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mediterranean action plan

Long-term Programme for Pollution Monitoring and Research in the Mediterranean Sea (MED POL - PHASE II)

ASSESSMENT OF THE PRESENT STATE OF POLLUTION BY MERCURY IN THE MEDITERRANEAN SEA AND PROPOSED CONTROL MEASURES

In co-operation with:

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
WORLD HEALTH ORGANIZATION

CONTENTS

INTRODUCTION

1. One of the primary aims of the Coordinated Mediterranean Pollution Monitoring and Research Progamme (MED POL Phase I), launched in 1975 following its adoption by the Coastal States of the region as the scientific component of the Mediterranean Action Plan at the Intergovernmental Meeting on the Protection of the Mediterranean Sea (Barcelona, 28 January - 4 February 1975), was to compile the maximum possible amount of data on the quality of the Mediterranean marine environment. Within this framework, the pilot project on baseline studies and monitoring of metals, particularly mercury and cadmium, in marine organisms (MED II), jointly coordinated by FAO and UNEP and implemented from 1975 to 1980, was designed to commence investigations on the concentrations of these metals in selected marine organisms on a regional basis. The eventual evaluation of data collected was also designed to provide an input on which to base the formulation of selected environmental quality criteria applicable to the Mediterranean Sea.

2. In keeping with this principle on general lines, the Intergovernmental Review Meeting of Mediterranean Coastal States and the First Meeting of the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against Pollution and its related protocols (Geneva, 5-10 February 1979) recommended (UNEP, 1979) that:

> "Work should be continued on the development of the scientific rationale for the criteria applicable to the quality of recreational waters, shellfish-growing waters used for aquaculture, and seafood. Based on this rationale and taking into account existing agreements, the criteria should be formulated on a scientific basis and submitted to the Governments and the EEC for their consideration".

3. Furthermore, the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources, adopted at the Conference of Plenipotentiaries of the Coastal States of the Mediterranean region for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources (Athens, 12-17 May 1980) stipulates (UNEP, 1980) that:

> "1. The Parties shall progressively formulate and adopt, in cooperation with the competent international organizations, common guidelines and, as appropriate, standards or criteria dealing in particular with:
>
> ....
>
> (c) the quality of seawater used for specific purposes that is necessary for the protection of human health, living resources and ecosystems;
>
> ....
>
> 2. Without prejudice to the provisions of article 5 of this Protocol, such common guidelines, standards or criteria shall take into account local ecological, geographical and physical characteristics, the economic capacity of the Parties and their need for development, the level of existing pollution and the real absorptive capacity of the marine environment".

4. The Bureau of the Contracting Parties, at its first meeting in Geneva on 26 and 27 June 1979, also considered the matter and urged the Secretariat to develop environmental quality criteria for bathing waters and for mercury in seafood. Following this recommendation, interagency consultations were held in November/December 1979 on the design and implementation of a cooperation programme on health-related aspects of mercury levels in edible marine organisms. The problem of mercury was also comprehensively reviewed by WHO in a consultation meeting to re-examine the environmental health criteria for mercury, held in Geneva from 21 to 25 April 1980 (WHO, 1980). The UNEP/FAO/WHO Meeting of Experts on Environmental Quality Criteria for Mercury in Mediterranean Seafood, held in Geneva from 3 to 8 November 1980 (UNEP, 1980), was also convened, in particular, to evaluate the hazards related to the intake of mercury from seafood by populations in the Mediterranean region and to develop recommendations on desirable environmental quality criteria for mercury in Mediterranean seafood. The detailed findings and recommendations of these meetings are contained in the appropriate sections of this document.

5. During the course of MED POL Phase I, tentative environmental quality criteria for a selected number of parameters, including mercury in edible seafood, were proposed on an interim basis (UNEP, 1981), pending the acquisition of more data on the situation regarding mercury concentrations in seafood, and, perhaps more important, the performance of epidemiological studies to correlate seafood quality with health effects.

6. In this context, the Second Meeting of the Contracting Parties, held in Cannes from 2 to 7 March 1981, approved the Long-term Programme for Pollution Monitoring and Research in the Mediterranean Sea (MED POL Phase II), including, under research and study topics, "Epidemiological studies related to the confirmation (or possible revision) of the proposed environmental quality criteria (standards of use) for bathing waters, shellfish-growing waters and edible marine organisms" as well as "Biogeochemical cycles of specific pollutants, particularly those relevant to human health" (including mercury) and "Development of sampling and analytical techniques for monitoring the sources and levels of pollutants" (UNEP, 1981).

7. Within the framework of these activities, and as a natural continuation of the earlier studies, including the results and recommendations of the various expert meetings mentioned above, WHO, in cooperation with FAO and UNEP, developed a project on "Methylmercury in Mediterranean populations and related health hazards" as part of the appropriate activity within the research component of MED POL Phase II. This project was finalized at a consultation meeting held in Athens from 13 to 17 September 1982 (WHO/UNEP, 1982), and is currently entering its initial operational phase.

8. The scope of this document is to make a preliminary assessment of mercury in the Mediterranean Sea based on results obtained during the course of MED POL II, to outline the scientific rationale for criteria applicable to mercury in Mediterranean seafood based on the latest information available, both in general and within the region, and to propose measures for adoption by the Contracting Parties at their next meeting.

ASSESSMENT OF MERCURY IN THE MEDITERRANEAN SEA

Introduction

9. Research carried out in the early 1970s in the Mediterranean region showed abnormally high concentrations of mercury in fish such as tuna (Thibaud, 1971; Cumont et al., 1972). Increased public concern about mercury led to this metal being given high priority within the framework of the Pilot Phase of MED POL. In fact, a large proportion of the work undertaken in Pilot Project MED POL II (Baseline studies and monitoring of metals, particularly mercury and cadmium, in marine organisms) jointly coordinated by FAO and UNEP, was related to mercury.

10. During the course of this pilot project (1975-1981), a considerable amount of data on mercury levels in the flesh of various species of fish, molluscs and crustaceans was compiled.

11. The present assessment of mercury levels in the Mediterranean is mainly based on such data, as well as on other data submitted in ICSEM/UNEP workshops on the pollution of the Mediterranean, and reported in other scientific publications.

Sources and inputs of mercury in the Mediterranean

12. Mercury is a natural constituent of the earth's continental and oceanic crust. It occurs in relatively high concentrations in zinc and copper sulphide ores, in shales and clays that are rich in organic matter, in phosphorites and in coal (Fleischer, 1973). Mercury enters the marine environment through rivers due to continental weathering and through the atmosphere due to the earth's degassing. (Gavis & Ferguson, 1972; Working Group on Mercury in Fish, 1979.)

13. Mining and industrial activities have significantly increased the flow of mercury into the marine environment. Mercury is widely used in industrial processes, notably the electrolytic production of chlorine and caustic soda in chlor-alkali plants, in the production of electrical equipment, paints and paper (Gavis & Ferguson, 1972; Peakall & Lovett, 1972).

14. The Mediterranean basin is an area rich in mercury deposits. Deposits of cinnabar (HgS) and metallic mercury occur in Algeria, Italy, Spain, Turkey and Yugoslavia (Figure 1). Active mining sites in the Mediterranean account for about 50% of the world's production (Gavis & Ferguson, 1972; Renzoni et al., 1978).

15. In view of the special geology with regard to mercury in the area, the question of anthropogenic versus natural sources of mercury for the Mediterranean becomes very complex. In addition to industrial activities and mining, the flux of mercury from the bedrock to water and air have been influenced by all the processes that affect weathering, erosion and hydrologic regime. Thus also preindustrial cultures are likely to have had their influence on the flux of mercury from land to sea.

16. The joint ECE/UNIDO/FAO/UNESCO/WHO/IAEA/UNEP Project (MED POL X) assessed the inputs of mercury from land-based sources and the results are summarized in Table 1 (UNEP, 1979).

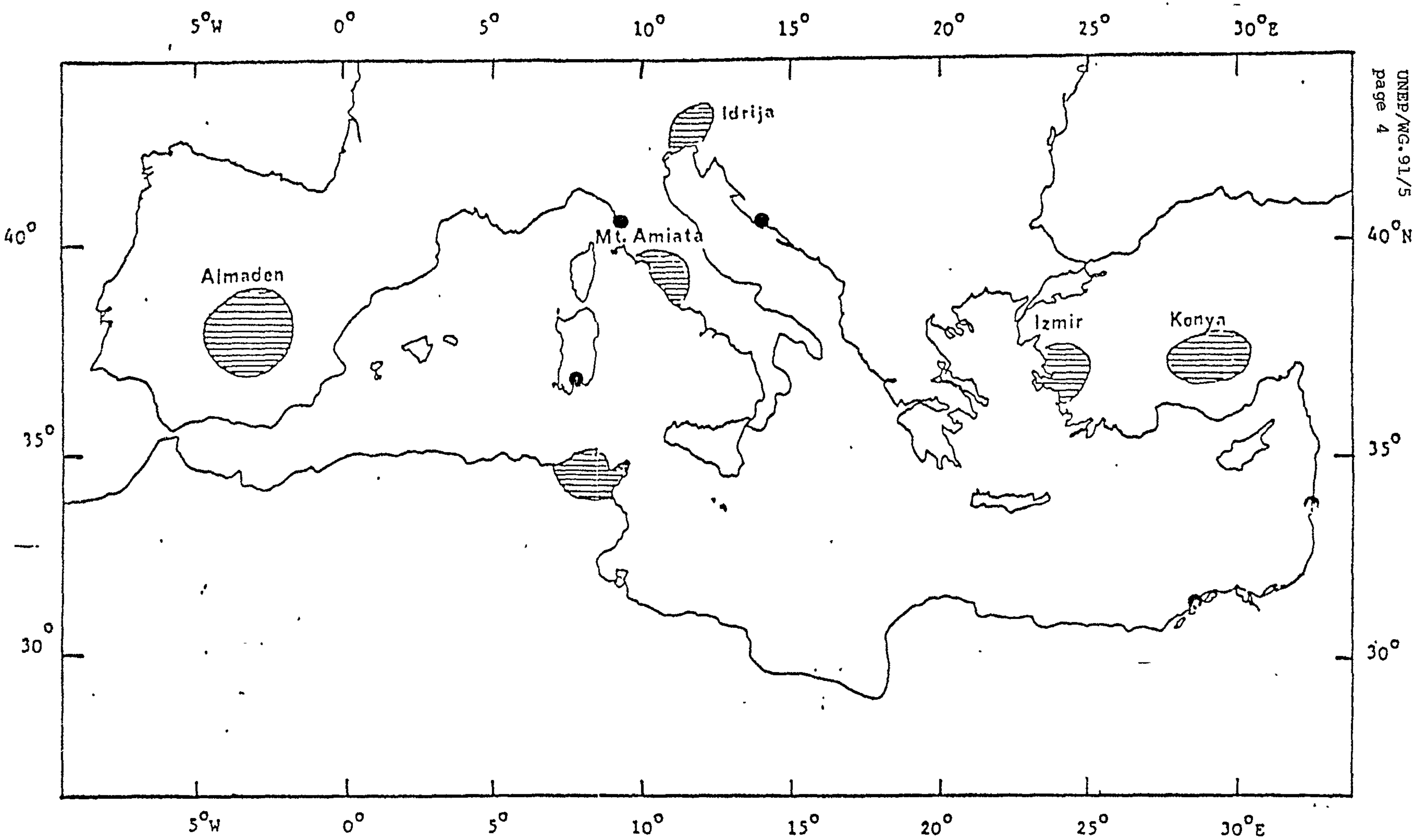


Figure 1. Location of mercury mining activities (▤) and chloralkali plants (●) in the Mediterranean region

Table 1

Sources and inputs of mercury in the Mediterranean

Region	Originating in coastal zone				Carried by rivers		Total
	Domestic		Industrial				
	t/a	%	t/a	%	t/a	%	t/a
I	0.04	2	0.60	24	1.8	74	2.5
II	0.28	1	2.7	8	30	91	33
III	0.04	1	0.20	7	2.5	92	2.7
IV	0.12	1	1.1	10	9.5	89	10.7
V	0.084	0 Appr.	0.540	1	40	99	41
VI	0.026	0 "	0.16	2	9.6	98	9.8
VII	0.032	2	0.16	9	1.5	88	1.7
VIII	0.054	0 Appr.	0.22	2	14	98	14.3
IX	0.01	0 "	0.05	1	7	99	7.1
X	0.074	1	1.2	17	5.6	82	6.9
TOTAL	0.76	0.6	6.9	5.4	122*	94	129.7

* Of this figure, 32 tons are considered as "background"

(UNEP, 1979)

Note: see also Figure 3

17. According to this study, the most important input of mercury to the Mediterranean occurs through rivers. A total of 122 tons was estimated to come via this route annually, out of which 90 tons originated from industrial and mining activities. The remaining 32 tons was termed "background" but include man's indirect effects on mercury mobilization from bedrock and soil and diffuse sources such as inland municipalities. Coastal sources are responsible for only about 6% of the total mercury transported into the Mediterranean. However, data used for the estimation of industrial mercury discharges were limited. In the Mediterranean area, several chlor-alkali plants are operating (Figure 1) and some could be responsible for mercury inputs of high local significance.

