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WORKSHOP ON JELLYFISH BLOOMS IN THE MEDITERRANEAN
RAPPORT DE JOURNEES D'ETUDE SUR LES PROLIFERATIONS ANORMALES DE MEDUSES EN MEDITERRANEE

(Athens, 31 October - 4 November 1983)

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

Programme à Long-terme de Surveillance Continue et de Recherche
des Pollutions en Méditerranée (MED POL - PHASE II)

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FOREWORD

At the Third Meeting of the Contracting Parties held in Dubrovnik (28 February - 4 March, 1983), the problem of the occurrence of jellyfish blooms in some areas of the Mediterranean was raised, and a request to UNEP for action in the framework of the Long-term Programme for Pollution Monitoring and Research in the Mediterranean Sea (MED POL - PHASE II) was then formulated. As a first step, in June 1983, a Seminar on jellyfish blooms organized by the Greek Government with UNEP support, helped to identify scientists from Mediterranean and other countries who had been particularly active in the field of jellyfish biology, health research and jellyfish combatting procedures. Subsequently, a Workshop on jellyfish blooms in the Mediterranean was organized by the MED UNIT in Athens from 31 October to 4 November 1983, as part of the MED POL - PHASE II activities, in co-operation with WHO and FAO. A call for papers was circulated by the MED UNIT to a large number of scientists in and outside the Mediterranean region. As a result, sixty-four experts from Mediterranean countries, the Federal Republic of Germany, Belgium and U.S.A. as well as representatives of FAO and WHO attended the Workshop and twenty-seven papers were presented.

The Workshop was divided into six sessions and a moderator was appointed for each of them, as follows:

SESSION I a : OCCURRENCE OF JELLYFISH BLOOMS IN THE MEDITERRANEAN
Moderator : Laura Rottini-Sandrini

b : IMPACT OF JELLYFISH BLOOMS ON HUMAN ACTIVITIES
Moderator : Heino Möller

c : IMPACT OF JELLYFISH BLOOMS ON HUMAN HEALTH AND RECREATION
Moderator : Zvonimir Maretic

SESSION II a : ASSESSMENT OF BIOLOGICAL CONDITIONS LEADING TO JELLYFISH BLOOMS
Moderator : Victor Axiak

b : ASSESSMENT OF ENVIRONMENTAL CONDITIONS LEADING TO JELLYFISH BLOOMS
Moderator : Jacques GANOULIS

SESSION III : METHODS TO CONTROL AND COMBAT BLOOMS OF JELLYFISH
Moderator : David G. CARGO

Each session was followed by a short discussion. At the end of the Workshop a round table discussion synthesized the major topics raised during the Workshop and adopted the conclusions and recommendations which are reported here below.

As a result of these conclusions and recommendations, a jellyfish programme in the Mediterranean was launched by the UNEP Co-ordinating Unit for the Mediterranean Action Plan in the framework of the MED POL - PHASE II programme and it is now ongoing in many Mediterranean countries.

In preparing these Proceedings, thanks are due, first to the session moderators who actively contributed to the success of the Workshop, and also to Mr. Thomas E. Graham for editing of the papers presented and to Mrs. C. Papageorgopoulos for computer typing and collating of all the material contained in these Proceedings.

Conclusions

Blooms of medusae are not of recent origin in the Mediterranean, neither are they limited to this sea. In fact reports of blooms of jellyfish date back as far as the early 19th century. Moreover they have been reported in several areas of the oceans.

Population fluctuations of medusae may very well be determined by seasonal rhythmic changes in the local environmental conditions, such as sea-water temperature.

Factors leading to the recent blooms of Pelagia noctiluca are not so easy to identify, mainly due to the apparent irregularity and complexity of the patterns of occurrences of such blooms. Another reason may be the lack of precise data on occurrences of past blooms and on the associated environmental parameters prevalent at the time of these blooms.

To explain this phenomenon, perhaps one should look at it at the global scale. Long-term global climatic fluctuations may lead to occasional changes in the dynamics of water masses which alter local environmental conditions, eventually increasing availability of food, or modifying the nature of foodwebs within the pelagic community, favouring an increase in the numbers of medusae. The possible role of environmental stress resulting from such uncommon conditions in inducing an increase in the fecundity of medusae was mentioned.

Present state of knowledge on the occurrence of this phenomenon in the various Mediterranean areas does not permit the establishment of a relationship with the levels of pollution in coastal areas, although it may be suspected.

Investigations under controlled laboratory conditions, including studies on the survival, predation, fecundity, feeding, and behaviour of the relevant species of medusae under different environmental conditions and studies on exposure to stress such as pollutants, assist in answering at least some of the aforementioned questions.

The development of new lines of investigation, such as trace element contents and lipid composition of medusae and of their usual predators and preys, may clarify and perhaps quantify the foodwebs involved. Similar biochemical investigations on medusae from polluted and unpolluted zones may also shed new light on the question of correlation of blooms and pollution.

Severe impacts of jellyfish blooms on human activities were reported, mainly in relation to the hinderance of fishing by clogging nets and stinging fishermen, clogging of power plant intake system and indirect impact on fisheries by affecting fish stocks by predation. Most of this information comes from north-east Atlantic waters, probably due to a relatively large amount of activities in this area. Nevertheless, one report proved that similar problems also exist in some areas of the Mediterranean.

Studies on the epidemiology, clinics, prevention and treatment of stings made by Pelagia noctiluca show that an average case is not serious and represents more a nuisance than a health hazard.

However, one can say that Pelagia noctiluca can present a significant problem for human health and recreation due to its frequent, but unpredictable, occurrence in some areas during some periods of time, especially because of psychological reasons.

As is the case with other animal venoms, such as those from hymenopterae (bees and wasps), intoxication by Pelagia noctiluca stinging depends on the condition and sensitivity of the victim, as well as on that of the animal itself.

Severe cases have been encountered mostly when the most sensitive parts of the body, such as eyes, are affected. Other serious cases may also appear when the victim suffers many stings at once, for instance, if falling into a swarm of medusae; sensitive victims may collapse though such cases are rare.

As concerns the environmental factors, which may bring about medusae blooms, we should distinguish on the one hand, the physical factors (currents, temperature, salinity), and on the other, the quality of the waters (waste waters, eutrophication).

Observations on the appearance of Pelagia noctiluca swarms have often shown a link between wind and the transport of these planktonic organisms. Therefore, sea currents due to winds or other causes appear to be responsible, mainly for the horizontal transport of medusae. The use of mathematical models for the transport of medusae by currents may give encouraging results.

Temperature seems to play an important role on the reproduction of Pelagia noctiluca by limiting its proliferation to the low winter temperatures.

No quantitative correlation between salinity and the concentration of Pelagia noctiluca has been reported. Further, many questions remain unanswered as to the relationship between water pollution and the growth of jellyfish.

As to the methods to control or combat jellyfish blooms, although it appears that practical and proved measures have not yet been successfully developed, a number of actions could be suggested in this direction.

The design of barriers (single or in combination) to protect sensitive industrial water usage locations, and esthetically acceptable, efficient protection for swimming beaches against the intrusion of noxious jellyfish could be developed by engineers in close collaboration with specialists in hydrodynamics, as well as biologists.

Further, it may be possible to develop means of reducing the numbers of medusae or their effects on man. These might include: habitat modification by the use of the behaviour of medusae to their own disadvantage, reduction of pollution levels which might be responsible for their proliferation, and establishment of models for predicting their occurrence on a seasonal or short-term local basis. This will require a wide range of biological, hydrographic and other studies.

Recommendations

After analysing the various aspects of jellyfish blooming, its impact and means to control it, the following recommendations obtained the consensus of the participants:

1. A Mediterranean-wide programme for monitoring the occurrence of jellyfish, especially *Pelagia noctiluca*, should be established using the infrastructure of the Long-term Programme for Pollution Monitoring and Research in the Mediterranean (MED POL - PHASE II), both in coastal and open-sea areas.

   Such a programme should also determine environmental conditions relevant to the swarming of jellyfish and pay special attention to space and time variability, as well as to medium and long-term trends at the regional level, and to the extent possible, the global level.

2. An assessment should be made of the actual social and economic impact of the occurrence of jellyfish blooms on fishing and tourism around the Mediterranean.

3. Research should be conducted on a number of topics:

   - Biology of these organisms and population dynamics.

   - Ecology, physiology, biochemistry and other, the study of which may assist in the understanding of the observed distributions.

   - Hydrodynamics of coastal and open-sea areas controlling the transport of jellyfish swarms.

   - Influence of pollution on the biology and food availability of the jellyfish.

   - Characterization of jellyfish poisoning and preventive and curative treatments.

4. Preventive measures should be taken, such as health education, beach management, elaboration of numerical models, mostly hydrodynamical, covering specific areas, possibly contributing to the development of criteria for general coastal area management.

AVANT - PROPOS

Lors de la Troisième Réunion des Parties contractantes, tenue à Dubrovnic (28 février - 4 mars 1983), le problème de l'apparition des proliférations anormales de méduses dans certaines régions de la Méditerranée a été soulevé; il a été demandé au PNUE d'agir dans le cadre du Programme à long-terme de surveillance continue et de recherche en matière de pollution dans la Méditerranée (MED POL - PHASE II). Comme première mesure, un séminaire sur les proliférations anormales de méduses, organisé par le Gouvernement grec avec le soutien du PNUE, a permis de trouver les chercheurs de pays méditerranéens et autres qui ont été particulièrement actifs dans le domaine de la biologie des méduses, des questions de santé quant à ce problème et des procédures de lutte contre les méduses. A la suite duquel, l'Unité MED a organisé à Athènes du 31 octobre au 4 novembre 1983 des Journées d'étude sur les proliférations anormales de méduses en Méditerranée comme faisant partie des activités de la PHASE II du Programme MED POL, en coopération avec l'OMS et la FAO. L'Unité MED avait distribué une demande auprès d'un grand nombre de chercheurs de la région méditerranéenne et hors de celle-ci afin qu'ils présentent des exposés. Il en est résulté que soixante-quatre experts de pays méditerranéens, de République Fédérale d'Allemagne, de Belgique et des Etats-Unis ainsi que des représentants de l'OMS et de la FAO assistèrent aux Journées d'étude. Vingt-sept exposés ont été présentés. Les Journées d'étude ont été divisées en six sessions avec un modérateur désigné pour chacune d'entre elles de la façon suivante:

SESSION I a : Modérateur : L. ROTTINI-SANDRINI
APPARITION DE PROLIFERATIONS ANORMALES DE MEDUSES EN MEDITERRANEE

b : Modérateur : H. MOLLER
INFLUENCE DES PROLIFERATIONS ANORMALES DE MEDUSES SUR LES ACTIVITES HUMAINES

c : Modérateur : Z. MARETIC
INFLUENCE DES PROLIFERATIONS ANORMALES DE MEDUSES SUR LA SANTE HUMAINE ET LES LOISIRS

SESSION II a : Modérateur : V. AXIAK
EVALUATION DES CONDITIONS BIOLOGIQUES ENTRAINANT DES PROLIFERATIONS ANORMALES DE MEDUSES

b : Modérateur : J. GANOULIS
EVALUATION DES CONDITIONS DU MILIEU ENTRAINANT DES PROLIFERATIONS ANORMALES DE MEDUSES

SESSION III : Modérateur : D.G. CARGO
METHODES DE CONTROLE ET DE LUTTE CONTRE LES PROLIFERATIONS ANORMALES DE MEDUSES

Chaque session a été suivie d'une courte discussion. A la fin des Journées d'étude, une discussion de table ronde a fait la synthèse des points les plus importants soulevés au cours de la réunion et a adopté les conclusions et recommandations rapportées ci-dessous.

A la suite de ces conclusions et recommandations, l'Unité de Coordination du Plan d'action pour la Méditerranée du PNUE a lancé un programme relatif aux méduses en Méditerranée dans le cadre de la PHASE II du programme MED POL, actuellement en cours dans plusieurs pays méditerranéens.

En ce qui concerne la préparation de ce compte-rendu, il faut remercier, tout d'abord les modérateurs des sessions qui ont contribué de façon active au succès des Journées d'étude, M. Thomas E. Graham pour la publication des communications présentées et Mme C. Papageorgopoulos qui a assuré la dactylographie sur ordinateur de tous les éléments qu'elle avait rassemblés que l'on retrouve dans ce compte-rendu.

Conclusions

Les proliférations de méduses ne sont pas d'origine récente dans la région de la mer Méditerranée. Elles ne sont pas non plus uniquement localisées dans cette mer. En fait, déjà dès 1800 des documents signalent des proliférations de méduses. De plus, elles ont été observées dans plusieurs régions des océaniques.

Les fluctuations des populations de méduses peuvent fréquemment être déterminées par des changements saisonniers rythmiques des conditions locales de l'environnement telles que la température.

Il n'est pas facile d'identifier les facteurs récemment à l'origine de ces proliférations des Pelagia noctiluca particulièrement à cause de l'irrégularité apparente et de la complexité de leurs modes d'apparition. C'est peut être aussi dû au manque de données précises sur l'apparition des prolifération dans le passé ainsi que sur les paramètres écologiques s'y rapportant qui prévalaient au moment de ces proliférations.

Pour expliquer ce phénomène, il faut peut être envisager le niveau planétaire. Les fluctuations climatologiques à long-terme peuvent aboutir à des changements occasionnels de la dynamique des masses d'eau qui agiraient sur les conditions écologiques locales en augmentant la nourriture disponible ou en modifiant la nature des chaînes alimentaires dans la communauté pélagique, favorisant ainsi une augmentation du nombre des méduses. L'aggression du milieu issue de telles conditions inhabituelles a été mentionnée comme pouvant jouer un rôle, en provoquant un accroissement de la fécondité des méduses.

L'état actuel de nos connaissances sur l'apparition de ce phénomème dans les diverses régions méditerranéennes ne permet pas d'établir qu'il existe un lien avec le niveau de la pollution dans les zones littorales bien qu'un tel rapport a été suggéré.

Les recherches dans des conditions de laboratoire contrôlées telles que : des études sur la survie, la prédation, la fécondité et l'alimentation de même que sur le comportement normal des espèces de méduses appropriées dans des conditions écologiques différentes et exposées à des aggressions comme les polluants, aident à répondre au moins à certaines de ces questions.

En développant de nouvelles lignes de recherche - telles que l'analyse des éléments en trace et de la composition lipidique des méduses et de leurs prédateurs et proies habituels, on pourrait éclaircir et peut être quantifier les données dont on dispose sur les chaînes alimentaires impliquées. Les études biochimiques du même genre sur les méduses des zones polluées et celles des zones non polluées peuvent aussi éclairer la question du rapport entre les proliférations et la pollution.

Des influences importantes des proliférations de méduses sur les activités humaines ont été signalées principalement du fait qu'elles entravent la pêche en obstruant les filets et en piquant les pêcheurs, qu'elles bouchent les systèmes d'apport d'eau des centrales électriques et ont un effet indirect sur la pêche en affectant les populations de poissons par prédation. La majeure partie de ces renseignements provient des eaux du nord-est de l'Atlantique, probablement à cause des activités relativement importantes dans cette région. Cependant un rapport a prouvé qu'il existe aussi des problèmes semblables dans certaines zones de la mer Méditerranée.

Des études sur l'épidémiologie, les soins cliniques, la prévention et le traitement des piqûres de Pelagia noctiluca montrent que le cas moyen n'est pas grave, provoquant plutôt une gêne sans mettre en danger la santé.

Cependant, on peut dire que, pour des raisons principalement d'ordre psychologique, les essaims de Pelagia noctiluca peuvent présenter un problème important pour les loisirs à cause de leur apparition fréquente mais souvent imprévisible.

Comme pour les autres venims animaux, tels que ceux des hyménoptères (abeilles et guêpes), l'empoisonnement par piqûre de Pelagia noctiluca dépend des conditions physiologiques et de la sensibilité de la victime ainsi que de celles de l'animal lui-même.

On voit les cas les plus graves surtout lorsque les parties les plus sensibles du corps sont touchées, comme les yeux. Il peut aussi s'agir de cas graves si la victime a de nombreuses piqûres en une seule fois, par exemple, en tombant sur un essaim de méduses; dans ce cas, par ailleurs très rare, il peut même y avoir un évanouissement.

En ce qui concerne les conditions d'environnement qui pourraient amener aux proliférations de méduses, il faut distinguer d'une part les facteurs physiques (courants, température, salinité) et d'autre part la qualité des eaux (eaux usées, eutrophication).

Des observations faites sur l'apparition d'essaims de Pelagia noctiluca ont souvent établi un rapport entre le vent et le transport de ces organismes planctoniques. Les courants marins induits par le vent ou par d'autres causes apparaissent donc comme responsables du transport des méduses surtout dans le sens horizontal. La modélisation mathématique du transport des méduses par les courants peut donner des résultats encourageants.

La température semble jouer un rôle régulateur sur la reproduction de Pelagia limitant sa multiplication avec les basses températures d'hiver.

Aucune corrélation quantitative entre la salinité et la concentration de Pelagia noctiluca n'a été rapportée. De même, la relation entre pollution des eaux et croissance des méduses semble laisser plusieurs questions ouvertes, .

En ce qui concerne les méthodes de contrôle ou de lutte des proliférations de méduses, bien qu'il semble que des mesures pratiques et prouvées n'aient pas encore été développées, un nombre d'actions dans ce sens peuvent être suggérées.

La conception de barrières (simples ou combinées) destinées à protéger les zones sensibles d'utilisation d'eau à des fins industrielles, qui soient acceptables sur le plan esthétique et offrent une protection efficace contre l'intrusion nuisible des méduses, peut être développée par des ingénieurs en étroite collaboration avec des spécialistes en hydrodynamique et des biologistes.

De plus, il peut être possible de développer des moyens pour réduire le nombre des méduses et diminuer leurs effets sur l'homme. Ceux-ci peuvent inclure: la modification de l'habitat en utilisant le comportement des méduses à leur propre désavantage, la réduction des niveaux de pollution qui peuvent être responsables de leur prolifération et l'établissement de modèles visant à prévoir leur apparition sur une base locale saisonnière ou à court-terme.

Recommandations

Après avoir analysé les divers aspects des proliférations de méduses, leurs effets et les moyens de lutte, les participants se sont mis d'accord sur les recommandations suivantes :

1. Il faudrait établir un programme pour l'ensemble de la Méditerranée ayant pour objectif la surveillance continue de l'apparition des méduses, particulièrement de *Pelagia noctiluca* en utilisant l'infrastructure du Programme à Long-terme de Surveillance Continue et de Recherche en Matière de Pollution dans la Méditerranée (MED POL - PHASE II), à la fois sur le littoral et en haute mer.

   Un tel programme devrait aussi déterminer les conditions de l'environnement ayant rapport aux essaims de méduses et souligner particulièrement la variabilité dans le temps et dans l'espace ainsi que les tendances à moyen et à long-terme au niveau régional et, dans le mesure du possible, au niveau mondial.

2. Il faudrait procéder à une évaluation de l'effet réel social et économique de l'apparition des proliférations de méduses sur la pêche et le tourisme dans toute la Méditerranée.

3. Il faudrait effectuer des travaux de recherche sur plusieurs sujets ayant un rapport important avec les essaims de méduses, tels que :

   - La biologie et la dynamique des populations de méduses.
   - L'écologie, la physiologie, la biochimie et d'autres domaines dont l'étude peut aider à comprendre les distributions observées.
   - L'hydrodynamique du littoral et de la haute mer qui contrôle le transport des essaims de méduses.
   - L'influence de la pollution sur la biologie des méduses et de la disponibilité de nourriture.
   - L'identification des poisons des méduses ainsi que des traitements préventifs et curatifs.

4. Il faudrait prendre des mesures de prévention telles que la formation sanitaire, la gestion des plages et l'élaboration de modèles numériques surtout hydrodynamiques, couvrant des régions spécifiques, contribuant sans doute au développement de critères pour une gestion générale du littoral.

List of papers

Liste des communications

Session I a

OCCURRENCE OF JELLYFISH BLOOMS IN THE MEDITERRANEAN

APPARITION DE PROLIFERATIONS ANORMALES DE MEDUSES EN MEDITERRANEE

Session I b

IMPACT OF JELLYFISH BLOOMS ON HUMAN ACTIVITIES

INFLUENCE DES PROLIFERATIONS ANORMALES DE MEDUSES SUR LES ACTIVITES HUMAINES

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* Paper not presented

Session I c

IMPACT OF JELLY-FISH BLOOMS ON HUMAN HEALTH AND RECREATION

INFLUENCE DES PROLIFERATIONS ANORMALES DE MEDUSES SUR LA SANTE HUMAINE ET LES LOISIRS

Session II a

ASSESSMENT OF BIOLOGICAL CONDITIONS LEADING TO JELLYFISH BLOOMS

EVALUATION DES CONDITIONS BIOLOGIQUES ENTRAINANT DES PROLIFERATIONS ANORMALES DE MEDUSES

Session II b

ASSESSMENT OF ENVIRONMENTAL CONDITIONS LEADING TO JELLY-FISH BLOOMS

EVALUATION DES CONDITIONS DU MILIEU ENTRAINANT DES PROLIFERATIONS ANORMALES DE MEDUSES

Session III

METHODS TO CONTROL AND COMBAT BLOOMS OF JELLY-FISH

METHODES DE CONTROLE ET DE LUTTE CONTRE LES PROLIFERATIONS ANORMALES DE MEDUSES

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SESSION Ia

OCCURRENCE OF JELLYFISH BLOOMS IN THE MEDITERRANEAN

APPARITION DE PROLIFERATIONS ANORMALES DE MEDUSES EN MEDITERRANEE

APPEARANCE OF THE JELLYFISH Pelagia noctiluca IN THE ADRIATIC SEA DURING THE SUMMER SEASON OF 1983

by

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Introduction

Since 1978, through various authors (Benovic and Maretic, 1978; Malej, 1981; Rottini-Sandrini and Stravisi, 1981; Vucetic, 1982; Piccinetti-Manfrin and Piccinetti, (in press)), and a number of newspaper articles, the appearance of the jellyfish Pelagia noctiluca bloom has been reported in various areas of the Adriatic Sea. The period of bloom reported was mostly during the swimming season, i.e. July-September.

Considering the great public interest as well as UNEP-MAP steps towards the definition and extent of the problem within the Mediterranean region, the Yugoslav National Co-ordinator for MED POL has distributed specially designed forms to the Yugoslav local coastal authorities, requesting answers on the occurrence of Pelagia noctiluca during the summer months of 1983.

The results of the answers received are discussed below.

Inquiry

A number of specially designed forms (see appended example) were distributed to the coastal municipal governments, asking for participation in the monitoring of jellyfish by the fishing and coastguard authorities during their usual supervision work.

The forms are designed to obtain information from people who are not trained biologists and do not necessitate the use of any equipment. Estimates of the number of specimens per m^3, diameter of the bell, colour of the species, location, wind, waves and cloudiness were requested. Answers were expected on a daily basis.

Completed questionnaires were received from only two regions of the Adriatic coast: Dubrovnik and Rijeka. However, these results represent the 20 per cent of completed questionnaires expected. Further, the results received corresponded with the actual occurrences of jellyfish along the eastern Adriatic coast during July, August and September of 1983. It has to be mentioned that many of the people answering the questionnaire wrote their own comments concerning the jellyfish blooms.

Results

Results are shown in the figure illustrating the occurrence of Pelagia noctiluca during the summer months. Altogether it was reported at 31 locations. Only for eight locations, situated nearer the open Adriatic, was the number of specimens observed higher than $100/m^3$. The only location in the southern Adriatic was Cavtat, reporting numbers up to 800 ind/m^3 and up to 5,000 individuals which were taken by gill-nets. The commentary made in this report was that many of the specimens observed were without tentacles and that their diameter was about 8 cm.

With the exception of the report from Palagruza (5-10/IX), all the other observations reporting higher numbers were from the northern Adriatic. The sporadic occurrence of a few individuals was noted from all the reported regions, close to the coast, in the bays and between the islands. The numbers were mostly from 1-3 ind/m^3 and only from the outer part of the island Losinj were numbers up to 20 ind/m^3.

At almost all the stations from the southern Adriatic coast and the many stations between the islands and close to the mainland, jellyfish were not observed.

In addition to the above comments, it has been noted that at all the stations in the southern Adriatic, jellyfish blooms were observed during the colder period from November to May. In the northern Adriatic reports, the comments were that other, larger, individual jellyfish (probably Cotylorhiza tuberculata) were observed, often followed by small fish. The diameter of the bell was reported as being between 1.5-8 cm. The weather conditions varied from completely calm with no clouds, to light winds of different directions, gentle waves and partly cloudy.

Discussion

The aim of this paper is to present the results of an inquiry addressed to people who are not trained biologists, who are professionally occupied with the supervision of fishery and navigation, and who are very often good field observers. It was expected that about 20 per cent of the questionnaires sent would be filled in and returned, and that the answers would serve as an indication of the occurrence of jellyfish. Taking into account that reports were received from two fairly large regions of the eastern Adriatic coast and that the people filling in the forms gave their own comments, particularly about colour, size and the occurrence of jellyfish in the other seasons of the year, it may be concluded that such a survey can offer a good flow of information at national and probably also at international levels.

The information furnished by this inquiry suggests that it would be possible to answer a few crucial questions concerning jellyfish blooms, at least in the Adriatic Sea.

Possible questions:

1. Are there any problems concerning the appearance of jellyfish?
2. If so, since when have there been problems?
3. Where are the problems located geographically?

Obviously, the answer to the first question is positive, primarily because of the larger quantities of jellyfish located near the beaches of the coastal and island sites, which are directly influenced by the main Adriatic inflow current. The larger number of jellyfish affects the recreational activities of the general public, directly by stings, and indirectly by the fear-induced abandonment of swimming. The answer to the existence of this problem can also be found in the public pressure and in newspaper articles asking for an explanation of the blooms and for the possible measures with which to combat the "invasion" of the jellyfish. Based on these articles, as well as the scientific reports on the "unusual" occurrences of Pelagia noctiluca, especially in the northern Adriatic area, the answer to the second question could be: since 1976.

Geographically, the most affected area is the northern Adriatic coast. According to the results of the inquiry for the months of July, August and September 1983, obviously larger quantities of jellyfish were reported only from the northern Adriatic, while in the southern Adriatic blooms were seen during the cold season, i.e. the non-swimming months. As for the zones between the islands and the mainland, there are either no observations or there are very few individual specimens present. Because of this, these areas do not have any problem regarding jellyfish blooms.

Considering the whole question of jellyfish blooms in the Adriatic Sea, it can be concluded that there is a need for a detailed project, covering all three topics of this UNEP-MAP workshop, which would be a part of the integrated Mediterranean project. This project should include as many Mediterranean countries as possible and would define the transport of the jellyfish throughout the region and unify the methods for control and combat of the blooms.

