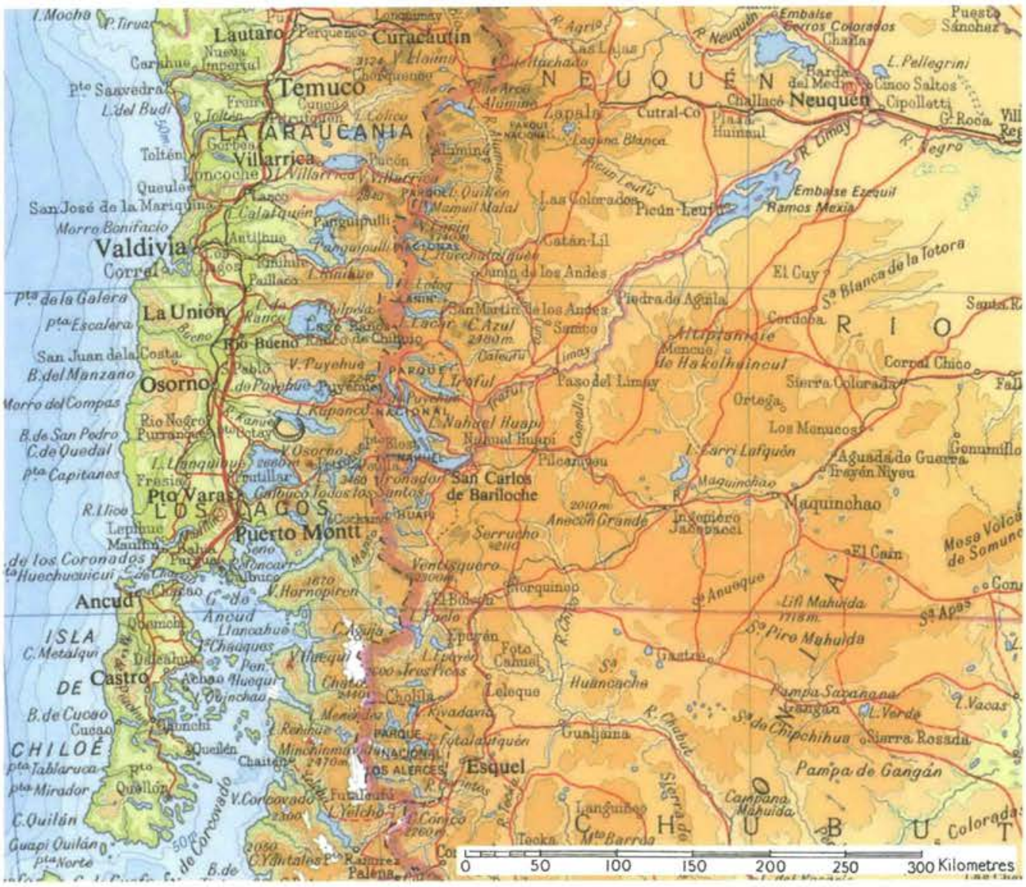


Photo: I. R. Wais-Badgen



A. LOCATION

§ Rio Negro Province, Argentina.
§ 40°40′-41°10′S, 71°10′-50′W ; 740-767 m above sea level.

B. DESCRIPTION

Nahuel Huapi is a glacial lake located along the eastern slope of Southern Andean Range with a maximum length of 67 km and a maximum width of 10 km. The lake resembles in its shape "a gigantic amoeba with enormous tentacles extending in all directions to form (1)" a number of arms or fjords. It is also encircled by many smaller lakes. Mountains fringe almost all its coastline ; there is a succession of bays and coves, shingle and sandy beaches, perpendicular rocky cliffs, steep promontories, and wooded isthmuses and peninsulas.

The lake offers one of the nicest landscapes in South America, and has been included since 1909 in Nahuel Huapi National Park, the largest of Argentine national parks (785,000 ha). The international city of San Carlos de Bariloche, growing up very fast on the southeastern margin of the lake, attracts every year lots of tourists with pleasant summer weather and winter sports.

The report of a Swedish South-American expedition in 1953-1954 (1) states that "the luxuriant forests of *Austrocedrus* and *Nothofagus* surrounding its solitary fjords contrast with the scanty aquatic macrophytes" and that "the scarcity of the latter is partly dependent on the very limited shallow water areas…". This situation, however, changed in the last years when a rapid cultural eutrophication was observed in some small and less deep inlets of the lake, particularly near the city of Bariloche, though the main body of Nahuel Huapi remains oligotrophic. Thus, a lot of macrophytes, especially *Scirpus californicus*, cover those inlets and are expanding in some arms. Those arms are also rich in nutrients and phytoplankton owing to the result of human activities. Protective measures should be taken before the eutrophication and other kinds of pollution spoil the value of the National Park, where the municipal authorities of Bariloche have jurisdiction of administration (Q).

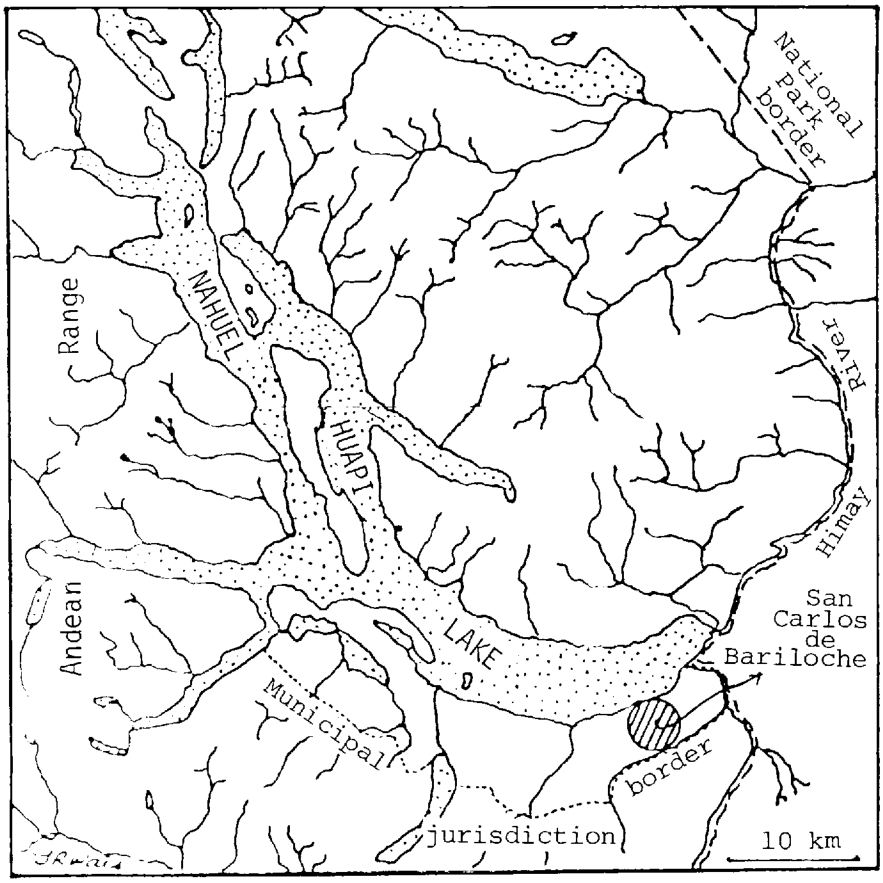
C. PHYSICAL DIMENSIONS (1)

Surface area [km^2]	646
Maximum depth [m]	More than 300
Water level	Unregulated
Length of shoreline [km]	357
Catchment area [km^2]	2,758

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL (Q)

Fig. SAM-2-1 Sketch map of the lake.