18. The question of exchange of mercury between the marine environment and the atmosphere has been the subject of debate over the years. Atmospheric transport of mercury has been reported to be an important source in the marine environment (Windom & Taylor, 1979). In the Paris Convention Area, it was estimated that atmospheric input of mercury was around 5.6% (Convention for the Prevention of Marine Pollution from Land-Based Sources, 1981). More recent analytical data and computations have indicated that globally the sea is a source rather than a sink of atmospheric mercury.

19. However, in view of the enclosed nature of the Mediterranean and the geology of the surrounding land, the Mediterranean may not be representative of the sea globally with regard to the mercury flux to or from the atmosphere. Thus there is a special need for estimating the flux in this area (WMO, 1982).

20. Besides river and possibly atmospheric input, dumping of waste is an important route for mercury to the marine environment. Within the Paris Convention area, waste dumping has been estimated to account for 35% of the mercury flux to the sea (Convention for the Prevention of Marine Pollution from Land-Based Sources, 1981).

Fate of mercury in the environment

21. Mercury enters the marine environment in a variety of physico-chemical forms such as mercury sulphide, metallic mercury, organomercurials, or bound to inorganic and organic suspended matter. In the marine environment, mercury can undergo a variety of physico-chemical reactions including sedimentation, absorption on particulate matter, oxidation-reduction and methylation. These reactions have been reviewed by several authors (Gavis & Ferguson, 1972; Jensen & Jernelov, 1972; Keckes & Miettinen, 1972; Peakall & Lovett, 1972; WHO, 1976).

22. Mercury is readily absorbed on inorganic or organic particulate matter in the sea. It is thus associated with sedimentating particulate matter and is transferred to the sediments where, if anaerobic conditions exist, it is transformed into mercury sulphide. Another important reaction of mercury in the marine environment is biomethylation. Divalent mercury can be methylated by certain bacteria in marine sediments to methyl and dimethyl mercury. These reactions have been studied extensively, both in laboratory experiments and in the field (Jensen & Jernelov, 1972; WHO, 1976).

23. Marine organisms can take up mercury directly from seawater, from food and from sediments.

24. Different forms of mercury have different properties with regard to bioaccumulation and toxicity. Methylmercury, which is very efficiently absorbed through biological membranes, is strongly bound to sulphydryl groups and excreted very slowly - if at all. Methylmercury is also the most toxic form of mercury, but it constitutes a very small fraction of the total mercury in the marine system. The most abundant form is inorganic divalent mercury that may be bound or complexed to a number of ligands. It is absorbed by or adsorbed on organisms but excreted with a half-life of days or weeks by higher organisms such as fish, birds and mammals.

25. Depending on the mode of accumulation and excretory capacity, the relative amount of methylmercury as compared to total mercury will vary from virtually 100% in marine predatory fish or in the feathers of marine birds to a small percentage in phytoplankton and most molluscs.

26. The question of the relative importance of uptake of mercury directly from water and from food for the resulting body burden depends on a number of factors. One obviously very important factor is the concentration of methylmercury (as distinct from total mercury) in water and in food. Available data are scarce and conclusions thus uncertain. As a generalized statement it can be said that the higher the trophic level, the more important is the uptake from food. For the overall food chain however, uptake from water is the key process (WHO, 1976). When comparing mercury levels in different fish species or populations, other factors besides trophic level and methylmercury concentration in prey organisms also become important. Age as well as growth-rate and food conversion efficiency and other metabolism-dependent factors are of general relevance. When tuna and swordfish are compared with most other fish species, dry content of the fresh fish muscle also becomes important.

27. As a consumer of fish and shellfish, man is at the upper level of the food-chain, taking up mercury from contaminated produce.

28. A generalized scheme for the circulation of Hg in the marine environment is presented in Figure 2 (UNEP, 1978).

Levels of mercury in the Mediterranean

(a) Seawater (dissolved and particulate matter)

29. The interpretation of mercury concentrations in seawater needs extreme caution due to the sampling and analytical problems encountered when determining this element at the µg/l level. Serious contamination can occur during sampling, storage, preconcentration and analysis. Loss of mercury during storage has also been reported (Coyne & Collins, 1972; Zief & Mitchell, 1976). Different preconcentrations and analytical techniques will determine different physico-chemical forms: total, particulate, dissolved and labile. A further complication in interpreting mercury concentrations in seawater is the time and space variability caused by the mixing of different seawater masses, and transport and dilution processes.

30. Mercury concentrations in Mediterranean seawater have been reviewed in UNEP's Preliminary Report on the State of Pollution in the Mediterranean Sea (UNEP, 1978). These results, as well as additional data reported since, are summarized by region in Tables 2 and 3. (See also Figure 3.)

Figure 2

Generalized scheme of inputs and fates of mercury in the marine environment

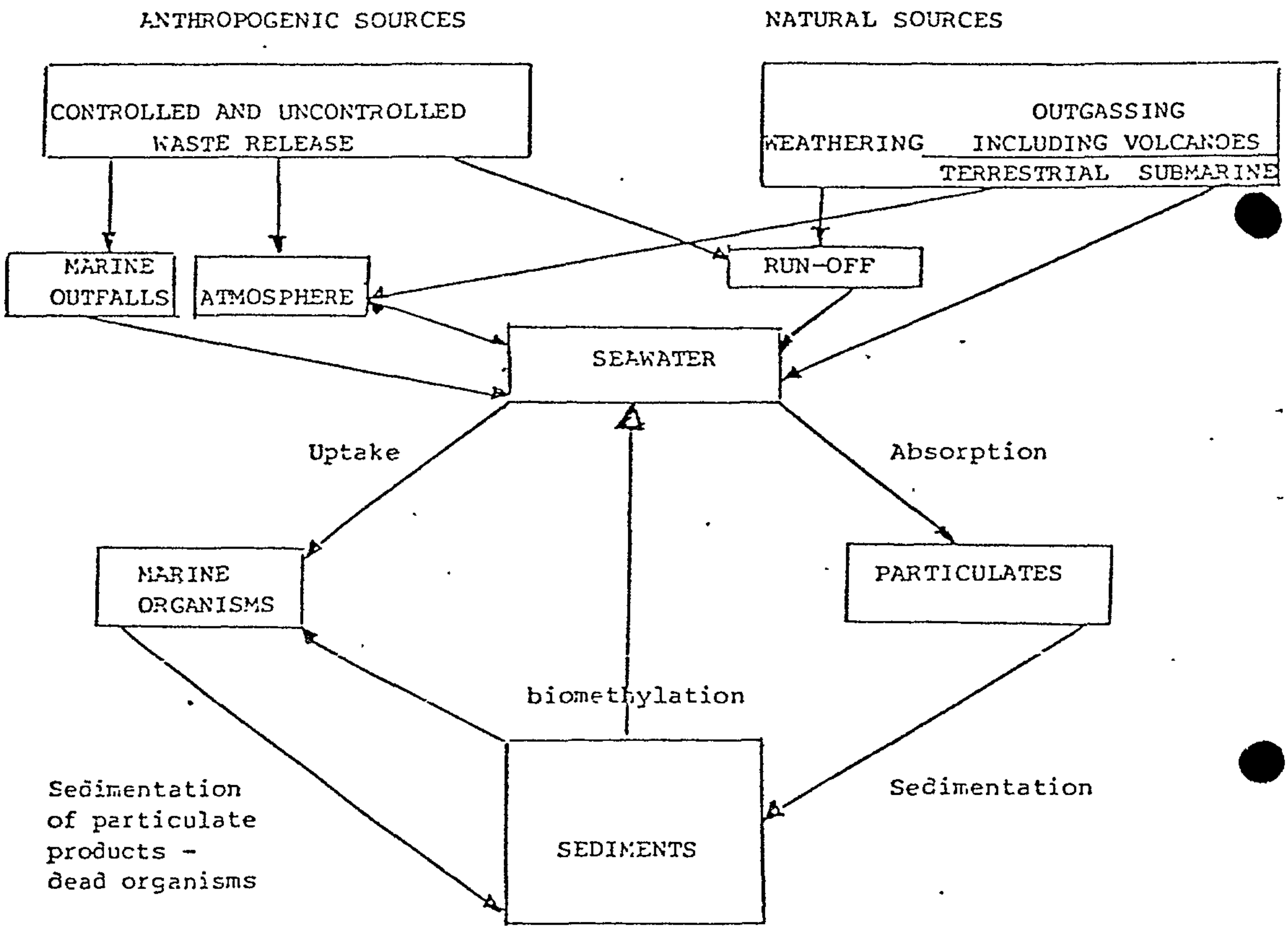


Table 2

Mercury concentrations in open waters of the Mediterranean

Region	Physico-chemical form	Concentration µg/l	Reference
I	Total	0.11 (0.062-0.17)	Robertson *et al.*, 1972
II	Particulate	0.0013	Buat-Menard *et al.*, 1980
	Dissolved	0.020 (0.008-0.032)	
III	Dissolved	0.014 (0.005-0.30)	Huynh-Ngoc & Fukai, 1978
IV	Dissolved	0.026 (0.010-0.040)	" "
VI-VII	Dissolved	0.030 (0.005-0.080)	" "
VIII	Dissolved	0.040 (0.015-0.080)	" "
X	Dissolved	0.016 (0.012-0.020)	" "
	Total	0.12 (0.09-0.14)	Robertson *et al.*, 1972

Table 3

Mercury concentrations in coastal waters of the Mediterranean

Region	Area	Physico-chemical form	Concentration µg/l	Reference
II	Rhone Delta	Dissolved	0.010-0.19	Martin *et al.*, 1978
	Ligurian Coast	Total	0.012-0.26	Breder *et al.*, 1980
	Coasts of Tuscany and Rosignano (close to chlor-alkali plant)		0.02 0.18	Renzoni *et al.*, 1973
	Cecina	Dissolved Total	0.012-0.031 0.032-0.061	Breder *et al.*, 1980
V	NW Adriatic	Particulate	1-7	Granzini *et al.*, 1975
	Istrian Coast	Total	0.04	Strohal & Dzajo, 1975
	Adriatic	Total	0.07	Kosta *et al.*, 1978
	Gulf of Trieste	Dissolved	0.073-0.17	Majori *et al.*, 1978
VIII	Saronikos Gulf (close to sewage outfall)	Total	0.15-0.60	Zafiropoulos, 1982
X	Israel	Dissolved (Labile)	0.06 (0.01-0.18)	Roth & Hornung, 1975
Mediterranean coasts			0.02-0.55	Aubert, 1980