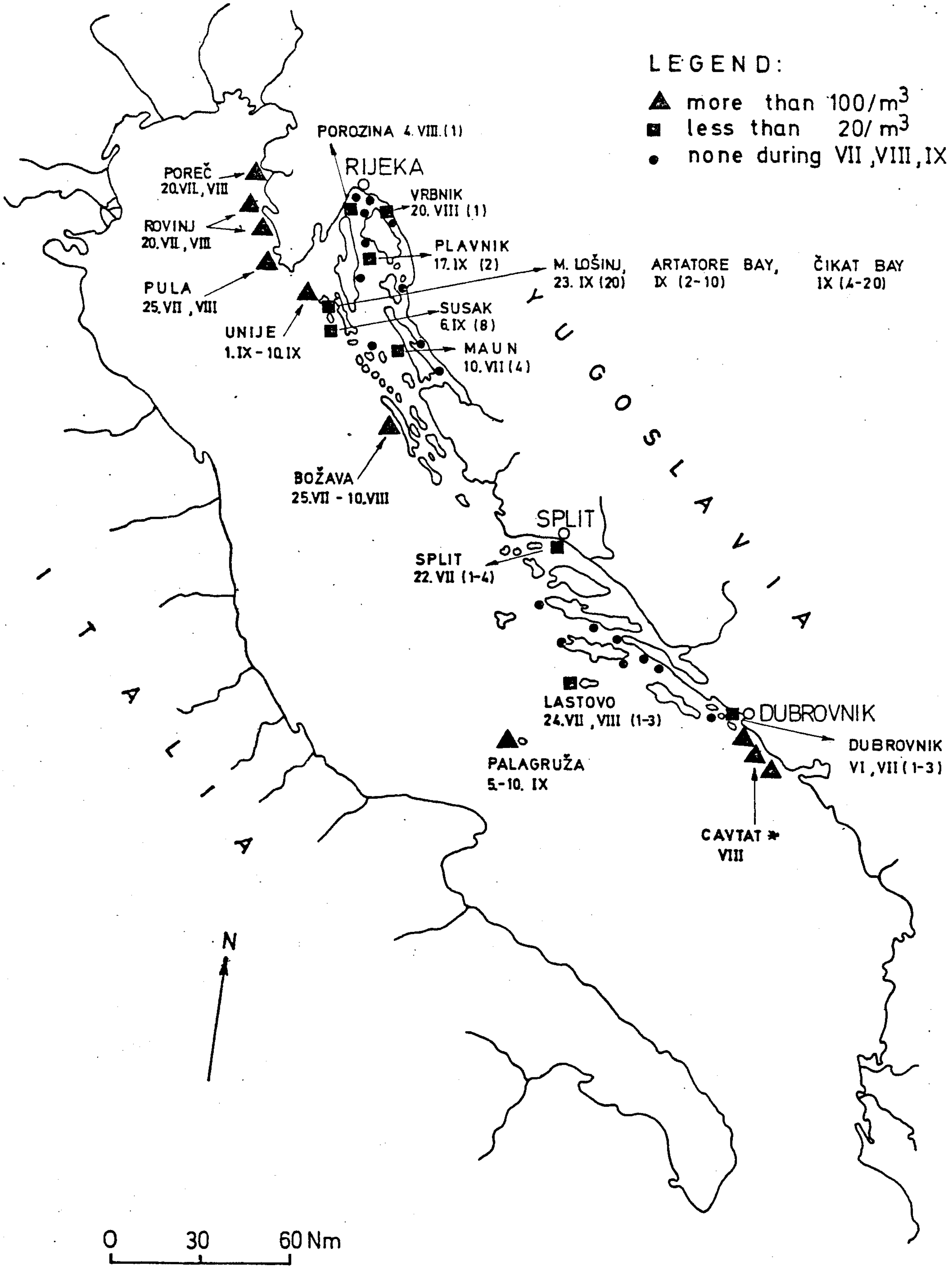


Figure I. Appearance of the jellyfish Pelagia noctiluca in the Adriatic Sea during July, August and September of 1983. Numbers in brackets show actual number of specimens observed. At location CAVTAT (*), many specimens were without mouth arms

EXAMPLE OF THE QUESTIONNAIRE FOR JELLYFISH DATA

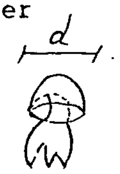
Month:

Date	Number of specimens	Bell diameter	Colour	Location	Weather conditions		
					Wind	Waves	Cloudiness
1.							
2.							
3.							
....							
Comments:							
Data collected by: Authority:							

Explanations:

Number of specimens: Write in estimation of jellyfish number per 1 m^3

Bell diameter: Write in average bell diameter



Colour: Write in dominant colour of the jellyfish

Location: Write in the nearest town

Wind and Waves: Write in speed and direction

Cloudiness: Write in per cent of clouds (0-100 %)

Figure II. Proposed questionnaire used for the gathering of information concerning the appearance of jellyfish by local authorities (i.e. port captains, fishery inspection, etc.)

References

Benovic, A. and Maretic, Z.,(1978). - Medusae, Fokus, 137, 14-17 (in Croatian).

Malej, A., (1981).-Preliminary report on the ephyrae of *Pelagia noctiluca* (Forskal) from the Bay of Trieste, North Adriatic. *Rapp. Comm. int. Mer Medit.* 27/7, 149-150.

Piccinetti-Manfrin, G. and Piccinetti, C.,(in press). - Distribution of *Pelagia noctiluca* (Forskal) in the Adriatic from 1976 to 1983. *Nova Thalassia*.

Rottini-Sandrini, L. and Stravisi, F., (1981). - Preliminary report on the occurrence of *Pelagia noctiluca* (Semaeostomeae, Pelagiidae) in the Northern Adriatic. *Rapp. Comm. int. Mer Medit*. 27/7, 147-148.

Vucetic, T., (1982). - Unusual occurrence of *Pelagia noctiluca* in the Adriatic III - Influence of water masses dynamic on the distribution of the *Pelagia noctiluca* in the Adriatic. *Acta Adr*. 23/1/2, 105-117.

MEDUSAE OF THE EGYPTIAN MEDITERRANEAN WATERS

by

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Introduction

Our knowledge of the medusae of the eastern Mediterranean in general and of the southern part of the Levant in particular is still far from being satisfactory. As stated by Kramp (1959) the north coast of Africa and the entire eastern basin of the Mediterranean have not been investigated at all adequately. The comprehensive report of Kramp (1924) gave valuable information on the occurrence and distribution of medusae in many parts of the Mediterranean, but unfortunately the routes of the Thor Expedition (1908-1910) did not include the south-eastern Mediterranean. Furthermore subsequent published works on Mediterranean medusae were generally restricted to areas in the western basin and the Adriatic Sea (Ranson, 1936; Babnik, 1948; Hure, 1955; Vannucci, 1966; Berhaut, 1969 a, b; Albartini-Berhaut, 1970; Brinckmann-Voss, 1970 and Goy, 1972). Except for the work of Schmidt (1973 and 1976), information on the medusae of the south-eastern Mediterranean was included in papers dealing with the general zooplankton of the area (cf. Dowidar, 1965; Dowidar and El-Maghraby, 1970; Pasteur et al., 1976). This paper is thus the first to deal with the medusae of the south-eastern region of the Mediterranean Sea.

Materials and methods

The present study is based on the examination of zooplankton samples collected from the Mediterranean waters off the Egyptian coast during the surveys made in 1966, 1970 and 1982. In each of these years four seasonal cruises were made. In each season seven to nine N-S transects comprising 25-30 stations were occupied. The stations sampled covered the neritic as well as the oceanic waters of the continental slope. In 1966 and 1970 samples were collected by a "judy" net, mesh size 0.33 mm and mouth diameter 36 cm. In 1982 an ichthyoplankton net was used, mesh size 2 mm and mouth diameter 1 m. Both horizontal and vertical hauls (maximum depth 100 m) were taken at each station. In 1970 additional fractional hauls, at 100 m intervals, were collected at deep stations (maximum depth 500 m). Samples were concentrated and preserved in 4 per cent neutralized formalin solution.

Results

The following are brief notes on the occurrence of the species so far identified in the plankton samples collected from the south-eastern Mediterranean waters off the Egyptian coast during 1966 and 1970 as well as from previous records. The samples of 1982 have not, as yet, been fully analysed.

ANTHOMEDUSAE

The following species belonging to this order were identified:

Bougainvillia ramosa (Van Beneden)

Ectopleura dumortieri (Van Beneden)

Oceanis armata (Kolliker)

Turritopais nutricula (McCrady)

Pandea conica (Quoy and Gaimard)

Bougainvillia ramosa

This species was recorded in the area during the winter season of 1970 (January-March) and it also occurred in January 1982. The maximum density, viz. 30-40 individuals/100 m^3, was recorded off Damietta in February 1970 and off Agami in January 1982. Otherwise it was always rare and irregular and almost completely absent from oceanic samples. The temperature and salinity ranges recorded for the species in the area were 16.5°-18.1°C and 38.5-39.2°/oo respectively. According to Schmidt (1976) B. ramosa had not previously been recorded in the eastern Mediterranean. The species may thus be considered new to the eastern basin, but whether it has immigrated from the Red Sea via the Suez Canal or from the western basin needs further investigation.

Recorded in the western Mediterranean and Adriatic Sea (Tregouboff, 1957; Razouls and Thiriot, 1968; Berhaut, 1969 b; Riedl, 1970); also known from the Atlantic (Kramp, 1959); Pacific (Kramp, 1968) and Indian Oceans (Schmidt and Klinker, 1974) as well as from the Red Sea (Schmidt, 1973, 1976).

Ectopleura dumortieri

This is also new to the south-eastern Mediterranean. It occurred in the area exclusively in winter. It was comparatively more numerous in the littoral zone off Damietta and Abukir (maximum 60 ind/100 m^3 in February 1970); temperature range 16.4°-18.1°C, salinity 38.5-39.2°/oo. The absence of the species from the oceanic stations may support the statement of Kramp (1968) that it prefers neritic waters.

Known from the western Mediterranean and Adriatic Sea, widely distributed in many parts of the main oceans, (Tregouboff, 1957; Kramp, 1959, 1968; Schmidt and Klinker, 1974).

Oceania armata

According to Kramp (1959) this species is widely distributed over the entire Mediterranean and is indigenous in the eastern basin. However, the present results showed that O. armata is remarkably rare and irregular. In 1966, three specimens were recorded in autumn, it escaped record in 1970 and in 1982 four specimens were recorded in January in the neritic waters off Damietta.

The species is also known from the Red Sea (Schmidt, 1973) and widely distributed in the three main oceans (Kramp, 1959, 1968; Schmidt and Klinker, 1974).

Turritopsis nutricula

This species occurred in the area during spring and summer 1966 and 1970; in 1982 it occurred in winter as well. Throughout it was always rare and irregular and with clear oceanic affinities. The highest density, viz., 6-15 ind/100 m^3 was recorded in the offshore neritic waters east of Port Said in January, 1982. Although the species is usually reported as an epipelagic form (Kramp, 1959) it may occur at deeper levels, i.e., 400-500 m (Dowidar, 1981). According to Kramp (op. cit.) T. nuctricula have immigrated into the Levant through the Suez Canal; temperature range 14.2°-26.5°C, salinity 38.5-39.4°/oo.

Widely distributed in the three main oceans as well as in the Mediterranean and the Red Sea (Kramp, 1924, 1959, 1968; Tregouboff, 1927; Schmidt, 1976).

Pandea conica

This is one of the common species in the circumlittoral zone off the Egyptian coast. In 1962 it was fairly common in the neritic waters off Alexandria from March to July with a peak in June (250 ind/100 m^3) (Dowidar, 1965). In 1966 it was recorded in spring and autumn when it occurred in 50 per cent of the neritic samples and 7 per cent of the oceanic samples; the maximum density, viz. 50 ind/100 m^3 was recorded in the neritic waters off Abukir; temperature range 19.4°-25.8°C, salinity 38.3-39.1°/oo. According to Kramp (1959) the partly oceanic distribution of P. conica is due to its hydroid being attached to shells of the pteropod Euclio = (Cleodora) cuspidata which has a circumglobal distribution. P. conica is a common and widely distributed species in the Mediterranean Sea and the warm waters of the Atlantic Ocean (Kramp, 1924, 1959; Vannucci, 1966); also reported from localities in the Pacific and Indian Oceans (Kramp, 1959, 1968; Schmidt and Klinker, 1974).

LEPTOMEDUSAE

The following species were identified:

Obelia spp.

Phialidium hemisphericum (Linnaeus)

Lovenella cirrata (Haeckel)

Eutima (Octorchis) gegenbauri (Haeckel)

Aequorea aequorea (Forskal)

Obelia spp.

The medusae belonging to this genus are derived from several different species of hydroids of which four species are known to occur in the Mediterranean, viz. O. dichotoma, O. gelatinosa, O. geniculata and O. polystyla (Hure, 1955, 1961; Vucetic, 1957, 1961 and Febvre-Chevalier, 1969). The medusae of these species cannot be specifically distinguished.

The hydroid stages of Obelia are probably indigenous to the neritic waters off the Egyptian coast; the medusae are rather frequent to common in the coastal zone in nearly all seasons. In Alexandria waters, periods of abundance were recorded in January, April, July and August to October. Large numbers (over 1,500 ind/m^3) were recorded in the coastal waters of Alexandria and Abukir in October 1961, August 1962 and August 1966, also in Port Said in July 1970 and off Agami in August 1982.

Temperature range 15.8°-28.2°C, salinity 38.5-39.0^o/oo, Obelia medusae have a worldwide distribution in coastal waters of the Mediterranean and the Rea Sea as well as in the three main oceans (Tregouboff, 1957; Kramp, 1959, 1968; Razouls and Thiriot, 1968; Berhaut, 1969 b; Schmidt, 1973, 1976; Schmidt and Klinker, 1974).

Phialidium hemisphericum

This is a rare species in the south-eastern Levant. Recorded in very small numbers from the coastal waters off Alexandria in February 1962, in the Arab's gulf (Khalig el Arab) in February 1966 and in the gulf of Tina (Khalig el Tina) in January 1982.

Recorded in the Mediterranean and Adriatic Sea (Kramp, 1924, 1959; Schmidt, 1973, 1976), also known from the Red Sea and Indian Ocean (Schmidt and Klinker, 1974).

Lovenella cirrata

Single specimens of this species were recorded in the neritic waters off Alexandria in winter and spring 1966. Probably a temporary visitor to the area.

Recorded from the Mediterranean, eastern and western basins (Kramp, 1959; Schmidt, 1976), also from the Pacific and Indian Oceans (Kramp, 1968; Schmidt and Klinker, 1974).

Eutima gegenbauri

Rare, neritic species, recorded only in two samples in February 1966.

Recorded from the Mediterranean and Adriatic Seas, also known from localities in the Atlantic and Indian Oceans (Kramp, 1959, 1968; Schmidt, 1973; Schmidt and Klinker, 1974).

Aequorea aequorea

Two specimens of this large medusa were caught in March 1962 off Agami where several individuals were seen floating on the sea surface. Otherwise it was not observed in subsequent samples. It seems that the species is a temporary visitor to the area.

Widely distributed in the western basin and the Adriatic Sea; also known from the Red Sea and the Indian Ocean (Tregouboff, 1957; Kramp, 1959, 1968; Schmidt, 1973, 1976; Schmidt and Klinker, 1974).

TRACHYMEDUSAE

Species recorded:

Geryonia proboscidalis (Forskal)

Liriope tetraphylla (Chamisso and Eysenhardt)

Aglaura hermistoma (Péron and Lesueur)

Rhopalonema velatum (Gegenbaur)

R. funerarium (Vanhöffen)

Pantachogon haeckeli (Maas)

Geryonia proboscidalis

This species occurred in 19 per cent of the samples collected during the winter of 1966 and it also occurred in the samples of January 1982; always rare, 2-5 ind/100 m^3; temperature 16.2°-18.4°C, salinity 38.6-39.4^o/oo.

This species is common in the western Mediterranean in winter (Tregouboff, 1957); reported also from the Red Sea (Schmidt, 1973). Otherwise it is widely distributed in all tropical and subtropical seas (Kramp, 1959, 1968).

Liriope tetraphylla

This is by far the most dominant medusa along the Egyptian Mediterranean coast. It occurred in nearly all seasons in both the neritic and oceanic samples. In the neritic waters off Alexandria, peaks of abundance were generally observed in May-June and in October-November. The optimum temperature range during these periods was 22.8°-25.8°C, salinity 36.2-39.1^o/oo. During these peaks the species occurred in large masses (over 1,200 ind/m^3) and caused remarkable depletion of other zooplankton elements. In the oceanic waters, it was particularly common in the upper layers in spring and early summer; maximum density 3-5 ind/m^3. According to Kramp (1959) L. tetraphylla is indigenous in the Levant being very common in the Aegean Sea and the Sea of Marmara. The species is common in the warm parts of all oceans as well as the Mediterranean and the Red Sea (Kramp, 1959).

Aglaura hemistoma

This is one of the indigenous species in the south-eastern Mediterranean. It was widely distributed in the collections of 1966 and 1970, being present in all seasons. The highest density, viz., 315 ind/100 m^3, was recorded in the offshore waters off Damietta in February. In other seasons it was less numerous (3-18 ind/100 m^3). The pattern of distribution of this species clearly demonstrates its oceanic affinity. As an epipelagic species it occurred in the upper 200 m stratum but was more frequent in the upper 50-100 m layer. Temperature range 15°-27.5°C, salinity 38.5-39.8^o/oo.

Widely distributed in the warm and temperate parts of all oceans as well as the Mediterranean and the Red Sea (Kramp, 1924, 1959, 1968; Hure, 1955; Tregouboff, 1957; Schmidt, 1973, 1976; Pasteur et al., 1976).

Rhopalonema velatum

This species is widely distributed in the oceanic waters of the south-eastern Mediterranean; recorded in all seasons, but usually in small numbers; more frequent in winter, maximum, 56 ind/100 m^3 recorded off Damietta. Otherwise it occurred sporadically with no definite pattern of spatial distribution. Throughout it occurred in the upper epipelagic layer, but occasionally it was also found in intermediate layers at 200-500 m. (Temperature 14.2°-27.5°C, salinity 38.5-39.8^o/oo). According to Kramp (1959) R. velatum is indigenous in the Levant.

Common in the warm parts of all oceans as well as the Mediterranean and the Red Sea (Hure, 1955; Tregouboff, 1957; Kramp, 1959; Schmidt, 1973, 1976; Schmidt and Klinker, 1974).

Rhopalonema funerarium

A rare species; single specimens were recorded in oceanic samples collected in January 1962 and 1966 off Alexandria; otherwise it was completely absent from the present collection. The scarcity of the species in the epipelagic layers may be due to its bathypelagic affinity (Tregouboff, 1957; Kramp, 1959).

Recorded from the three main oceans as well as in the Mediterranean and the Red Sea (Ranson, 1936; Tregouboff, 1957; Kramp, 1959, 1968; Schmidt, 1973, 1976; Schmidt and Klinker, 1974).

Pantachogon haeckeli

This is again a rare species, recorded in a few oceanic samples collected off Alexandria in winter in 1962 and 1966. Like R. funerarium this species belongs to the bathypelagic fauna (Kramp, 1924; Russell, 1953). The occurrence of such forms in the surface waters of the area in winter is mostly correlated with the vertical mixing processes caused by the winter convection.

P. haeckeli is widely distributed in all oceans as well as in the Mediterranean and the Red Sea (Russell, 1953: Kramp, 1959, 1968: Schmidt, 1973, 1976).

SCYPHOMEDUSAE

The following species were recorded in the Egyptian Mediterranean waters during the present survey: Nausithoe punctata (Kolliker); Pelagia noctiluca (Péron and Lesueur) and Aurelia aurita (Linnaeus); to these may be added Discomedusa lobata (Claus) which was mentioned by Mayer (1910) as occurring in Alexandria waters. Due to their large size these animals are not easily caught by the small plankton nets used for collecting other zooplankton groups. A few specimens of N. punctata were caught by the ichthyoplankton net in February 1966 and 1970 and in January and April 1982 off Alexandria. Swarms of Aurelia aurita were recorded on 16 January, 1962 off Agami (west of Alexandria) when the sea was seen to be littered with specimens floating on the sea surface. The sea was calm and it was easy to collect a few of them in a bucket. It is most probable that these animals were driven towards the shore by the rather strong north-westerly wind which had prevailed a week before the date of sampling. Irregular invasions of Aurelia, Pelagia and Nausithoe on to the beaches of Alexandria during the summer months (June to August) are not infrequent. Swarms of Pelagia noctiluca are also frequently reported from Damietta beaches during the summer months. Bathers are well aware of the noxious effect of their sting. In many cases the presence of a few specimens of any of these medusae causes the bathers to desert the water.

Discussion

In the eastern Mediterranean the numerical contribution of hydromedusae to the total zooplankton crop is generally of minor importance. In the Egyptian Mediterranean waters, hydromedusae constituted 0.05 to 4.0 per cent of the zooplankton standing crop. However in terms of biomass their contribution is, most probably, much higher.

The number of species recorded in the study area (16 species) is strikingly low compared to other areas in the Mediterranean.

According to Schmidt (1976) only 30 species of hydromedusae are known from the eastern Mediterranean as compared to 115 species in the western basin and 86 species in the Red Sea. The scarcity of species of hydromedusae in the eastern Mediterranean in general and the south-eastern part in particular is mostly due to lack of extensive research on this group. Of the species recorded only Liriope tetraphylla and Obelia spp occur in relatively large numbers. L. tetraphylla was also reported as a dominant element of the zooplankton in the eastern Mediterranean (Komarovsky, 1959). During its peaks of abundance it causes widespread depletion of other zooplankton elements. The biology of these animals and their importance in the food-chain of the pelagic ecosystem requires further investigation. Also the factors controlling the seasonal blooms of some hydromedusae and the coastal swarming of scyphomedusae need to be studied.

References

Albertini-Berhaut, J., (1970 a). - Distribution des Trachyméduses Persa incolorata (McCrady 1857), Aglaura hemistoma (Péron and Lesueur 1809) dans le Golfe de Marseille. Bull. Soc. Zool. France 95/4, 677-687.

Albertini-Berhaut, J., (1970 b). - Variations saisonnières de la Trachyméduse Rhopalonema velatum (Gegenbaur 1856) dans le Golfe de Marseille. Comparaison avec celles déjà observées dans d'autres régions méditerranéennes. Bull. Soc. Zool. France 95, 241-247.

Babnik, P., (1948). - Hydromedusae from the Middle and South Adriatic 1939 and 1940. Acta Adr. 3/9, 1-68.

Berhaut, J., (1969 a). - Variations mensuelles de la Trachyméduse Liriope tetraphylla (Chamisso et Eysenhardt, 1821) dans le Golfe de Marseille. Bull. Mus. Hist. nat. Paris 40/6, 1222-1231.

Berhaut, J., (1969 b). - Etude qualitative, quantitative et écologique des Hydroméduses du Golfe de Marseille. Téthys 1/3, 667-708.

Brinchmann-Voss, A., (1970). - Anthomedusae/Athecata (Hydrozoa, Cnidaria) of the Mediterraneana. Fauna Flora Golfo Napoli, Monografia 39, 96 p.

Dowidar, N.M., (1965). - Distribution and ecology of marine plankton in the region of Alexandria, Egypt. Ph.D. thesis, Alexandria University, 334 pp. (unpublished manuscript).

Dowidar, N.M. and El-Maghraby, A.M., (1970). - The neritic zooplankton of the south-eastern Mediterranean at Alexandria. 1. Distribution and ecology of the zooplankton organisms with special reference to Copepoda. Bull. Inst. Ocean. Fish. A.R.E. 1, 225-273.

Dowidar, M.M., (1981). - Systematic and distribution studies of pelagic coelenterates in Egyptian Mediterranean waters. M.Sc. thesis, Alexandria University, 245 pp.

Edwards, C., (1966). - The hydroid and the medusa. Bougainvillia principes, and a review of the British species of Bougainvillia. J. Mar. Biol. Assoc. U.K. 46, 129-152.

Fèbvre-Chevalier, C., (1969). - Etude bionomique des substrates meubles dragables du Golfe de Fos. Téthys 1/2, 421-476.

Goy, J., (1972). - Les hydroméduses de la mer Ligure. Bull. Mus. Hist. Paris 62, 965-1008.

Hure, J., (1955). - Distribution annuelle verticale du zooplancton sur une station de l'Adriatique méridionale. Acta Adr. 7/7, 3-69.

Hure, J., (1961). - Migration journalière et distribution saisonnière verticale du zooplancton dans la région profonde de l'Adriatique. Acta Adr. 9/6, 60 p.

Komarovsky, B., (1959). - A study of the food Sardinella aurita V. off the Mediterranean coast of Israel during a peak season (May - June, 1958). Proc. Gen. Fish. Coun. Medit. 5, 311-319.

Kramp, P.L.,(1924). - Medusae. Rep. Danish Oceanogr. Exped. Medit. 2/1, 1-67.

Kramp, P.L., (1959). - The hydromedusae of the Atlantic Ocean and adjacent waters. Dana Rep. 46, 1-283.

Kramp, P.L., (1961). - Synopsis of the medusae of the world. J. Mar. Biol. Ass. U.K. 40, 1-469.

Kramp, P.L., (1968). - The hydromedusae of the Pacific and Indian Oceans. Dana Rep. 72, 1-200.

Mayer, A.G., (1910). - Medusae of the world. 3 vols. Washington D.C., Carnegie Institute of Washington.

Pasteur, R., Berdugo, V. and Kimor, B., (1976). - The abundance, composition and seasonal distribution of epizooplankton in coastal and offshore waters of the Eastern Mediterranean. Acta. Adr. 18/4, 53-80.

Ranson, G., (1936). - Méduses. Res. Camp. Sci. Princ. Monaco 92, 90 p.

Razouls, S. and Thiriot, A., (1968). - Le macroplancton de la région de Banyuls-sur-Mer (Golfe du Lion). Vie Milieu 19/1-8, 133-184.

Riedl, R., (1970). - Fauna und Flora der Adria. Hamburg und Berlin, Verlag Paul Parey, 702 pp.

Russell, F.S., (1953). - The Medusae of the British Isles. Cambridge Univ., Press.

Schmidt, H.E., (1973). - Hydromedusae from the eastern Mediterranean Sea. Israel, J. Zool. 22, 151-167.

Schmidt, H.E., (1976). - A comparison between the Hydroida fauna of the Eastern Mediterranean and the Red Sea. Acta Adr. 18/15, 257-266.

Schmidt, H.E. and Klinker, J., (1974). - Hydromedusae (Coelentarata) from the Indian ocean. Meteor-Forschungserg. D, 18, 29-38.

Tregouboff, G., (1957). - (in Tregouboff and Rose) Manuel de planctologie Méditerranéenne. 2 vols., 587 p. 207 pl. Paris, C.N.R.S.

Vannucci, M., (1966). - Total net plankton volume and hydromedusae from fixed stations in the Gulf of Naples. Cont. Stud. Mar. Sci., 675-697.

Vucetic, T., (1957). - Zooplankton investigations in the sea-water Lakes Malo Jezero and Veliko Jezero on the Island of Mijet (1952-1953). Acta Adr. 6/4, 51 p.

Vucetic, T., (1961). - Vertical distribution of zooplankton in the Bay of Velike Jezero on the Island of Mijet. Acta Adr. vol. 6/9, 20 p.

NOTE SUR L'INVASION DE LA MEDUSE *Pelagia noctiluca* SUR LA RIVIERA FRANCAISE DURANT L'ETE 1982

par

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Au cours de l'été 1982, durant les mois de juin, juillet et août, à intervalles irréguliers, les eaux des côtes françaises du département du Var et celles des Alpes-Maritimes englobant les eaux de la Principauté de Monaco furent envahies par des bancs de milliers de petites méduses.