§ Main islands : Victoria.

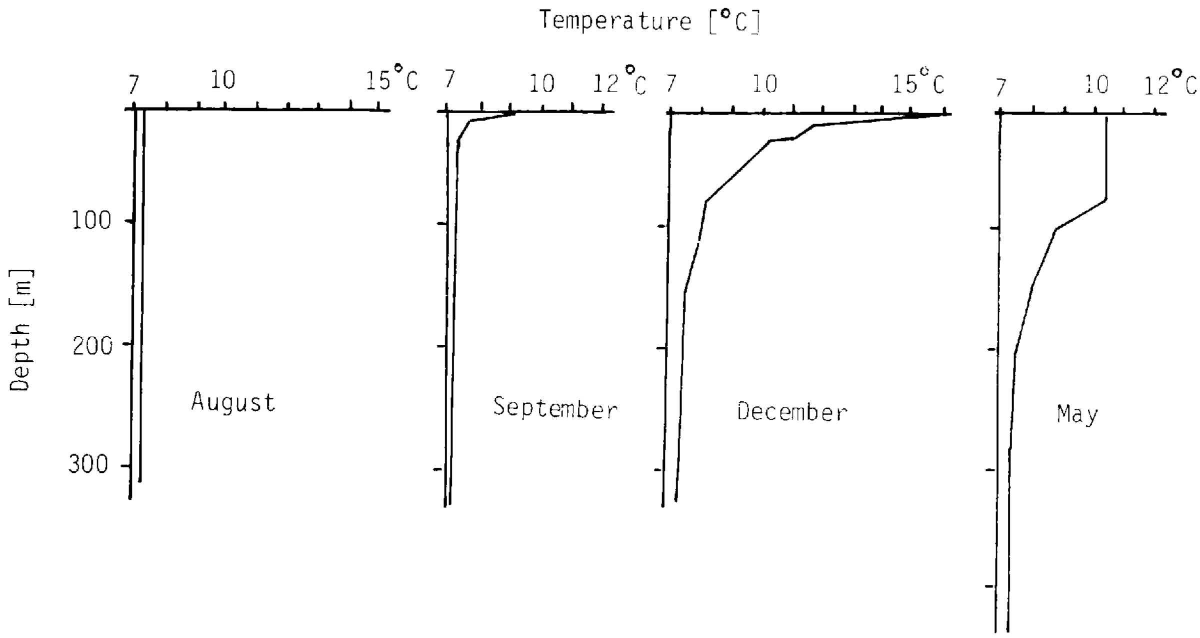
§ Outflowing rivers and channels (number and names) : 1 (Himay R., belonging to Rio Negro system draining into the Atlantic Ocean).

D2 CLIMATIC

§ Precipitation around the lake : Bariloche 1,009 mm yr^{-1} (2) ; Puerto Blest (western side of the lake) 3,590 mm yr^{-1} (3) 4,026 mm yr^{-1} (2).

§ Water temperature (Fig. SAM-2-2).

Fig. SAM-2-2 Water temperature profiles (4, 1).



§ Freezing period : None.
§ Mixing type : Monomictic (holomictic).
§ Notes on water mixing and thermocline formation : Nahuel Huapi is a subtropical lake, in which the overturn takes place throughout entire depths once a year in winter (Jul.-Aug.). The summer stratification is well developed and the temperature of hypolimnion is 7-8 °C throughout the year (Q).

F. BIOLOGICAL FEATURES

F1 FLORA

§ Emerged macrophytes : *Scirpus californicus, Isoetes savatieri* (Q).
§ Submerged macrophytes : *Ceratophyllum demersum, Miriophyllum elatinoides* (Q).
§ Phytoplankton : *Dictyosphaerium pulchellum, Melosira granulata* (winter spring), *Rhizosolenia eriensis, Dinobryon divergens, D. cylindricum, Melosira granulata* (summer-autumn) (5).

F2 FAUNA

§ Zooplankton : Rotatoria (*Keratella cochlearis, Polyarthra vulgaris, Pompholyx sulcata, Filina longiseta, Gastropus stylifer*) ; Copepoda (*Boeckella gracilipes*) ; Cladocera (*Bosmina chilensis*) (5).
§ Benthos : Decapoda (*Samastacus spinifrons, Aegla riolimayana*) ; Amphipoda (*Hyallela curvispina*) ; Mollusca (*Chilina puelcha, Ch. parchappei, Diplodon patagonicus*) ; Oligochaeta (*Chaetogaster limnaei, Stratiodrilus aeglophilus*) (Q).
§ Fish : *Percichthys trutta, P. colhuapiensis, Salmo trutta* (introduced), **S. gaudneri* (introduced), *Diplomistes* sp., *Hatcheria* sp., *Aplochiton* sp., *Galaxias maculatus* (*economically important) (Q).
§ Supplementary notes : The biota of all the Andean Patagonic area is characterized by a high degree of endemism, at a species or genus level in some cases but even at a family level in others (6-11).

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Navigation and transportation, sightseeing and tourism, recreation (swimming, sport fishing, yachting) and source of water.

H2 THE LAKE AS WATER RESOURCE (Q)

Domestic water and some industrial water.

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : None.

I2 TOXIC CONTAMINATION (Q)

§ Present status : Detected but not serious (?).

§ Supplementary notes : There is still very poor information ; serious studies as well as continued complete monitoring and assessment are lacking.

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication : Unusual algal bloom.

§ Supplementary notes : Limited to small inlets near the city of Bariloche. Refer to B (Description).

I4 ACIDIFICATION (Q)

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (C) Limited pollution with wastewater treatment.