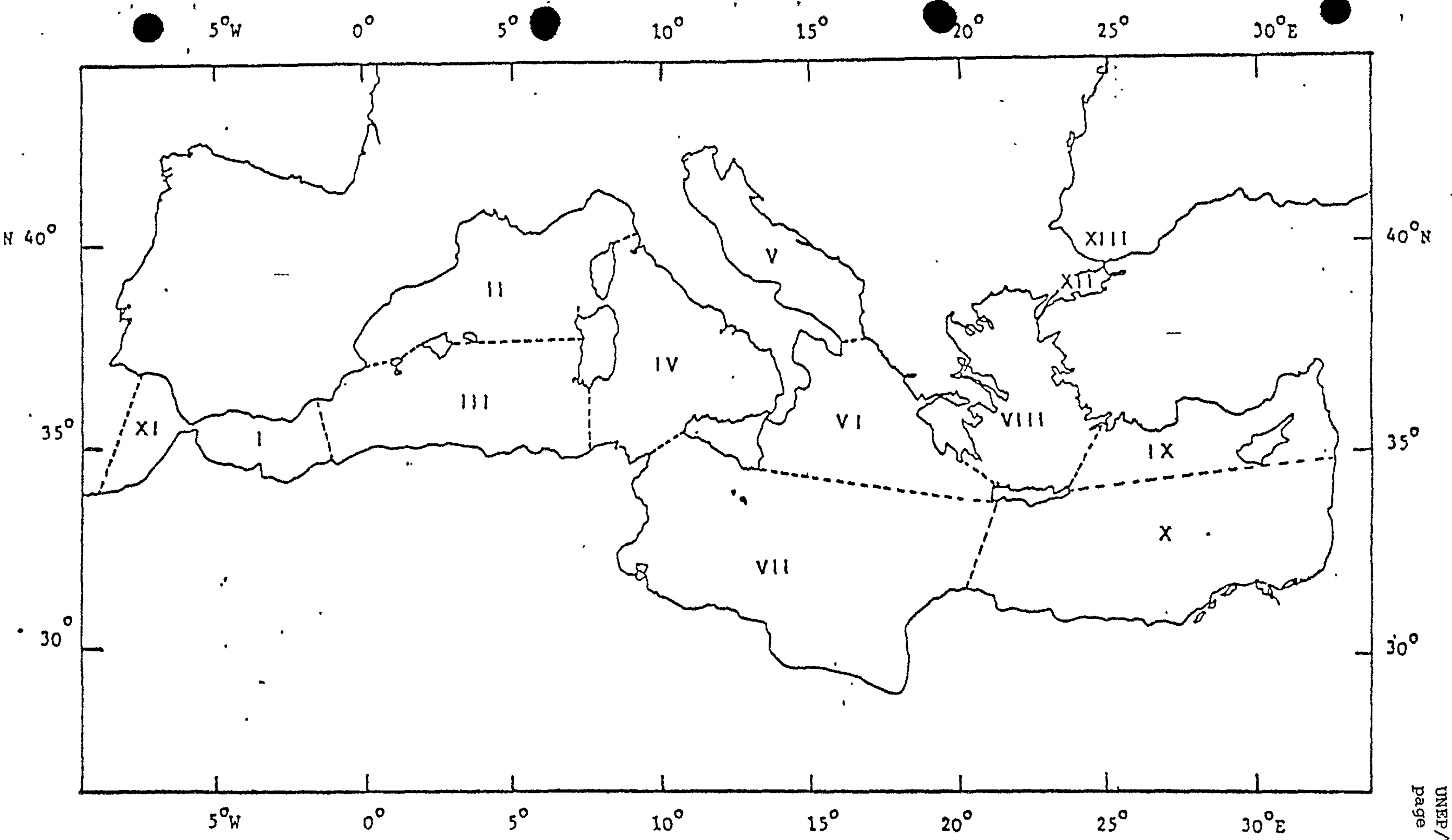


Figure 3. Regional divisions of the Mediterranean Sea in Pilot Project MED POL II

31. Considering the above-mentioned need for caution in the interpretation of analytical data for seawater, it cannot be concluded that Mediterranean open waters have significantly higher concentrations of mercury than other open oceans, although there appears to be a slight tendency in that direction. As demonstrated in a recent mathematical model calculation (Bernhard, 1983), the difference required in water concentration to explain the different mercury concentrations in Atlantic and Mediterranean tuna (Renzoni et al., 1978) is so small that it would be impossible to detect it with existing accuracy in sampling and analysis.

32. In coastal waters the recorded mercury levels are significantly higher than those in the open Mediterranean. In several local areas, mercury levels are one order of magnitude or more higher than in areas without local mercury sources.

33. There is a need for more data on mercury concentrations in both coastal and open Mediterranean waters. These data, in order to be comparable, have to be a result of standardized sampling, storage and intercalibrated analytical techniques. Even then, for the interpretation of mercury concentrations, oceanographic data on the different Mediterranean water masses and circulation patterns will be needed. Information on the physico-chemical forms of mercury, especially particulate and dissolved, methylated and inorganic, will be of great importance in assessing the overall mercury problem.

(b) Sediments

34. Marine sediments have been considered as the ultimate sink for toxic elements. However, recent work has shown that mercury can be mobilized even from anoxic sediments to the water column (Bothner et al., 1980). The concentration of mercury in sediments depends on factors such as mineralogic and cocciometric characteristics of the sediment, organic carbon content, sedimentation rate and remobilization rate of mercury to the water column (Phillips, 1977).

35. The determination of mercury in sediment samples usually involves the extraction of mercury from the sample. Different combinations of acids or different extraction techniques yield results that are not always comparable.

36. Concentrations of mercury in Mediterranean sediments were reviewed in UNEP's Preliminary Report on the State of Pollution of the Mediterranean Sea (UNEP, 1978). In addition, a considerable amount of monitoring of mercury in coastal sediments in areas receiving industrial or domestic sewage has been done in recent years. Data are summarized in Table 4.

37. Another important factor to take into account is the fraction of the sediment analysed. Very little information is usually reported by authors.

38. In the limited data available for mercury concentrations in deep-sea sediments from the Mediterranean and open oceans there seems to be somewhat of a tendency to higher values in the Mediterranean. Given the uncertainties, however, this increase for the Mediterranean compared to oceanic values cannot be termed statistically significant.

Table 4

Mercury concentrations in sediments of the Mediterranean

	Region	Extraction method	Concentration µg/g dry weight	Reference
I	Alboran Sea	Total	0.26 (mean)	Robertson et al., 1972
II	Ligurian coasts	HNO_3,HCI	0.16-5.4	Breder et al., 1980
	Ebro delta	conc. HNO_3	0.065-1.1	Obiols & Peiro, 1980
	Area of Marseille	HNO_3	0.07-21	Arnoux et al., 1980a 1980b, 1980c
	Bay of Cannes	HNO_3,HPO_4 fraction 63 µ	0.1-0.4	Ringot, 1982
	Gulf of Nice	HNO_3,$HClO_4$	0.01-0.16	Flatau et al., 1982
	Catalan coasts	conc. HNO_3	0.2-1.0	Peiro et al., 1980
III	Santa Gilla lagoon, Cagliari	HSO_4,HNO_3	0.7-37	Sarritzu et al., 1982
IV	Tyrrhenian Sea	-	0.05-0.24	Selli et al., 1973
	Tuscany Coast	-		
	near Solvay plant		1.1-1.3	Renzoni et al., 1973
	4 km S and N		0.1-0.8	
	10 km S and N		0.04-0.1	
V	Gulf of Trieste (close to cinnabar mine)	-	1.4-14.8 19.4	Majori et al., 1978
	Gulf of Venice	H_2SO_4	0.15-3.0	Donazzolo et al., 1978 Angela et al., 1980
	Kastela Bay Dalmatia (chlor-alkali plant)	Total	8.5	Stegnar et al., 1980
	Adriatic Sea	Total	0.07-0.97	Robertson et al., 1972
VIII	Evoikos Gulf Aegean Sea	0.5 HCl fraction 55 µ	0.3-0.8	Angelidis et al., 1980
	Saronikos Gulf, Athens	Total	0.5-1	Grimenis et al., 1976
	Athens outfall	Total	0.5-3	Papakostidis et al., 1975
IX	Coasts of Turkey	HNO_3	0.019-048	Tuncel et al., 1980
X	Region of Alex-andria (close to chlor-alkali plant)	conc. HNO_3	0.8 9 - 15	Elsokkary, 1978 El Sayed & Halim, 1978
	Haifa Bay	HNO_3 fraction 250 µ	0.008-0.73	Krumgalz & Hornung, 1982
	Hanigra to Hafifa		0.01-0.57	Roth & Hornung, 1977

39. In coastal areas, high mercury concentrations in sediments constitute serious local problems, especially in areas receiving effluents from chlor-alkali plants or other industrial activities, and in coastal areas close to mercury mining sites.

(c) Organisms

40. A considerable amount of data on mercury concentrations in Mediterranean marine biota has been reported to date. These data were the result of the MED POL Project "Baseline studies and monitoring of metals, particularly mercury and cadmium, in marine organisms". Mercury concentrations in 18 species of fish, three species of molluscs and three species of crustaceans, are summarized in Table 5.

41. In interpreting these data one should keep in mind that most of the marine organisms, with the exception of some pelagic fish like tuna, were collected from coastal areas, where mercury levels are higher than in the open sea. However, most fish in the Mediterranean that is caught for consumption is collected close to the shore.

42. A considerable amount of the data reported refer to marine organisms collected from the known mercury geochemical anomaly area of Monte Amiata, Italy. Since these samples have quite high body burdens, the result is significantly increased average Mediterranean values.

43. Tuna and other pelagic fish. Cumont et al. (1972) reported mercury concentrations in bluefin tuna (*Thunnus thynnus thynnus*) caught in the Mediterranean ranging from 50 to 2500 µg/kg (wet weight). The same authors reported values for Atlantic bluefin tuna ranging from 20 to 800 µg/kg.

44. The work of Renzoni et al. (1978) identified two bluefin tuna populations in the Mediterranean (Figure 4):

(1) Tuna that spend their entire life in the Mediterranean. They have high mercury body burdens (up to 4000 µg/kg) and show a positive correlation between concentration and body weight.

(2) Tuna that migrate from the Atlantic into the Mediterranean for spawning and then return to the Atlantic. These tuna have lower mercury body burdens and do not show any clear correlation between concentration and body weight.

45. Results reported from the MED POL II project show a considerable variation of mercury concentrations. A total of 325 samples of tuna were analysed and concentrations ranged from 20 to 6300 µg/kg with a mean value of 1050±760 µg/kg. These values are significantly higher than oceanic values which are in the range of about 50-1000 µg/kg (Cumont et al., 1972; Zook et al., 1976).

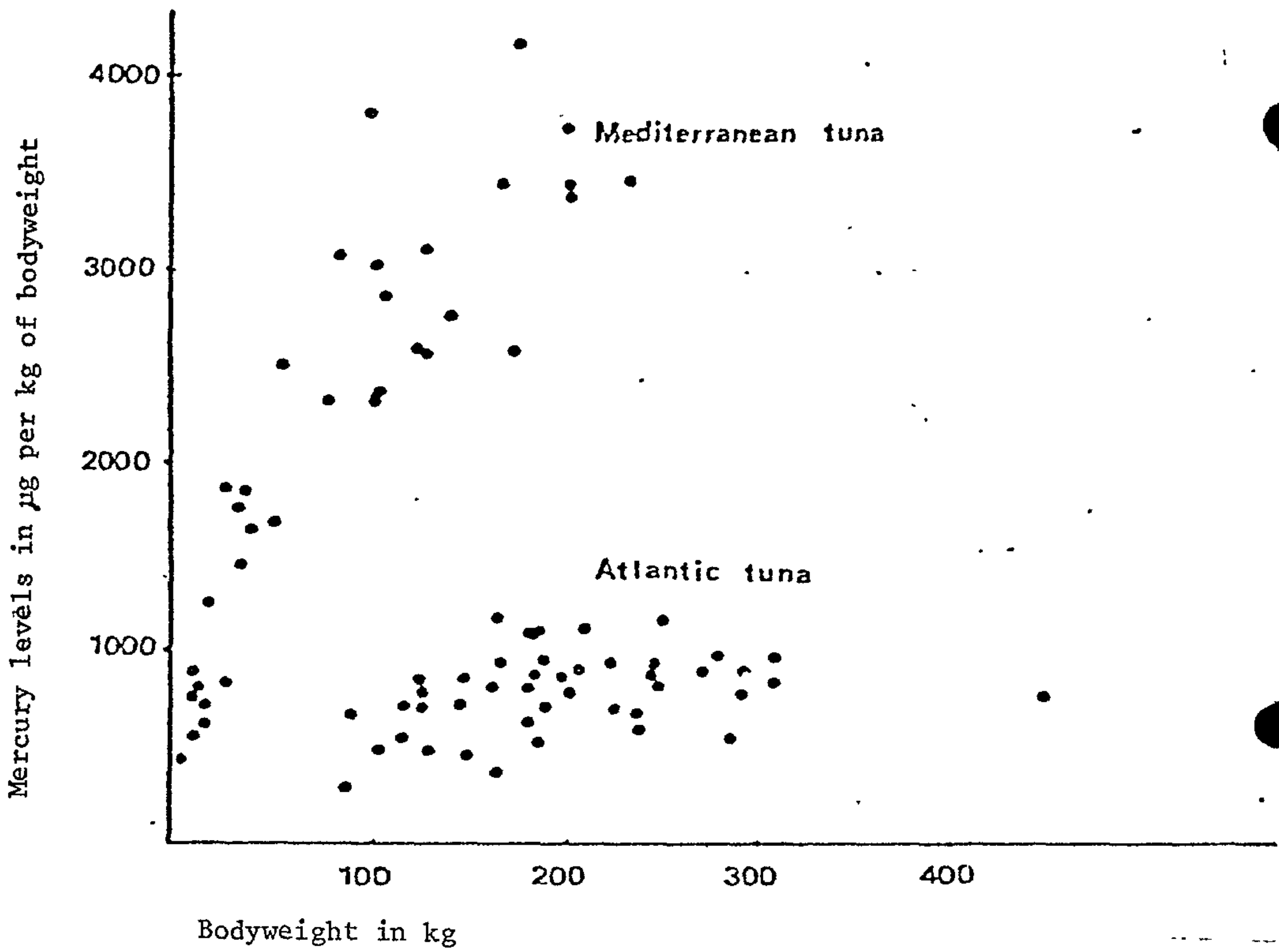
Table 5

Mercury concentrations in Mediterranean fish
(µg/kg wet weight)

Species	Number of Samples	Minimum	Maximum	Mean	Standard Deviation
Boops boops	15	20	432	125	104
Dentex gibbosus	12	99	178	135	19
Engraulis encrasicolus	254	20	580	167	85
Merluccius merluccius	16	31	258	131	77
Mugil auratus	39	1	5600	171	880
Mullus barbatus	1265	2	7900	694	960
Mullus surmuletus	234	0	510	91	57
Pagellus acarne	12	30	337	159	92
Pagellus erythrinus	112	53	805	203	115
Sarda sarda	11	290	2300	1150	644
Sardinella aurita	47	120	390	248	70
Saurida undosquamis	143	42	649	137	93
Scomber scombrus	16	125	510	335	122
Solea vulgaris	10	10	220	71	65
Thunnus alalunga	38	60	399	262	76
Thunnus thynnus thynnus	325	20	6300	1050	760
Trachurus mediterraneus	54	8	955	116	160
Upeneus moluccensis	127	38	1112	426	290
Mercury concentrations in Mediterranean molluscs (µg/kg wet weight)					
Donax trunculus	42	35	909	210	220
Mytilus galloprovincialis	488	4	7000	232	596
Perna perna	192	20	370	76	50
Mercury concentrations in Mediterranean crustaceans (µg/kg wet weight)					
Nephrops norvegicus	554	59	3000	917	494
Parapenaeus longirostris	39	110	1195	345	233
Squilla mantis	20	65	455	152	86

Figure 4

Mercury concentrations vs body weight in _Thunnus_ _thynnus_ _thynnus_
(Renzoni et al., 1978)



46. The mercury analyses reported in pilot project MED POL II for bluefin tuna showed that most values were below 1500 µg/kg and only a few above 2000 (Figure 5). A plot of mercury concentration versus weight (Figure 6) gives a much more scattered picture than the one reported in Figure 4.