L'espèce répertoriée en son plus grand nombre s'est révélée être *Pelagia noctiluca* (Forskål). De la classe des acalèphes (méduses sans flotteur) ou classe des scyphozoaires (animaux en forme de coupe), cette méduse de la famille des lucernariidés (en forme de lanterne) est également surnommée "ortie de mer". Pouvant atteindre la taille d'un poing et plus, *Pelagia noctiluca*, de couleur rose-violette, possède huit tentacules urticants alternant avec huit corpuscules sensoriels et quatre bras buccaux.

Les laboratoires des centres scientifiques du littoral méditerranéen français et plus particulièrement celui de la Station Océanographique du C.N.R.S. de Villefranche et celui du S.C.11 de l'Institut National de la Santé et de la Recherche Médicale de Nice se sont penchés sur les circonstances ayant conduit à cette invasion. Il faut cependant noter que l'apparition massive de méduses sur le littoral n'est pas exceptionnelle. Ce phénomène a été constaté en octobre 1981 dans la rade de Villefranche-sur-mer. Toutefois, l'ampleur prise par l'invasion de l'été 1982 a été telle que certaines plages du littoral furent temporairement interdites à la baignade et cet évènement fut abondament commenté dans la presse régionale.

Les causes de cette invasion restent obscures. Parmi les hypothèses retenues, citons la conjonction de conditions climatiques particulières (élévation de la température de l'eau de mer) favorisant soit un baby boom de l'espèce, soit une prolifération des espèces pélagiques (copépodes, petits poissons) servant de proies aux méduses. Des courants marins ont été invoqués pour le rejet sur les côtes françaises. Mais quelle est la part du courant de Ligurie, celle du vent (Mistral) ou de la houle?

Les désagréments occasionnés par ces méduses furent de natures diverses. En bordure même du littoral, nombreux furent les baigneurs atteints par *P. noctiluca* provoquant des érythèmes. Le simple fait d'être effleuré par un filament produit une brûlure dont l'effet se fait sentir pendant près d'une heure. De plus lorsque la méduse s'accroche à la peau, les dermatocystes (batterie de minuscules harpons venimeux) provoquent des cloques comme des brûlures qui apparaissent immédiatement, la douleur pouvant être intense et la cicatrisation assez longue (parfois deux à trois semaines). On sait que chez certaines personnes une seule "piqûre" peut provoquer un état de choc. Les premiers remèdes consistent à désinfecter localement la plaie (alcool à 90°, eau vinaigrée). Par la suite, des applications de pommades anti-histaminiques sont recommandées. Sur le plan touristique, en pleine saison balnéaire, l'impact a été également ressenti. Les autorités déconseillèrent pendant plusieurs jours et à plusieurs reprises (par articles de presse et pavillon rouge sur les plages) de se baigner dans les zones infestées. Aucune méthode, mis à part le barrage par flotteurs d'une petite plage alvéolaire, n'a été mise au point pour combattre ce genre d'invasion et il fallut s'armer de patience en attendant qu'un courant marin chasse ailleurs ces méduses.

ON THE OCCURRENCE OF JELLYFISH ON THE EASTERN MEDITERRANEAN COAST OF TURKEY

by

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Abstract

Jellyfish occurrence east of the Göksu river delta (Cilician Basin) is summarized as total catches from the monthly cruises to different stations.

During a series of quantitative fishery studies extending from May 1980 to November 1982 the occurrence of jellyfish in different fishing grounds (figure I) were recorded and the results are summarized in the table and figure II.

The trawl net used during the investigation had a stretched mesh size of 22 mm in the cod end and was suitable for soft grounds. The cod end cover had a stretched mesh size of 60 mm. The vertical mouth opening of the net measured about 60-80 cm.

The data collected indicate that most of the jellyfish during the study period were caught in May-June-July in the inshore region of the Gulf of Mersin in depths ranging between 8-15 m. (figures I and II). This area is located in the delta region of the Tarsus and Seyhan rivers. These rivers carry run-off from regions in which considerable agricultural and industrial activity (agrochemical, petrochemical, textile and food industries) take place. Most of the industries in the province of Adana discharge their wastes into these two rivers. It is, therefore, not surprising to find most of the jellyfish within the area of influence of these two rivers. A similar situation is expected to exist off the Ceyhan river delta in the Gulf of Iskenderun. Unfortunately the data from this region are not conclusive.

In the Göksu river delta no jellyfish were caught during the investigation period. This was expected because the Göksu river flows through a relatively non-industrialized and agriculturally underdeveloped region.

Dates of cruises and jellyfish occurrences at different stations between May 1981 and November 1982

Name of station	Month of the year	Date of the cruise	Number of hauls	Number of jellyfish caught
Tirtar	May 1980	09/05/1980	4	1 200
Göksu	" "	15/05/1980	4	-
Seyhan	" "	21/05/1980	2	4 448
	" "	29/05/1980	2	2 053
Tirtar	June 1980	09/06/1980	4	-
Göksu	" "	10/06/1980	5	-
Seyhan	" "	12/06/1980	4	54 500
Tirtar	July 1980	02/07/1980	4	1 500
Seyhan	" "	04/07/1980	4	750
Göksu	" "	08/07/1980	4	-
Seyhan	February 1980	03/02/1981	4	5 200
Göksu	" "	04/02/1981	4	-
Tirtar	" "	09/02/1981	4	-
Seyhan	April 1981	09/04/1981	4	89 000
Tirtar	" "	10/04/1981	4	-
Göksu	" "	13/04/1981	4	720

Notes

1. In September and November 1981 only two stations (Tirtar and Göksu) were visited.
2. In October 1981 and January-February 1982 there were no cruises. Last data collection was in November 1982.
3. There was no catch of jellyfish in the months not indicated.

Dates of cruises and jellyfish occurrences (cont'd)

Seyhan	May 1981	11/05/1981	4	93 615
Göksu	" "	12/05/1981	4	-
Tirtar	" "	13/05/1981	4	-
Göksu	June 1981	05/06/1981	4	-
Tirtar	" "	06/06/1981	4	-
Seyhan	" "	07/06/1981	4	30 400
Tuzla	" "	07/06/1981	4	-
Karatas	" "	08/06/1981	4	186 000
Yumurtalik	" "	08/06/198	4	460
Botas	" "	09/06/1981	4	-
Seyhan	March 1982	04/03/1982	4	-
Göksu	" "	09/03/1982	2	-
Tirtar	" "	09/03/1982	4	-
Tuzla	" "	20/03/1982	4	-
Karatas	" "	21/03/1982	3	-
Yumurtalik	" "	21/03/1982	4	11 700
Botas	" "	22/03/1982	4	-
Göksu	April 1982	21/04/1982	4	-
Tirtar	" "	26/04/1982	4	-
Seyhan	" "	27/04/1982	3	1 180
Tuzla	" "	27/04/1982	2	-
Karatas	" "	28/04/1982	4	-
Yumurtalik	May 1982	01/05/1982	4	-
Botas	" "	01/05/1982	4	-
Seyhan	May 1982	11/05/1982	3	-
Tuzla	" "	11/05/1982	4	-
Botas	" "	13/05/1982	3	-
Yumurtalik	" "	14/05/1982	3	-

Dates of cruises and jellyfish occurrences (cont'd)

Karatas	May 1982	14/05/1982	3	660
Tirtar	" "	18/05/1982	4	-
Göksu	" "	21/05/1982	4	-
Seyhan	June 1982	07/06/1982	3	-
Tuzla	" "	07/06/1982	2	-
Karatas	" "	08/06/1982	4	33 700
Yumurtalik	" "	08/06/1982	4	-
Botas	" "	09/06/1982	3	-
Göksu	" "	11/06/1982	4	-
Tirtar	" "	17/06/1982	4	-
Seyhan	July 1982	05/07/1982	4	4 700
Karatas	" "	07/07/1982	3	-
Yumurtalik	" "	07/07/1982	4	-
Botas	" "	08/07/1982	4	-
Tirtar	" "	12/07/1982	4	-
Göksu	" "	13/07/1982	4	-
Tirtar	August 1982	20/08/1982	3	-
Seyhan	" "	24/08/1982	4	33 200
Karatas	" "	27/08/1982	3	-
Yumurtalik	" "	27/08/1982	3	-
Botas	" "	28/08/1982	4	-
Göksu	October 1982	05/10/1982	3	-
Tirtar	" "	06/10/1982	4	-
Seyhan	" "	12/10/1982	4	260
Karatas	" "	13/10/1982	3	-
Yumurtalik	" "	13/10/1982	1	-
Botas	" "	15/10/1982	4	-

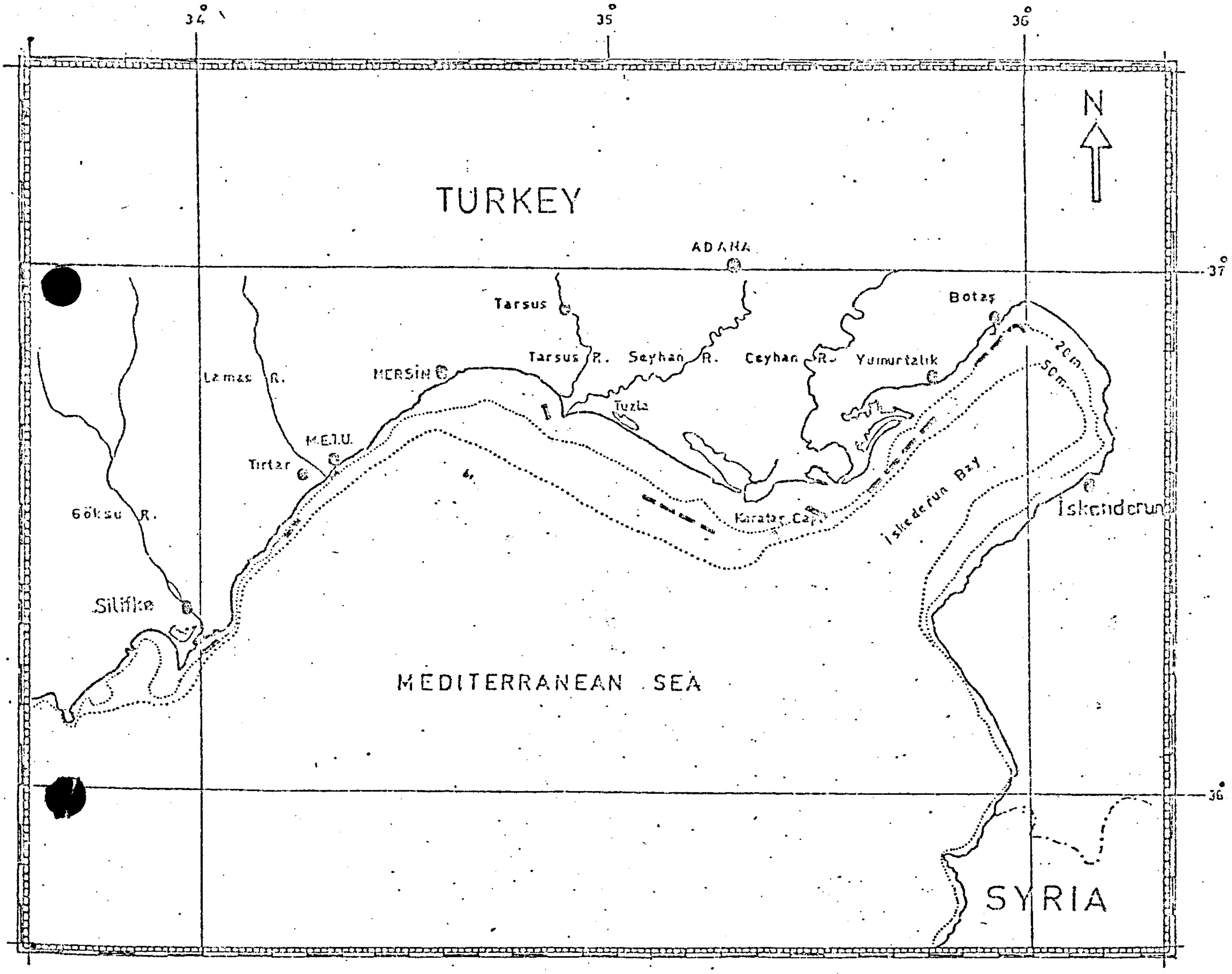

Figure I. Stations of quantitative fishery east of Gôksu river delta

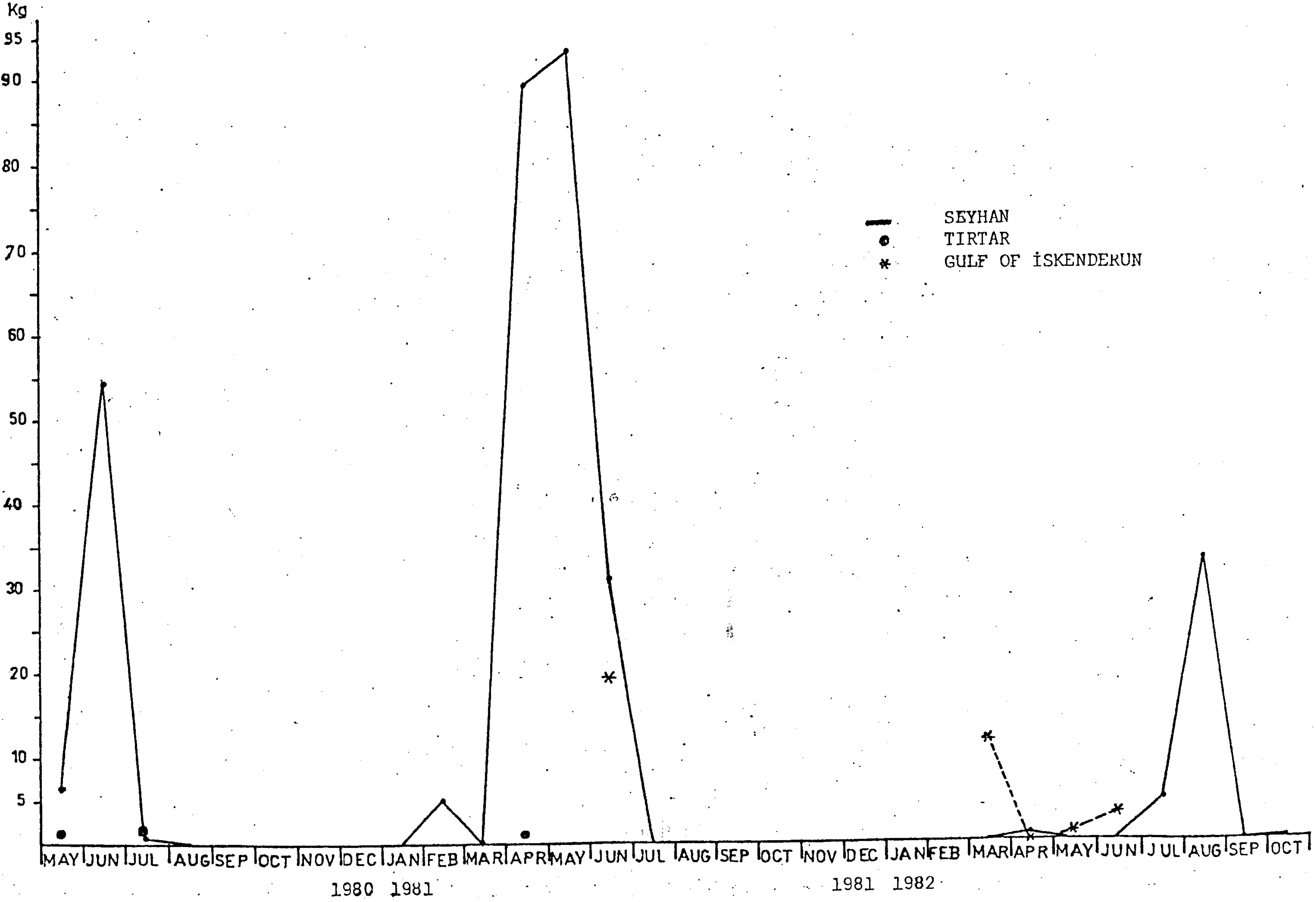

Figure II. Time series of the monthly total catches of jellyfish at differe[illegible] stations during the sampling period

DISTRIBUTION DE Pelagia noctiluca (FORSKAL) EN MEDITERRANEE DANS L'ETE 1983

par

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Résumé

Pendant l'été 1983 le Laboratoire de Biologie marine et Pêche de Fano a réalisé trois campagnes de prélèvements quantitatifs de zooplancton en Méditerranée, une en Adriatique, une en Méditerranée occidentale avec 100 points de prélèvements et une autre en Méditerranée orientale avec 50 points de prélèvements.

L'étude du matériel permet d'améliorer la connaissance de la distribution de Pelagia noctiluca.

On considère les relations avec la salinité et la température superficielle.

Introduction

L'importance croissante que la diffusion de la méduse Pelagia noctiluca (Forskal) a pris dans différents secteurs de l'économie des zones côtières a sollicité le Laboratoire de Biologie marine et Pêche de Fano à utiliser le matériel planctonique recueilli pendant les campagnes de recherche sur l'ichthyoplancton, pour l'étude de la distribution et abondance de cette méduse. Le long des côtes italiennes il existe une situation très critique causée par la présence de bancs de méduses qui empêchent souvent la baignade et rendent quelquefois impossible la pêche au chalut pélagique pour poisson bleu.

Les résultats de l'étude du matériel recueilli pendant 16 campagnes de pêche de plancton en Adriatique réalisées entre 1976 et 1983 par le Laboratoire de Fano ont été présentés en septembre à Trieste au congrès de la Société italienne de Biologie marine; ici nous presentons les résultats pour ce qui concerne la distribution des méduses en zones diverses de la Méditerranée pendant l'été 1983.

Matériel et méthodes

Les prélèvements de plancton ont été réalisés entre mi-juillet et la fin août, en utilisant trois bateaux de pêche loués par le Laboratoire. Un bateau a couvert d'une façon détaillée la haute et moyenne Adriatique, en faisant 65 stations distribuées de la même façon que les campagnes des années précédentes en Adriatique. Le deuxième bateau a couvert l'Adriatique du sud, la mer Ionienne près des côtes italiennes et une partie de la Méditerranée occidentale pour un total de 100 stations. Le troisième bateau a réalisé 50 prélèvements sur une transversale en Méditerranée orientale entre l'Adriatique du sud et les côtes de l'Egypte.

Les trois bateaux ont réalisé les prélèvements quantitatifs au moyen de deux différents engins à plancton, le Bongo 60 et le filet FAO d'un mètre de diamètre d'ouverture de la bouche. Les mailles étaient de 500 µ pour le filet FAO et de 335 et 500 µ pour le filet Bongo 60.

Les pêches ont été réalisées en double oblique en utilisant un enregistreur de profondeur et un indicateur de la quantité d'eau filtrée, de façon à avoir des résultats quantitatifs pour la nappe d'eau explorée. La profondeur touchée par chaque trait de plancton était variable en fonction de la sonde, mais en général se situait entre 70 et 100 mètres.

Le matériel recueilli a été fixé à bord en formol 4 % et ensuite en laboratoire les méduses Pelagia noctiluca one été séparées successivement à l'aide d'une loupe à partir de la taille de 5 mm, pour le calcul des nombres d'exemplaires par m^3 et par m^2.

Les principaux paramètres du milieu ont été mesurés dans chaque station.

Résultats et discussion

L'étude du matériel permet de connaître la distribution de Pelagia noctiluca sur une vaste zone pendant la même saison.

Dans les figures I, II et III sont indiquées les quantités de méduses par 100 m^2 de surface relativement aux trois campagnes. Les points sans aucun numéro à côté indiquent les stations négatives.

La distribution est irrégulière et souvent des zones à forte présence s'alternent avec des stations où les méduses sont absentes ce qui semble être dû à la distribution par bancs de cette espèce. Il y a une présence notable en Adriatique et dans la zone entre la Sicile et la Sardaigne, tandis que dans la mer Tyrrhénienne et dans la Méditerranée orientale les stations positivies en Pelagia sont très réduites.

La concentration maximale a été trouvée en Adriatique, loin des côtes en pleine eau; il a été précisé (G. Piccinetti Manfrin et C. Piccinetti, en presse) que cette zone d'abondance est variable dans le temps.

La comparaison avec les quantités de méduses recuillies pendant les campagnes reálisées en Adriatiqué en juillet 1981 et 1982 avec la même méthodologie montre une augmentation de la population de méduses dans cette zone en 1983 (voir tableau).

Pendant le mois de mars 1983 on a trouvé une quantité de Pelagia plus élevée qu'en juillet 1982 et en juillet 1983, ce qui peut indiquer que la population de Pelagia a une dynamique trés intense avec fluctuations évidentes d'abondance même dans une brève période. Ces fluctuations peuvent être liées à la saisonalité de la natalité et mortalité qui varient dans le temps, et au déplacement d'une partie de la population.

Il est évident que la zone de distribution de Pelagia est plus vaste de l'Adriatique et qu'il y a une ingression de méduses et une sortie avec les mouvements des masses d'eau. Il est possible que pendant la journée Pelagia descend au-delà de 70-100 mètres de profondeur, nappe que nous avons explorée et cela pourrait limiter la validité quantitative de nos résultats.

Une étude détaillée de la répartitions par tailles, station par station, de Pelagia au cours de différentes croisières pourra nous fournir des indications pour la connaissance de la dynamique de la population.

La relation entre les conditions du milieu, en particulier température, salinité et nitrates, et abondance de méduses, etudiée en Adriatique par Tegaccia (en presse), a montré la liaison entre cette espèce et les eaux du large à salinité plus élevée et plus pauvres en nitrates. La présence de Pelagia et sa distribution en Adriatique au cours des dernières années (Piccinetti Manfrin et al., en presse) montre la progressivité de la pénétration de Pelagia en Adriatique de provenance du détroit d'Otranto.

Sur la base de ces observations, une influence directe de la pollution côtière, ou de l'eutrophisation de la haute Adriatique dans le développement des populations de Pelagia, semble peu probable.

L'étude des relations abondance des méduses/conditions du milieu dans l'été 1983 ne montre pas de relations étroites; les valeurs de salinité en surface (figure IV) comparées avec la présence de Pelagia en Adriatique montrent l'existence de deux zones aux valeurs extrêmes de salinité, supérieure à 38,5°/oo et inférieur à 33°/oo, où les méduses étaient presque totalement absentes pendant la campagne de recherche.

En Méditerranée il y a une présence plus élevée de méduses en relation aux salinités inférieures à 38°/oo et Pelagia est rare ou absente aux salinités très élevées.

La constatation de l'existence de déplacements verticaux des méduses, en profondeur de jour et en surface de nuit, eaux qui ont des valeurs de salinité et de température bien différentes, nous amène a considérer l'existence d'une véritable barrière de salinité ou de température comme peu probable.

Il nous semble qu'une plus grande concentration de Pelagia se trouve en relation avec les zones de divergence de courant, par exemple entre la Sardaigne et la Sicile où se partage le courant atlantique, ou bien au large du Conero (Ancône) où existe une divergence vers l'est du courant qui descend le long de l'Adriatique.

Il serait possible d'admettre comme hypothèse que les méduses soient entrées en Méditerranée avec le courant atlantique et diffusées par ce courant dans tout le bassin. Les salinité très élevées (plus de 38,5°/oo) ou très faibles (inférieures à 33°/oo) pourraient indiquer des eaux "locales" qui ne sont pas mêlées avec les eaux atlantiques.

Il est nécessaire de souligner que nos observations se réfèrent à des zones de mer ouverte et les indications obtenues pour la distribution et les quantités pourraient être très différentes des informations obtenues par d'autres auteurs dans les zones côtières où les courants locaux jouent un rôle important dans la concentration ou dispersion des méduses.

Il serait important de poursuivre les campagnes en mer ouverte sur une zone de la Méditerranée aussi vaste que possible et de coordonner les résultats avec les indications plus détaillées provenant des zones côtières; l'ensemble du matériel étudié dans l'optique de la dynamique des populations pourra nous fournir plusieurs informations nécessaires pour mieux comprendre l'origine et l'évolution des "blooms" de Pelagia noctiluca.