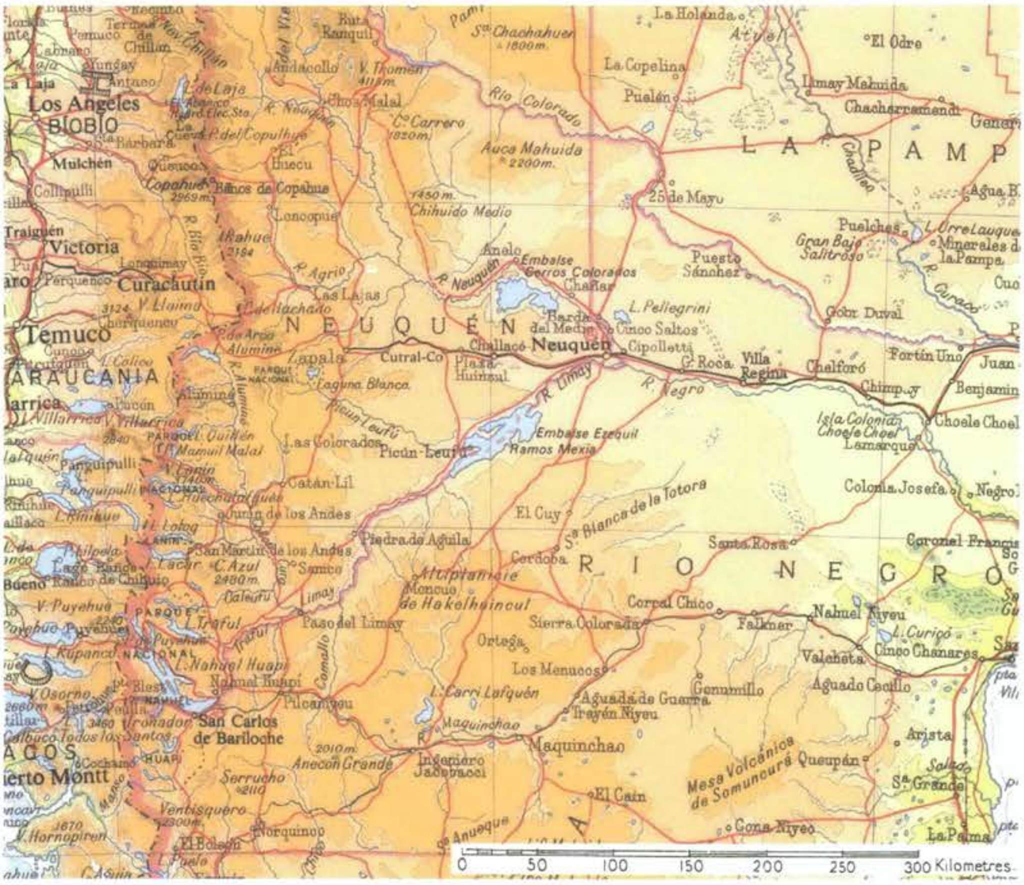
N. SOURCES OF DATA

(Q) Questionnaire filled by Lic. Irene R. Wais-Badgen, Instituto Nacional de las Ciencias Naturales, Buenos Aires.
(1) Tomasson, K. (1959) Acta Phytogeogr. Suec., 42 : 1-83.
(2) Ljungner, E. (1959) Nahuel Huapi. Uppsala Univ., Arsskr.
(3) Jefferson, M. (1921) The Rainfall of Chile. Amer. Geogr. Soc. Res. Ser. 7 (in Spanish).
(4) Cordini, I. R. (1939) Nahueal Huapi Lake. Bol. Direc. Min. Geol. B. Aires, 47 (in Spanish).
(5) Thomasson, K. (1963) Acta Phytogeogr. Suec., 47 : 1-139.
(6) Wais, I. R. (1984) Ann. Limnol., 20 (1-2) : 115-122.
(7) —— (1985) Verh. Intern. Verein Limnol., 22 : 2167-2172.
(8) —— (1985) Com. Mus. Arg. Cienc. Nat. Hidrobiol., 2 : 148-154 (in Spanish).
(9) —— (1986) Spheniscus, 4 : 39-44 (in Spanish).
(10) —— (in press) Macrozoobenthos of Negro River basin, Argentine Patagonia. Stud. Neotrop. Fauna & Environ.
(11) —— (in press) Verh. Intern. Verein Limnol., 23.

EZEQUIEL RAMOS MEXÍA RESERVOIR

A view from the lakeside

Photo : A. Mariazzi



A. LOCATION

§ Rio Negro Province, Argentina.
§ 39°50′S, 66°20′W; 381 m above sea level.

B. DESCRIPTION (Q)

Ezequiel Ramos Mexia Reservoir is a man-made lake in the Southern Andean Range, about 600 km away from Bahia Blanca. The lake was formed in 1972 by the damming of Limay River, which flows out from Lake Nahuel Huapi. The Limay Valley is formed by the 10–30 m thick layer of well-graded pebbles mixed with 30 % of sand. The stratigraphic structure of the lake district consists of three kinds of sediments; a) Cretaceous sediments emerging continuously on both sides of the reservoir, b) Cenozoic sediments of conglomerates of variable sandy and clayey matrix, and c) recent sediments of fine to very fine sands forming dunes up to 7 m high on the northeastern side of the reservoir.

The lake water is soft, neutral to slightly alkaline, basically bicarbonate-calcic. The chlorophyll concentration and primary production are relatively low because of the low concentrations of nutrients (inorganic nitrogen and total phosphorus) and the short residence time. Therefore, the reservoir may be classified as an oligo-mesotrophic lake.

C. PHYSICAL DIMENSIONS (Q)

Surface area [km^2]	816
Volume [$10^9 m^3$]	20.2
Maximum depth [m]	60
Mean depth [m]	24.7
Water level	Regulated
Length of shoreline [km]	346
Residence time [yr]	1
Catchment area [km^2]	24,420

D. PHYSIOGRAPHIC FEATURES (Q)

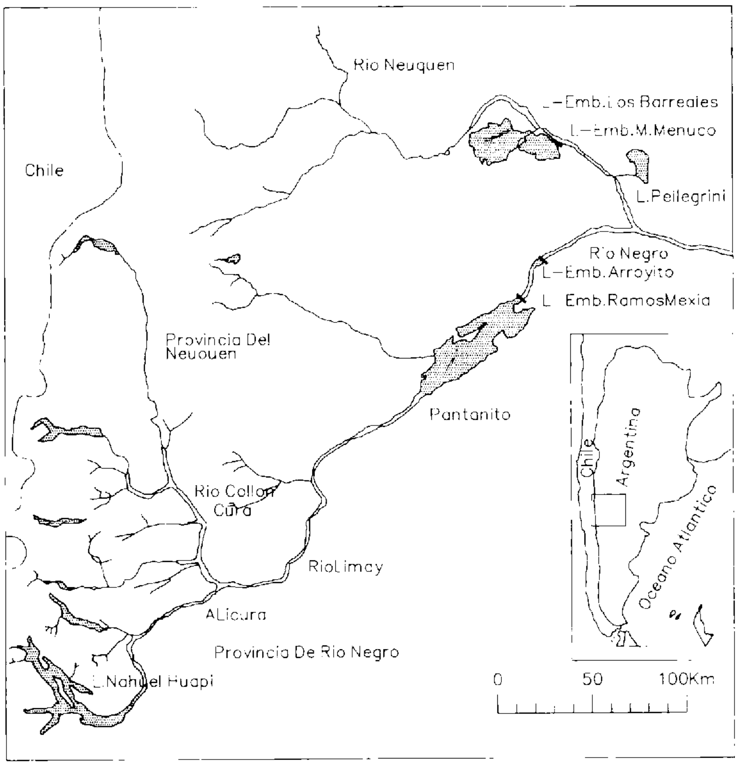
D1 GEOGRAPHICAL

§ Sketch map (Fig. SAM-3-1).

§ Main islands : None.

§ Outflowing rivers and channels (number and names) : 1 (R. Negro).