47. A possible explanation could be that several subpopulations of Mediterranean bluefin tuna are included in the material in Figure 6.

48. The mercury concentrations in albacore tuna (Thunnus alalunga) reported in Table 5 are similar to those reported for different species of oceanic tuna that range from 70 to 1250 µg/kg (Working group on mercury in fish, 1979). However, concentrations in the white tissues of 27 albacore tuna sampled from the Northern Tyrrhenian Sea had mercury body burdens ranging from 700 to 4200 µg/kg.

49. High mercury concentrations in Mediterranean pelagic fish such as Sardina pilchardus, Engraulis encrasicolus and Scomber scombrus have been reported (Baldi et al., 1978).

50. Stoeppler et al. (1979) reported significant correlation of mercury concentrations in Sardina pilchardus with body weight. They report that fish caught off the coast of Tuscany, Italy, have considerably higher concentrations than fish caught from the Straits of Gibraltar. The concentration versus body length plot (Figure 7) is similar to that reported for bluefin tuna by Renzoni et al. (1978).

51. Average values for pelagic fish calculated from MED POL II results range from 116 µg/kg for Trachurus mediterraneus to 1150 µg/kg in Sarda sarda (Table 5).

52. Mercury concentrations are generally correlated both with body weight and length as for Trachurus mediterraneus in Figures 8 and 9. When such correlation is absent, it may be due to differences in growth rate or feeding habits in different subpopulations and on an uneven distribution of samples from different areas.

53. Mullus barbatus and other benthic fish. Concentrations of mercury reported in the benthic fish Mullus barbatus range from 2.0 to 7900 µg/kg (wet weight) with a mean of 690 µg/kg. However, almost half of the samples analysed were collected from coastal zones close to the mercury geochemical anomaly area of Monte Amiato, Italy. These samples had considerably higher concentrations (mean value of 1200 µg/kg). Disregarding these data, a more representative Mediterranean value for mercury in Mullus barbatus can be estimated as 160 µg/kg.

54. Significant correlation between mercury concentrations and body weight or length have been reported for Mullus barbatus (Stoeppler et al., 1979; Capelli et al., 1980). Such a correlation is not apparent from the Pilot Project MED POL II results for Mullus barbatus, probably due to the masking by high mercury values in samples from geochemical anomalous areas.

55. Also in samples from commercial trawling along the Israeli coast, the correlation between mercury concentration and length was low. Instead the mercury concentration of this species seemed to increase with depth (Hornung et al., 1980).

Figure 5

Mercury concentrations in *Thunnus thynnus thynnus*

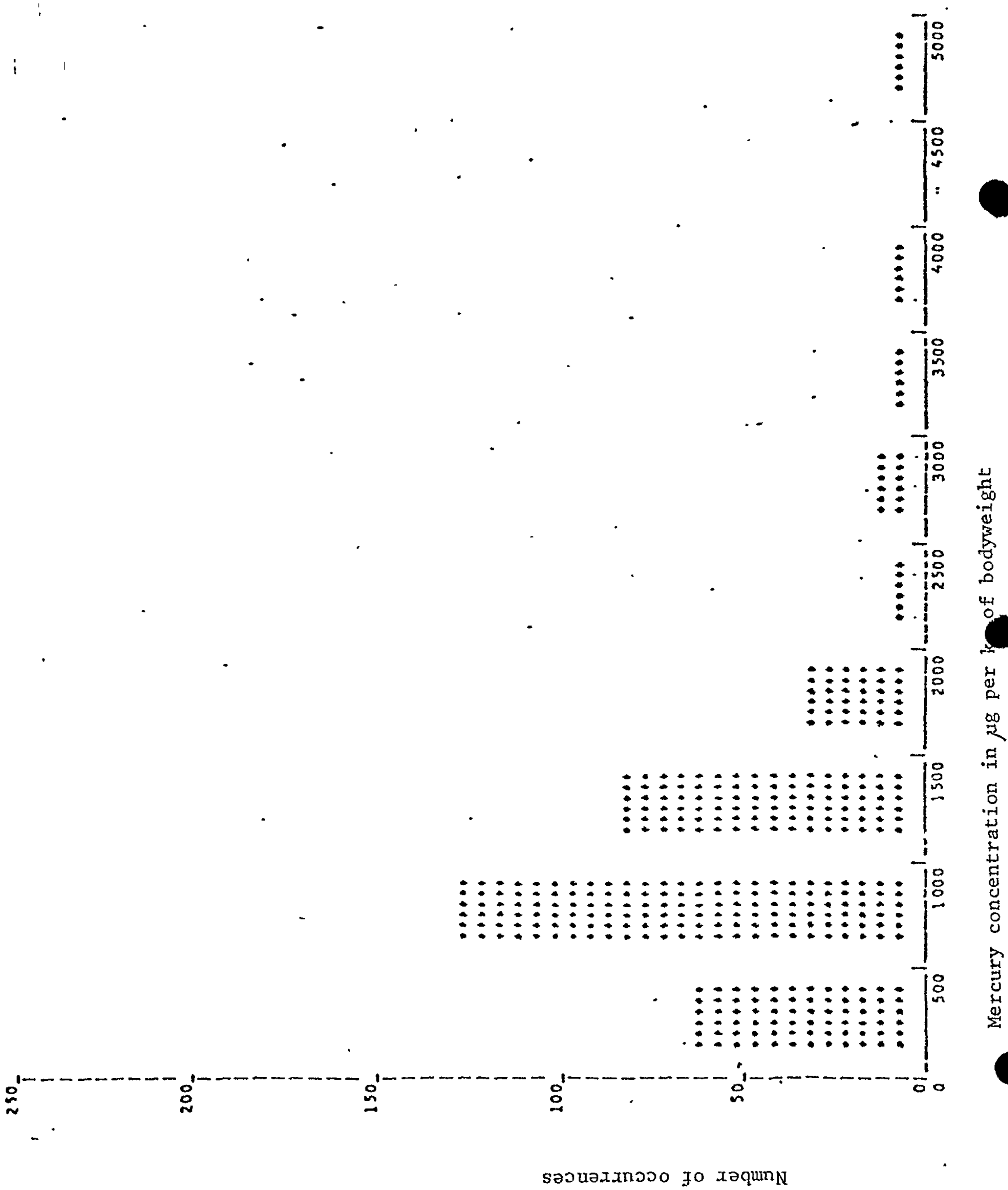


Figure 6

Mercury concentrations vs body weight in _Thunnus thynnus thynnus_

(MED POL II data)

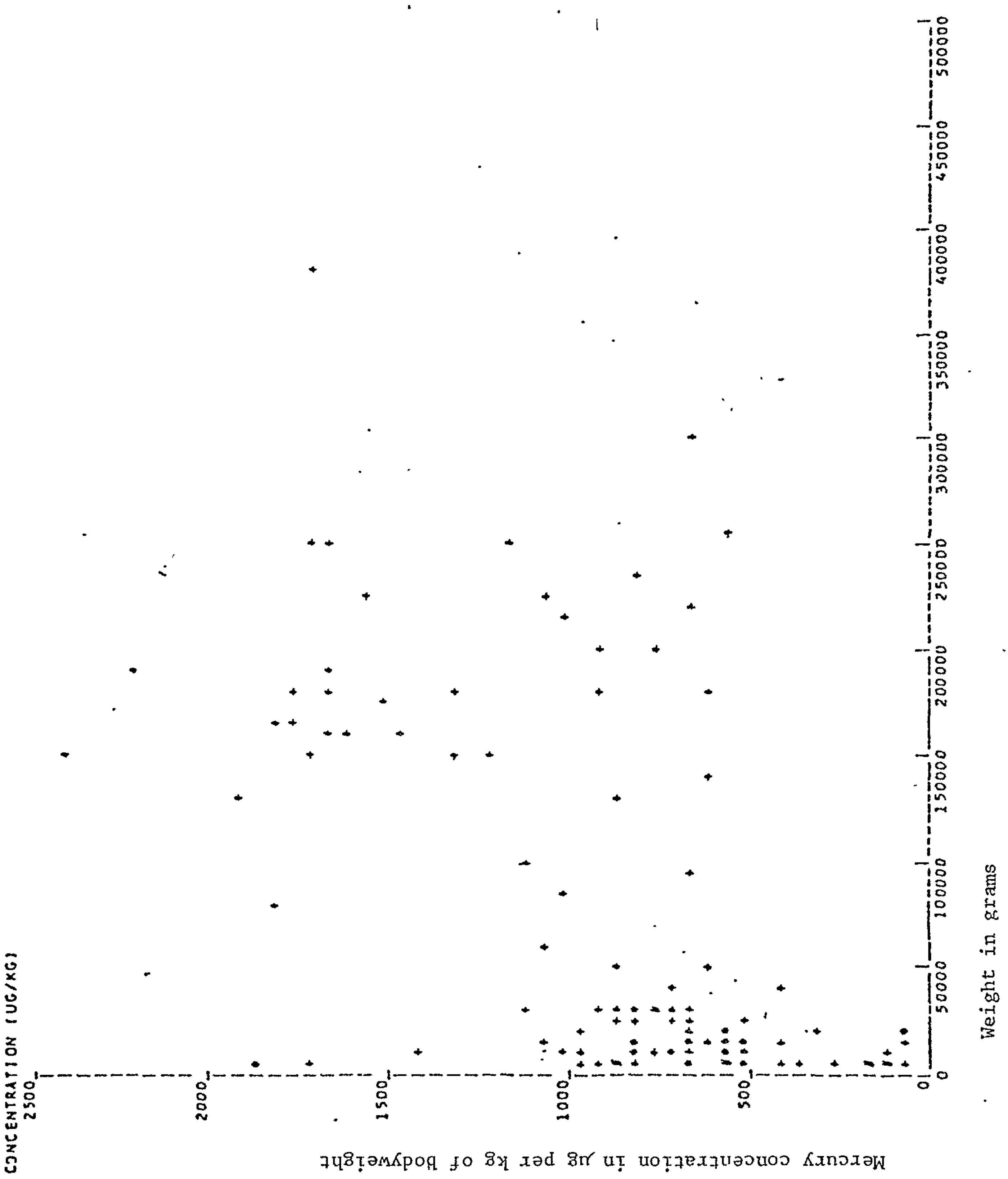


Figure 7

Mercury concentrations vs weight in Sardina pilchardus
(Stoeppler et al, 1979)