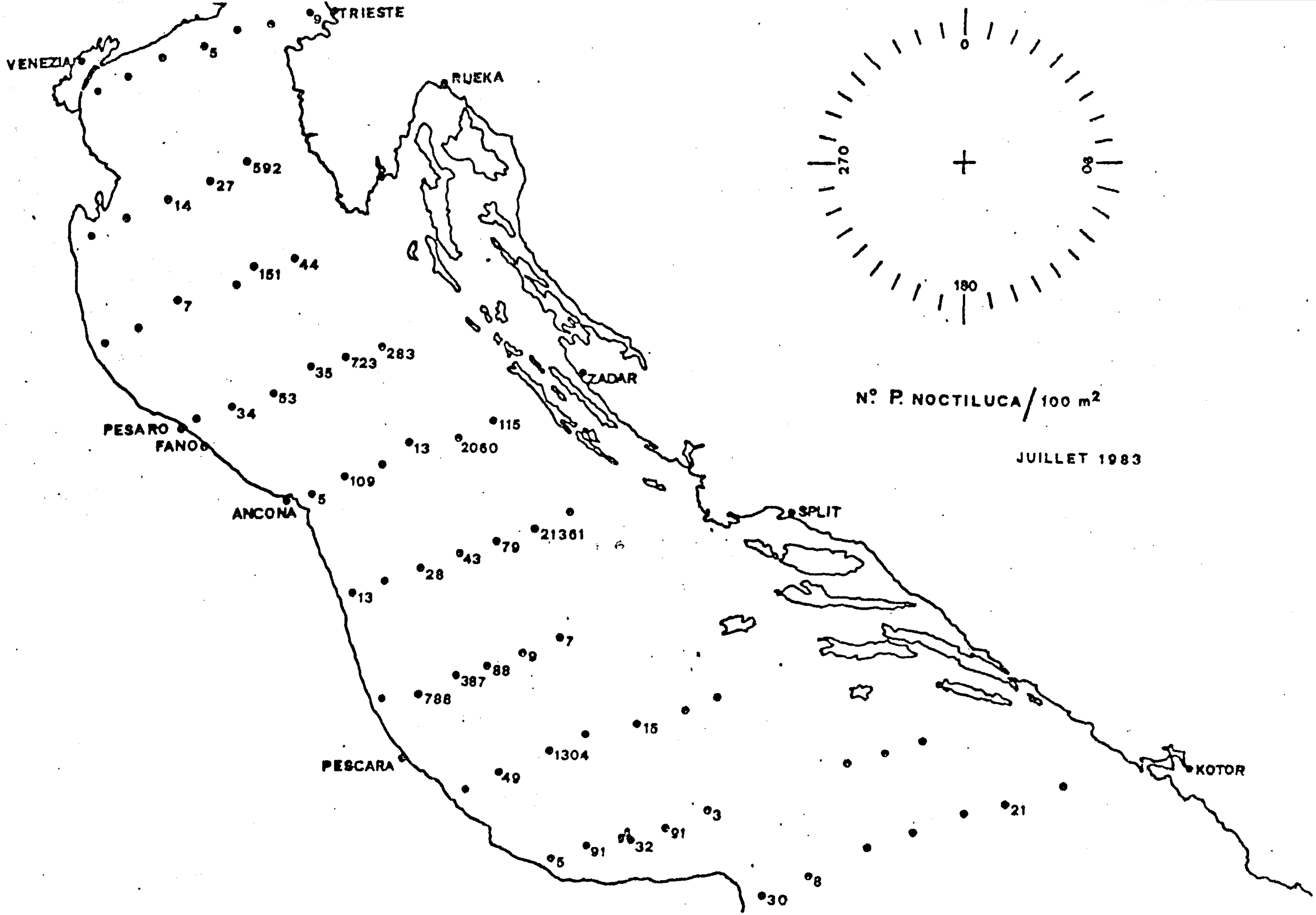

Figure I. Carte des stations de la campagne en Adriatique avec l'indication de l'abondance de *Pelagia*

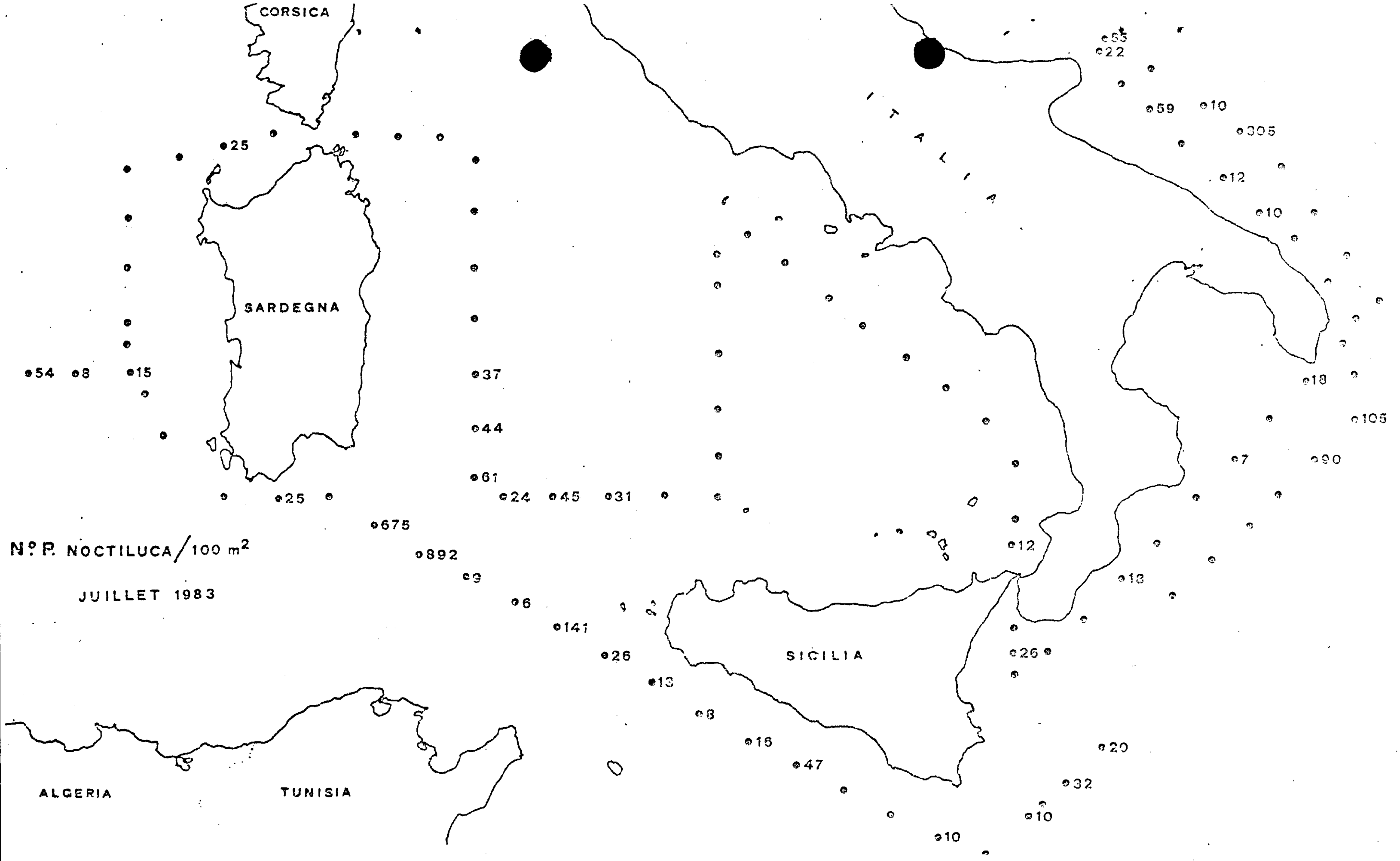

Figure II. Carte des stations de la campagne en Méditerranée occidentale avec l'indication de l'abondance de Pelagia

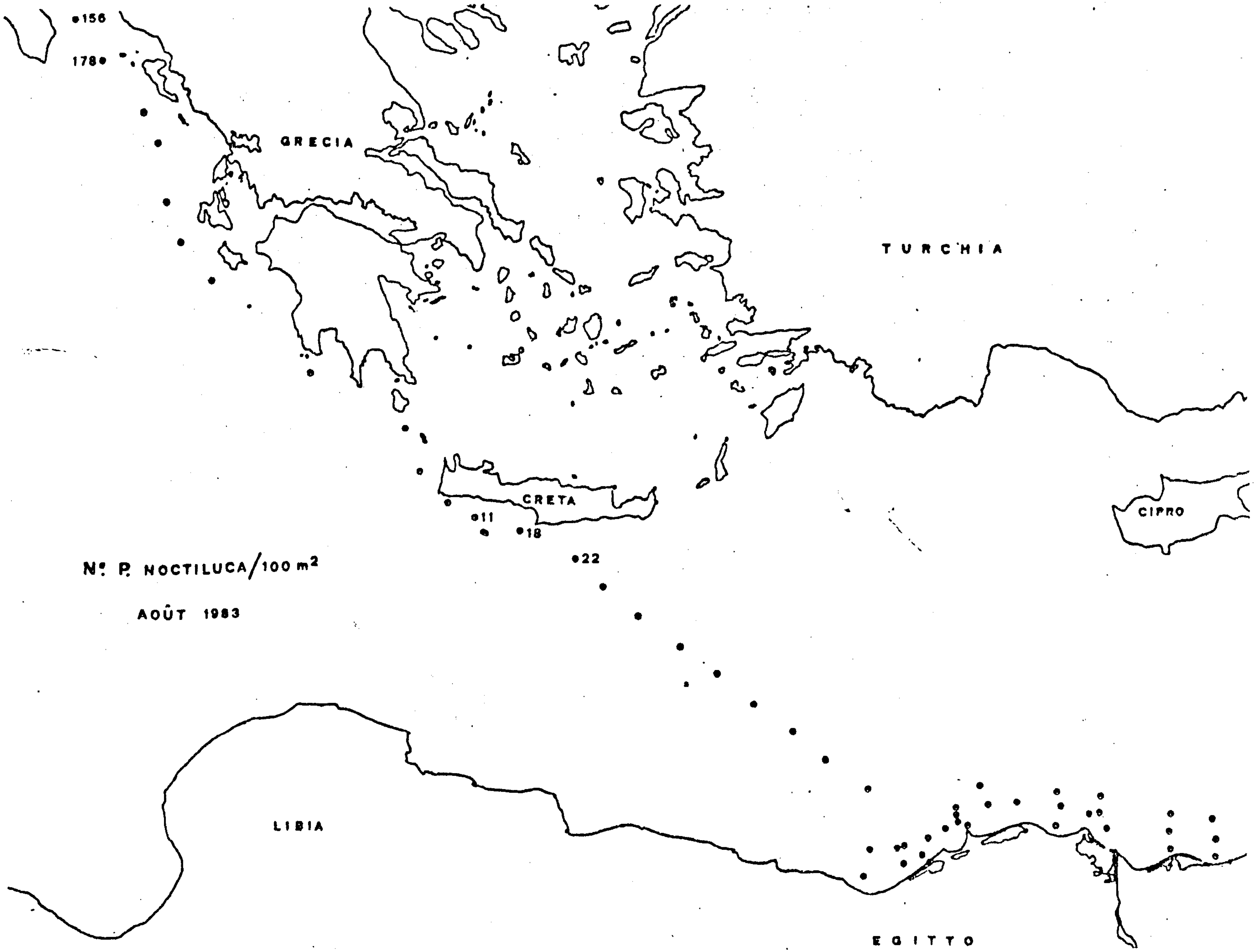

Figure III. Carte des stations de la campagne en Méditerranée orientale avec l'indication de l'abondance de Pelagia

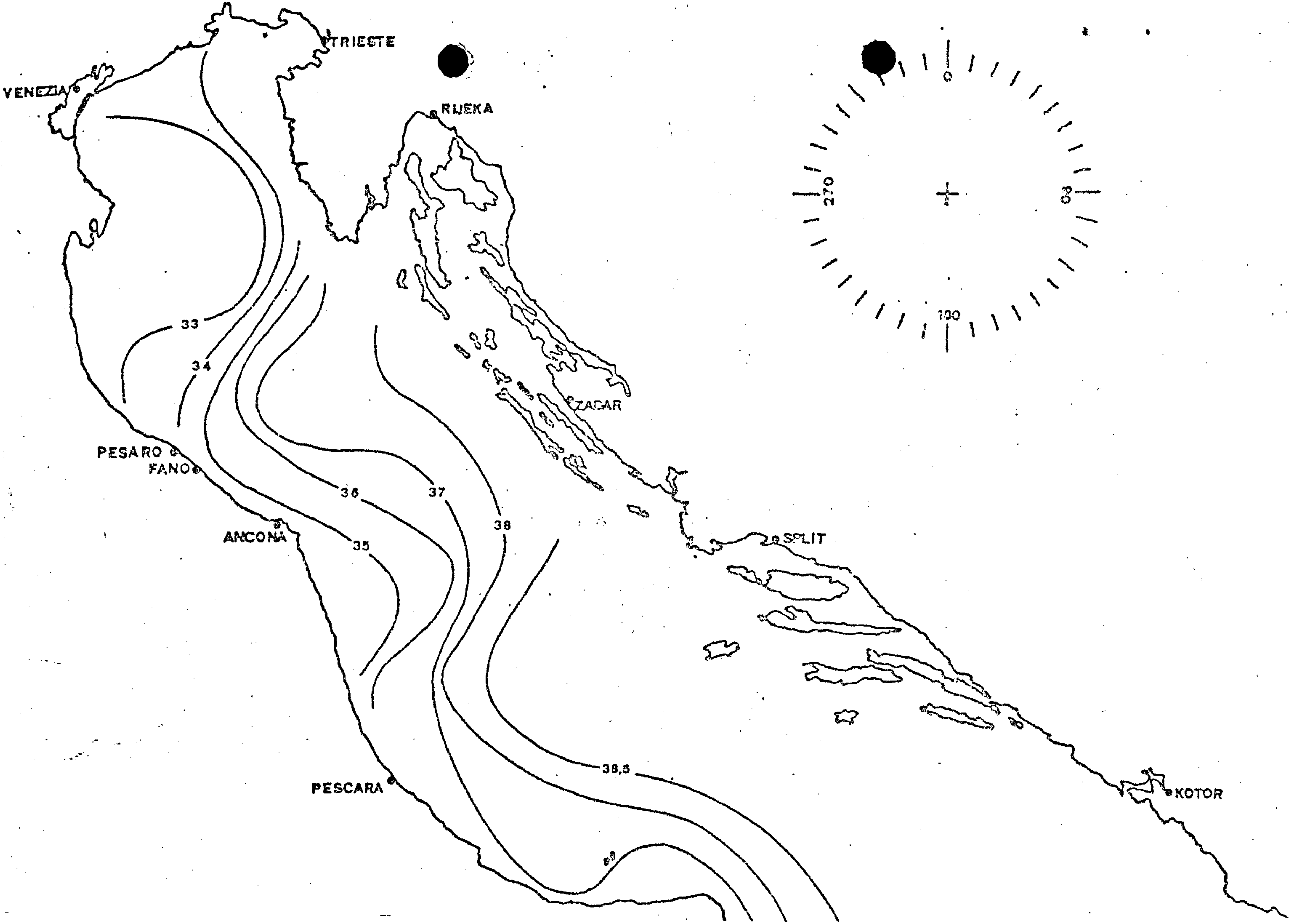

Figure IV. Distribution des salinités de surface en Adriatique pendant la campagne de juillet 1983

Fluctuation d'abondance de *Pelagia noctiluca* en haute et moyenne Adriatique

Date	Nombre des stations réalisées	Nombre moyenne de *Pelagia* par m^2	Estimation de l'abondance de *Pelagia* sur la zone explorée
Juillet 1981	64	0,15	$15,3 \cdot 10^9$
Juillet 1982	63	1,78	$181,0 \cdot 10^9$
Juillet 1983	65	4,42	$449,5 \cdot 10^9$
Mars 1983	64	12,88	$1309,0 \cdot 10^9$

Références

Piccinetti Manfrin, G. et Piccinetti, C., (en presse). - Distribuzione di *Pelagia noctiluca* in Adriatico dal 1976 al 1983. *Nova Thalassia*.

Tegaccia, N. et Tegaccia, T., (en presse). - Condizioni idrologiche collegate alla presenza di *Pelagia noctiluca* in Adriatico. *Nova Thalassia*.

SESSION Ib

IMPACT OF JELLYFISH BLOOMS ON HUMAN ACTIVITIES

INFLUENCE DES PROLIFERATIONS ANORMALES DE MEDUSES SUR LES ACTIVITES HUMAINES

LE DERANGEMENT ET LE DOMMAGE QUE LES FLORAISONS DE MEDUSES CAUSENT A LA PECHE

par

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Introduction

On n'a guére, jusqu'à présent, de données en ce qui concerne les dommages que les floraisons des méduses causent à la pêche.

On a essayé, dans cette optique, d'étudier le problème dans deux régions de pêche de l'Adriatique du Nord, Marano Lagunare et Grado.

Méthodes

Région de Marano Lagunare - Pendant les mois d'avril, mai, juin, août, septembre 1983, un bateau de pêche de 14 tonnes avec moteur diesel de 200 CV, a pêché à la traîne de fond, tous les jours, dans la mesure où les conditions météréologiques le permettaient, avec un chalut de 35 m de longueur, embouchure de 12.5 m, vide de maille à l'embouchure de 50 mm, 40 mm au fond du filet, avec une fréquence de 4 traits de chalut par jour de 2 heures chacune; pour chaque trait de chalut on a compté et pesé les méduses (poids frais), pesé les poissons (poids frais), calculé le pourcentage de poids des méduses sur le poids total par jour (tableaux 1-5; figures I, II).

Pendant les tirées on a étudié la conduite des filets par rapport à la quantité des méduses récoltées.

Région de Grado - Les données récoltées dans la région de Grado ont seulement une valeur indicative due à la difficulté de suivre personnellement la pêche.

A partir du mois d'avril jusqu'à septembre 1983, 9 bateaux ont pêché au barrage, 3 à la traîne de fond, 8 à la traîne volante, 1 à l'harpon (tableau 6)

On a déterminé les espèces de méduses sur les bateaux (Marano Lagunare - Rhizostoma pulmo Macri; Grado - Pelagia noctiluca Förskal).

Résultats

Région de Marano Lagunare - Les tableaux 1 - 5 rapportent les résultats obtenus à partir du comptage qu'on a fait chaque jour sur le bateau. On rapporte:

1. La quantité journalière des méduses par trait de chalut, ainsi que la quantité totale;
2. Le poids frais total journalier des méduses;
3. Le poids frais total journalier du poisson;
4. Le rapport en pourcentage entre le poids des méduses et le poids total.

La figure I indique la quantité de Rhizostoma pulmo pêché chaque semaine pendant les mois étudiés.

La figure II indique les poids frais journaliers des méduses et du poisson.

Région de Grado - Le tableau 6 présente les résultats obtenus grâce à la surveillance faite à la mer deux fois par semaine, pendant la pêche au barrage, à la traîne de fond, à la traîne volante et à l'harpon, pour étudier la conduite des filets.

Conclusions

Les résultats obtenus démontrent que les poids des méduses est le facteur principal qui cause le dommage à la pêche. A Marano, ainsi qu'à Grado, le poids des méduses rétrécit l'embouchure du chalut, augmente l'effort du moteur pendant la pêche, abaisse, à Grado, le filet de barrage, et compromet la rente.

En outre à Grado, le fait que Pelagia noctiluca soit plus nombreuse que les poissons cause d'autres dommages:

1. L'impossibilité de séparer le poisson des méduses, dont la plupart sont brisées et mêlées au poisson;
2. Le grave risque pour les pêcheurs (qui manient le filet) de se brûler la peau.

Donc, le cas échéant, le trait de chalut ne peut pas être consideré.

Tableau 1. Stat. Marano Lagunare, avril 1983. Quantité journalière des méduses par trait de chalut, poids frais total des méduses, poids frais total du poisson, rapport en pourcentage entre le poids des méduses et le poids total.

Jour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I Trait	21	34			55	35	45	45			48	55	8	39	7			45	41	39	51	6	35			40	38	34	27		
II Trait	18	28			31	28	31	40			42	41	5	32	5			40	38	36	49	5	30			35	35	29	32		
III Trait	20	7			28	30	35	35			38	45	6	9	6			35	50	32	41	6	31			7	28	31	31		
IV Trait	22	5			34	31	28	10			29	42	7	6	6			41	38	29	35	5	40			6	30	29	25		
Tot.	81	74			148	124	139	130			157	183	26	85	23			161	167	136	176	22	136			88	131	123	115		
Poids de méduses	10.5	9.6			19.2	16.1	18.7	16.9			20.4	23.7	3.3	11.	3.			20.9	21.7	17.6	22.8	2.8	17.6			11.4	17.	16.	14.9		
Poids de poissons	1.3	1.5			0.8	1.	0.9	1.			0.7	0.7	1.8	1.5	2.1			0.8	0.6	1.2	0.5	2.	0.6			1.9	1.	1.1	0.9		
P. MED.% / TOT.	89.	86.5			96.	94.1	95.2	94.4			96.6	97.1	65.2	88.	58.7			96.3	97.3	93.6	97.8	58.8	96.7			85.7	94.4	93.5	94.3		

Poids en q

Tableau 2. Stat. Marano Lagunare, mai 1983. Quantité journalière des méduses par trait de chalut, poids frais total des méduses, poids frais total du poisson, rapport en pourcentag entre le poids des méduses et le poids total.

Jour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I Trait		35	38	35	38	39			31	49	41	29	22				35	33	24			28	5	29	8	21	16			18	22
II Trait		30	40	21	36	29			34	37	25	25	25				31	12	14			21	4	16	7	19	18			19	18
III Trait		31	12	29	31	36			7	29	35	26	26				34	13	15			23	6	17	6	20	19			17	19
IV Trait		25	15	20	28	28			5	25	31	21	22				19	7	8			16	8	20	7	17	15			15	16
Tot.		121	105	105	133	132			72	137	144	101	95				119	65	61			88	23	82	28	77	68			69	75
Poids de méduses		15.7	13.6	13.6	17.3	17.1			9.3	17.8	18.7	13.1	12.3				15.4	8.4	7.9			11.4	3	10.6	3.6	2.3	8.8			9	9.7
Poids de poissons		0.7	1	1.2	1	0.9			1.7	0.8	1.3	1.5	1.9				1.3	1.9	2			1.6	2.1	1.4	2	1.6	1.7			1.5	1.3
P. $\frac{\text{MED.}}{\text{TOT.}}$ %		95.7	93.1	91.9	94.5	95			84.6	95.7	93.5	89.7	86.6				92.2	81.6	79.8			87.7	58.7	88.3	64.5	59	83.8			85.6	84.4

Poids en q

Tableau 3. Stat. Marano Lagunare, juin 1983. Quantité journalière des méduses par trait de chalut des méduses, poids frais total du poisson, rapport en pourcentage entre le poids des méduses et le poids total.

Jour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I Trait	19	21	18			9	16	13	14	13			11	11	9	12	13			10	13	14	9	9			16	15	13	6	
II Trait	18	24	15			11	14	14	12	14			10	12	10	11	11			11	11	12	4	4			18	16	10	7	
III Trait	17	23	16			13	9	11	11	15			13	14	11	14	9			12	12	13	10	12			17	15	7	8	
IV Trait	15	17	14			8	11	13	12	9			14	7	9	13	7			6	9	10	11	9			19	13	7	5	
Tot.	69	85	63			41	50	51	49	51			48	44	39	50	40			39	45	49	34	34			70	59	38	26	
Poids de meduses	8.9	11	8.2			5.3	6.5	6.6	6.3	6.6			6.2	5.7	5	6.5	5.2			5	5.8	6.3	4.4	4.4			9.1	7.6	4.9	3.3	
Poids de poissons	1.8	1.5	1.9			1.8	1.8	2	2	1.9			2	1.9	2.1	2	1.9			2	1.9	1.8	2.3	1.9			1.7	1.9	2	2.5	
P. $\frac{\text{MED.}}{\text{TOT.}}$ %	83.2	88	81.1			74.7	78	76.8	76.1	77.7			75.7	75	70.7	76.4	73.2			71.7	75.4	77.9	65.7	70			84.2	30	71.1	54.4	

Poids en q

Tableau 4. Stat. Marano Lagunare, août 1983. Quantité journalière des méduses par trait de chalut, poids frais total des méduses, poids frais total du poisson, rapport en pourcentage entre le poids des méduses et le poids total.

Jour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I Trait	3	2	4	1	4			2	4	2	3						4	1	3			1	4	2	3	1			2	2	2
II Trait	2	2	2	2	2			1	3	3	2						2	3	4			4	3	3	3	2			2	2	2
III Trait	2	3	3	3	3			3	4	1	2						3	2	3			3	4	2	2	1			4	3	5
IV Trait	1	1	1	2	2			1	2	0	1						2	1	5			1	2	2	2	1			3	3	1
Tot.	8	8	10	8	11			7	13	6	8						11	7	15			9	13	9	10	5			11	10	10
Poids de méduses	1.0	1.0	1.3	1.0	1.4			0.9	1.7	0.8	1						1.4	0.9	1.9			1.1	1.7	1.1	1.3	0.6			1.4	1.3	1.3
Poids de poissons	2	2	1.9	2.1	1.7			2	1.8	2.2	2						1.9	2.1	1.9			2.1	2.2	2	2.1	1.9			2	2.1	2
P. $\frac{MED.}{TOT.}$ %	33.3	33.3	40.6	32.2	45			31	48.5	26.6	33.3						42.4	30	50.6			35.7	43.4	37	38.2	25.4			41.6	38.2	39.3

Poids en q

Tableau 5. Stat. Marano Lagunare, septembre 1983. Quantité journalière des méduses par trait de chalut, poids frais total des méduses, poids frais total du poisson, rapport en pourcentage entre le poids des méduses et le poids total.

Jour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
I Trait	1	1			3	4	1	1	1			0	0	0	0	0			0	0	1	1									
II Trait	7	1			2	2	0	0	0			0	0	0	0	0			0	1	0	0									
III Trait	1	1			3	3	1	0	1			1	0	0	0	0			0	0	1	0									
IV Trait	2	0			1	1	1	1	2			0	0	0	0	0			0	0	0	0									
Tot.	11	3			9	10	3	2	4			1	0	0	0	0			0	1	2	1									
Poids de méduses	1.4	0.4			1.1	1.3	0.4	0.2	0.5			0.1	0	0	0	0			0	0.1	0.2	0.1									
Poids de poissons	1.9	2			2.1	1.9	2	2.2	2.1			2	2.1	2.2	2.3	2			2.2	2.2	2.5	3									
P. $\frac{MED.}{TOT.}$ %	42.9	16.3			35.7	40.6	16.3	10.5	19.8			6.1	0	0	0	0			0	6.1	9.42	4.1									

Poids en q

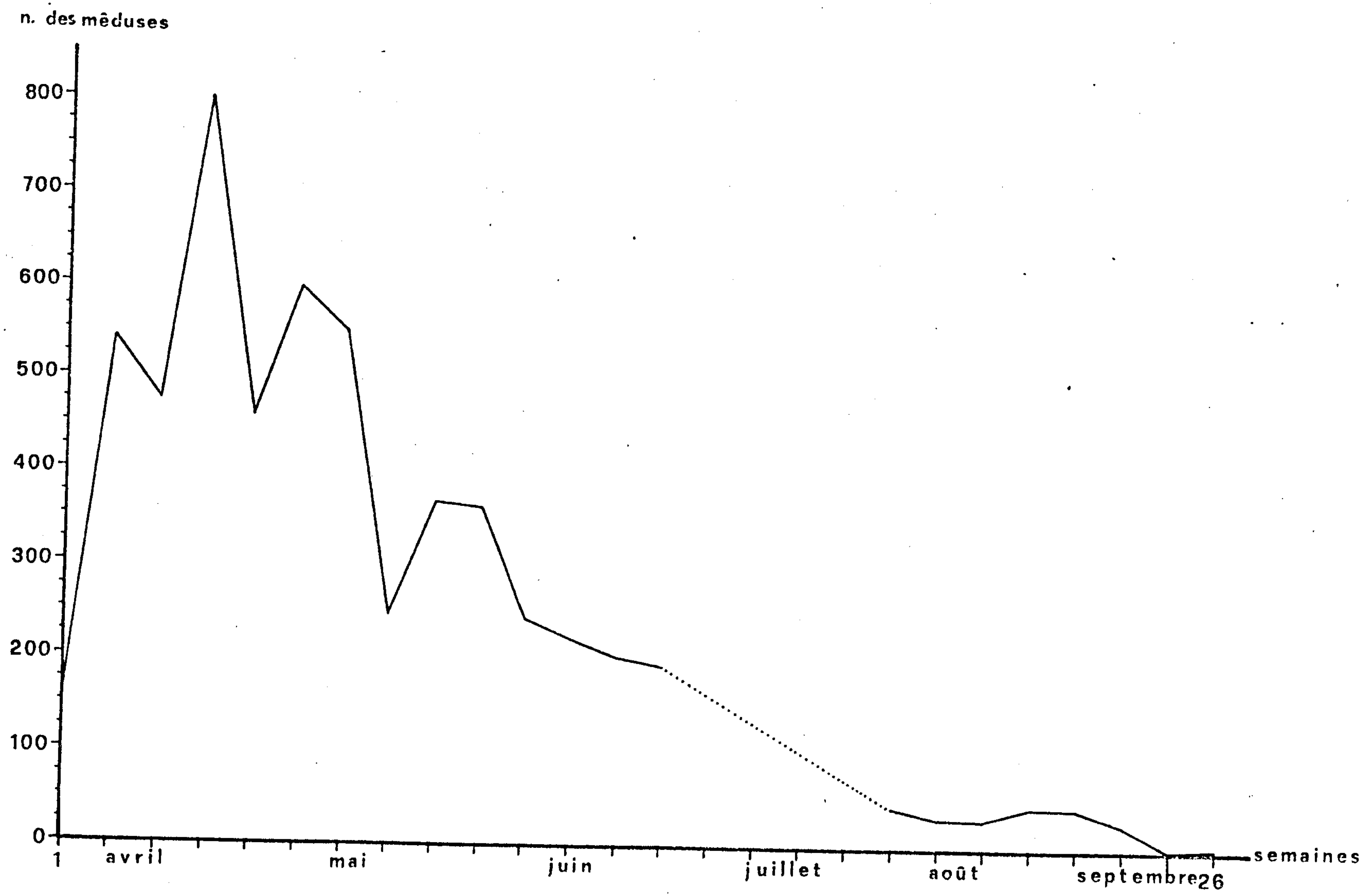

Figure 1. Marano Lagunare; la courbe représente le nombre de Rhizostoma pulmo pêché par semaine.