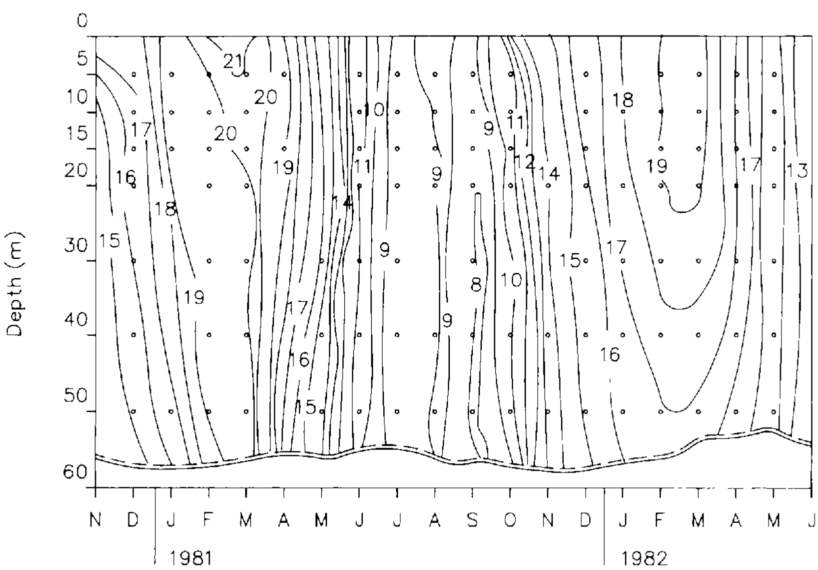
Fig. SAM-3-1 Sketch map of the lake system.



D2 CLIMATIC

§ Water temperature

Fig. SAM-3-2 Spatial-time distribution of water temperature [°C].

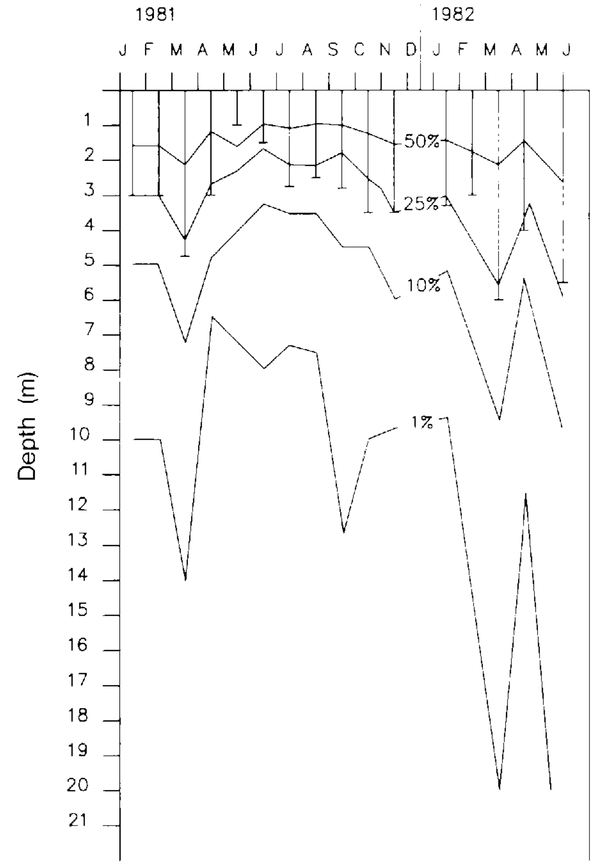


§ Mixing type : Monomictic.

E. LAKE WATER QUALITY (Q)

E1 TRANSPARENCY

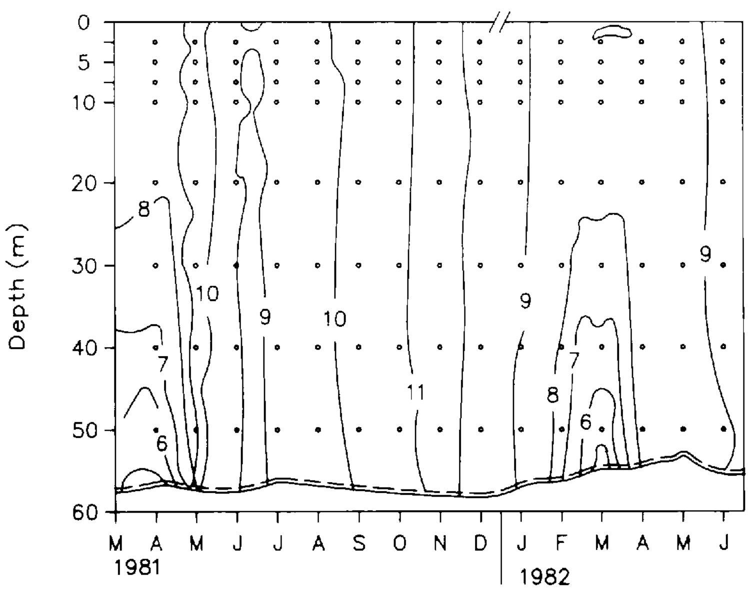
Fig. SAM-3-3 Seasonal trend of transparency [m] and relative light transmission [%].



E3 SS [mg l^{-1}]: Mean value (annual range): 57.8 (52.1-69.5).

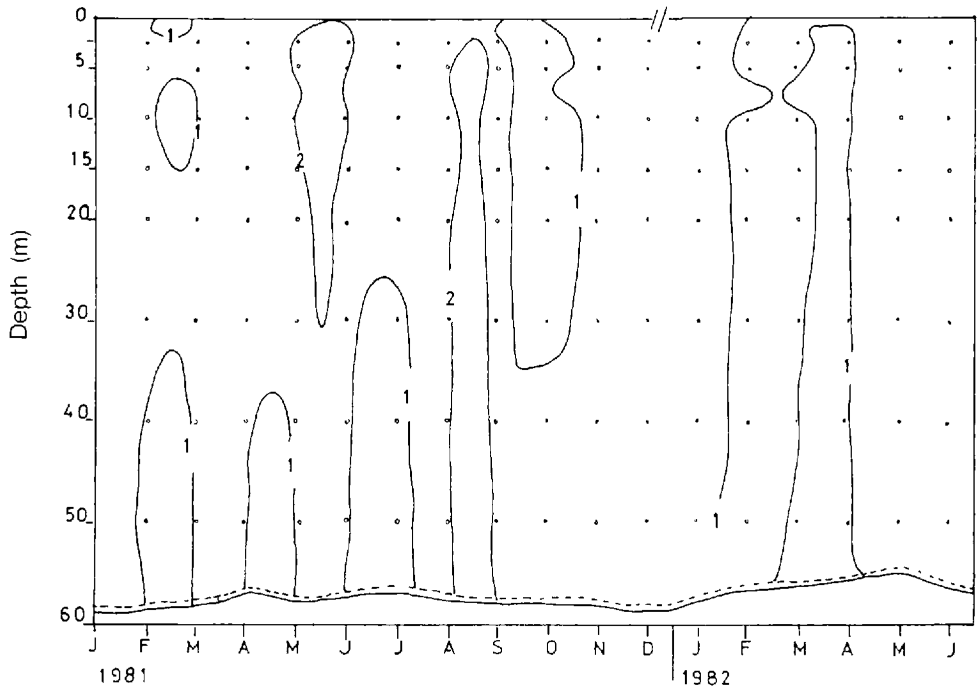
E4 DO

Fig. SAM-3-4 Spatial-time distribution of DO [mg l^{-1}].