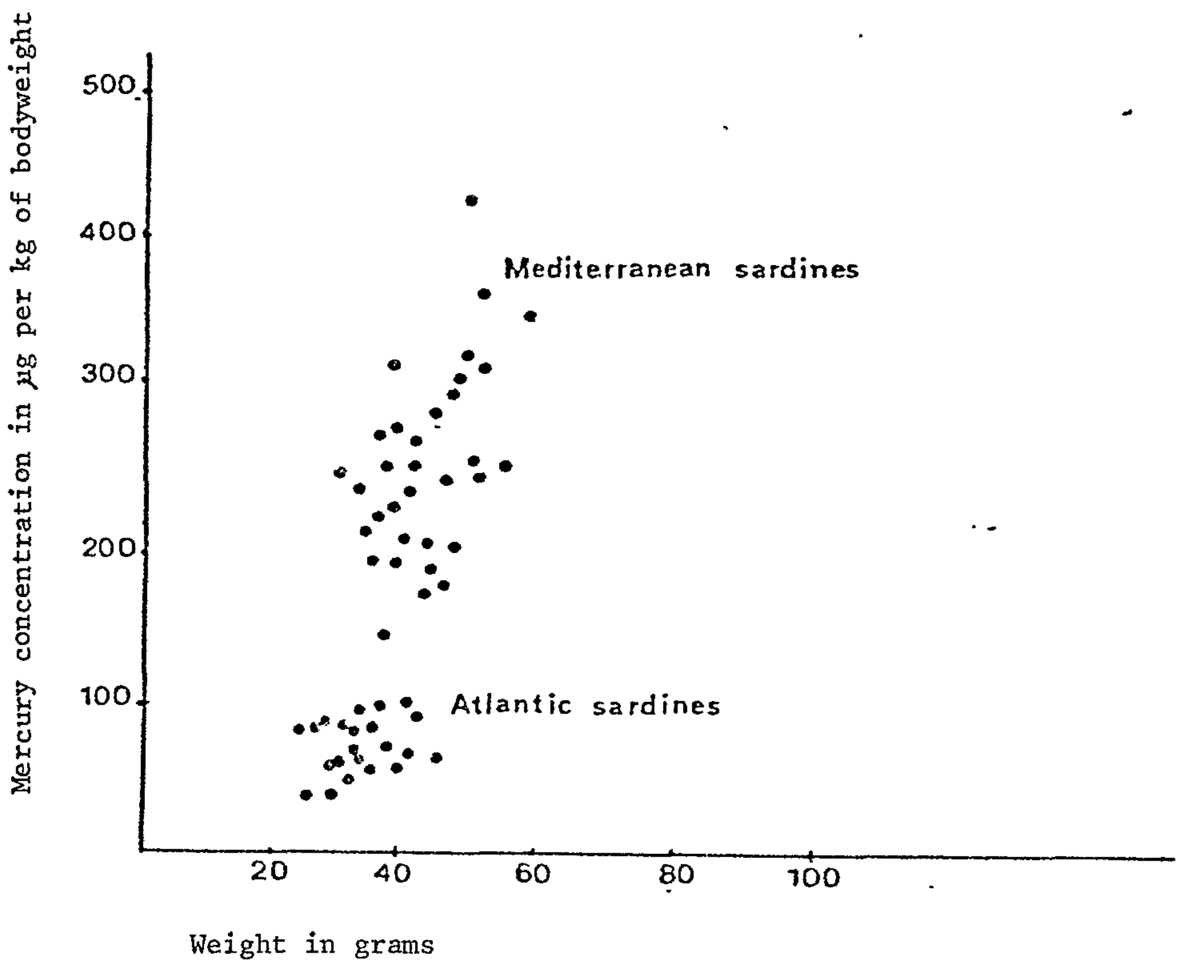


Figure 8

Mercury concentrations vs body length in Trachurus mediterraneus
(MED POL II data)

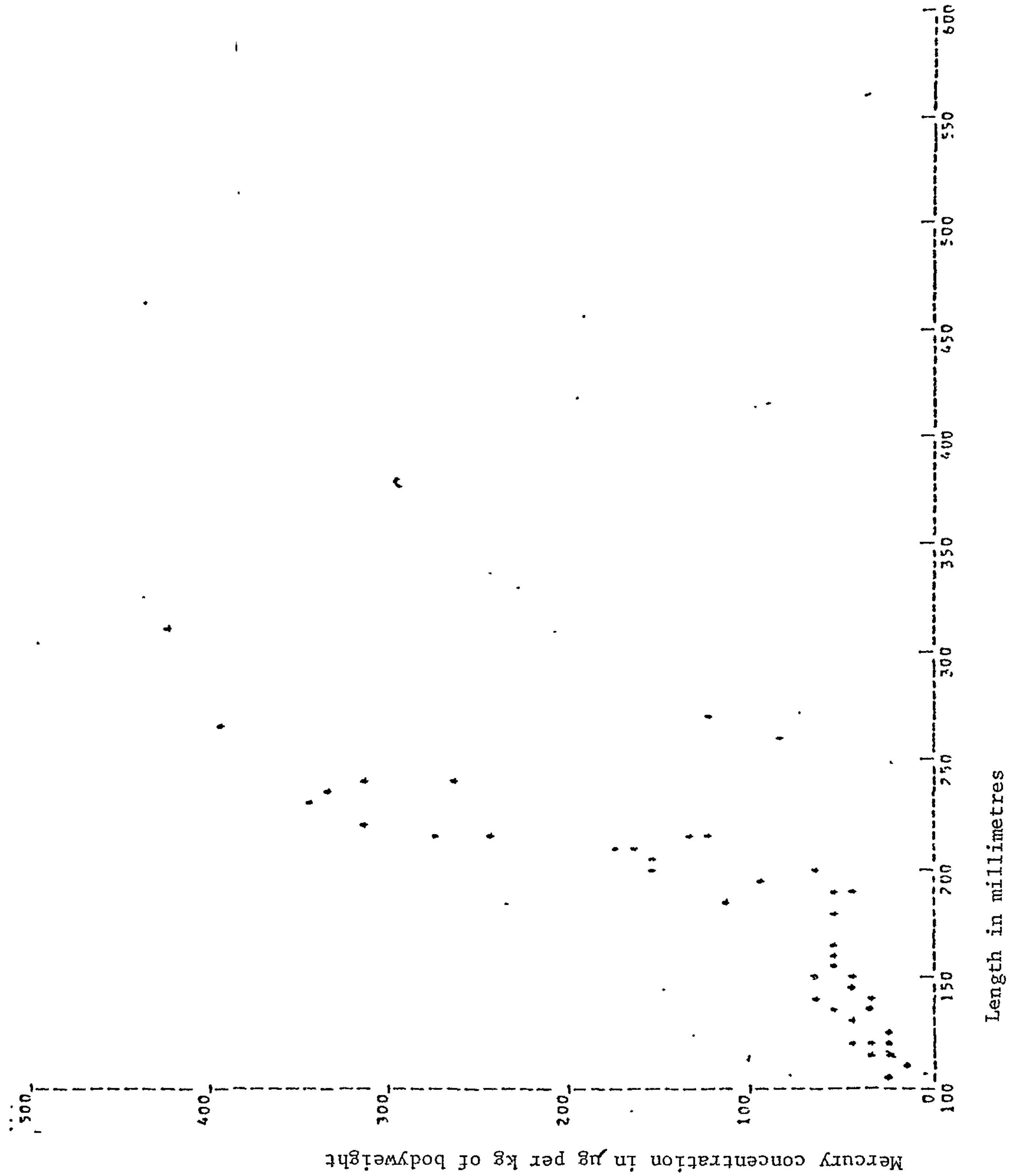
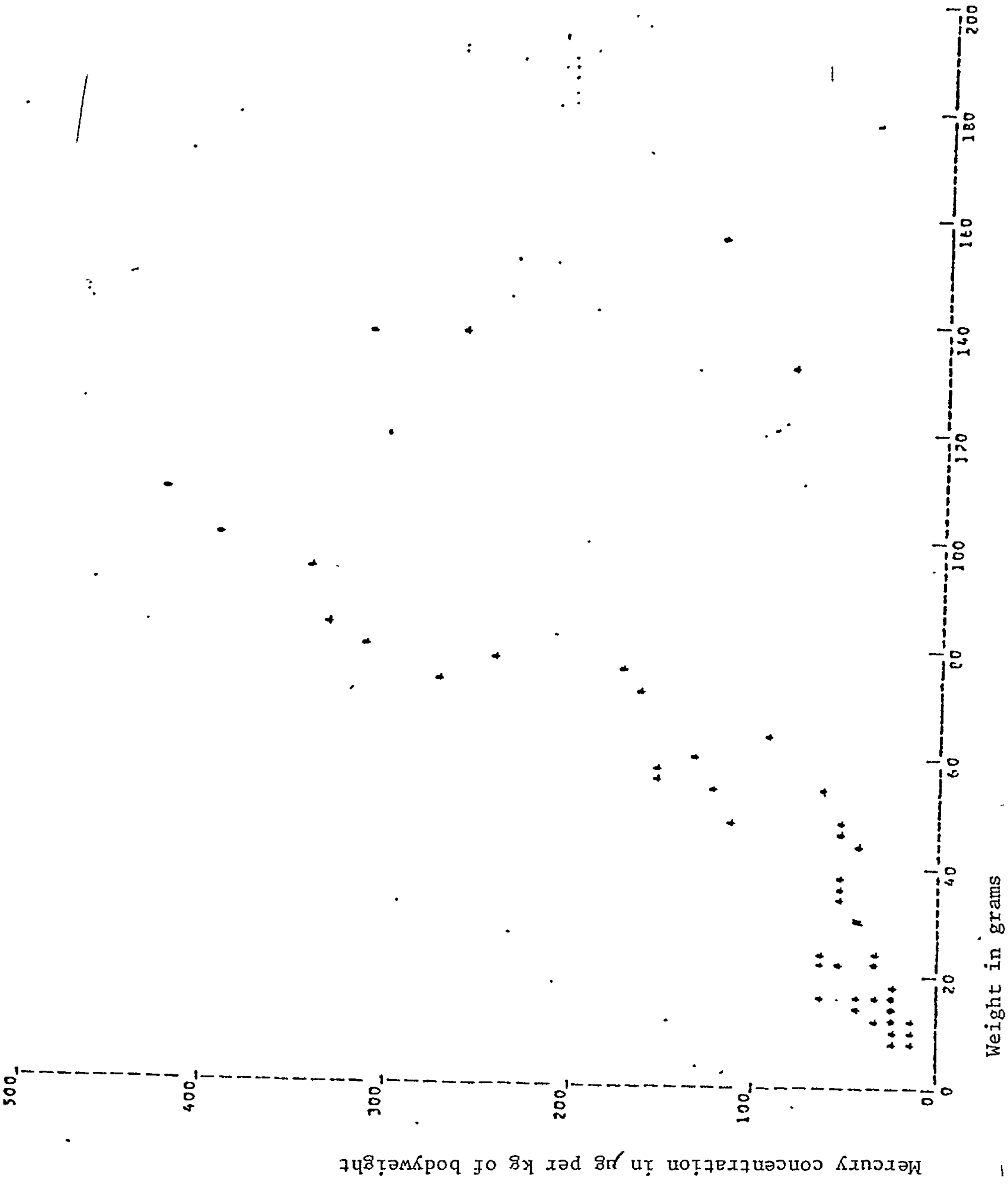


Figure 9

Mercury concentrations vs bodyweight in *Trachurus mediterraneus*
(MED POL II data)



56. High concentrations of mercury in Mullus barbatus sampled from the coasts of Tuscany, Italy, of up to 3700 µg/kg, have also been reported by UNEP (1978). In other coastal areas of the Mediterranean, concentrations ranged from 60 to 900 µg/kg.

57. Capelli et al. (1980) reported average mercury concentrations of 270 µg/kg in Mullus barbatus from the Gulf of Genova. In clean areas of the Aegean Sea, average values are around 50 µg/kg, but in areas receiving industrial or domestic sewage they increase to 290 µg/kg (Grimanis et al., 1980; Uysal, 1980). In the Levantine coasts of Turkey, values of 40 µg/kg were reported (Balkas et al., 1978).

58. Majori et al. (1978) reported mercury concentrations ranging from 40 to 220 µg/kg in Mullus barbatus from the Gulf of Trieste. Exceptionally high concentrations of up to 1200 µg/kg were found in the coastal area of Alexandria, Egypt (El Sokkary, 1982), probably as a result of mercury inputs from a chlor-alkali plant.

59. Mercury concentrations in 234 samples of Mullus barbatus ranged from 0.1 to 510 µg/kg with a mean of 91 µg/kg.

60. High concentrations of mercury have been reported in Mullus surmuletus from the area of Alexandria, Egypt (up to 2200 µg/kg) (El Sokkary, 1982). In the Aegean and North Levantine Seas, concentrations ranged from 40 to 103 µg/kg (Balkas et al., 1978; Uysal, 1980).

61. Upeneus moluccensis was sampled only from the Eastern Mediterranean and the average concentration was 426 µg/kg.

62. Hornung et al. (1980) reported concentrations of mercury in Upeneus moluccensis from the coasts of Israel ranging from 110 to 707 µg/kg with an average value of 259 µg/kg. They also observed a significant correlation between mercury concentration and length.