(________): Données obtenues
(.......): Pas de données

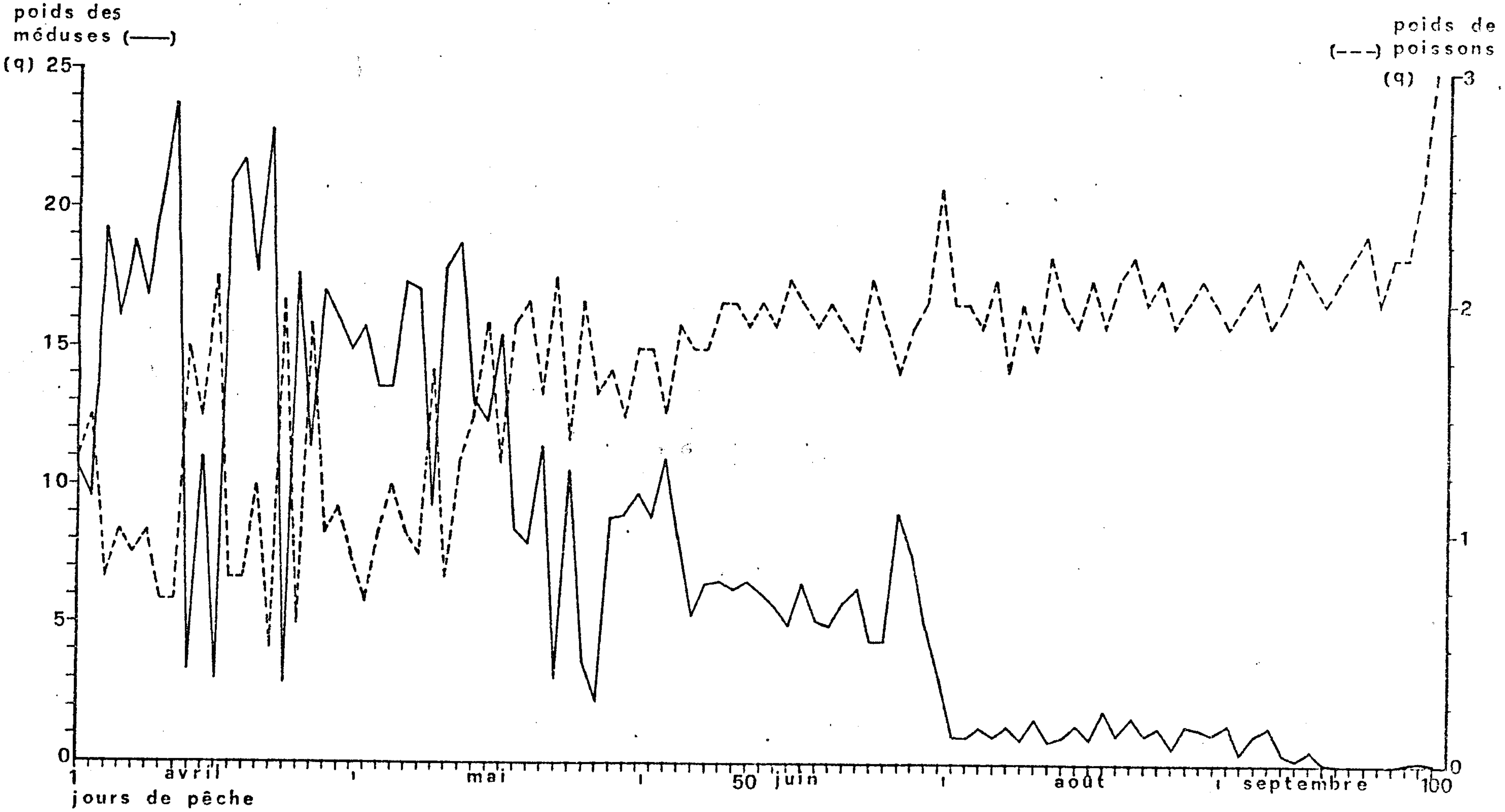

Figure 2. Marano Lagunare;rapport poids méduses/poids poissons, données par jour.

(________): Poids des méduses (q)
(........): Poids de poissons (q)

Tableau 6. Grado, avril - septembre 1983

FILET	BARRAGE	TRAINE DE FOND	TRAINE VOLANTE	HARPON
BATEAUX	9	3	8	1
BATEAUX ENDOMMAGES	3	3	8	-
DOMMAGE AU FILET	ABAISS FILET OBSTR. MAILLE	OBSTR. MAILLE RESTR. EMBOUCH.	OBSTR. MAILLE RESTR. EMBOUCH.	RIEN
DOMMAGE AU POISSONS	PERTE DES POISSONS	PERTE DE MARCHÉ *	PERTE DE MARCHÉ *	RIEN
DOMMAGE ÉCONOMIQUE POUR 1 CALÉE PERDUE	DONNÉES MANQUANTS	POISSON: Lit 100.000 GAS-OIL: Lit 30-40.000	POISSON: Lit 150.000 GAS-OIL: Lit 60-80.000	-

* MOINS QUANTITÉ, GOUT ALTERÉ

EFFECTS OF JELLYFISH PREDATION ON FISHES

by

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Abstract

Inverse relationships between the stock developments of planktonic crustacea and medusae or ctenophores have been reported on three occasions, suggesting that these coelenterates have the potential to act as serious food competitors and predators of larval fish and plankton-feeding adult stages. Numerous observations of jellyfish preying on fish larvae have been made, but quantitative data from the field are scarce.

The effect of predation on larval herring (Clupea harengus) by the scyphomedusae Aurelia aurita was studied in Kiel Fjord in the western Baltic Sea, in 1979-1981. During May, on average 1.2 larvae per Aurilia stomach were found. The highest number observed was 68 larvae in one medusa, 4 cm in bell diameter. Based on data from population studies of the fish larvae and of the medusae and from studies of the digestion rate, the daily loss of the herring larva population by jellyfish predation was estimated to be at least 2-5 per cent.

Introduction

The mass occurrence of jellyfish has aroused increasing interest in the public during recent years. It has been supposed that man-made eutrophication in certain coastal areas might be responsible for increasing populations of medusae. However, insufficient quantitative data are available from any area before the 1970s to prove the validity of this hypothesis and it has to be mentioned that mass occurrence of scyphomedusae had already been reported as early as in the 18th century (Eimer, 1878; Kramp, 1939).

In various coastal areas jellyfish are regarded as a nuisance by clogging fishing nets and power plant intake systems and by stinging fishermen and swimmers. Most reports in the scientific literature come from coastal waters of the NE Atlantic area (table 1), but additional comments from many scientists indicate that jellyfish may cause problems in nearly all parts of the world.

The population dynamics and the ecological role of scyphomedusae have been neglected subjects until recently. Their large size, their enormous growth rates, and their extremely patchy distribution, influenced by a variety of environmental factors, still present problems when quantifying the abundance of these animals. Quantitative data on a larger scale exist only for Aurelia aurita and Cyanea species among the scyphomedusae, and for various species of hydromedusae and ctenophores. In Japanese coastal waters Yasuda (1968, 1969, 1971, 1979) studied the development and distribution of Aurelia aurita. Hay and co-workers have been monitoring the presence of scyphomedusae in the North Sea every summer since 1974 during the Scottish young-gadoid-survey (Hay and Hislop, 1981). The proportion of various jellyfish species among the total zooplankton in the North Sea and Baltic Sea in summer 1978 was described by Möller (1980 a) (figures I and II). More detailed studies on the development of an Aurelia population and its impact on the plankton system were carried out in Kiel Bight in the western Baltic Sea (Möller 1979, 1980 b, c). During these surveys it became evident that under certain conditions jellyfish may interfere significantly with the develoment of young fish populations - a fact that is less spectacular than the hindrance to human fishing activities by jellyfish but might well be of much greater economic importance.

How can jellyfish affect a fish population?

Numerous observations on the stomach contents of jellyfish have been published, mostly concerning the finding of fish larvae. Hunter (1983), when reviewing the literature on predation on marine fish larvae, identified at least 34 species of medusae and five species of ctenophores that are known to feed on fish larvae in the field or under laboratory conditions. Quantitative data on the food consumption under natural conditions were compiled by Kerstan (1977) for Aurelia aurita in Kiel Bight and he classified it as an omnivorous feeder. According to the local plankton composition, copepods dominated as food times. Jellyfish therefore have to be considered as potential predators on fish as well as competitors for food of larval fish and of plankton-feeding adult species.

Jellyfish as food competitors for fish

Fraser (1969) calculated from feeding experiments that an adult Aurita of 25 cm in diameter during its life-time has consumed about 10 g dry weight of zooplankton. This equals about 1 million Pseudocalanus elongatus or 200,000 yolk-sac herring larvae (Möller, 1983). Based on various studies on the oxygen demand (Nicoll, 1960; Thill, 1937), Kerstan (1977) estimated the daily food requirement of 100 g Aurelia at nearly 10 mg dry weight.

With the average biomass of Aurita in a certain area known, the food demand of the whole population can be calculated, as shown for Kiel Bight in table 2. In this special case it is demonstrated that the food demand per month of the local Aurelia population equals four times the standing stock of the local copepod population during the period July to September - all developmental stages and all species included. Although the production rate of the copepods is not sufficiently known and although these calculations are based on very rough estimates, these figures justify the speculations that (a) the predation of jellyfish should have a measurable effect on the copepod stock and (b) a reduction of the copepod stock as the main food resource should have a feed-back effect on the development of the jellyfish population.

There is some evidence for the validity of both speculations: a drastic decrease in the standing stock of the copepods in Kiel Bight occurs from 26.4 mg C_{org} m^{-3} in May to 12.4 mg in June, and 8.4 mg in July (table 3). During the same period the biomass of the Aurelia population increases from 1.1 mg C_{org} m^{-3} in May to 12.8 mg in June and 37.9 mg in July. Obviously, there is a causal inverse relationship between the development of both stocks. Along with the decrease in the copepods, a shrinkage of the average bell diameter of Aurelia can be observed from the end of July onwards (figure III). This dwindling in the size of the jellyfish is attributed to starvation - an effect that can easily be reproduced under experimental conditions (Hamner and Jenssen, 1974).

It is supposed that similar changes in the zooplankton community take place, wherever jellyfish occur in large swarms. However, no additional information is available yet for scyphomedusae from other areas, but similar observations were made during the blooming of ctenophores. Kamshilov (1959, cited by Fraser, 1962) found relatively low quantities of Calanus during years when Bolinopsis infundibulum occurred in high numbers. Burrell and Engel (1976) described an inverse relationship between the abundance of Mnemiopsis leydigi and the crustacean plankton in the York River estuary.

Jellyfish as predators of fish

Reports on the predation of jellyfish on fish deal mainly with early larval stages. Fish eggs have only occasionally been reported in the stomach of jellyfish (Bieri, 1961, 1970; Burrel and Engel, 1976; Delap, 1907; Lebour, 1922, 1923; Phillips et al., 1969). No fish eggs were found during the investigation of nearly 6,000 Aurelia in the spring of 1979 and 1980 in Kiel Fjord (Möller, 1984a).

Fish beyond the larval stage can usually avoid predation by jellyfish. The only noticeable exceptions from this rule seem to have been reported from Kiel Fjord, when on two occasions swarms of young clupeids entered harbour areas that were densely occupied by large Aurelia.

The potential impact of large jellyfish swarms on larval fish populations is made evident by the studies of Fraser (1962, 1969). One Aurelia of 50 mm in bell diameter caught all 60 fish larvae from a 6 l aquarium within only [illegible].5 hours. Fraser speculated that in Newfoundland coastal waters one hydromedusa during its life-time might consume 50-250 fish larvae, while one Aurelia might catch 450-500 larvae, and one Cyanea as many as 15,000 larvae. The effect of jellyfish predation on larval fish in the sea, however, is too complicated to be assessed. It requires data not only on the population of predator and prey, but also on food uptake rate and digestion rate.

Quantitative information on fish larva mortality by jellyfish predation in nature is scarce. When studying survival rates of larval Pacific herring, Stevenson (1962) described ctenophores as the main predators. In one sample, 45 per cent of the larvae had been devoured by Pleurobrachia sp., containing one to two larvae each. Hoewever, ctenophores with herring larvae in their stomach were found in less than 2.5 per cent of all samples taken. The consumption rate of the siphonophore Rhizophysa eysenhardti in a shallow bay in the Gulf of California was estimated to be nearly nine fish larvae per day and predator (Purcell, 1981).

The only quantitative examination of the consumption by scyphomedusae of fish larvae in the sea was carried out in Kiel Fjord on Aurelia aurita (Möller, 1980 c). Spring spawning herring enter this fjord every year in April. When hatching in May, the larvae are exposed to a large population of young medusae that had also been produced in the inner parts of the fjord.

In May 1979 and also in 1980, altogether 5,873 medusae of 6-50 mm in bell diameter (alive) were examined for their stomach contents and herring larvae were found to be a major part of the diet during both periods. More than 98 per cent were yolk-sac larvae of 5-7 mm in length when preserved in formaldehyde. No herring larger than 8.5 mm was found. No increase of larva uptake with increasing jellyfish diameter was evident, contradictng results of Bailey and Batty (cited by Hunter, 1983) who pointed out that efficiency of capture as well as encounter rates increased with medusa size under laboratory conditions.

In Kiel Fjord no clear periodicity in the larva uptake could be demonstrated. The smallest Aurelia that had caught a herring larva was 6 mm in diameter. At a size of 12 mm up to 10 larvae and at a size of 42 mm up to 68 larvae were found per stomach (figure IV). The average of both surveys revealed 1.2 larvae per Aurelia. The daily loss of the herring larva population by jellyfish predation was estimated to be at least 2-5 per cent.

Indications of significant impacts of jellyfish predation on larval fish populations

If the effects of jellyfish predation or competition were of any significance to larval fish populations, these effects should become evident in three ways:

1. Within the spawning area of a fish species, low numbers of larvae should be present in regions with a high abundance of jellyfish.

2. Relatively low numbers of fish larvae should be present during those periods of the spawning season when high numbers of jellyfish occur.

3. Low numbers of fish larvae should be present during those years when the abundance of jellyfish is relatively high.

These three relations will be discussed, using data collected from 1978 to 1981 in Kiel Fjord. Weekly samples were taken at 26 stations (figure V), beginning every year with the first occurrence of herring larvae in the plankton and ending when less than 1 larva per 100 m^3 was caught (table 4). Vertical hauls were made with a CalCOFi-net of 1 m mouth opening and 0.5 mm mesh size. On an average, 188 m^3 water were filtered per haul. Only herring larvae of 5.0-7.9 mm total length (when preserved in formaldehyde) were considered. The abundance of Aurelia medusae is expressed as ml volume per 100 m^3.

Relations medusae/herring larvae on single surveys

In table 4 all surveys with more than one herring larva per 100 m^3 based on the average of all 26 stations are listed. For each single survey, the correlation between the abundance of herring larvae and medusae was tested (rank correlation after Spearman).

Negative correlations were present for twelve surveys. They were found on all occasions when more than six herring larvae as well as more than 90 ml Aurelia were caught taking an average of all stations.

The conclusion can be drawn that mass occurrence of jellyfish reduces larval fish populations locally. This relation only becomes evident when the stock sizes of both species exceed certain limits - otherwise they are masked by environmental or stock specific factors.

Relations medusae/herring larvae during a spawning season

The developments of the larval herring populations in Kiel Fjord during the spring months of 1978-1981 are shown in figure VI.

In all four years, the abundance of herring larvae in the plankton decreased sharply as the biomass of medusae increased. As soon as the Aurelia biomass exceeded a level of about 75 ml per 100 m^3, the numbers of herring larvae were reduced by more than 50 per cent. In 1981, this happened about five weeks, in 1978 and 1979 about four weeks, and in 1980 only about two weeks after the hatch of the first larvae.

Relations medusae/herring larvae during different years

The average abundance of herring larvae and the biomass of Aurelia aurita during the spring months of 1978-1981 are listed in table 4 and illustrated in figure VII.

Herring larvae were most abundant in spring 1979. In 1981, only 81 per cent, in 1980, 35 per cent and in 1978, 29 per cent of this basic value were caught. During the two years with highest larval abundance, the lowest biomass of medusae occurred: in 1979 only 11 per cent and in 1981 only 15 per cent of the maximum value of the year 1980.

Obviously the average abundance of larval herring and medusae were negatively related for the four years examined. On the other hand, no positive relation was evident between the landings of spawning herring from the fjord as an indicator for the size of the spawning stock and the abundance of herring larvae in the same year.

Table 1: Hindrance to fishing and cooling systems by jellyfish (Möller, 1980 c)

A. Hindrance to fisheries

Locality	Species	Source
Skagerrak	*Tima bairdii*	Bernt (1967)
Bergen (Norway)	*Aurelia aurita*	Inst. Mar. Res. Blomsterdalen
Western Baltic	*Aurelia aurita*	original
Central Baltic	*Aurelia aurita*	Hela (1951)
Netherlands	*Aurelia aurita*	Maaden (1942)
Faror	*Aurelia aurita*	Russell (1970)
Constanta (Romania)	*Aurelia aurita*	Mar. Res. Inst. Constanta
Wakasa Bay (Japan)	*Aurelia aurita*	Yasuda (1979)
Skagerrak	*Cyanea capillata*	original
Scotland	*Cyanea* sp.	Dep.Agric.Fish.Scotl. Aberdeen
Peru	*Chrysaora* sp.	original
Hongkong	scyphomedusae	Agric. Fish. Dep. Hongkong
Falkland Islands	scyphomedusae	Inst. Nac. Invest. Desarrollo Pesquero Mar del Plata
Gulf of Maine	*Nanomia cara*	Rogers *et al.* (1978)
Weser estuary	*Pleurobrachia pileus*	original
Gulf of Maine	coelenterates	Sherman *et al.* (1979)

B. Clogging of cooling water inlets

Locality	Species	Source
Ringhals (Sweden)	*Aurelia aurita*	Svenska Vattenfall
Kiel	*Aurelia aurita*	original
Japan	*Aurelia aurita*	Matsueda (1969)
Peru	*Chrysaora* sp.	Schweigger (1959)

Table 2. Size and food demand of the <u>Aurelia</u> population in Kiel Bight and standing stock of copepods (calculated from data of various authors after Möller, 1984a)

	<u>Aurelia aurita</u> abundance (g wet weight per 100 m^3	<u>Aurelia aurita</u> food demand (g dry weight per month	copepods (abundance in g dry weight per 100 m^3
May	70	0.3	8.3
June	850	3.6	3.9
July	2 530	10.6	2.6
August	2 500	10.5	2.6
September	1 850	11.8	2.4
October	1 220	5.1	1.0
November	40	0.2	0.4

Table 3. Standing stocks of coelenterates and copepods in Kiel Bight ($mg\ C_{org}\ m^{-3}$) (Möller, 1984a)

	coelenterates	copepods
May	1.1	26.4
June	12.8	12.4
July	37.9	8.4

Table 4. Abundance of herring larvae (5 - 7 mm) and of *Aurelia aurita* per 100 m^3 in the plankton of Kiel Fjord based on the average of 26 stations and confidence levels for negative correlations between both groups (Möller, 1984a)

Date	Herring larvae (numbers)	*Aurelia aurita* (ml volume)	Confidence level
27/04/1978	13.6	1.2	-
09/05/1978	32.2	1.2	-
17/05/1978	39.1	9.8	-
25/05/1978	111.1	38.8	95 %
31/05/1978	36.5	1 273.0	99 %
08/06/1978	9.2	524.0	99 %
14/06/1978	11.3	443.7	99 %
22/06/1978	1.4	976.6	-
average	31.8	408.5	
09/05/1979	2.4	0.1	-
16/05/1979	80.5	0.2	-
23/05/1979	482.2	0.9	-
31/05/1979	240.7	2.6	-
06/06/1979	19.3	87.2	-
11/06/1979	29.7	182.0	95 %
20/06/1979	9.3	22.8	-
27/06/1979	5.4	609.3	99 %
average	108.7	113.1	
08/05/1980	37.5	24.4	90 %
14/05/1980	(146.0)	(27.9)	
21/05/1980	16.6	72.0	99 %
28/05/1980	11.1	1 297.4	95 %
04/06/1980	7.2	510.7	90 %
11/06/1980	4.1	4 163.3	90 %
average	37.1	1 015.9	
23/04/1981	22.3	1.3	-
29/04/1981	43.2	4.8	-
05/05/1981	24.7	1.6	-
13/05/1981	54.9	23.3	-
20/05/1981	409.3	28.6	-
01/06/1981	147.0	81.0	90 %
10/06/1981	5.8	987.0	-
19/06/1981	1.3	77.5	-
average	88.6	150.7	

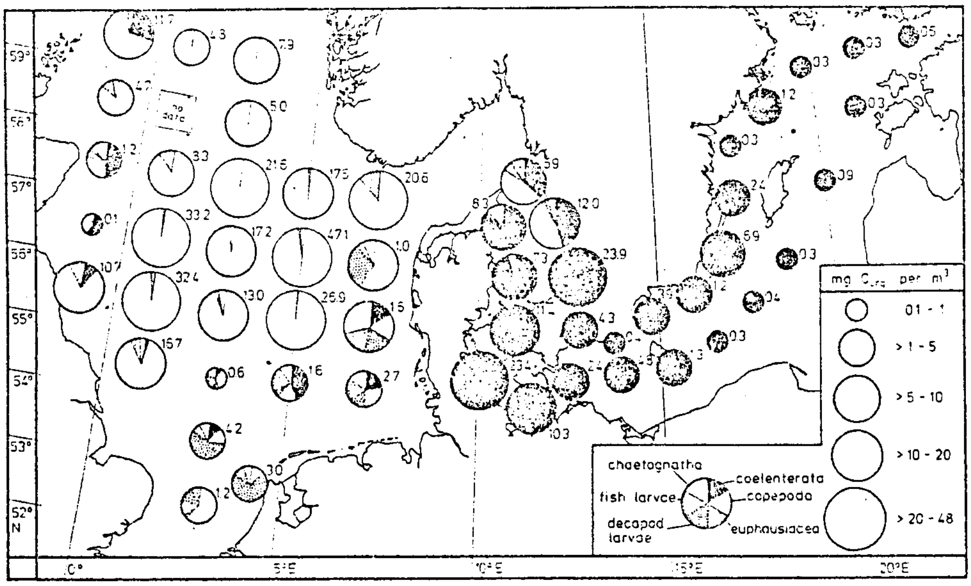

Figure I. Total biomass and composition of zooplankton > 500 µm in North Sea and Baltic Sea, 01/08 - 15/09/1978 (Möller, 1980 a)

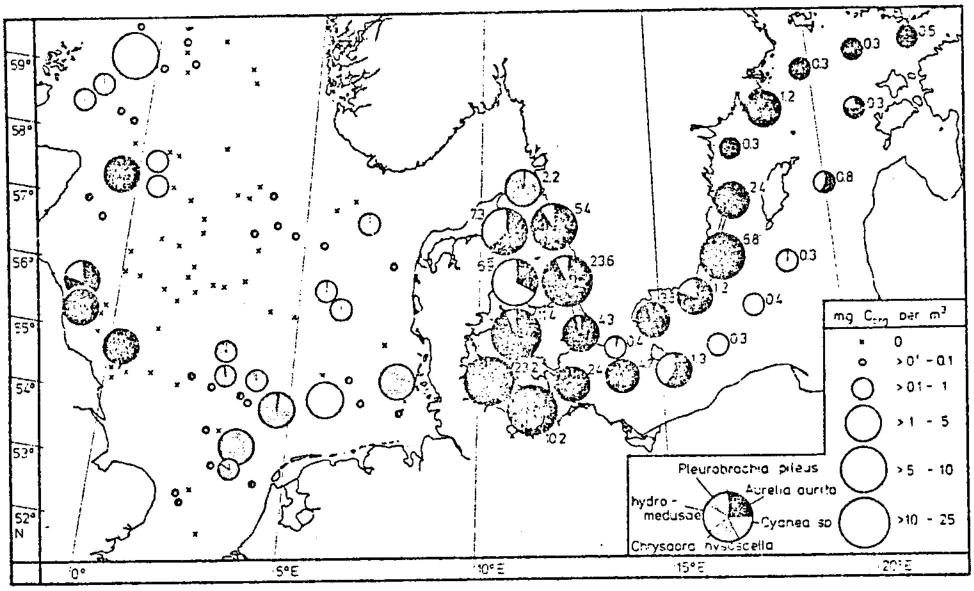

Figure II. Biomass and composition of coelenterate plankton in North Sea and Baltic Sea, 01/08 - 15/09/1978 (Möller, 1980 a)

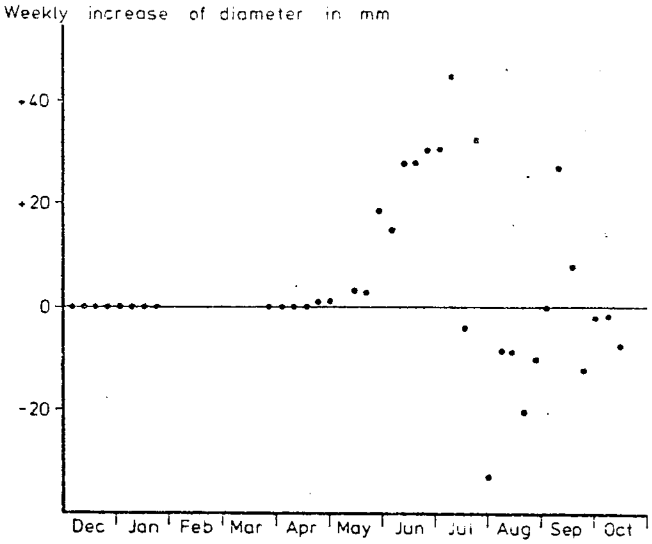

Figure III. Weekly growth of Aurelia aurita 1978-1979 in Kiel Fjord, gliding averages on three values (Möller, 1980 b)