E6 CHLOROPHYLL CONCENTRATION

Fig. SAM-3-5 Spatial-time distribution of Chlorophyll-a [$\mu g\ l^{-1}$].



E7 NITROGEN CONCENTRATION

§ Mean value of annual variation of NH_4-N [$\mu g\ l^{-1}$]: 10.
§ Mean value (range) of annual variation of NO_3-N [$\mu g\ l^{-1}$]: 10 (10-50).
§ Mean value of annual variation of NO_2-N [$\mu g\ l^{-1}$]: 10.

E8 PHOSPHORUS CONCENTRATION

§ Mean value (range) of annual variation of PO_4-P [$\mu g\ l^{-1}$]: 5 (5-47).
§ Mean value (range) of annual variation of Total-P [$\mu g\ l^{-1}$]: 10 (5-53).

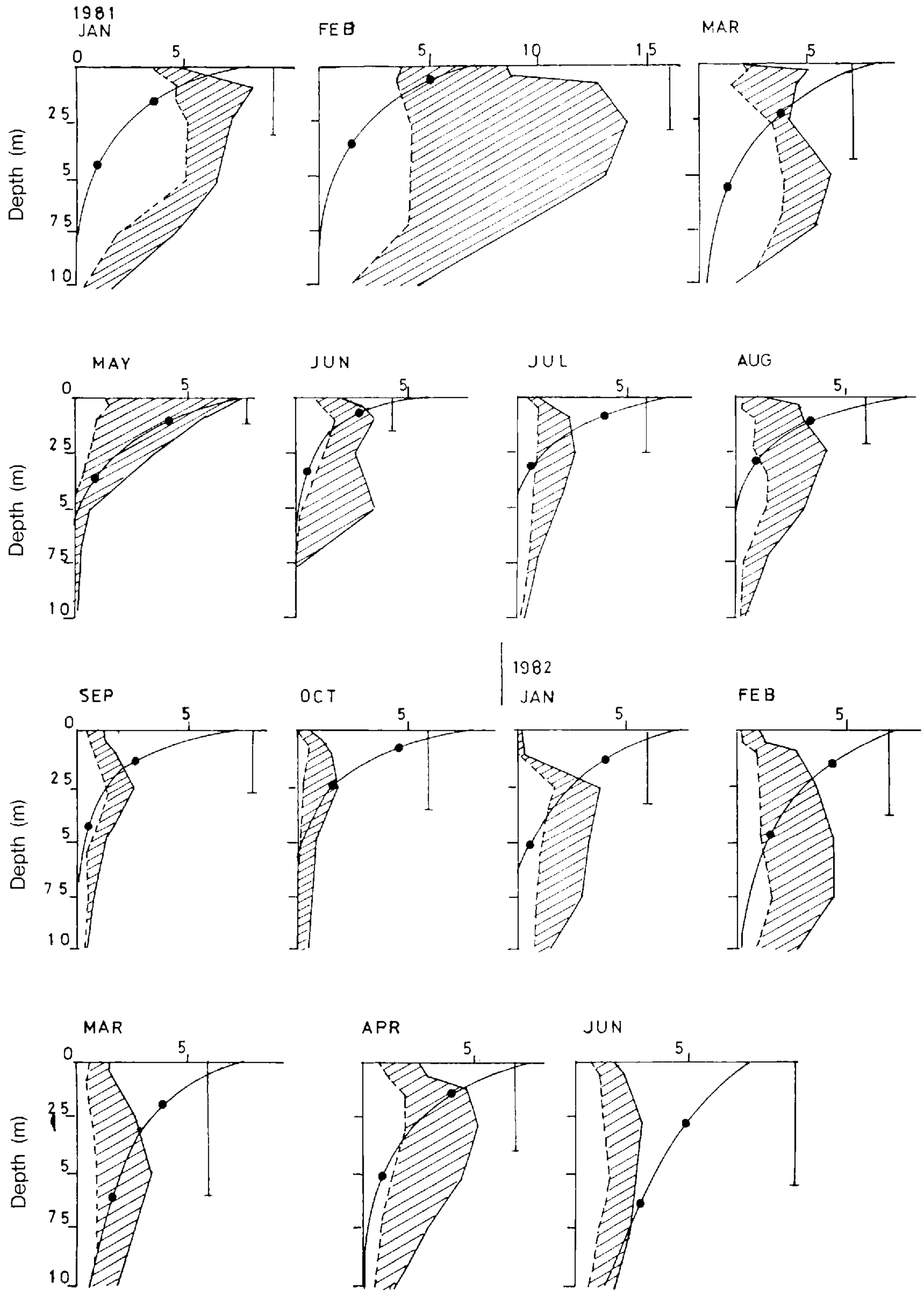
F. BIOLOGICAL FEATURES (Q)

F1 FLORA

§ Phytoplankton: *Anabaena circinalis, Pandorina morum, Eudorina elegans, Binuclearia eriensis, Cyclotella stelligera, Melosira italica, M. granulata, M. granulata* var. *angustissima* f. *spiralis, Dinobryon divergens, Gymnodinium* sp.

F3 PRIMARY PRODUCTION RATE

Fig. SAM-3-6 Vertical distribution of primary production [mg C m^{-3} h^{-1}]: ▨ total phytoplankton and [ ] below 25 μm fraction. (⊥) Secchi disc depth and (—•—) light extinction (the upper end of the curve corresponds to 100% of light intensity).



F4 BIOMASS

Fig SAM 3-7 Monthly fluctuation of phytoplankton density; (——) total cells, (•-•-) Bacillaryophyceae, (- x -) Chlorophyta and (······) Cyanophyta.