63. Molluscs (Mytilus galloprovincialis and Perna perna). Mussels have been proposed as a heavy metal indicator organism ("Mussel Watch"). They represent local conditions better than any other marine organism since they are sessile and filter-feeding (Phillips, 1977).

64. Concentrations of mercury reported in mussels (Mytilus galloprovincialis) from the Mediterranean range from 4 to 7000 µg/kg (wet weight) with a mean value of 232 µg/kg. As in the case of Mullus barbatus, many samples were collected from the Northern Tyrrhenian Sea. A more representative average of 70 µg/kg can be calculated, disregarding results from these areas.

65. Concentrations of mercury in Mytilus galloprovincialis were reviewed by Bernhard (1978). Exceptionally high concentrations were reported in samples from the Adriatic Sea (up to 1500 µg/kg). From other areas of the Mediterranean, concentrations ranged from 20 to 300 µg/kg.

66. Recent publications report average concentrations of 26 µg/kg in the Gulf of Genova (Capelli et al., 1980a), 32 - 155 µg/kg in the Gulf of Trieste (Majori et al., 1978), 54 - 230 µg/kg in the Aegean Sea (Uysal, 1980; Grimanis et al., 1982). High concentrations (250 - 3460 µg/kg) were reported for the coasts near Barcelona (Obiols, 1980) and could be the result of high mercury inputs due to industrial activities.

67. Samples of Perna perna monitored in the Pilot Project MED POL II had an average concentration of 76 µg/kg with a range of 20 - 370 µg/kg. This average value is very close to the average for Mytilus galloprovincialis of 70 µg/kg (excluding the results from the Northern Tyrrhenian Sea).

68. Marine crustaceans. Levels of mercury in Mediterranean marine crustaceans were reviewed in the past (UNEP, 1978; Bernhard, 1978 and 1980) and a considerable amount of results were presented during the Mediterranean Pollution Workshops (ICSEM/UNEP, 1978, 1980 and 1982). These data do not represent an even distribution throughout the Mediterranean and most refer to samples collected from polluted areas of the North Mediterranean coast or geochemical anomalous areas.

69. Nephrops norvegicus, the average mercury concentration in the abdomen in 489 samples from regions II, IV and VI was 966 µg/kg, and in Parapenaeus longirostris from region VIII was 337 µg/kg. Incomplete geographical coverage of monitoring of mercury in these organisms does not allow any conclusions to be drawn.

(d) Comparisons with other regions

70. Comparative analytical data for the mercury content of fish muscle sampled in various seas are shown in Table 6. Data for the Mediterranean have been mainly taken from figures shown elsewhere in this document, those for other seas mainly from the data profiles on mercury (IRPTC, 1980) and Piotrowski & Inskip (1981). On the basis of these figures, it is evident that in general, levels of mercury in fish are higher in the Mediterranean than elsewhere. However, a final confirmation of this statement can only be obtained after a more comprehensive assessment of mercury in the Mediterranean region.

Health effects of mercury

71. Humans may be exposed to both inorganic and organic forms of mercury. Exposure to inorganic mercury compounds of health significance generally constitutes an occupational hazard, whereas exposure of the general population to methylmercury occurs mainly through seafood consumption. In this regard, high concentrations of methylmercury in fish and shellfish can cause adverse health effects and even death to consumers (Takeuchi, 1968; Wood, 1976). A considerable amount of literature is available on the toxicity of mercury to living organisms and its effects on humans. Two recent global reviews on environmental health aspects of mercury are the WHO/UNEP Environmental Health Criteria document on mercury (WHO, 1976) and the report by Piotrowski and Inskip (1981) on the health effects of methylmercury. A review of international activities relating to health hazards from methylmercury in the Mediterranean region has been made by Saliba and Silano (1982).

Table 6

Range of approximate mean concentrations of mercury (expressed in mg/kg wet weight) recorded in muscle tissue of various marine species (modified after Piotrowski & Inskip, 1981)

Fish species	Ocean/Sea			
	Atlantic	Pacific	Indian	Mediterranean
Mackerel	0.07 - 0.20	0.16 - 0.25	0.005	0.335
Sardine	0.03 - 0.06	0.03	0.006	0.248
Miscellaneous non-predatory species	0.08 - 0.27	0.07 -0.09	0.02 - 0.16	0.07 - 0.694
Predatory species				
Tuna spp.	0.30 - 0.80	0.30	0.06 - 0.40	0.26 - 1.15
Swordfish	0.80 - 1.30	1.60*	-	1.20 - 1.80*
Various elasmo-branch species (sharks & rays)	1.00	0.70 - 1.10	0.04 - 1.50	0.06 - 2.0

* based on very limited data

72. *Biological monitoring of human populations exposed to methylmercury* poisoning has been performed in various countries, including Iraq (Bakir et al, 1973), Japan (Takeuchi & Eto, 1975; Tsubaki & Irukayama, 1977) and Canada (Methylmercury Study Group, 1980). Estimates of blood mercury levels still play the dominant role for the assessment of exposure to methylmercury, and in populations considered to be under exposure from fish consumption, determination of total or organic mercury are considered equally valid, as the latter represents 95% or more of the total (Phelps et al., 1980). Recently, hair analysis has been increasing in value as an indicator independently linked with health effects (Marsh et al., 1979), the hair:blood ratio appearing to be constant provided that blood samples are compared with properly time-matched segments of hair (Clarkson, Amin-Zabi & Al-Tikriti, 1976). Within the Mediterranean region, levels of mercury in blood and hair exceeding those recognized as normal have been reported from certain coastal regions (Paccagnella et al., 1973; Bacci et al., 1976; Riolfatti, 1977).

73. The most significant adverse effect observed in humans poisoned by methylmercury is on the central nervous system (WHO, 1976; Piotrowski & Inskip, 1981), signs and symptoms observed in adults including sensory (e.g. paresthesia, pain in limbs, visual and hearing disturbances), motor (e.g. disturbance of gait, weakness, unsteadiness of legs, dysarthria and tremor) and non-specific (e.g. headaches, rashes and mental disturbances) categories. Damage to the central and peripheral nervous system and congenital disorders have been observed following long-term oral exposure to methylmercury (OECD, 1974). A number of embryotoxic effects, including teratogenicity, have been observed in several species of laboratory animals and several behavioural, electrophysiological and biochemical changes have been reported to occur before the appearance of any clear symptoms of intoxication, though the relevance of many of these observations to humans is still unclear (Gatti et al., 1979).

74. Methylmercury ingestion during pregnancy may have a very serious effect on the human foetus (WHO, 1976), and the effects of congenital exposure can be observed even when maternal toxic symptoms are absent. Perinatal exposure to methylmercury (which can occur through contaminated human milk) also induces early symptoms of a neurological nature in infants and children. Pregnant women therefore constitute a high-risk group. There is some controversy regarding the sensitivity of infants and children to methylmercury poisoning, some authors regarding this group as particularly vulnerable, others considering that children are not especially susceptible and that their capacity to improve or even recover is greater than in adults (Piotrowski & Inskip, 1981).

75. Selenium salts can protect experimental animals against the toxic effects of inorganic mercury and methylmercury, and the elevated levels of selenium in tuna fish may be sufficiently high to give similar protection (Piotrowski & Inskip, 1981). The mechanism of selenium with methylmercury toxicity in animals has not yet been clarified, and while consumption of marine fish with high methylmercury levels usually involves the intake of correspondingly high levels of selenium, proof of a protective effect in humans is still lacking (Saliba & Silano, 1982).

76. Assessment of the health hazards from seafood consumption in the Mediterranean region, leading to the eventual establishment of environmental quality criteria for mercury in seafood, can only be effected following the acquisition of detailed data on mercury concentrations in seafood (as well as in the general environment) together with consumption patterns and the correlation of these with appropriate epidemiological studies. These studies, which have just been commenced by WHO/UNEP within the framework of the research component of MED POL Phase II, should serve to identify high-risk groups, evidence of which has already been indicated (Nauen et al., 1982), and enable Governments to take appropriate legislative action.

Summary

77. The Mediterranean region is rather unique in its richness in mercury deposits, some of which are mined, representing 50% of the world mercury production. Anthropogenic activities, and especially mining, might have significantly increased weathering and thus inputs of mercury into the marine environment of the Mediterranean. The question of availability of this mercury for biomethylation and bioaccumulation has not been well studied.

78. With the accuracy of existing data it cannot be concluded that mercury levels in Mediterranean open waters and deep-sea sediments are significantly higher than those in the open oceans. The same applies to the limited data that exist on mercury levels in planktonic organisms. Mediterranean pelagic fish, especially tuna and *Sarda sarda*, undoubtedly have higher body burdens than oceanic fish. However, the mechanisms of this accumulation are not clear.

79. Elevated levels of mercury in the marine environment are evident in areas of mercury anomalies and mining sites in the vicinity of chlor-alkali plants, and in some cases in areas receiving industrial effluents and domestic sewage. High concentrations have been reported by many investigators in water, sediments and organisms.

80. Data compiled up to now through the MED POL II project do not provide a good basis for a final assessment of mercury in the Mediterranean. Samples from clean "reference" areas should be included in future monitoring in order to provide a basis for comparison. Areas in the Mediterranean were not equally covered as most data were reported from the north-western part of the Mediterranean. The statistical analysis of the compiled data should be continued with correlation of mercury concentrations versus body size for different geographic locations. High concentrations could thus be related to specific mercury sources.

PREVENTION AND CONTROL OF POLLUTION BY MERCURY IN MEDITERRANEAN SEAFOOD

Fish production and consumption

81. The average annual per capita consumption of fish (the term including all consumable aquatic organisms), expressed in kg, live-weight equivalent, over the three-year period 1978-80, in each of the Mediterranean countries, is shown in Table 7. Consumption is highest in Spain (34.2), followed by France (23.8), Malta (17.5) and Greece (16.7). Syria (2.0) and Algeria (2.1) represent the lowest.

Table 7

Average fish consumption in kg/per capita/year
1978-1980

Algeria	2.1	Libya	6.7
Cyprus	7.8	Malta	17.5
Egypt	4.6	Morocco	5.5
France	23.8	Spain	34.2
Greece	16.7	Syria	2.0
Israel	15.0	Tunisia	8.0
Italy	12.9	Turkey	5.3
Lebanon	3.1	Yugoslavia	3.1

82. The figures in Table 7 have been calculated by dividing the total fish supply in each country by the number of inhabitants. The total fish supply figures can be broken down into (a) Mediterranean catch, (b) catch outside the Mediterranean proper, and (c) net imports. This information insofar as 1980 is concerned is given in Table 8. Column 2 of this table shows the total production, i.e. catches from anywhere in the world as well as freshwater production. Column 3 indicates the net fish imports for each country. The total fish supply is the sum of the figures in columns 2 and 3. Column 4 shows only Mediterranean catches, excluding those from the Black Sea. This only concerns Turkey's catch.

83. The other columns in the table show a breakdown of the Mediterranean catch into the most important species or groups of species from the production point of view.

84. The following observations can be made as far as the total fish supply is concerned.

(a) Only three countries (Morocco, Tunisia and Turkey) have been net exporters in 1980. All the other countries imported fish. In some cases the imports exceed the total country production (Cyprus, Lebanon, Libya, Malta and Syria).

(b) About half of the countries also fish outside the Mediterranean proper. In many cases, landings from outside the Mediterranean Sea proper account for a large percentage of the total production, e.g. France (94.1%), Morocco (91.6%), Turkey (90.3%), Spain (88.2%), Israel (85.6%).

(c) Assuming that the imports come from outside the Mediterranean (which is most probably correct), none of the countries (except Tunisia) relies solely on Mediterranean fish. Based on this assumption, calculations were made to show what part of the fish consumed actually comes from the Mediterranean. The results for 1980 are shown in Table 9. A study of these figures shows significant differences among the various countries in consumption of fish caught in the Mediterranean in relation to total fish consumption.