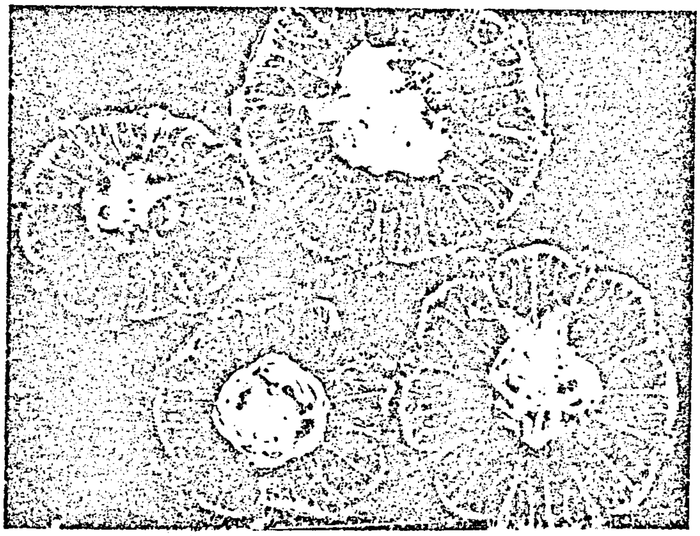

Figure IV. Numerous herring larvae in the stomachs of young Aurelia aurita

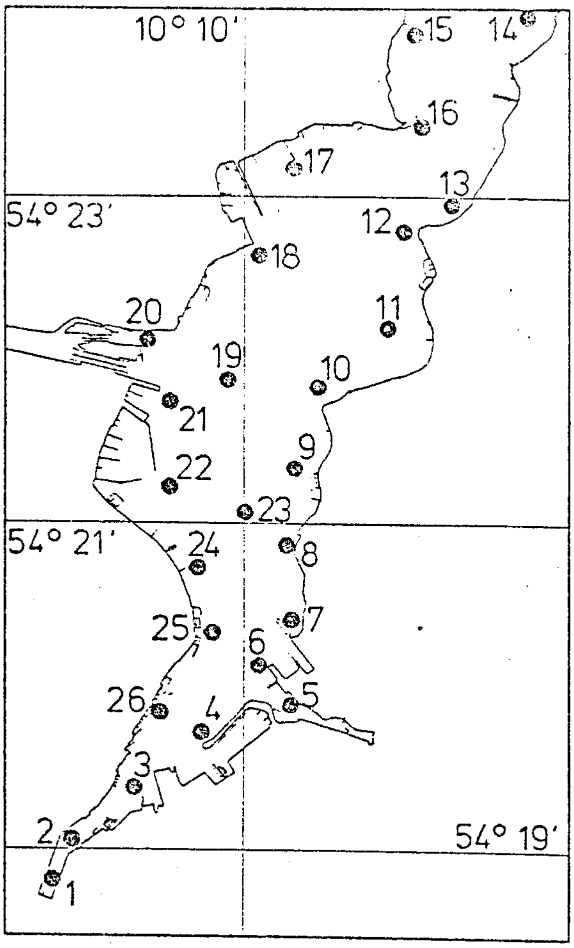

Figure V. Station map of jellyfish and herring larva survey in Kiel Fjord 1978-1981

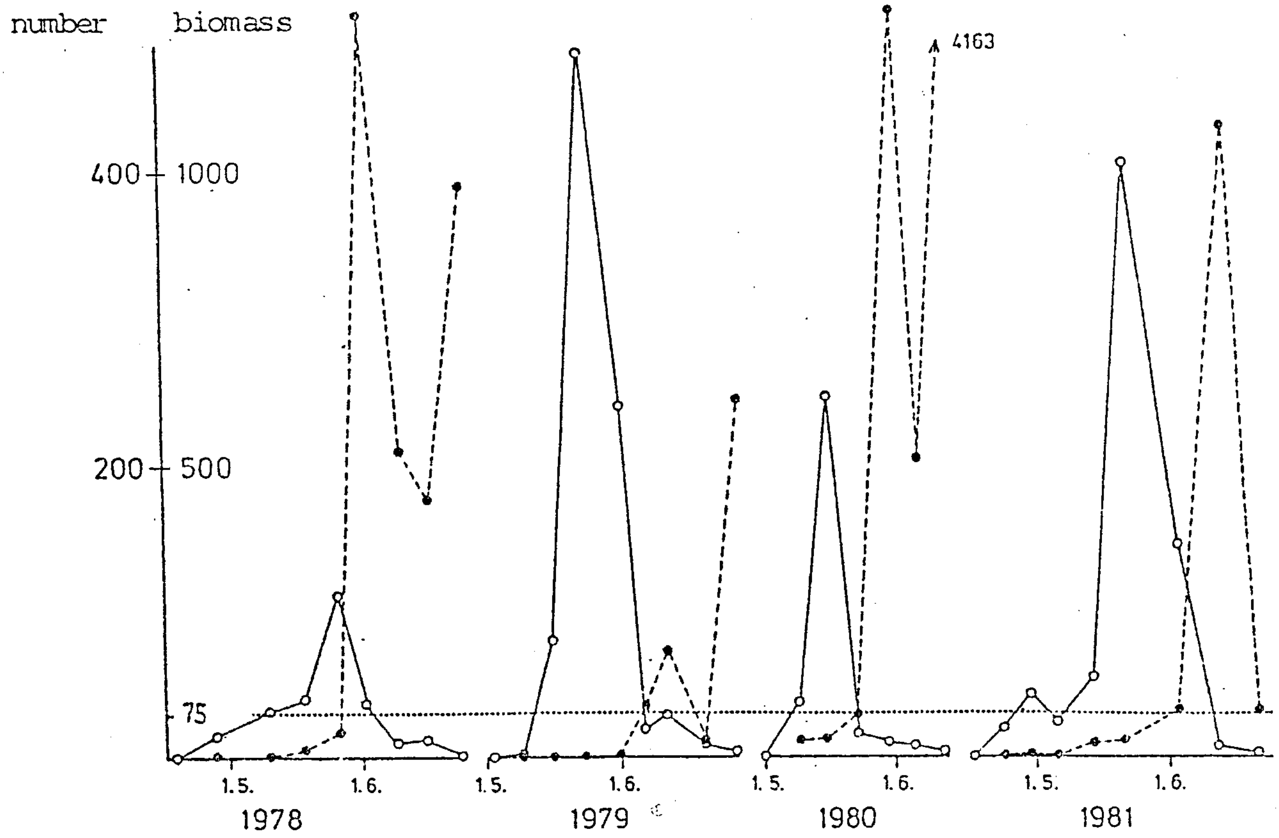

Figure VI. Number of herring larvae (5-7 mm, unbroken line) and biomass of Aurelia aurita (in ml, broken line) per 100 m^3 based on the average of 26 stations in Kiel Fjord (Möller, 1984b)

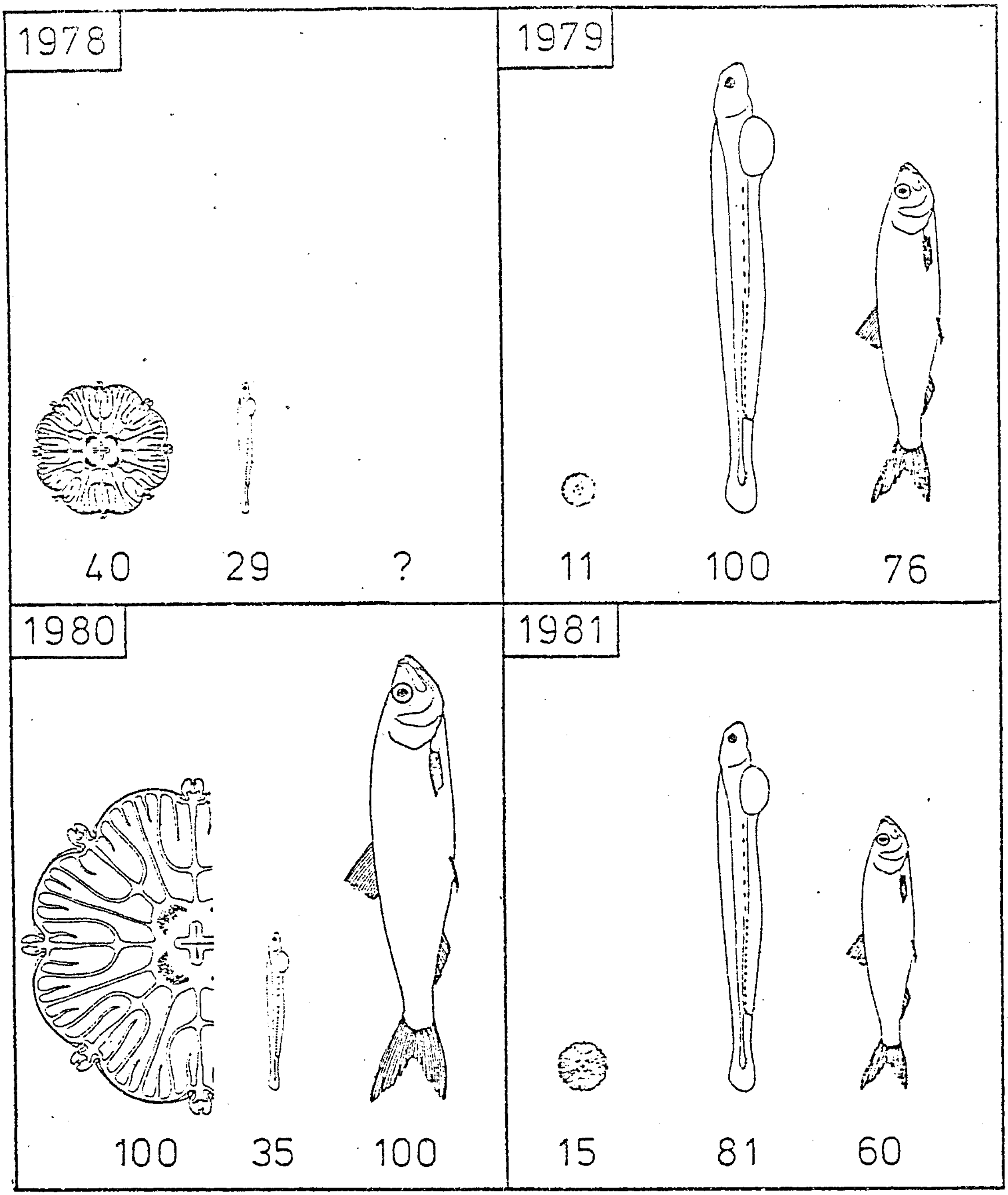

Figure VII. Relative abundance of Aurelia aurita and of herring larvae in the plankton of Kiel Fjord and relative landings of herring at Kiel fish market.

Herring larvae: yearly averages of all surveys with more than 1 larva (5-7 mm) per 100 m^3.

Aurelia aurita: average volumina at corresponding stations.

Herring: landings of size group I and II gill-netted herring from Kiel Fjord in April (Möller, 1984b).

References

Bieri, R., (1961). - Post-larval food of the pelagic coelenterate, Velella lata. Pac.Sci. 15, 553-556.

Bieri, R., (1970). - The food of Porpita and niche separation in three neuston coelenterates. Publ. Seto. Mar. Biol. Lab. 17, 305-307.

Burrell, V.G. and Engel, W.E. van, (1976). - Predation by and distribution of a ctenophore, Mnemiopsis leydigi A. Agassiz, in the York River estuary. Estuar. Coast. Mar. Sci. 4, 235-242.

Delap, M.J., (1907). - Notes on the rearing, in an aquarium, of Aurelia aurita L. and Pelagia perla (Slabber). Rep. Sea Inld Fish.Ireland 1905 (II), 160-164.

Eimer, T., (1878). - Die Medusen, physiologisch und morphologisch auf ihr Nervensystem untersucht. Tübingen Lauppsche Buchhandlung, 277 pp.

Fraser, J.H., (1962). - The role of ctenophores and salps in zooplankton productivity and standing crop. Rapp. P. -v. Réun. Cons. Int. Explor. Mer 153, 121-123.

Hamner, W.M. and Jenssen, R.M., (1974). - Growth, degrowth and irreversible cell differentiation in Aurelia aurita. Am. Zool. 14, 833-849.

Hay, S.J. and Hislop, J.R., (1981). - The distribution and abundance of scyphomedusae in the North Sea during the summer of 1980. Int. Counc. Explor. Sea, C.M./L:22.

Hunter, J.R., (1983). - Inferences regarding predation on the early life stages of cod and other fishes. Flødevigen rapportser. 3 (in press).

Kerstan, M., (1977). - Untersuchungen zur Nahrungsökologie von Aurelia aurita Lam. Diplomarbeit, Inst. Meeresk. Univ. Kiel.

Kramp, P.L., (1939). - Medusae, siphonophora and ctenophora. Zoology of Iceland 2/5, 1-37.

Lebour, M.V., (1922). - The food of plankton organisms. J. Mar. Biol. Ass. U.K. 12, 644-677.

Lebour, M.V., (1923). - The food of plankton organisms. II. J. Mar. Biol. Ass. U.K. 13, 70-92.

Möller, H., (1979). - Significance of coelenterates in relation to other plankton organisms. Meeresforschung 27, 1-18.

Möller, H., (1980 a). - A summer survey of large zooplankton, particularly scyphomedusae, in North Sea and Baltic. Meeresforschung 28, 61-68.

Möller, H., (1980 b). - Population dynamics of Aurelia aurita medusae in Kiel Bight, Germany (FRG). Mar. Biol. 60, 123-128.

Möller, H., (1980 c). - Scyphomedusae as predators and food competitors of larval fish. Meeresforschung 28, 90-100.

Möller, H., (1984a). - Okologie der Quallen und Jungfische in der Kieler Bucht. Kiel: H. Möller (in press).

Möller, H., (1984b). - Reduction of a larval herring population by jellyfish predator. Science, N.Y., 224, 621-622.

Nicol, J.A., (1960). - The biology of marine animals. London, Pitman & Sons, 707 pp.

Phillips, J.H., Burke, W.D. and Keener, E.J., (1960). - Observations on the trophic significance of jellyfish in Mississippi - Sound with quantitative data on the association behaviour of small fishes with medusae. Trans. Am. Fish. Soc. 98, 703-712.

Purcell, J.E., (1981). - Feeding ecology of Rhizophysa eysenhardti, a siphonophore predator of fish larvae. Limnol. Oceanogr. 26, 424-432.

Stevenson, J.C., (1962). - Distribution and survival of herring larvae (Clupea pallasi Valenciennes) in British Columbia waters. J. Fish. Res. Bd Can. 19, 735-810.

Thill, H., (1937). - Beiträge zur Kenntnis der Aurelia aurita (L.). Z.wiss. Zool. 150, 51-96.

Yasuda, T., (1968). - Ecological studies on the jellyfish Aurelia aurita in Urazoko Bay, Fukui Prefecture. II. Occurrence pattern of the ephyra. Bull. Jap. Soc. Sci. Fish. 34, 983-987.

Yasuda, T., (1969). - Ecological studies on the jellyfish Aurelia aurita in Urazoko Bay, Fukui Prefecture. I. Occurrence pattern of the medusa. Bull. Jap. Soc. Sci. Fish. 35, 1-6.

Yasuda, T., (1971). - Ecological studies on the jellyfish Aurelia aurita in Urazoko Bay, Fukui Prefecture. IV. Monthly change in the bell-length composition and breeding season. Bull. Jap. Soc. Sci. Fish. 37, 364-370.

Yasuda, T., (1979). - Studies on reproductive biology of harmful marine animals - the common jellyfish, Aurelia aurita, along coast of Wakasa, Japan Sea. Proc. 7th Japan-Sov. Joint Symp. Aquacult., Tokyo, 185-195.

SESSION Ic

IMPACT OF JELLYFISH BLOOMS ON HUMAN HEALTH AND RECREATION

INFLUENCE DES PROLIFERATIONS ANORMALES DE MEDUSES SUR LA SANTE HUMAINE ET LES LOISIRS

MAST CELL SECRETION: BASIS FOR JELLYFISH POISONING AND PROSPECTS FOR RELIEF

by

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Much of the work I have been doing deals with a subject called anaphylaxis. This term describes a conglomerate of events that include itching, swelling, redness, constriction of the bronchi, generalized oedema and hypotension which may lead to shock. What is particularly intersting from the point of view of this Workshop is that the term anaphylaxis was first used in 1902 (1) to describe the effect of introducing jellyfish extract systemically into dogs. It has then taken more than eighty years to "rediscover" that anaphylaxis can be caused by jellyfish stings. I will first briefly describe how toxins may be elaborated from jellyfish; I will then go into the methods we use in the laboratory to assay for the presence of toxins. I hope to be able to convince you that these methods not only allow us to assay for the toxins, but may provide us with the possible mechanism via which these toxins cause their deleterious effects in the organism.

The coelenterates are called cnidarians because they have tentacles equipped with stinging batteries. These organisms have the capacity to contract their tentacles in such a way that the superficial layer of the tentacle contracts less than the deeper ones; as a result, the tentacle is thrown into folds which expose the stinging batteries or "heads" containing the nematocysts. The nematocyst is often erroneously called the stinging "cell" although it is not a cell; instead, it is a specialized part of a cell called the cnidoblast. Neamtocyst heads occur at fairly regular intervals and may contain as many as 500 large and over 2,000 small nematocysts; an extended filament may then contain as many as 750,000 nematocysts. Each nematocyst is equipped with a cnidocil, a specialized sensor which can be triggered primarily by pressoreceptors; chemoreceptors are also, however, known to do the same. Upon triggering, a hollow filament which is tightly coiled within the nematocyst, the nema, is uncoiled and is ejected with such force that it may penetrate a glove or bathing suit. It is through this hollow filament that the nematocyst toxins are elaborated, having been produced in gastrodermal cells, travelled through mesoglia and having been stored inside the nematocyst.

Toxins elaborated from jellyfish do not necessarily come only from the nematocysts; they are also produced and stored in other gastrodermal cells and may be released when vigorous resistance of the target organism causes disruption of the tentacle. Such toxins may differ in composition and, depending on their composition, may be susceptible to inactivation by heat or lytic enzymes. Passage through the gastrointestinal tract and exposure to high acidity or digestive enzymes may be some reasons why certain marine organisms such as the loggerhead turtle Caretta caretta, or Obtada melanura may feed on Physalia or Pelagia respectively. Moreover, it still remains a mystery how the nudibranchs Glaucus and Glaucilla not only consume the nematocysts, but apparently also store them for their own defensive use! (2-4).

The extent of damage caused by the jellyfish sting depends on the toxins released but also on the length of time the tentacles remain in contact with the body surface involved. This is particularly important because the tentacles retain their ability to discharge the nematocysts even after they have been severed from the jellyfish.

We considered a number of different jellyfish as potential sources of toxin, but most proved quite difficult to get. Included in these are: Pectanthis asteroides, Aequorea forskalea, Chrysaora mediterranea, Rhizostoma pulmo, Cotylorhiza tuberculata, Pelagia noctiluca and Nausithoe punctata. These species apparently produce different toxins but hardly anything is known about their composition. Instead, most of our information comes from the anthozoa. The first such report was published in 1902 when extracts from Anemonea sulcata were introduced into dogs so that the animals might develop resistance to subsequent exposure to the toxins. Unfortunately, the animals went into shock instead, and the researchers decided (1) to use the term anaphylaxis to denote the antithesis (Gk. ana) of protection (Gk. phylaxis). Similar results were later observed by other investigators in cats (5), and with Cyanea extracts, too (6).

Stinging is the first sensation experienced when jellyfish nematocysts are discharged on a body surface both because of the nema penetrating the skin and the elaboration of certain chemicals from human cells. It is important to stress that these chemicals are not jellyfish toxins. They derive from particular cells in human tissues which are triggered to secrete in response to jellyfish toxins. In addition to the stinging sensation, these chemicals irritate local nerve endings and create an electric shock-like sensation which spreads from the area of contact and is followed by redness, swelling and itching. These symptoms may persist for a considerable time and they may be evident in a linear pattern reminiscent of the shape of the tentacle at the site of contact with the skin.

Other, more serious, effects of these chemicals which are relased in response to jellyfish toxins may occur at some distance from the site of contact. They include generalized oedema, bronchial constriction, hypotension and possible syncope and shock. Laryngeal and brain oedema can be quite dangerous especially in hypersensitive individuals.

The first slide shows a sting by Pelagia and it can be seen that the affected area is well-demarcated and the swelling is usually short-lived. Physalia stings, on the other hand, shown in the subsequent slides, involve a much larger area of skin with prominent redness and swelling which are long-lasting.

At the cellular level, the effect of jellyfish toxins is quite interesting. It appears that they almost selectively affect a type of cell which has been closely associated with anaphylaxis and is known as the mast cell. These cells were first described by Paul Ehrlich in 1887 who termed them Mastzellen, which in German means well-fed cells, because they were full of granules which stained light violet with certain dyes (7). Since then, mast cells have been shown to be responsible for allergic and anaphylactic reactions but very little else is known about them (8-11). Each cell contains about 500 or so secretory granules which are enclosed by a double membrane somewhat similar to the plasma membrane. The latter, however, contains a number of specialized molecules which serve as receptors and bind one particular class of immunoglobulins known as E (IgE). There may be as many as 500,000 receptors on one mast cell and because they bind and concentrate IgE specifically, this action has been called homocytotropism (12).

Once the IgE molecules bind to these receptors, one molecule per receptor, they then need to be "bridged" or connected at least two at a time in order to trigger the cell. This is done by the IgE binding to various molecules, termed antigens, through its free Fab portions which bind to antigens specifically. When antigens bridge IgE molecules, a cascade of biochemical reactions begins and culminates in the fusion of the perigranular membrane with the plasma membrane and the release of the granule contents to the outside of the cell (13). The secretory granules contain a great number of biologically active molecules, of which the best known are: histamine, serotonin, heparin, slow reacting substances of anaphylaxis (SRS-A) now known as leukotrienes C and D, and a variety of lytic enzymes among others (14, 15). I would like to stress that the secretory granules contain more than 40 potent substances of which histamine, the leukotrienes and various kinins produce pain (16).

Although IgE molecules are the best-studied substances which can trigger mast cell secretion, there also exist a variety of other chemicals which can induce secretion from mast cells (17-21). Many of these are cationic in nature and include such physiologically important molecules as somatostatin [illegible]22) and parathormone (23); they also include toxins from bee and wasp venom (24-27), from ants (28), sea-urchins (30), and more recently jellyfish (31). In all cases, the process of secretion is absolutely dependent on metabolic energy and calcium ions; it is not yet definitely known, however, in what precise biochemical steps these parameters are utilized. For instance, prostaglandins and leukotrienes appear to be synthesized during the relase reaction when fusion of membranes occurs. These and other molecules can influence distant organs such as the brain or the adrenals and cause these organs to release substances which react and influence mast cell secretion. Mast cell-derived mediators can therefore affect end-organs directly or through their effects on central organs which in turn act on mast cells or other organs themselves.

Mast cells for our studies are obtained from the peritoneal cavities of rats. We first inject about 15 ml of a physiologic salt solution (Locke's buffered with 5 mM Hepes at pH 7) into the peritoneal cavity of rats killed by CO_2 asphyxiation and decapitation. The abdomens are massaged for 90 sec to dislodge the mast cells and the peritoneal fluid is collected (about 12 ml) with a plastic Pasteur pipette. This fluid contains about 10^7 cells of [illegible]ich about 7 per cent are mast cells. These cells are washed and concentrated by centrifugation so that the cells from each rat are resuspended in 1 ml Locke's solution (1 ml per the equivalent of 1 rat-worth of cells). Each ml of cell suspension is then layered on top of 2.0 ml of an iodinated derivative of glucose called Metrizamide (figure I) centrifuged for 5 mins at about 180 x g at 240°C in a swinging bucket rotor. The upper 2 ml are removed by suction and the bottom 1 ml is saved; this ml contains a small white pellet which is made up of more than 95 per cent pure mast cells with a yield of about 75 per cent (22, 32). The purified rat mast cells appear fairly homogeneous with a well-delineated plasma membrane, prominent granular cytoplasm and a rather obvious nucleus (figure II). The clear area around the periphery of the cell is an artifact of the optics (Phase contrast) which allow focusing on the top of a more or less spherical cell.

On a low magnification electron photomicrograph, the mast cell appears full of electron dense granules with homogeneous matrix (figure III). The cell is enclosed by a well-delineated plasma membrane which, like the perigranular membrane, is made up of a phospholipid bilayer. The two types of membranes, however, differ in their composition of both the phospholipid and the protein content. When mast cells are incubated with 0.1 µg/ml of the classic cationic mast cell secretagogue compound 48/80, a number of granules appear quite different from those seen in control cells (figure IV). These altered granules are swollen, have lost much of their electron density, are often found within interconnecting pits, and are in continuity with the extracellular space. During this process, the perigranular membrane fuses with the plasma membrane and the contents of the granule are relased to the outside; the core of the granule is made up of various negatively charged proteoglycans to which small cationic molecules are attached electrostatically (33). Upon exposure to the extracellular aqueous medium, these cationic molecules are immediately released by exchange with sodium and potassium in the medium. Since the proteoglycan core is not particularly water soluble, it persists for a longer period of time and can often be seen outside the periphery of the cell (figure IV). The sequence of events from arrival of the stimulus at the plasma membrane to the final release of granule contents has been termed stimulus-secretion coupling (34); the actual mechanism of secretion observed is known as exocytosis (35, 36).

Incubation of mast cells with crude nematocyst venom obtained from differentially centrifuged nematocysts of Physalia had a much more dramatic effect on mast cell secretion. Figure V shows a mast cell section with many intact secretory granules prior to treatment. Incubation with 10 µg/ml of venom resulted in total degranulation of mast cells. Figure VI shows a mast cell section from the same sample of cells as the ones in Figure V after incubation with the venom for 5 mins at 37°C; in this section, which also includes the nucleus, it can be seen that only about six granules have remained intact. All other granules are swollen, have lost their electron density and are inside large exocytotic pits which are in continuity with the extracellular space. It is important to note that the plasma membrane is still intact and can be clearly seen delineating the exocytotic cavities. Indeed, extensive as the degranualtion may be it is still dependent on energy and calcium and is not cytotoxic.

In contrast, mast cell incubation with crude homogenate of Physalia fishing tentacles resulted in cell lysis. Figure VIII shows a mast cell in an early state of dissolution following incubation with 10 µg/ml of crude tentacle homogenate for 1 min at 37°C. The plasma membrane and most of the cytoplasms have totally disappeared and there are numerous vesicles probably composed of disrupted membrane phospholipids. Although some granules appear altered, most of them still retain their electron density; this is perhaps an indication that the perigranular membrane may be more resistant than the plasma membrane to lysis. Figure IX shows a mast cell in an advanced stage of dissolution following 5 mins incubation with the same treatment as in figure VIII. The membrane and the cytoplasm have almost completely disappeared, as have most of the secretory granules. There is an abundance of small vesicles probably composed of disrupted membrane phospholipids; the nucleus is also seen in advanced stage of karyorrhexis.

It is fairly evident then that jellyfish tentacles contain substances, other than the ones contained in the nematocysts, which are capable of lysing the cell. The presence of these substances becomes critical in those instances when a patient severs the tentacles in an effort to dislodge them from his body; the damaged tentacle is likely to liberate toxins other than those present in the nematocyst venom, and the two together could be particularly damaging to skin mast cells Their combined effect would not only be more immediate, but it would be massive and irreversible with a greater likelihood of leading to systemic complications.

Unfortunately, the means available to us at present to prevent or treat jellyfish poisoning are quite inefficient. They can theoretically be divided into five broad categories.:

1. Preventive measures to avoid jellyfish and/or stinging;
2. Inhibition of toxin release and/or its subsequent action on mast cells;
3. Inhibition of mast cell secretion;
4. Inhibition of mast cell mediator effects on end-organs;
5. Clinical support for the patient with systemic manifestations.