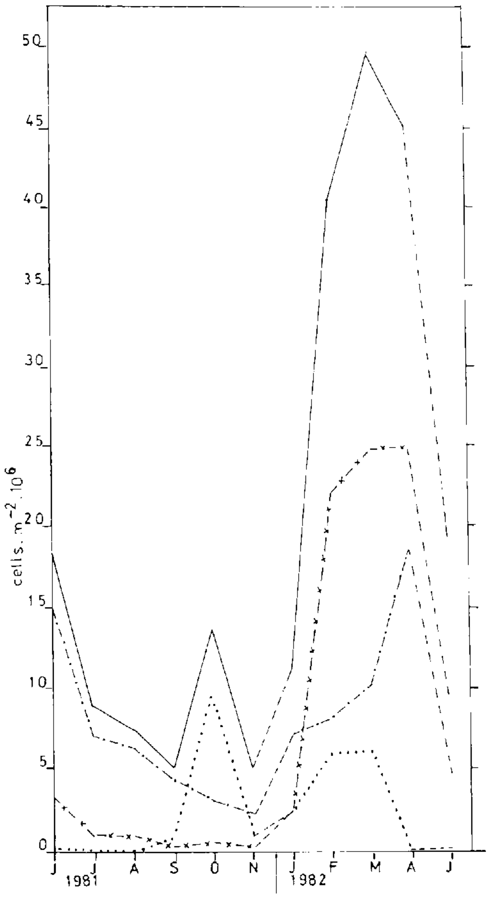
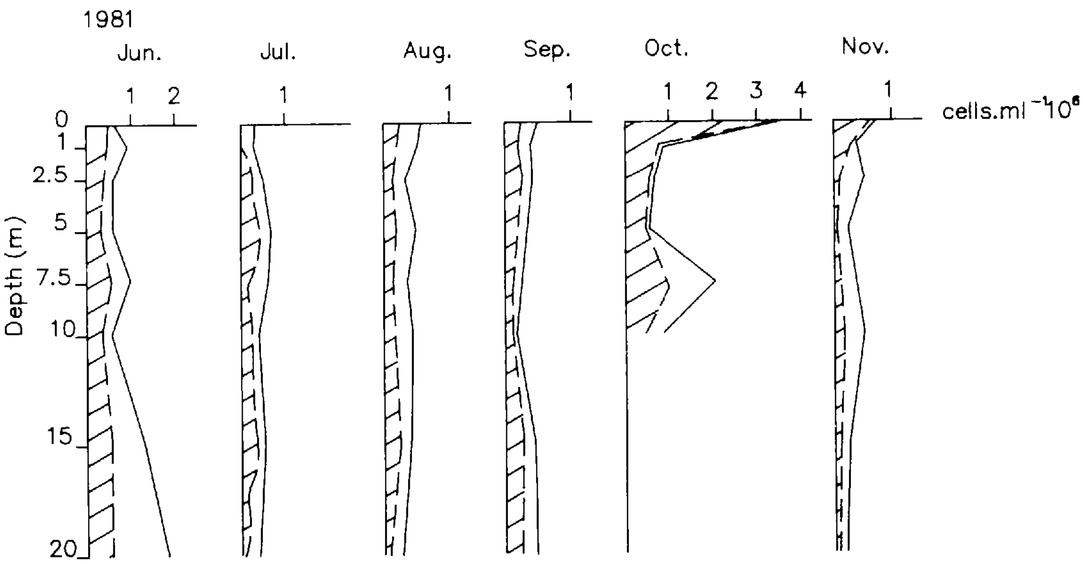
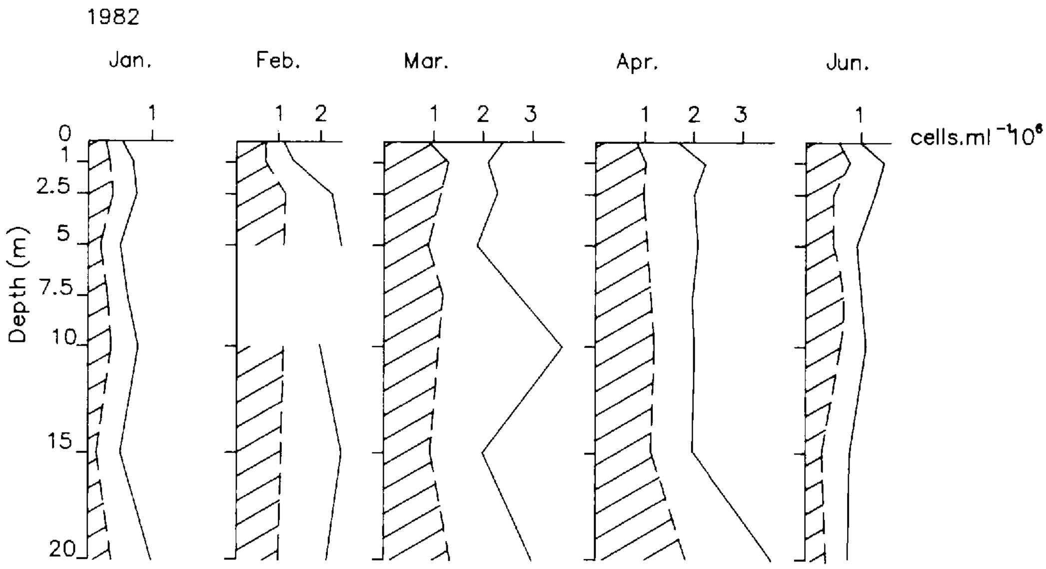


Fig. SAM-3-8 Vertical distribution of phytoplankton density; [ ] total and [////] dominant algal group.





G. SOCIO-ECONOMIC CONDITIONS

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (Q)

§ Secondary and tertiary industries : None.

§ Number of domestic animals in the catchment area : None.

G3 POPULATION IN THE CATCHMENT AREA (Q)

	Population	Population density [km^{-2}]	Main cities
Rural	2,000		None
Total	2,000	0.08	(One small villege)

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Sources of water, navigation and transportation, sightseeing and tourism, recreation (swimming and sport-fishing) and fisheries.

H2 THE LAKE AS WATER RESOURCES (1987)

	Use rate
Domestic water Irrigation Industrial water	Negligible
Power plant	1,200 MW

I. DETERIORATION OF LAKE ENVIRONMENTS AND HAZARDS

I1 ENHANCED SILTATION (Q)

§ Extent of damage : Not serious.

I2 TOXIC CONTAMINATION (Q)

§ Present status : Not detected.

I3 EUTROPHICATION (Q)

§ Nuisance caused by eutrophication : None.

Mean values and ranges of annual variation of nitrogen and phosphorus concentration in affluents [$\mu g\ l^{-1}$]

Affluent	Collon Cura River		Limay River (Alicura)		Limay River (Pantanito)	
	Average	Range	Average	Range	Average	Range
PO_4-P	5	—	5	—	5	
Total P	17	5-34	8	5-11	9	5-11
NO_3-N	10	—	10	—	10	—
NO_2-N	10	—	10	—	10	—
NH_4 N	10	—	10	—	10	—

I4 ACIDIFICATION (Q)

§ Extent of damage : None.

J. WASTEWATER TREATMENTS

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (b) No sources of significant pollution (Q).

J3 SANITARY FACILITIES AND SEWERAGE (Q)

§ Wastewater treatment systems : One small-scale domestic wastewater treatment plant.

K. IMPROVEMENT WORKS IN THE LAKE

None (Q).

L. DEVELOPMENT PLANS

None (Q).

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. A. Mariazzi, Facultad de Ciencias Naturales y Museo, Instituto de Limnologia, La Plata, Argentina.

LAGO TITICACA (LAKE TITICACA)

An inlet of Lago Pequeño with totora stands and totora boats

Photo: T. Kira

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A. LOCATION

§ Puno, Peru ; and La Paz, Bolivia.
§ 14°07′-17°08′S, 68°02′-71°06′W ; 3,812 m above sea level.

B. DESCRIPTION

Lake Titicaca is the largest freshwater lake in South America, located on the border between Peru and Bolivia between the two snowy mountain ranges of East and West Cordillera in the central Andes. The lake is 8,372 km^2 wide, including both the deep main basin (Lago Mayor) and the shallow sub-basin (Lago Pequeño), and its altitude (3,812m) is unrivalled among large lakes of this size class in the world.