Table 8

Nominal catches and net imports of fish (in metric tons) in the Mediterranean for 1980

Country	Total production	Net imports	Mediterranean catch	Clupeidae (sardines)	*Engraulis encrasicolus* (anchovy)	Carangidae (*Trachurus*)	Bonito and tuna	Gadiformes	Sparidae	Mullidae	Cephalopoda
Algeria	38 678	69	38 678	22 773	3 290	1 597	515	1 739	3 676	1 090	
Cyprus	1 336	2 771	1 304			11	17	4	324	126	112
Egypt	140 397	47 502	19 939	6 501		100			2 162	1 576	743
France and Monaco	793 458	299 557	46 800	15 393	2 448	812	1 701	3 706	1 684	276	1 735
Greece	103 042	25 732	75 745	12 541	9 860	8 300	794	2 385	8 284	2 397	2 320
Israel	25 718	20 644	3 702	816		187		52	627	277	
Italy	447 696	209 701	352 631	47 712	79 282	8 126	4 299	14 895	12 950	8 134	31 937
Lebanon	2 500	7 713	2 400	800							
Libya	4 803	10 167	4 803	634			634	130	634		
Malta	1 023	4 223	1 023	3		192	43	40	118	7	26
Morocco	323 907	-59 857	27 316	9 403	7 127	3 205	56	50	3 871	185	174
Spain	1 264 680	121 731	149 606	37 083	31 239	7 244	3 415	16 919	8 248	2 575	3 436
Syria	3 911	9 692	976	121		50	80	70	90	80	
Tunisia	60 154	-6 398	60 154	13 969	536	1 534	2 646	620	5 608	2 336	5 489
Turkey	426 855	-9 085	41 405	8 384	1 509	1 421	15 301	220	2 780	1 435	354
Yugoslavia	58 396	19 576	34 968	24 004	2 214	1 283	639	799	922	228	743
TOTAL	3 696 554	703 738	861 450	200 137	137 505	34 062	30 140	41 629	51 978	20 722	52 069

Sources: (a) FAO, 1981. Yearbook of Fishery Statistics: (i) Catches and landings, Vol. 52
(ii) Fishery commodities, Vol. 53

(b) FAO/GFCM, Statistical Bulletin No. 4

Table 9

Fish consumption in kg/per capita/year
(1980 figures)

Country	Annual consumption Total	Mediterranean origin	
Algeria	2.1	2.1	(100.0%)
Cyprus	9.6	3.1	(32.3%)
Egypt	4.8	0.5	(10.4%)
France	24.3	1.0	(4.1%)
Greece	16.5	9.7	(58.8%)
Israel	14.8	1.2	(8.1%)
Italy	13.2	7.1	(53.8%)
Lebanon	3.0	0.7	(23.3%)
Libya	7.8	2.5	(32.1%)
Malta	20.9	4.1	(19.6%)
Morocco	5.6	0.6	(10.7%)
Spain	35.1	3.8	(10.8%)
Syria	2.1	0.2	(9.5%)
Tunisia	8.1	8.1	(100.0%)
Turkey	5.4	0.5	(9.3%)
Yugoslavia	3.0	1.3	(43.3%)

85. Another factor which must be taken into consideration is the fact that the figures in the various tables are live-weight and not all of this is actually consumed, especially in the case of molluscs and crustaceans.

Existing national provisions and relevant international agreements

86. The mercury poisoning which occurred in the areas of Minimata and Niigata in Japan (1953-1960), in Iraq (1956, 1960 and 1971) and elsewhere, stimulated the concern of Governments regarding the hazards of mercury ingestion by human populations through consumption of contaminated food material, particularly (though not only) seafood. In this context, efforts were made to investigate the sources and levels of mercury in the environment, especially in relation to food contamination, and to establish regulatory measures for the control of mercury in various parts of the environment for the protection of the health of populations in general. The matter of occupational exposure to mercury, which presents a high-level hazard to a limited population-sector, is outside the scope of this document.

87. Fish and other seafood, and their products, were found to constitute the major, and in many instances the only, source of intake of mercury for most people investigated. As a result, the regulatory approach to the prevention and control of consumption of contaminated products has so far been primarily directed at limiting the levels of mercury in fish and shellfish and their

products destined for human consumption. Control of the problem at source through limiting the anthropogenic emission of mercury into the environment has been considered of secondary importance. In this context, in the regulatory measures adopted to date, the present limitations in the knowledge of the cause/effect relationship of mercury in the physical environment and in living organisms have necessitated the adoption of a significant safety factor in standards and criteria applied, for ensuring the protection of human health.

88. As part of the preliminary studies for determining the need to set maximum levels for mercury in food, a number of countries conducted surveys of the dietary intakes of their populations. Particular studies relating to mercury levels in fish and to the amount of fish consumed by populations in the Mediterranean area were conducted in France and Italy.

89. Table 10 shows the standards and criteria applied by a number of Mediterranean countries, based on responses to specific requests for information. As can be seen from this, the limits applied by those countries having legislation on the subject vary between 0.5 and 0.7 mg mercury per kg of fish or seafood flesh. There is also evidence to indicate that in some of the countries where no ad hoc national legislation has been promulgated, though facilities for control exist under general health regulations, standards used in other countries, or recommended by international organizations are applied. No specific information on this point is however available.

90. The Commission of the European Communities has issued a Council Directive in 1982 on the limit values and quality objectives for mercury discharge by the chlor-alkali electrolysis industry. The quality objectives, as set out in Annex II to this Directive, are quoted hereunder:

"1.1 The concentration of mercury in a representative sample of fish flesh chosen as an indicator must not exceed 0.3 mg/kg wet flesh.

1.2 The total concentration of mercury in inland surface waters affected by discharges must not exceed 1 µg/l as the arithmetic mean of the results obtained over a year.

1.3 The concentration of mercury in solution in estuarine waters affected by discharges must not exceed 0.5 µg/l as the arithmetic mean of the results obtained over a year.

1.4 The concentration of mercury in solution in territorial seawaters and internal coastal waters other than estuary waters affected by discharges must not exceed 0.3 µg/l as the arithmetic mean of the results obtained over a year.

1.5 The quality of the waters must be sufficient to comply with the requirements of any other Council Directive applicable to such waters as regards the presence of mercury.

Table 10

Maximum limits of permissible mercury levels in seafood in Mediterranean countries

Country	Year of enactment	Maximum permissible mercury concentrations	Remarks
Albania	*	*	*
Algeria	*	*	*
Cyprus	-	-	-
Egypt	*	*	*
France	1976	0.5 mg/kg	All fish, crustacea and mollusca, except tuna and swordfish.
	-	0.7 mg/kg	Tuna and swordfish. No legislation in force, but random tests made on important fish. Those which exceed limits are banned from the the market. Both of the above levels apply to domestic and imported products.
Greece	1974	0.7 mg/kg (methylmercury)	Limit for all seafood caught locally or imported, and intended for local consumption. Enforcement through veterinary practice. New legislation under preparation.
Israel	*	0.5 mg/kg	Maximum level for both domestic and imported fish. Tuna receives special attention. New legislation under preparation.
Italy	1971	0.7 mg/kg	In force for fish and fishery products imported from outside the EEC region.
	1976	0.7 mg/kg	In force for frozen tuna (Thunnus thunnus) and other tunas and bonitos of domestic and EEC origin.

- no standards in force

* no information available

(continued)

Table 10
(continued)

Maximum limits of permissible mercury levels in seafood in Mediterranean countries

Country	Year of enactment	Maximum permissible mercury concentrations	Remarks
Italy (contd)	1978	0.7 mg/kg	In force for bivalve molluscs of domestic production.
	1980	0.7 mg/kg	In force for fresh sharks and dogfish.
Lebanon	*	*	*
Libya	*	*	*
Malta	*	*	*
Monaco	*	*	*
Morocco	*	*	*
Spain	1973	0.5 mg/kg	In force for fresh, chilled and frozen fish and seafood if at least 5 kg weight, and for any canned or processed fish and fishery product.
Syria	*	*	*
Tunisia	*	*	*
Turkey	-	-	Analysis of canned sardines, anchovy and tuna showed concentrations of mercury below "action levels in most countries, thus precluding necessity for legislation to date.
Yugoslavia	1978	-	No actual standards laid down. Legislation deals with general quality of fish.

- no standards in force
* no information available

2. The concentration of mercury in sediments or in shellfish must not increase significantly with time.

3. Where several quality objectives are applied to waters in an area, the quality of the waters must be sufficient to meet each of them.

4. The numerical values of the quality objectives specified in 1.2, 1.3 and 1.4 may, as an exception and where this is necesssary for technical reasons, be multiplied by 1.5 until 30 June 1986, provided that the Commission has been notified beforehand.

91. As fish-eating habits would be expected to vary between different populations and subgroups, and mercury levels in seafood differ according to species, the best approach to solving the problem would have to be connected with mercury intake levels. However, it would not be easy to alter taste preference patterns, particularly where fish may constitute a readily-available source of protein for which no easy substitute exists.

Scientific rationale for regional environmental quality criteria for mercury

92. At the present time, an accurate evaluation of health hazards through the consumption of Mediterranean seafood is difficult due to the very limited data available for those population sectors likely to have a mercury intake in excess of acceptable levels. However, it is generally agreed that the intake of methylmercury in seafood may constitute a health hazard to certain population sectors. In this regard, the main international criterion regarding intake has been established by a joint FAO/WHO expert committee on food additives (JECFA) in 1972, in the form of a provisional tolerable weekly intake (PTWI) of 0.3 mg total mercury per capita, of which no more than 0.2 mg should be present as methylmercury (expressed as mercury). These amounts are equivalent to 5 µg and 3.3 µg respectively per kg of bodyweight. In this respect, it was considered that such an intake should not pose any significant risk to health.

93. On the basis of the concentrations of mercury in Mediterranean seafood shown in Table 5, and assuming that all (100%) the mercury in seafood is present as methylmercury, the following hypothetical conclusions may be reached. In this regard, the term "safe consumption" is interpreted as meaning that consumption within the limits given should not result in any significant health effects.

(a) For the majority of seafood, the highest mean concentration recorded was just below 0.25 mg of mercury per kg wet weight of fish. Taking into account the higher figures recorded in a number of individual specimens as a safety factor, it would not be expected that the average mercury content of fish consumed over a long period should exceed 0.3 mg/kg wet weight - one meal of 150 g would therefore on the average be equivalent to a methylmercury content of 45 µg. For an adult with normal bodyweight (70 kg), this would mean that the JECFA PTWI would not be exceeded on the basis of consumption of just under four fish meals per week (allowing 10-20% of the PTWI for a methylmercury intake from other sources).

(b) In the case of mackerel (scomber scombrus) and albacore tuna, the mercury concentrations were of 0.335 and 0.262 mg/kg wet weight respectively. On the basis of these, following the calculations at (a) above, the PTWI would not be exceeded with three fish meals per week. The same would apply in the case of the deep-water pink shrimp (Parapenaeus longirostris), with a mean concentration of 0.345 mg/kg. On the other hand, Atlantic bonito and bluefin tuna had 1.15 and 1.05 mg/kg respectively, restricting their "safe consumption" to one meal per week. The same would apply to Norway lobster.

(c) Striped mullet and goldband goatfish fall into an intermediate category, average concentrations recorded being 0.694 and 0.426 mg/kg respectively, the "safe consumption" being one and a half and two meals per week respectively.

(d) Mean mercury concentrations in swordfish are of the order of 1.20 to 1.80 mg/Kg wet weight (on the basis of very few specimens analysed). This places swordfish on a higher level than bonito, tuna and Norway lobster, and therefore the "safe consumption" limit would be less than one meal per week, assuming that the figures (which are based on very limited data) are really representative.

94. All the above can, at best, only be generalities, as account has to be taken of (a) the enormous discrepancy in concentrations between different individuals of the same species, (b) the relatively small number of species analysed in the majority of cases, and (c) consumption patterns. In any case, even taking the above hypotheses as a basis, fish consumption would have to be lower in adults with a subnormal bodyweight and in children, if the PTWI is not to be exceeded.

95. However, these tentative calculations do suggest that the bulk of Mediterranean populations probably has a low intake of methylmercury, and is therefore at a negligible risk. In this context, another factor that must be taken into consideration is the extent to which consumers in the Mediterranean include seafood imported from outside the region in their diet. This factor, which would probably result in a reduced methylmercury intake, is of unknown value.

96. The average annual per capita consumption of fish and shellfish in the Mediterranean region ranges from 2.1 to 34.2 kg. In certain areas, however, annual per capita consumption can be much higher.

97. On the basis of these differences in seafood consumption, and of the high-mercury concentrations found in fish from certain areas of the Mediterranean, five groups of consumers can be distinguished:

(1) General populations, consuming average or lower than average amounts of fish, in areas where average mercury concentrations are found in fish. This group does not seem to exceed the maximum intake of 0.2 mg of methylmercury (UNEP, 1978).

(2) General populations in areas where high mercury concentrations in fish have been observed. Assuming a weekly per capita consumption of local fish ranging from 0.5 to 0.7 kg and concentrations of 1200 µg/kg (average for Mullus barbatus in the Tuscany coasts), the weekly intake is 0.6 to 0.8 mg.

(3) High-risk groups consuming higher than average amounts of seafood. These groups can exceed the maximum weekly mercury consumption as has been reported (UNEP, 1978). Nauen et al. (1982) also report that a sizeable number of persons in three selected Italian villages were found to exceed the maximum weekly intake.

(4) High-risk groups consuming higher than average amounts of seafood in areas where high concentrations of mercury in fish are found. Undoubtedly, these groups exceed the maximum weekly mercury intake.

(5) Groups with special food habits, e.g. with preference for tuna.