Most of the therapeutic modalities we can offer to the patient are limited to categories 1 and 4 above. Even then, we can only inhibit the action of one or two of the more than 40 active substances released by mast cells (37, 38). It would certainly be more attractive to develop ways to block mast cell secretion altogether. If this were the case, the jellyfish stinging would probably be limited to a local pin-prick sensation due to the ejection of the nema against the skin surface. The currently used therapeutic or support methods of treatment for jellyfish victims may be summarized as follows:

a. Jellyfish tentacle should be rubbed off any body surface using a towel and alcohol; fresh water should not be used because it, itself, causes the discharge of the nematocysts.

b. Application of hot water or a meat tenderizer solution could be helpful if the venom toxins have not yet triggered mast cells because they may inactivate some of the toxins. Application of a tourniquet above the site of contact may prevent the spread of mast cell mediators and reduce the possibility of any systemic effects.

c. Corticosteroids "stabilize" cell membranes non-specifically and application of such a cream to the affected area will probably reduce secretion from those mast cells which have not been activated. In serious cases where anaphylactic shock or widespread urticaria are feared, systemic steroid administration may be necessary.

d. Antihistamines counteract the effect of histamine released from mast cells and application of such a cream to the affected area will probably reduce swelling, redness and itching. Oral antihistamines may be useful if systemic effects are anticipated over a long period of time, but they are slow acting and are active only against one of the numerous molecules released from the mast cells. Leukotrienes, for instance, which are produced during the release reaction are 10,000 times as active as histamine in causing broncho-constriction and we have no drugs to block their effect.

e. In allergic or hypersensitive individuals, or in the presence of systemic symptoms, epinephrine must be given immediately, subcutaneously, to counteract end-organ effects especially hypotension and bronchoconstriction.

f. Support treatment of victims with systemic manifestations could include the following modalities provided by a qualified health professional:

   (i) hypertonic glucose solutions to limit oedema and hypotension;
   (ii) calcium-gluconate to counteract muscle spasms;
   (iii) morphine-sulphate for pain and sedation;
   (iv) artificial respiration, if necessary.

Other studies may be directed to isolating and characterizing the active principles in venom. Such studies have been undertaken for Physalia (31) and Chrysaora (39), but not for any jellyfish common to the Mediterranean area. Identification of the particular toxins in jellyfish venom would lead to:

a. Investigation of how they trigger mast cell secretion and the possible inhibition of this process;

b. Production of antivenom which may be given after stinging to neutralize the toxins liberated in the skin;

c. Use in humans to either hyposensitize sensitive individuals by injecting small quantities of toxins which could lead to the production of blocking antibodies, or,

d. Desensitize such individuals by injecting sub-clinical amounts of toxins which would degranulate a few mast cells at a time and make them refractory to further secretion.

Our work has focused on ways to prevent mast cell secretion in response to many different stimuli (40-42). We identified that mast cells treated with substances that induce mast cell secretion result in the increased incorporation of radioactive phosphate in three specific protein bands; the approximate molecular weight of these bands was 42,000; 59,000 and 68,000 daltons respectively. One more protein band of about 78,000 daltons appeared to incorporate radioactive phosphate when mast cells were recovering from secretion. The first three protein bands required calcium and incorporated radioactive phosphate in less than 60 secs by which time secretion in response to compound 48/80 was complete. In contradistinction, the 78,000 dalton protein band did not require calcium and incorporated radioactive phosphate over a period of at least 5 mins. Figure IX shows a time-course of these phosphorylation patterns and it is evident that the incorporation of radioactive phosphate in the three lower protein bands is quite apparent in 10 secs. A similar phosphorylation pattern was also obtained when mast cells were treated with 10 µg/ml of crude Physalia nematocyst venom.

We therefore hypothesized that calcium-dependent phosphorylation of the three lower protein bands may be associated with stimulation of secretion. Conversely, the slow, non-calcium-dependent phosphorylation of the 78,000 dalton protein band could be associated with *inhibition* of secretion (41, 42). We tested this latter possibility by investiating whether any drug known to inhibit mast cell secretion would give the same pattern of phosphorylation of the 78,000 dalton protein band. We fist employed a drug used prophylactically in the treatment of bronchial asthma. Addition of 10^{-5} M of this drug known as disodium cromoglycate or cromolyn together with 0.1 μg/ml 48/80 inhibited mast cell secretion measured 1 minute later at 37°C. Addition of cromolyn alone in the same concentration induced incorporation of radioactive phosphate only in the 78,000 dalton protein band. Furthermore, preincubation with or repeated application of cromolyn resulted in loss of inhibitory ability (tachyphylaxis) and loss of radioactive phosphate incorporation in the 78,000 dalton protein band (figure X). These findings have now been confirmed in mast cells triggered by IgE and antigen, as well (43).

Similar results were obtained when cromolyn was added together with *Physalia* venom extract. We are currently investigating certain substances which are water-soluble (cromolyn is not) and appear to be much more active than cromolyn in inhibiting mast cell secretion. These substances appear to act by "freezing" mast cell membranes via alteration of the phosphorylation pattern of this 78,000 dalton protein band. Incorporation of such drugs in cream preparations suitable for application to surface areas likely to come in contact with jellyfish, such as suntan lotions, could provide highly effective temporary protection against jellyfish stinging.

Other studies may be directed to an understanding of how certain marine organisms mentioned above are able to consume jellyfish without any detrimental effects. Finally, jellyfish may also be used for possible profit: a chemoluminescent protein from *Aequorea forskalea*, called aequorin, has the ability to bind to nanomolar concentrations of calcium resulting in light emission (45). This property has permitted scientists to measure intracellular calcium concentratons by following light generated by aequorin micro-injected inside suitable cells. Such studies have yielded invaluable information for the levels of calcium ions required to trigger secretion. Due to this extraordinary ability, aequorin is both expensive to obtain and in high demand. Proteins with similar properties may be sought and isolated from other fluorescent jellyfish of Mediterranean origin; such a use may provide an additional incentive to collect and remove jellyfish and could provide funds for further research on the biology of jellyfish.

Legend of figures*

Figure I.
Purification of rat peritoneal mast cells. Peritoneal cells from one rat (about 10^7 cells) in 2.0 ml of Hepes-buffered Locke's solution (pH 7) were layered on top of 3.0 ml 24 per cent bovine serum albumin (Miles) in sterile plastic tubes (Falcon). The cells were then centrifuged at 40 x g for 4 min at 24°C. Alternatively, 2.0 ml of cell suspension can be layered on top of 4.0 ml 38 per cent bovine serum albumin and centrifuged at 450 x g for 20 min at 24°C. Most recently, we have been layering 1.0 ml of cell suspension on top of 2.0 ml 24 per cent Metrizamide (Gallard- Schlesinger) and centrifuging the cells at about 180 x g for 5 min at 24°C (44). All but the bottom 1.0 ml present in the tube is removed by suction, and the remaining 1.0 ml is transferred to a new tube with a plastic Pasteur pipette, washed and resuspended in Locke's solution. This procedure results in over 95 % pure mast cells with a yield of about 75 per cent.

Figure II.
Purified rat peritoneal mast cells. A population of purified mast cells after purification as described in figure I is observed and photographed with phase contrast optics. Only one cell in the lower right-hand side of the field is not a mast cell. Purified mast cells are best preserved at 4°C in a solution containing 1 % bovine serum albumin or gelatin.
Magnification = 480X.

Figure III.
Transmission electron photomicrograph of a rat peritoneal mast cell following purification as described in figure I. The plasma membrane is well delineated and numerous granules appear electron dense with homogeneous matrix.
Magnification - 7,500X.

Figure IV.
Transmission electron photomicrograph of a rat peritoneal mast cell following stimulation with 0.1 μg/ml 48/80 for 5 min at 37°C. Many granules have lost their electron density, are swollen, and are often clustered inside interconnecting exocytotic pits which are in continuity with the extracellular space. The core of some granules can also be seen outside the periphery of the cell.
Magnification - 12,500X.

Figure V.
Transmission electron photomicrograph of a mast cell section showing many electron dense granules and intact plasma membrane. This cell is from an untreated population of mast cells.
Magnification = 45,000X.

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* Figures were shown at the Workshop but could not be reproduced in the Proceedings

Figure VI.
Transmission electron photomicrograph of a mast cell section following incubation with 10 µg/ml Physalia nematocyst venom for 5 min at 37° C. Most of the granules are swollen, have lost their electron density, and are found inside large exocytotic pits which are in continuity with the extracellular space. There is a prominent nucleus and a few unaltered granules above the nucleus. Note that the plasma membrane is still intact and nicely delineates the exocytotic cavities.
Magnification = 45,000X.

Figure VII.
Transmission electron photomicrograph of a mast cell following incubation with 10 µg/ml Physalia entacle homogenate for 1 min at 37°C. The plasma membrane and most of the cytoplasm have disappeared and there exist numerous small vesicles which are probably composed of disrupted membrane phospholipids. Note that most of the granules have not lost their electron density indicating that their perigranular membranes are more resistant than the plasma membrane to lysis.
Magnification = 40,000X.

Figure VIII.
Transmission electron photomicrograph of a mast cell following incubation with 10 µg/ml Physalia tentacle homogenate for 5 min at 37°C. Most of the plasma membrane, the cytoplasm, and the secretory granules have disappeared. There is an abundance of small vesicles probably composed of disrupted membrane phospholipids. The nucleus is in an advanced staged of karyorrhexis.
Magnification = 40,000X.

Figure IX.
Incorporation of radioactive phosphate in purified mast cells during secretion in response to 0.1 µg/ml at 37° C. Mast cells had been preincubated with ^{32}Pi for 60 min at 37° C and then washed repetitively. At each time point indicated, mast cells were treated with a stop solution and were processed for sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) on 10 % gels. Each lane represents mast cells from 15 male Sprague/Dawley rats weighing approximately 370g (Charles River Breedings Labs). An autoradiograph developed on X-ray film exposed to the gels for 8 hr was then photographed on high grain Kodak paper. The arrows at the left indicate the approximate molecular weight of the protein bands as was determined by comparison to proteins of known molecular weight.

Figure X.
Incorporation of radioactive phosphate in purified rat peritoneal mast cells incubated with 10^{-5}M cromolyn (Fisons) for 1 min at 37°C (right lane) or with a second similar dose of cromolyn at 1 min and further incubation for one more min (middle lane). The conditions of the SDS-PAGE, autoradiography and labelling are as described in figure IX.

References

1. Portier, P. and Richet, C., (1902). - *C.R. Soc. Biol. Paris* 54, 170-172.
2. Haeckel, E., (1879). - *Die System der Medusen* und (1881) *Organismus der Medusen*. Verlag von Gustav Fischer: Jena.
3. Southcott, R.V., (1963). - *Venomous and Poisonous Animals and Noxious Plants of the Pacific Region*. (H.L. Keegan and W.V. MacFarlane, eds.), MacMillan: New York, pp. 41-65.
4. Halstead, B.W., (1978). - *Poisonous and Venomous Marine Animals of the World*. The Darwin Press: Princeton.
5. Jacques, R. and Schachter, M., (1954). - A sea anemone extract (thalassine) which liberates histamine and slow cotracting substances. *Brit. J. Pharm.*, *9*, 49-52.
6. Uvnäs, B., (1960). - Mechanism of action of histamine-liberating principle in jellyfish (*Cyanea capillata*). *Ann. N.Y. Acad. Sci.*, *90*, 751-759.
7. Ehrlich, P., (1877) - Beitrage sur Kenntis der Anilintarbungen und ihrer Verwendung in der mikroskopischen Tecknik. *Arch. Mikrosk. Anat.*, *13*, 263-377.
8. Selye, H., (1965). - *The Mast Cells*. Butterworths: Washington.
9. Padawer, J., (1978). - The mast cell in immediate hypersensitivity. In: *Immediate Hypersensitivity: Modern Concepts and Developments* (M. Bach, ed.), Dekker: New York, pp. 301-367.
10. Lagunoff, D. and Chi, E.Y., (1980). - Cell biology of mast cells and basophils. In: *Cell Biology of Inflammation*, *2* (G. Weissmann, ed.), Elsevier: Amsterdam, pp. 217-265.
11. Metcalfe, D.D., Kaliner, M.A. and Donlon, M.A., (1981). - The mast cell. *CRC Crit. Rev. Immunol.*, *3*, 23-74.
12. Metzger, H., (1979). - Early molecular events in antigen-antibody cell activation. *Ann. Rev. Pharmacol. Toxicol.*, *19*, 427-445.
13. Henson, P.M., Ginsberg, M.H. and Morrison, D.C., (1978). - Mechanisms of mediator release by inflammatory cells. In: *Membrane Fusion* (G. Poste and G.L. Nicolson, eds.), Elsevier: Amsterdam, pp. 407-508.
14. Hô, P.C., Lewis, R.A., Austen, K.F. and Orange, R.P., (1979). - Mediators of immediate hypersensitivity. *Compr. Immunol.*, *6*, 179-229.
15. Bach, M.K., (1982). - Mediators of anaphylaxis and inflammation. *Ann. Rev. Microbiol.*, *36*, 371-413.
16. Theoharides, T.C., (1983). - Mast cells and migraines. *Persp. Biol. Med.*, *26*, 672-675.
17. Paton, W.D.M., (1957). - Histamine release by compounds of simple chemical structure. *Pharm. Rev.*, *9*, 269-328.
18. Rothschild, A.M., (1966). - Histamine release by basic compounds. In: *Histamine and Anti-Histamine* (M. Rocha e Silva, eds.), Springer-Verlag: New York, pp. 386-430.
19. Mota, I., (1966). - Release of histamine from mast cells. *Ibid.*, pp. 549-636.
20. Goth, A., (1967). - Effect of drugs on mast cells. *Adv. Pharmacol.*, *5*, 47-78.
21. Lagunoff, D., Martin, T.W. and Read, G., (1983). - Agents that release histamine from mast cells. *Ann. Rev. Pharmacol. Toxicol.*, *23*, 331-351.
22. Theoharides, T.C. and Douglas, W.W., (1978). - Somatostatin induces histamine secretion from rat peritoneal mast cells. *Endocrinology*, *102*, 1637-1640.
23. Tsakalos, N.D., Theoharides, T.C., Kraeuter Kops, S. and Askenase, P.W., (1982). - Induction of mast cell secretion by parathormore. *Bioch. Pharm.*, *32*, 355-360.

24. Haberman, E., (1972). - Bee and wasp venoms. Science, 177, 314 - 322.
25. Hartter, P., (1976). - Basische Peptide des Bienengifts, II. Synthese zweier Pentapeptide aus der Sequenz des Mastzellen-degranulierenden Peptids. Hoppe-Seyler's Z. Physiol. Chem., 357, 1683-1693.
26. Birr, C. and Wengert-Müler, M., (1979). - Synthesis of the mast cell degranulating (MCD) peptide from bee venom. Angewandte Chemie, 18, 147-148.
27. Higashijima, T., Wakamatsu, K., Takemitsu, M., Fujino, M., Nakajima, T. and Miyazawa, T., (1983). - Conformational change of mastoparan from wasp venom on binding with phospholipid membranes. FEBS Lett. 152, 227-230.
28. Schmidt, J.O. and Blum, M.S., (1978). - A harvester ant venom: chemistry and pharmacology, Science, 200, 1064-1066.
29. Read, G.W., Lind, N.K. and Oda, C.S., (1978). - Histamine release by fire ant (Solenopsia) venom. Toxicon, 16, 361-367.
30. Nakagawa, H., Kimura, A., Takei, M. and Endo, K., (1982). - Histamine release from rat mast cells induced by an extract from the sea urchin Toxopneustes pileolus. Toxicon, 20, 1095-1097.
31. Flowers, A.L. and Hessinger, D.A., (1981). - Mast cell histamine release induced by Portuguese man-of-war (Physalia) venom. Bioch. Biophys. Res. Comm., 103, 1083-1901.
32. Theoharides, T.C. and Douglas, W.W., (1978). - Secretion in mast cells induced by calcium entrapped within phospholipid vesicles. Science, 201, 1143-1145.
33. Uvnäs, B., (1974). - The molecular basis for the storage and release of histamine in rat mast cell granules. Life Sci., 14, 2355-2366.
34. Douglas, W.W., (1968). - Stimulus-secretion coupling: the concept and clues from chromaffin and other cells (The First Gaddum Memorial Lecture). Brit. J. Pharm., 34, 451-474.
35. Douglas, W.W., (1974). - Involvement of calcium in exocytosis and the exocytosis-vesiculation sequence. Bioch. Soc. Symp., 39, 1-28.
36. Palade, G., (1975). - Intracellular aspects of the process of protein synthesis. Science, 189, 347-358.
37. Wilson, A.F. and McPhillips, J.J., (1978). - Pharmacological control of asthma. Ann. Rev. Pharmacol. Toxicol., 18, 541-561.
38. Foreman, J.C., (1981). - The pharmacological control of immediate hypersensitivity. Ann. Rev. Pharmacol. Toxicol., 21, 63-81.
39. Kelman, S.N., Calton, G.J. and Burnett, J.W., (1984). - Isolation and partial characterization of a lethal sea nettle (Chrysaora quinquecirrha) mesenteric toxin. Toxicon, 22, 139-144.
40. Sieghart, W., Theoharides, T.C., Alper, L.S., Douglas, W.W. and Greengard, P. (1978). - Calcium-dependent phosphorylation during exocytotic release of mast cell secretory granules. Nature, 275, 329-331.
41. Theoharides, T.C., Sieghart, W., Greengard, P. and Douglas, W.W., (1980). - Antiallergic drug cormolyn may inhibit histamine secretion by regulating phosphorylation of a mast cell protein. Science, 207, 80-82.
42. Sieghart, W., Theoharides, T.C., Douglas, W.W. and Greengard, P., (1981). - Phosphorylation of a single mast cell protein in response to drugs that inhibit secretion. Bioch. Pharm., 30, 2737-2738.
43. Wells, E. and Mann, J., (1983). - Phosphorylation of a mast cell protein in response to treatment with anti-allergic compounds. Implications for the mode of action of sodium cromoglycate. Bioch. Pharm., 32, 837-842.
44. Coutts, S.M., Nehring, R.E. and Jariwala, N.U., (1980). - Purification of rat peritoneal mast cells: Occupation of IgE-receptors by IgE prevents loss of the receptors. J. Immunol., 124, 2309-2315.
45. Blinks, J.R., Prendergast, F.G. and Allen, D.G., (1976). - Photoproteins as biological calcium indicators. Pharm. Rev. 28, 1-93.

NOUVELLES TECHNIQUES POUR LES ESSAIS DES ACTIVITES BIOLOGIQUES DANS LA SEPARATION ET L'IDENTIFICATION DES PRINCIPES DERMATOTOXIQUES DES MEDUSES

par

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Le but de cette presentation est d'examiner brièvement les problèmes que l'on rencontre lorsqu'on veut étudier les effets que la piqûre par un animal urticant provoque sur la peau. On exposera aussi une esquisse du programme concernant Pelagia noctiluca, que nous venons de mettre en train au Centre pour l'Etude des Méduses de Trieste.

A notre avis une bonne connaissance des phénomènes qui se passent après la piqûre par une méduse est fondamentale pour avancer des propositions thérapeutiques, et la méthode galiléenne nous conseille d'essayer de reproduire ces effets en laboratoire. Un schéma général d'expérimentation est proposé à titre éventuel avec la figure I. Le prémier problème qui se pose est d'obtenir des échantillons portant les principes toxiques sous une forme encore active: la méthode la plus usagée est de plonger les méduses, aussitôt qu'elle ont été pêchées, dans l'azote liquide ou dans la glace sèche. Nous préférons, au contraire, les garder vivantes dans un aquarium, ce qui nous permet d'avoir toujours à disposition du matérial frais.

A ce moment nous devons préparer des extraits qui puissent être examinés pour leur action sur la peau. La méthode la plus simple est d'homogénéiser l'animal tout entier ou ses parties urticantes (1). A notre avis ce procédé donne des extraits dans lesquels la dilution des principes urticants par d'autres composants extra-nématocystiques complique toutes l'expérimentation suivante. La méthode ideale serait de séparer les nématocystes sans qu'ils se déchargent: il y a des descriptions de ce procédé dans la littérature (2, 3), mais il semble peu reproductible et d'autres rechercheurs qui l'ont appliqué n'ont pas eu de bons résultats (4, 5).

Nous préférons provoquer la décharge des nématocystes tant qu'ils se trouvent sur l'animal encore vivant. Comme nous avons observé que, quelques jours après une décharge, Pelagia noctiluca reconstitue son potentiel agressif, ce procédé nous permet de "traire" plusieurs fois le même animal. Dans ce but nous nous servons d'un simple appareil constitué d'un entonnoir en acier portant des filtres millipore, et d'un matras à vide. L'animal est posé plusieurs fois sur la surface mouillée du filtre de sorte que la stimulation mécanique provoque la décharge des nématocystes. Ensuite on applique le vide qui porte dans le matras la solution obtenue, qui est ensuite lyophilisée.

La démarche suivante est de provoquer sur un animal à expérimenter une lésion cutanée par nos extraits pour en étudier l'activité. Cela signifie choisir un procédé expérimental qui puisse découvrir les actions dermatotoxiques des extraits: c'est un problème complexe que nous verrons sous peu dans ses détails.

Lorsqu'on a induit une lésion cutanée par l'extrait brut, on peut faire deux choses: on peut analyser les caractéristiques de l'action toxique de l'extrait entièr dans tous ses aspects et en tirer des suggestions thérapeutiques, ou bien on peut procéder à un fractionnement de l'extrait pour reconnaître le, ou les, principes dermatotoxiques. Il faut par ailleurs souligner que l'entreprise sera plus simple si le fractionnement est dirigé par un test qui puisse reconnaître, d'une façon simple et "time-saving" (qui économise du temps) les fractions les plus actives.

Lorsque nous aurons isolé un composé, ou du moins une fraction dermatotoxique, nous pourrons en étudier les effets au niveau histologique, le développement dans le temps de l'action toxique et les effets sur ce développement des inhibiteurs spécifiques des médiateurs de l'inflammation (antihistaminiques, inhibiteurs des kinines et des prostaglandines, etc.). Toutes ces données nous permettront de formuler des hypothèses sur le mécanisme de l'action dermatotoxique. La comparaison des effets de chaque principe avec ceux de l'extrait total mettra enfin en évidence d'éventuels synergismes.

Revenant aux tests d'activité toxique, il faut souligner que la plupart des tests utilisés dans l'étude des venins d'animaux marins ont été des tests de neurotoxicité et, en conséquence, ils ont permis d'isoler des principes neurotoxiques. Mais nous ne somme pas sûrs que les principes neurotoxiques aient aussi une activité dermotoxique: Burnett, par exemple, a démontré que dans le venin de Physalia physalis il y a au moins quatre facteurs bien distincts, l'un avec action hémolytique, un autre cardiotoxique, le troisième est une neurotoxine et le quatrième a une action dermonécrotique (6). Il est évident dans ce cas que si l'on eût choisi un seul test de neurotoxicité pour découvrir le principe actif du venin de P. physalis, on aurait pu individualiser la neurotoxine mais nous n'aurions pas obtenu d'indications sur l'activité au niveau de la peau. Il nous faut donc un test spécifique, qui se base sur l'évalution de paramètres correlés avec la lésion sur la peau et qui donne des résultats possiblement quantitatifs et pas d'évaluations en "scores".

La figure II montre les principales possibilités que l'on doit considérer dans le choix d'un modèle expérimental pour l'étude de l'activité qui nous intéresse. Il faut d'abord choisir le sujet pour l'expérimentation: il y a l'homme (7), les cultures de tissus cutané "in vitro" (8) et les animaux (9). Nous avons choisi la souris car, au contraire de l'homme, elle nous permet de conduire les tests en conditions contrôlées et reproductibles, aussi bien que d'obtenir des données quantitatives et objectives, sans nous éloigner trop des situations réelles du "stinging". L'induction de la lésion cutanée peut être obtenue par simple application du venin sur la peau ("patch test"), mais si la peau est intacte il est possible que les principes toxiques ne puissent pas pénétrer; d'autre part il n'est pas simple d'obtenir une abrasion reproductible. L'injection intradermique de petits volumes n'est pas bien reproductible non plus. Nous avons préféré la simulation de la piqûre par des aiguilles qui perforent la peau de l'oreille de la souris à travers une solution de la substance à examiner.

Lorsque l'action toxique est développée on peut considérer les paramètres histologiques, ou biochimiques, ou bien l'entité de l'oedème induit. A notre avis le mesurage quantitatif de ce dernier paramètre est le plus simple.

Sur la base de ces considérations nous venons de mettre au point une modification du test proposé par Strettle pour l'étude des actions histaminiques et sérotoniniques (10). La méthode se base sur l'induction d'un oedème dans l'oreille de la souris, après avoir coloré le plasma avec du Bleu d'Evans. Ensuite une oreille est mouillée par la solution à tester, l'autre par de l'eau. Après la piqûre des oreilles, les composants irritants pénètrent dans le derma et provoquent la formation d'un oedème constitué par le plasma coloré. Lorsque l'oedème est développé les oreilles sont coupées et le colorant est extrait et déterminé par voie spectrophotométrique (11). La différence entre les quantités du colorant dans les deux oreilles nous donne une mesure objective de l'entité de l'oedème.

Cette méthode nous permet non seulement de mesurer l'activité des différentes fractions que nous allons séparer mais aussi d'évaluer les effets des inhibiteurs spécifiques des différents stades de l'inflammation et, en général, des remèdes antiphlogistiques, administrés par voie générale ou topique.

Pour terminer cette présentation, je voudrais mentionner la méthode proposée par Meyer pour un "screening" préliminaire de produits de n'importe quelle origine (12). Il s'agit d'un test de létalité conduit sur les larves d'Artemia salina, qui se base sur l'observation que ces larves sont très sensibles à la plupart des substances douées de n'importe quelle activité biologique. Le test est complètement aspécifique mais, grace à sa simplicité, il pourrait être très utile pour un tri préliminaire des produits de notre fractionnement, en nous permettant d'écarter les fractions dépourvues de composants actifs.