The distribution of old coastal terraces indicates that a huge body of water reaching as far south as the Uyuni Depression once existed during an interglacial period of the Pleistocene, but the lake's size has been greatly reduced due to the increasing aridity of climate and the formation of an effluent stream. The water of Titicaca is now drained via the Rio Desaguadero into Lago Poopó, which, however, has no outlet to the sea.

The whole catchment area on the high plateau of Altiplano remains almost treeless, and is covered by coarse grasses with scattered fields of potato, barley, quinoa (*Chenopodium quinoa*) and the other local crops. The lake is fringed by a swampy zone of totora (*Scirpus tatora*), which is indispensable for the life of inhabitants on the shore, furnishing materials for the famous reed-boats and floating gardens where they grow potatoes.

The line between Puno (Peru) at the northwestern end of the lake and Guaqui (Bolivia) on the southwestern shore is an important shipping route for Bolivia, an inland country without seaside territory. Recent development of cities with manufacturing industry and a few sightseeing sites are going to affect the quality of the lake water to a certain extent.

C. PHYSICAL DIMENSIONS (Q. 3)

Surface area [km^2]	8,372
Volume [10^9m^3]	893
Maximum depth [m]	281
Mean depth [m]	107
Water level	Unregulated
Length of shoreline [km]	1,125
Residence time [yr]	1,343
Catchment area [km^2]	58,000

D. PHYSIOGRAPHIC FEATURES

D1 GEOGRAPHICAL

§ Sketch map (Fig. SAM-4-1).

§ Outflowing rivers and channels (number and names) : 1 (Desaguadero R.).

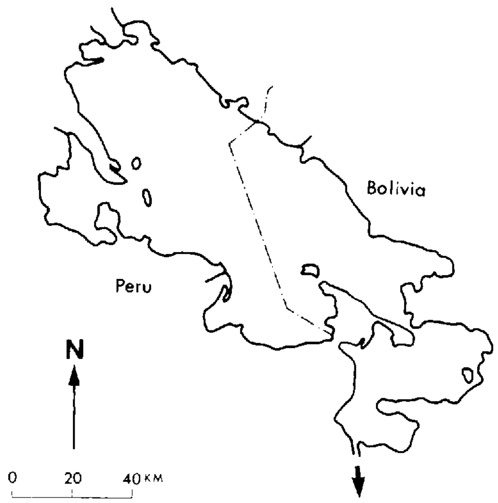
D2 CLIMATIC

§ Climatic data at Puno, 1973 (Q)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temp. [°C]	10.7	10.7	10.3	9.5	8.0	6.2	5.7	7.4	8.3	10.4	10.7	10.3	9.0
Precipitation [mm]	238	132	159	98	13	0	2	6	33	16	30	71	797

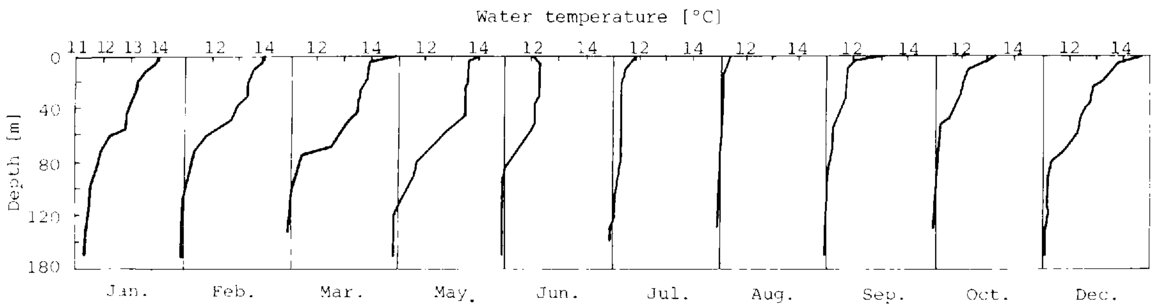
§ Number of hours of bright sunshine (Puno, 1973) : 3,034 hr yr^{-1}.

Fig. SAM-4-1 Sketch map of the lake (Q).



§ Water temperature

Fig. SAM-4-2 Seasonal trend of water temprature [°C] profile, 1975 (1).



§ Mixing type : Monomictic.

§ Notes on water mixing and thermocline formation : Thermal profiles in the lake show a thick epilimnion with relatively little difference between epilimnetic (16°C max.) and hypolimnetic (11.1°C) temperatures. There is a period of almost complete overturn in the dry season from July to September.

E. LAKE WATER QUALITY

E1 TRANSPARENCY [m], 1973 (Q)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.3	4.5	5.8	6.5	7.0	8.5	10.0	10.5	8.7	9.3	6.2	6.0

E2 pH

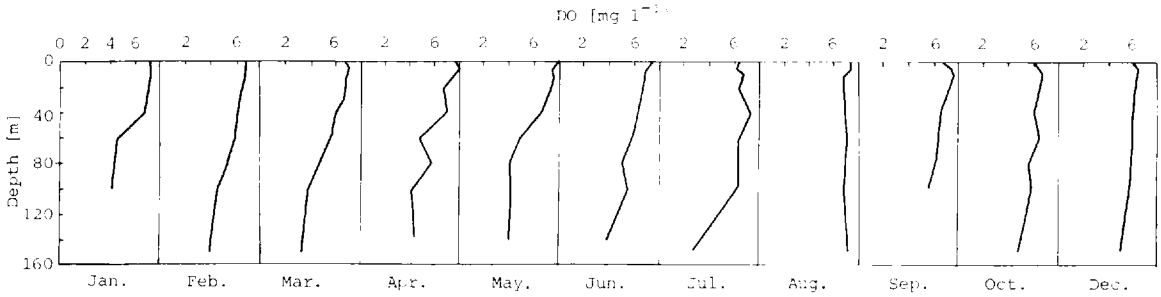
Surface water : 8.6 (annual mean) (Q).

E3 SS

780 mg l^{-1} (annual mean) (Q).

E4 DO

Fig. SAM-4-3 Seasonal and vertical distribution of DO [mg l^{-1}], 1975 (1).



E7 NITROGEN CONCENTRATION

§ NO_3-N [mg l^{-1}], 1973 (2)

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-30	.060	.060	.065	.110	.120	.165	.240	.130	.105	.070	.115	.105
>30	.060	.085	.095	.190	.190	.130	.240	.120	.105	.060	.125	.120

E8 PHOSPHORUS CONCENTRATION

§ PO_4-P [mg l^{-1}], 1973

Depth [m]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-30	.023	.016	.017	.013	.013	.016	.020	—	.023	.016	.009	.007
>30	.065	.038	.049	.029	.044	.046	.027	—	.039	.028	.016	.025

F. BIOLOGICAL FEATURES

F1 FLORA (Q)

§ Emerged macrophytes : *Scrirpus tatora, Hydrocotyle* sp., *Lilaeopsis* sp.

§ Floating macrophytes : *Lemna* sp., *Azolla* sp.