98. Special attention should be paid to these high-risk groups and to women of child-bearing age, as prenatal life is considered to be the stage of the life cycle most sensitive to methylmercury.

99. There is very little information available regarding the level of methylmercury intake by the population sectors considered to be at risk. Data from Italy (Nauen et al., 1982) suggest that some intakes may be up to 3.5 µg/kg body weight per day, i.e. 1.7 mg/70 kg/week. There is clearly a need for further study of the mercury intake in these critical groups, especially in areas where high mercury concentrations occur, as well as a study of mercury concentrations in blood or hair. Moreover, the effect of selenium in decreasing mercury toxicity should also be further investigated (Piotrowski & Inskip, 1981).

100. Actual measurements by biological monitoring of mercury in hair and/or blood in some fishing villages in Italy have shown concentrations mostly inferior to the critical levels, but above the recommended ones (Pacagnella et al., 1974; Bacci et al., 1976; Riolfatti, 1977). In practically every case, no neurological effects were observed, even though some of the subjects had mercury levels associated with the earliest clinical symptoms. Additional data from other Mediterranean countries may have been compiled, but are not available in published form. On the whole, however, very few studies have been performed.

101. The main gaps in existing knowledge, as summarized following the series of international expert meetings and working groups held in 1979 and 1980, are as follows:

(1) biological monitoring data on mercury levels in populations with high methylmercury intakes;

(2) patterns of seafood consumption in various sectors of the Mediterranean area, including seasonal variations;

(3) anthropogenic sources of mercury and other selected pollutants and their contributions to methylmercury in fish;

(4) methylmercury concentrations in various types of seafood in certain sectors of the Mediterranean Sea; and

(5) identification of populations with a relatively high methylmercury intake and estimation of their size.

102. The recently-initiated project on evaluation of methylmercury in Mediterranean populations and related health hazards is designed to fill these gaps to the extent possible. In addition, for the assessment of the overall mercury pollution in the Mediterranean, the following information should be collected:

(1) inputs and outputs of mercury including exchange with atmosphere;

(2) flow of mercury to and from the sediments;

(3) mercury distribution in sediment core samples;

(4) concentrations of different chemical forms of mercury in organisms, water and sediments from the open Mediterranean;

(5) mercury concentrations in the water column for various Mediterranean water masses;

(6) migrating patterns and feeding habits of tuna and other pelagic fish;

(7) food chain magnification.

103. For the assessment of local mercury pollution in areas close to mining sites or chlor-alkali plants, which constitute a major anthropogenic source, the following information should be collected:

(8) levels of mercury in marine organisms from polluted coastal areas and from reference areas;

(9) mechanism of mercury accumulation in marine biota;

(10) resolubilization of mercury from polluted sediments.

104. Provision for the performance of all the above studies with the exception of (6) has been made in the appropriate activities within the framework of the research component of MED POL Phase II.

105. The Consultation to re-examine the WHO environmental health criteria for mercury (Geneva, 21-25 April 1980) and subsequent studies, acknowledged that the JECFA Provisional Tolerable Weekly Intake of 200 µg of methylmercury within 300 µg of total mercury for a person of 70 kg body weight remains a valid recommendation in the light of presently available data. Based on present data on fish consumption in the Mediterranean area, and on the concentration of methylmercury reported in fish, as previously mentioned in this document, it is considered that the major part of the population has an intake well below the PTWI. In these circumstances, there does not seem to be any general hazard to the general population, and the legal imposition at regional level of an upper limit for mercury levels in edible marine organisms would not therefore appear necessary.

106. However, since limited population sectors in the Mediterranean area have an intake of methylmercury through seafood which exceeds the PTWI, it would be advisable to limit the total intake of methylmercury through seafood in order to protect such population sectors. It is realized that any such action may be contingent upon the availability of adequate data. In such situations the following courses of action could be considered:

(a) The establishment of environmental quality criteria for mercury in seafood, based on the present range of standards both in Mediterranean countries (where these exist) and elsewhere, either for all seafood, or for selected species.

(b) The establishment of environmental quality criteria for mercury in other parts of the marine ecosystem which could result in the banning or limitation of certain fishing activities, and/or the limitation of anthropogenic mercury discharged in certain areas with exceptionally high environmental mercury levels.

(c) Advice on dietary intake, including:

- (i) choice of the species and/or the size of fish allowed for consumption;
- (ii) frequency and number of fish meals;
- (iii) diversified sources of protein.

107. The advantages and disadvantages of the various actions are set out in Table 11.

108. Since almost all marine species fit for human consumption are likely to have greatly elevated levels of methylmercury when caught in areas adjacent to anthropogenic mercury discharges, it is clearly important to reduce as far as possible such sources of contamination. However, in the light of the natural sources of mercury found in the Mediterranean Basin this is unlikely to be an effective measure for the general Mediterranean mercury problem unless taken together with other steps. Any health effects will be the result of the total intake of mercury which is itself a function of the levels in the seafood, the quantity ingested per meal and the frequency of such meals. As has been indicated, the complete elimination of methylmercury from dietary fish is not feasible. However, where there is evidence of intakes of mercury above the recommended JECFA Provisional Tolerable Weekly Intake this should be reduced by the recommendation of suitable dietary modifications.

<u>Proposed environmental quality criteria for mercury in Mediterranean seafood</u>

109. Based on the results and experience gathered from the joint FAO/UNEP pilot project on baseline studies and monitoring of metals, particularly mercury and cadmium, in marine organisms (MED POL II) and in accordance with the above review of the scientific rationale presently available, the following is proposed as the FAO/WHO/UNEP environmental quality criteria for mercury, for application on an interim basis to seafood of Mediterranean origin.

Table 11

Advantages and disadvantages of various actions that could be taken to reduce mercury intake by populations at risk

Administrative measures	Advantages	Disadvantages
	I. Measures concerning fisheries (indirect)	
Establishment of standards in all seafood	Equal handling of all seafood; rejection of commodities with contaminant levels higher than those prescribed from the market according to enforcement.	High costs of monitoring system as prior condition of enforcement; little chance of enforcement for those with direct access to the resource, such as fishermen; thus, little protective effect on health and a negative effect on the fishery and the marketing of fish products in general
Establishment of standards in selected species	More specific measures, as directed at only relevant species. Relatively low enforcement costs	Apart from enforcement costs, subject to disadvantages given above
Restriction on the size of fish allowed for consumption for certain species in which mercury concentrations are known to be a function of size	Reduction of amount of commodities that need to be rejected from the market or discarded from the catch; reduction of enforcement costs; could partly be achieved through mesh size regulation	Difficult to enforce due to high appreciation of large specimens
Prohibition or restriction of fishing in certain areas	Selective exclusion or reduction of availability of seafood species from "hot spot" areas to consumers	Difficult and costly to enforce if many large areas are affected; in addition, one possible side-effect of reduced fishing pressure in such areas could be an increase (a) in the average size of individual specimens and (b) in the total fish population, with subsequent migration due to increased intraspecific competition
	II. Measures concerning anthropogenic discharge of mercury (indirect)	
Limitation of anthropogenic discharges of mercury	Reduction of the number of anthropogenic "hot spots" in which seafood tends to have elevated mercury levels because of contaminated discharge	Since anthropogenic discharge of mercury acccounts for a minor part of total mercury in the Mediterranean, control measures towards the sources alone cannot solve this problem
	III. Measures concerning seafood consumption (direct)	
Advice on dietary intake: choice of species	No necessity to reject any fish or shellfish with relation to mercury levels, but spread the distribution of species with known high mercury levels, substitute them by species with lower levels as much as possible	Food consumption patterns are generally very conservative and taste preferences are particularly difficult to change: requires costly information campaigns, if large populations have to be addressed
Advice on dietary intake: frequency of fish meals and other available sources of protein	As above; reduce the frequency of consumption especially of species with high mercury load and substitute by other sources of protein. Feasible method for sub-populations particularly at risk	In view of easy and cheap accessibility, a reduction in total seafood consumption or in some species is difficult to achieve unless the message convincingly comes across and either low level fish species or other protein sources become as readily available

"Seafood of Mediterranean origin is considered to present no hazard for consumption by the general population, provided that the JECFA Provisional Tolerable Weekly Intake (PTWI) of 300 µg of mercury, of which not more than 200 µg should be present as methylmercury, for a person of 70 kg bodyweight is not exceeded. Compliance with this interim criterion shall be established on the basis of the concentration of mercury in relevant species of seafood sampled at quarterly (3-month) intervals and on seafood consumption patterns. The concentraton of mercury should be determined by an agreed reference method, or by other methods yielding comparable results, proved by intercalibration with the relevant reference method. Consumption patterns shall be determined by agreed methods and protocols for those sectors of populations where either a high level of fish consumption is known or suspected, or where exposure to mercury from sources other than seafood is similarly known or suspected."

110. The reference method recommended for adoption in connexion with analysis of seafood for mercury is:

- UNEP/FAO/IAEA: Determination of total mercury in selected marine organisms by flameless atomic absorption spectrophotometry. Reference Methods for Marine Pollution Studies No.8, UNEP, 1982.

111. Although the general public can be considered to be temporarily safeguarded through regular monitoring of seafood and of consumption patterns, the problem of those sectors of the population known or suspected to be at risk remains. Prior to taking the necessary steps to safeguard these particular sectors, the magnitude and extent of this problem has to be discovered. The necessary activities designed to obtain the relevant information, planned to be performed in particular through MED POL Phase II, include:

- The compilation of existing national data on the subject to obtain indications of areas and localities within the region where population sectors can be considered as actually or potentially at risk.

- The conduction of dietary surveys on seafood consumption on these populations, and the evaluation of methylmercury intake, based on the results of the surveys and on available data on levels of mercury in seafood.

- The performance of studies to (a) correlate the amounts of total mercury and methylmercury in selected Mediterranean seafood species, and (b) obtain an indication of the effect of cooking on the methylmercury content of seafood.

- The sampling and analysis of human hair and whenever appropriate of other tissues, for total mercury and methylmercury, among the target populations surveyed.

- The carrying out of appropriate clinical epidemiological studies on indicated subgroups within the population samples, to correlate mercury levels with health effects.

MEASURES RECOMMENDED FOR ADOPTION BY THE CONTRACTING PARTIES

112. In view of the fact that, as stated earlier in this document, all the available evidence to date indicates that, on the basis of present concentrations of mercury in Mediterranean seafood and of general seafood consumption within the region, the general public cannot be considered at risk, it is considered that, at this stage, the imposition of upper limits for mercury concentrations in seafood on a common regional basis would not be justified, although individual countries not already applying these could consider their introduction if national circumstances so require.

113. On the basis of the assessment of the quality of Mediterranean seafood with regard to its mercury content as described above, the following recommendations are submitted for the consideration of the Working Group, with a view to their transmission by UNEP to the Contracting Parties.

(a) Adopt the proposed FAO/WHO/UNEP interim environmental quality criteria for mercury in Mediterranean seafood (see paragraph 109) and implement them to the extent possible by appropriate national legal and/or administrative measures as the minimal common measures safeguarding the general public.

(b) Adopt the method for determination of total mercury in selected marine organisms by flameless atomic absorption spectrophotometry (Reference Methods for Marine Pollution Studies No.8, UNEP/FAO/IAEA, 1982) developed to support the proposed interim environmental quality criteria (see paragraph 110) as the reference method to be used in connexion with these criteria.

(c) Include, to the extent possible, in their national monitoring programmes within the framework of MED POL Phase II, the sampling and analysis of all species of seafood known to accumulate mercury.

(d) Limit, to the extent possible, anthropogenic discharges of mercury into the Mediterranean Sea, pending the eventual formulation of emission standards for mercury, as a result of the entry into force of the Protocol for the Protection of the Mediterranean Sea aganist Pollution from Land-Based Sources, and in terms of Article 5 of that Protocol, commence as early as possible, the elaboration of the necessary programmes and measures with respect to mercury.

(e) Provide the secretariat to the Convention with the fullest information possible on:

- present legislation and administrative measures on existing national criteria for levels of mercury in seafood;
- measures taken on (a), (c) and (d) above;
- relevant monitoring data on (c) above.

(f) Continue to provide full support to the monitoring and research component of MED POL Phase II relevant to the assessment of the mercury content of Mediterranean seafood, and the hazards affecting all sectors of the population arising from seafood consumption (see paragraphs 101-102), in particular:

- identification of population groups at risk;
- surveys on seafood consumption patterns among such populations;
- surveys on mercury levels in affected population groups;
- epidemiological studies to obtain the necessary information on the relationship between mercury intake and health effects;
- studies of the relationship between total mercury and methylmercury content of seafood, and the effects of cooking on such content;
- studies on biogeochemical cycles of mercury in the Mediterranean;
- acquisition of the data detailed in paras 102 and 103 of this document.

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