§ Submerged macrophytes : *Myriophyllum elatinoides, Chara* sp., *Elodea potamogeton, Nitella clavata, Potamogeton strictus, Ruppia filifolia.*

§ Phytoplankton : *Lyngbya vacuolifera, Anabaena sphaerica, Nodularia harveyaba, Ulothrix subtilissima, Oocystis borgei, Ankistrodesmus falcatus, Selenastrum minutum, Cyclotella stelligera.*

F2 FAUNA

§ Zooplankton : Copepoda (*Boeckella titicacae, Microcyclops leptopus*), Cladocera (*Bosmina hagmanni*), Rotifera (*Asplanchna* sp.) (Q).

§ Benthos : *Taphius* spp., *Littoridina* spp. (3).
§ Fish : *Orestias agassii, O. luteus, O. pentlandii, Trichomycterus rivulatus, Salmo gairdnerii, Basilichthys bonariensis* (Q).

F3 PRIMARY PRODUCTION RATE [g C $m^{-2}day^{-1}$], 1973 (2)

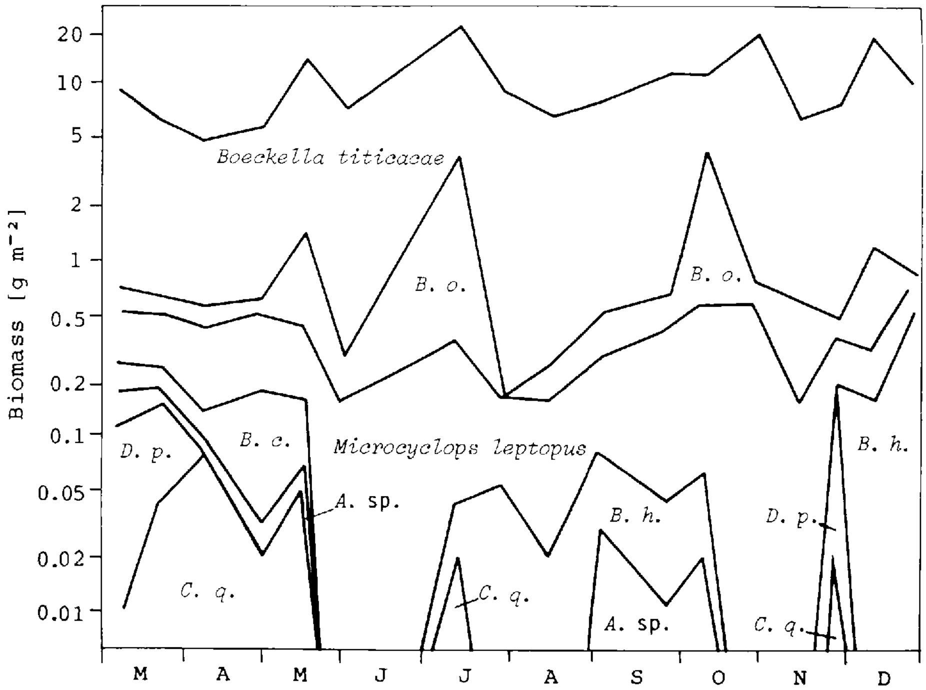
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
1.35	1.11	1.25	1.17	1.47	1.64	1.48	2.01	1.20	0.74	1.28	2.79	1.46

F4 BIOMASS

§ Phytoplankton biomass [mg C m^{-3}], 1973

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
17.4	58.5	29.4	23.5	30.9	30.9	28.1	29.3	16.7	13.5	13.2	28.0	26.8

Fig. SAM-4-4 Zooplankton biomass [g m^{-2}], 1973 (1).



B. o.: *Boeckella occidentalis*, B. h.: *Bosmina hagmanni*,
A. sp.: *Asplanchna* sp., D. p.: *Daphnia pulex*,
C. q.: *Ceriodaphnia quadrangula*.

F5 FISHERY PRODUCTS

§ Annual fish catch in 1980 : 6,327 [metric tons].

G. SOCIO-ECONOMIC CONDITIONS (Peru only)

G1 LAND USE IN THE CATCHMENT AREA (1983)

	Area [km^2]	[%]
Natural landscape		
Woody vegetation	25	0.0
Herbaceous vegetation	36,375	74.8
Swamp	210	0.4
Others	4,120	8.5
Agricultural land	2,500	5.2
Settlement area	10	0.0
Others	5,380	11.1
Total	48,620	100.0

§ Main types of woody vegetation: *Budelia ccolli, Polylepis incana.*

§ Main types of herbaceous vegetation: *Festuca dolichopylla, Muhlenbergia fastigiata, Carex* sp., *Calamagrostis heterophylla, C. curvila.*

§ Main species of swamp vegitation: *Juncus* sp., *Scirpus* sp.

§ Main kinds of crops: Barley, potato and quinoa.

G2 INDUSTRIES IN THE CATCHMENT AREA AND THE LAKE (1981) (Q)

	Gross product during the year [$\times 10^6$ Soles]	No. of persons engaged	No. of establishments
Primary industry			
Agriculture	1,809	3,200	31
Fisheries	21	180	9
Secondary industry			
Manufacturing	1,027	869	22
Mining	425	231	10
Tertiary industry	N.A.	425	37

* Main agricultural products: Barley, potato and livestock (sheep, alpaca, llama).

G3 POPULATION IN THE CATCHMENT AREA (1981) (Q)

Population	Population density [km^{-2}]	Main cities (population)
890,300	12.3	Juliaca (200,000), Puno Ilave, Ayaviri.

H. LAKE UTILIZATION

H1 LAKE UTILIZATION (Q)

Source of water, fisheries, navigation, tourism and recreation (sport-fishing).

H2 THE LAKE AS WATER RESOURCE (1982) (Q)

	Use rate [$m^3 sec^{-1}$]
Domestic	0.40
Irrigation	0.25
Breeding	0.29
Industrial	0.004
Mining	0.03
Power plant	0.40

J. WASTEWATER TREATMENTS (Peru only)

J1 GENERATION OF POLLUTANTS IN THE CATCHMENT AREA : (f) Limited pollution without wastewater treatment.

J3 SANITARY FACILITIES AND SEWERAGE (Q)

§ Municipal sewerage system : Not present.

M. LEGISLATIVE AND INSTITUTIONAL MEASURES FOR UPGRADING LAKE ENVIRONMENTS

M1 NATIONAL AND LOCAL LAWS CONCERNED (Peru) (Q)

§ Names of the laws (the year of legislation)

(1) Water Code (Law No. 17752) (1969)

§ Responsible authorities

(1) Ministry of Health (water quality) and Ministry of Agriculture (water managements)

N. SOURCES OF DATA

(Q) Questionnaire filled by Dr. José Vera Rivas Plata, the Peruvian Sea Institute, Callao.

(1) Hanek, G. (ed.) (1982) La Pesqueria en el Lago Titicaca (Peru), Presente y Futuro. Proyecto FAO-PER/76/022.

(2) Richerson, P., Widmer, C. & Kittel, T. (1977) The Limnology of Lake Titicaca (Peru-Bolivia), a Large High Altitude Tropical Lake. 79 pp. Univ. Calif. Davis.

(3) Serruya, C. & Pollingher, U. (1983) Lakes of the Warm Belt. 569 pp. Cambridge University Press, London.