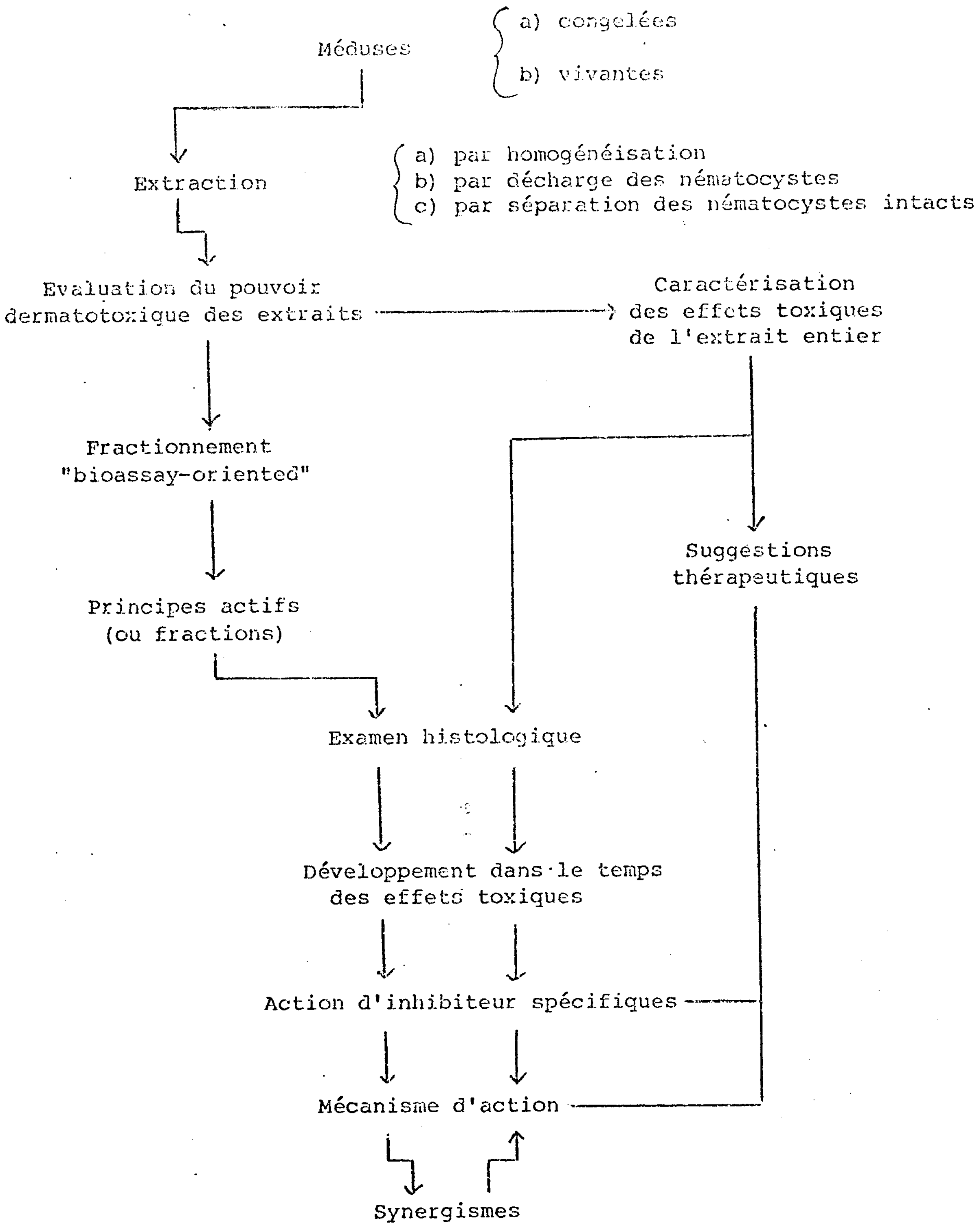

Figure I. Schéma général d'expérimentation pour l'etude des actions dermatotoxiques du venin des méduses

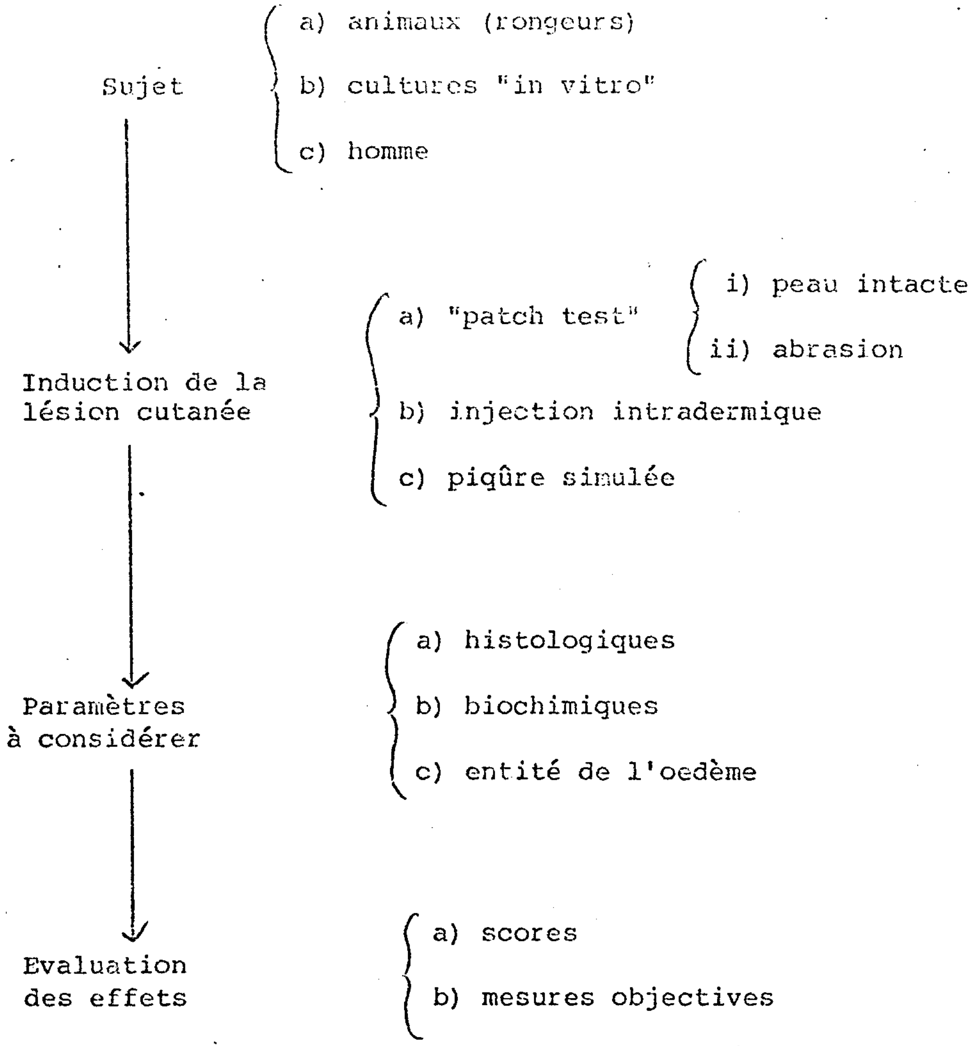

Figure II. Modèles expérimentaux possibles pour l'étude des effets dermatotoxiques

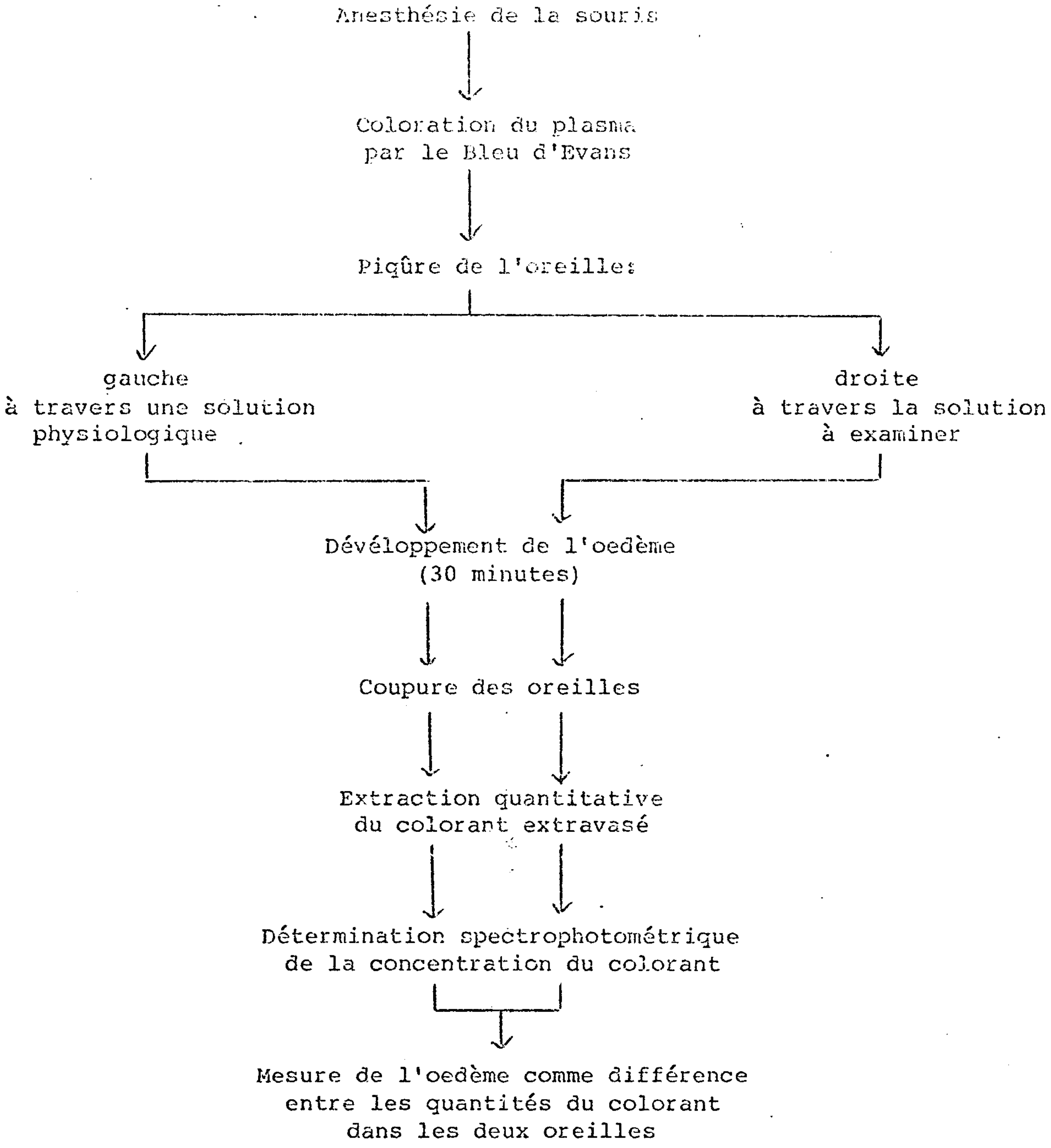

Figure 3. Modification du test de Strettle

Références

1. Freeman, S.E. and Turner, R.J., (1971). - Br. J. Pharmac., 41, 154.
2. Endean, R., Duchemin, C., McColm, D. and Fraser, E.H., (1969). - Toxicon, 7, 303.
3. Blanquet, R., (1972). - Toxicon, 10, 103.
4. Burnett, J.W. and Goldner, R., (1970a). - Proc. Soc. Expl. Biol. Med., 133, 978.
5. Rottini, L. Communication personnelle.
6. Burnett, J.W. and Calton, G.J., (1977). - Toxicon, 15, 177.
7. Albrecht, H., Lucker, P.W. and Veniz, J., (1983). - Arzneim. Forsch., 33, 900.
8. Kao, J., Hail, J. and Holland, J.M., (1983). - Toxicol. Appl. Pharmacol., 68, 206.
9. McCreesh, A.H. and Steinberg, M., (1977). - Skin irritation testing in animals. In: Dermatotoxicology and Pharmacology, F.N. Marzulli, H.I.Maibach Eds., Advances in Modern Toxicology, Vol IV, Washington.
10. Strettle, R.J, Bates, R.F.L. and Bukley, G.A., (1980). - J. Pharm. Pharmac. 32, 192.
11. Harada, M., Takeuchi, M., Fukao, T. and Katagiri, K., (1971). - J. Pharm. Pharmac., 23, 218.
12. Meyer, B.N., Ferrigni, N.R., Putnam, J.E., Jacobsen, L.B., Nichols, D.E. and McLaughlin, J.L., (1982). - Planta Medica, 45, 31.

THE BLOOM OF JELLYFISH *Pelagia noctiluca* ALONG THE COASTS OF PULA AND ISTRIA 1977 - 1983, WITH SPECIAL REFERENCE TO EPIDEMIOLOGY, CLINICS AND TREATMENT

by

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Introduction

Working from 1947 in the General Hospital and Medical Centre in Pula as a physician, but with special biological interests, particularly in venomous and poisonous animals and plants, until 1977, I saw less than ten clinical cases due to jellyfish stings. At this time, among the cnidarians there were sea anemones, particularly *Anemonia sulcata* of by far greater medical significance (3). During my very frequent trips on the sea I saw only single specimens of *Aurelia aurita* and other jellyfish which I myself could not identify. In big swarms I saw only *Cotylorrhiza tuberculata*. However according to my own experience, this jellyfish cannot be considered venomous: I had occasion to see playful children rubbing each other with it - without any ill-effects.

Observations on the jellyfish *Pelagia noctiluca* and its appearances

In early summer 1977 a great number of small jellyfish with a yellowish-brown bell of 2 cm diameter, determined by the author as *Pelagia noctiluca* (juvenile forms), were noticed for the first time.

It was now that we also had the first patients, since even the young jellyfish could inflict a venomous sting. In the chronology of events Piccinetti (in his letter of 1979) mentions 1 June 1978 as the date they were noticed between Fano and Pesaro in Italy. He called it "an unusual phenomenon" for the Adriatic (8). I interviewed many fishermen with long experience of our area and could obtain no information about previous appearances. Also Riedl, in his book on fauna and flora of the Adriatic, says: "This jellyfish is rare. However, it is more frequent in the south Adriatic, where it appears in swarms from autumn till spring some years; nevertheless single specimens have also been seen in summer" (9).

The next year, 1978, the number of *Pelagia noctiluca* increased still more. For illustration I can say that while swimming I was stung by them seven times that season. Moreover, frequently while bathing in the sea one could feel a burning on the body without visible consequences on the skin - perhaps the stings of nematocysts of destroyed jellyfish. The invasion of *Pelagia noctiluca* lasted the whole year through the winter, continuing into 1979.

From 1979 to 1981 the number of jellyfish was very high (4), (5), (7). Since they are not good swimmers, their agglomerations in single places were due to the wind, waves and currents. Big waves, especially when driven by the south wind (*jugo*, scirocco) sometimes hurled them out in great quantities onto the shores.

As mentioned above, juvenile forms appeared in late spring or early summer. In the course of the summer they became larger, so that in autumn the bells of the adult specimens measured up to 7 cm in diameter, the whole upper surface being marked by a broad cross. At this stage the colour of the jellyfish is lilac-brownish and it is fluorescent. Owing to this, its English name is "mauve stinger", German "Leuchtqualle" (=shining jellyfish), and in Dalmatia people call it "morska mjesecina" (=sea moon). The surface of the bell of the adult animal is wrinkled, and the oral arms full of "excrescences" (containing cnidocysts). According to Halstead, Pelagia noctiluca, which is cosmopolitan, differs in its appearance in various parts of the world (1).

In 1982 the number of jellyfish along our coasts, especially near Pula, seemed to be lower and remained the same in early spring 1983. However in July 1983 they appeared again in large numbers though perhaps not quite so numerous as in 1978. (In the 1983 season the author was stung three times).

Possible explanations of the bloom

With regard to the aetiology of this Pelagia noctiluca "explosion", there is considerable uncertainty. It may be a question of nothing more than an excessive cyclic proliferation, as can be observed in other animals when the number of their predators decreases and/or the number of organisms serving them as food increases. One can observe this not only in grasshoppers and spiders, but also in snails, frogs and even fishes. The possible increase in plankton which serves as food for jellyfish might be favoured by pollution, i.e. the introduction into the sea of substances which favour the growth of this plankton. Another reason for this phenomenon could be the decreased mortality of the larvae of this jellyfish, which can lead to an excessive number of adult specimens.

The venomous apparatus and the venom

The venomous apparatus consists of cnidocysts (nematocysts) which are located singly or in batteries on the tentacles and on the bell of the jellyfish. The cnidocysts are small (5 µ in size) with very long threads which are coiled inside the capsule of the nematocysts. When the cnidocyst "explodes" the thread emerges and conveys the venom into the tissues of the victim. Since millions of cnidocysts can be activated the total amount of venom injected can be significant (5)(7).

Preliminary studies of the venom of Pelagia noctiluca showed that the toxic components are of protein nature. While being heated for 20 minutes at 70° C they lose about 75 per cent of their activity; they are not stable for sedimentation with alcohol or acetone since they become denatured irreversibly. Applied instravenously to mice they caused death. Their action is cytotoxic, since they act upon the lipid part of the membranes. They also have a haemolytic action (2).

Epidemiology

Epidemiologically the bloom of <u>Pelagia noctiluca</u> represents if not a danger then surely a nuisance to bathers and it has negative repercussions on tourism. It can also be the source of an occupational disease in fishermen. A mass of jellyfish can also wind round the propellors of boats and immobilize them.

According to our random inquiry among 214 bathers in Pula in 1978, 52 per cent had been stung by jellyfish during the summer (4), some of them several times. It is certain that this year several hundreds of bathers along the Yugoslav coast would have been stung, although the majority of them did not seek medical aid.

It happens not infrequently that on days when the jellyfish are numerous the bathers do not dare enter the sea and prefer to sun-bathe instead.

With regard to fishermen, it sometimes happens that currents sweep tons of jellyfish into their nets and on taking the fish out of this venomous jellied mass they sustain many stings on their hands and forearms, an occupational disease indeed (4).

The clinical problem

The bather experiences the sting as a pain, describing it frequently "as if one had had an electric shock". From his own experiences, the author always first felt the winding round of the tentacles, and then within a second or less a sharp pain. The patch of skin affected immediately whitens, becomes infiltrated and is raised like an urticarial plaque on a red base. However the infiltrates soon became red, and then in a few hours brownish-red, appearing mostly as a print of the tentacles which usually inflict the sting with their cnidocysts. However since the bell also contains cnidocysts, not infrequently the affected area represents the print of the whole jellyfish. The lesions can cause small vesicles to appear, which later develop crusts. The sting is at first painful, and later itches. Scratching is contra-indicated, since in this way lesions which have already abated can become active again after a week or more. The skin affected can later eczematize, necrotize and heal leaving a scar or keloid. A long time later hyperpigmentations are still visible or more rarely hypopigmented marks.

Lesions are very frequently found on the lower part of the forearm representing the print of tentacles and having the shape of a bracelet. Such lesions are a result of breast-stroke swimming when the swimmer pushes aside the water and with it the jellyfish.

Though rarely, general symptoms can also occur, i.e. dizziness, nausea, vomiting and fainting, particulalry in sensitive individuals. Exposure of bathers or board surfers to repeated stings may develop sensitivity in some individuals. According to the experiences of Russell in Southern California, with the advent of board surfing and the increase in surfing generally during the past decade and a half, an increasing number of persons have become sensitive to jellyfish stings. Many years of experience with jellyfish stings along the Southern California coasts do not point to any tendency towards immunity (7).

There is also a possibility that the swimmer could be exposed to multiple stings, e.g. if he should suddenly find himself in a swarm of jellyfish. In this case also, general signs and symptoms could appear which could incapacitate the victim and even cause drowning.

Prevention

Except for health education there are no other methods of prevention of jellyfish stings. Bathers in a small protected cove for instance, sometimes help themselves, by removing jellyfish with small butterfly or fishing nets. It is also conceivable that some suitable coves could be protected by nets preventing the entrace of jellyfish. By using the mask while swimming, one can also avoid contact with jellyfish.

First aid and treatment

If any tentacles are left clinging to the injured parts, one must remove them. Then one should wash the lesion abundantly with sea-water. In no case should fresh water be used. After this, the affected area should be soaked in vinegar, weak ammonia or Burrow's solution (aluminium subacetate). Similar remedies are in use in other parts of the world. On Southern Californian coasts, under the direction of Russell, for more than 25 years the lifeguards have used aluminium subacetate soaks, 1:10 dilution, for 30 minutes. There are now similar preparations under the trade names "Domeboro" (aluminium sulphate and calcium acetate), "Burdeo" (aluminium acetate base, boric acid and a preservative) and in Australia "Stingose" (aluminium sulphate 20 per cent w/v) (6). The author has frequently applied alcohol locally to *Pelagia noctiluca* stings with some success.

If the stings of a cnidarian are very severe, prior to any soaking, shaving-soap, flour, baking-powder or dry sand should be applied to the injured part and then scraped with a sharp knife with the aim of removing any remaining cnidocysts sticking to it. After this, a corticosteroid-antihistamine-analgesic cream should be applied. In California "Russell's balm" (hydrocortisone 1.5 per cent, tetracaine 2 per cent, and Denadryl 1.5 per cent) is used (6).

In patients with systemic signs and symptoms, antihistamines plus calcium gluconate (e.g. Sandosten-Calcium or Dimidril-Calcium) and corticosteroids administered parenterally or orally, can be used as well as other symptomatic treatments according to the signs and symptoms.

Conclusions

The excessive blooms of the jellyfish *Pelagia noctiluca*, unusual in the Adriatic, especially in its northern part, which have been occurring since 1977, represent not only a biological phenomenon, but also have implications in other spheres of life. They cause problems in tourism and fisheries and may be the cause of health hazards, even of occupational disease. Because of its manifold effects the approach to this problem must be multidisciplinary.

References

1. Halstead, B.W., (1965). - *Venomous and poisonous marine animals of the world,* Gov. Print. Off., Washington, D.C.
2. Lebez, D., Maretic, Z., Macek, P. and Sedmak, B., (1979). - Laboratorijska opazanja kod nekih nasih coelenterata (Laboratory observations in some of our coelenterates), *Pom. med. Beograd 2*: 413.
3. Maretic, Z., (1975). - Zivotinje otrovnice i otrovne zivotinje Jadranskog mora (Venomous and poisonous animals of the Adriatic), *JAZU - Yug. Acad. Sci. Arts, Zagreb,* pp. 13, 16.
4. Maretic, Z., (1979). - Epidemija uboda meduze *Pelagia noctiluca* u Jadranu 1978 (An epidemic of stings of the jellyfish *Pelagia noctiluca* in the Adriatic, 1978), Zbornik III Kongresa infektologa Jugoslavije, Liber, Zagreb.
5. Maretic, Z.; Lebez, D., Ladavac, J., Macek, P., Sedmak B. and Zekic, R., (1979). - Epidemiologija i klinika nekih zarnjaka Jadrana (Epidemiology and clinics of stings of some cnidarians of the Adriatic), *Pom. med. Beograd 2*, 381.

[illegible]. Maretic, Z. and Russell, F.E., (1983). - Stinging by the sea anemone *Anemonia sulcata* in the Adriatic Sea, *Am. J. Trop. Med. Hyg. 32*/4/, 891.

7. Maretic, Z., Russell, F.E. and Ladavac, J., (1980). - Epidemic of the stings by the jellyfish *Pelagia noctiluca* in the Adriatic. In: *Natural Toxins,* Ed.: D. Eaker and T. Wandström, Oxford, New York, Pergamon Press, p. 77.
8. Piccinetti, C., (1979). - Personal communication.
9. Riedl, R., (1963). - *Fauna und Flora der Adria.,* P. Parey Verl., p. 151.

SOME DATA ON THE OCCURRENCE AND BIOLOGY OF THE SCYPHOMEDUSA *Pelagia noctiluca* IN THE GULF OF TRIESTE, AND THE IMPACT OF JELLYFISH SWARMING ON HUMAN ACTIVITIES

by

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Introduction

Gelatinous marine zooplankton comprises representatives of several phyla and interest in their ecological importance has been increasing in recent years (Purcell and Kremer, 1983).

Few comprehensive studies have been made on "jellies" in the Mediterranean, though their abundance has from time to time been significant.

Recent swarms of more noticeable gelatinous zooplankton-scyphomedusae have promoted studies on the occurrence patterns of medusae and ephyrae, their growth, sexual maturity and breeding seasons, as well as the occurrence of swarming in relation to basic environmental parameters.

Some data on *Pelagia noctiluca* in the Gulf of Trieste

The presence of *Pelagia noctiluca* in the Northern Adriatic was an exception before 1976, while Babic (1913) considered it quite common in the southern Adriatic Basin. Since 1977, coastal and offshore swarmings of this species have been recorded in northern Adriatic waters, and were more frequent in 1977 - 1980 and again in 1983. From time to time great quantities of two other jellyfish, *Cotylorhiza tuberculata* and *Rhizostoma pulmo*, have occurred both offshore and along the coast.

The swarming of jellyfish in the northern Adriatic is not a new phenomenon (Stiasny, 1912; Babic, 1913); in some years these organisms were so abundant that Issel (1922) called the summer period (July-October) "periodo dell'invasione di grosso plancton". The organisms involved were *Cotylorhiza tuberculata* and *Rhizostoma pulmo* and to a lesser extent *Chrysaora hysoscella* and *Aurelia aurita*, but never *Pelagia noctiluca*. The coastal swarming of *Pelagia noctiluca* in recent years gave us the opportunity to study some aspects of the ecology of this species in the Gulf of Trieste.

Though an oceanic species without sessile scyphostoma, it can survive and even reproduce in the wide range of environmental conditions encountered in the Gulf of Trieste (tables 1 and 2, figure). *Pelagia noctiluca* formed coastal swarms in the Gulf of Trieste only from mid-march to the end of October, and most frequently from April to September. During the coldest months only isolated specimens were observed in deeper strata. In the zooplankton hauls taken from different parts of the Gulf of Trieste we found young specimens from May to November (table 2).

With regard to the natural enemies of *Pelagia* we can note only *Boops boops*, which, when hauled together with *Pelagia*, always had pieces of this jellyfish in their stomachs. Quite often *Pelagia* specimens were observed with missing oral arms but still swimming, indicating that some other pelagic animals feed on them. We also noted small isopods associated with *Pelagia* which we have so far been unable to determine, but which seem to be a parasitic species.

The feeding behaviour of *Pelagia noctiluca* was studied; they can accept a wide range of food organisms and the diet of most medusae comprised: Appendicularia, Siphonophora, Hydromedusae, *Doliolum*, *Penilia avirostris*, *Evadne*, *Noctiluca scintilans*, Copepoda, *Clupea* eggs, and *Engraulis encrasicholus* eggs.

The impact of medusae swarming on human activities

Swarms of jellyfish can affect human activities in several ways: they might have negative consequences on fisheries and tourism, they represent a health hazard to bathers, and can cause clogging of boat motors or the cooling systems of coastal industries when sea-water is used.

In this contribution we will consider the impact of medusae swarming on tourism, human health and fisheries in the eastern part of the Gulf of Trieste.

The Yugoslav coast of the Adriatic is a well-known holiday area and tourism is indeed affected by coastal swarms of jellyfish. Different problems arise from the mass presence of medusae on the beaches: the invaded areas are unsuitable for swimming (the phenomenon can persist for several days, as was for instance reported from some beaches along the Istrian coastline), people who are not familiar with these animals can be stung and become frightened by the abrupt pain and skin irritation. It seems that there were less complaints where tourists were acquainted with the phenomenon. Along the Slovenian coast, local tourist workers did not claim any direct losses due to swarming of jellyfish.

In order to estimate the impact of medusae swarms on human health, we obtained some data from the tourist surgery in Portoroz (a tourist resort with an average daily tourist population of about 26 000 in June, 49 000 in July, 49 000 in August, and 28 000 in September). From 15 June to 30 September 1983 about 3 000 persons came for medical advice (Rostan, pers. comm.). In the same period 67 persons suffering from jellyfish stings sought medical help.

Number of persons suffering from jellyfish stings
during summer 1983 (data from the tourist surgery in Portoroz)

Month	June	July	August	September	Total
No. of patients	4	23	31	9	67

The injured were from age 7 to 87 and there were approximately equal numbers of females and males. The majority of the injuries were local and limited to small areas, most frequently on the arms and chest. Contact with jellyfish causes a burning pain, swelling and erythema. The symptoms usually disappeared shortly after local therapy was applied. The complications that sometimes occurred included necrosis, secondary infections, and lymphadenitis (Weilguny, pers. comm.). Two cases of erysipelas (children) were recorded (Cermelj, pers. comm.). Systematic reactions (nausea, collapse, hyperthermia) were rarely observed (three cases). Eye injuries can be very dangerous (Kolar et al., 1982).

Swarming of jellyfish can cause serious damage to fisheries either directly when fishing and/or indirectly in the long term, by predatory action on fish larvae, thus diminishing the fish stock; Fraser (1969) for instance claims that a 5 cm medusa can catch 80 larval fish in 6.5 hours.

Local fishermen consider swarming of Pelagia noctiluca especially noxious because they cause net clogging, while bigger Cotylorhiza and Rhizostoma do not close the mesh completely. Besides, it is practically impossible to sort the catch when relatively small Pelagia are caught en masse between the fish, and the trawls are cleaned with great difficulty.

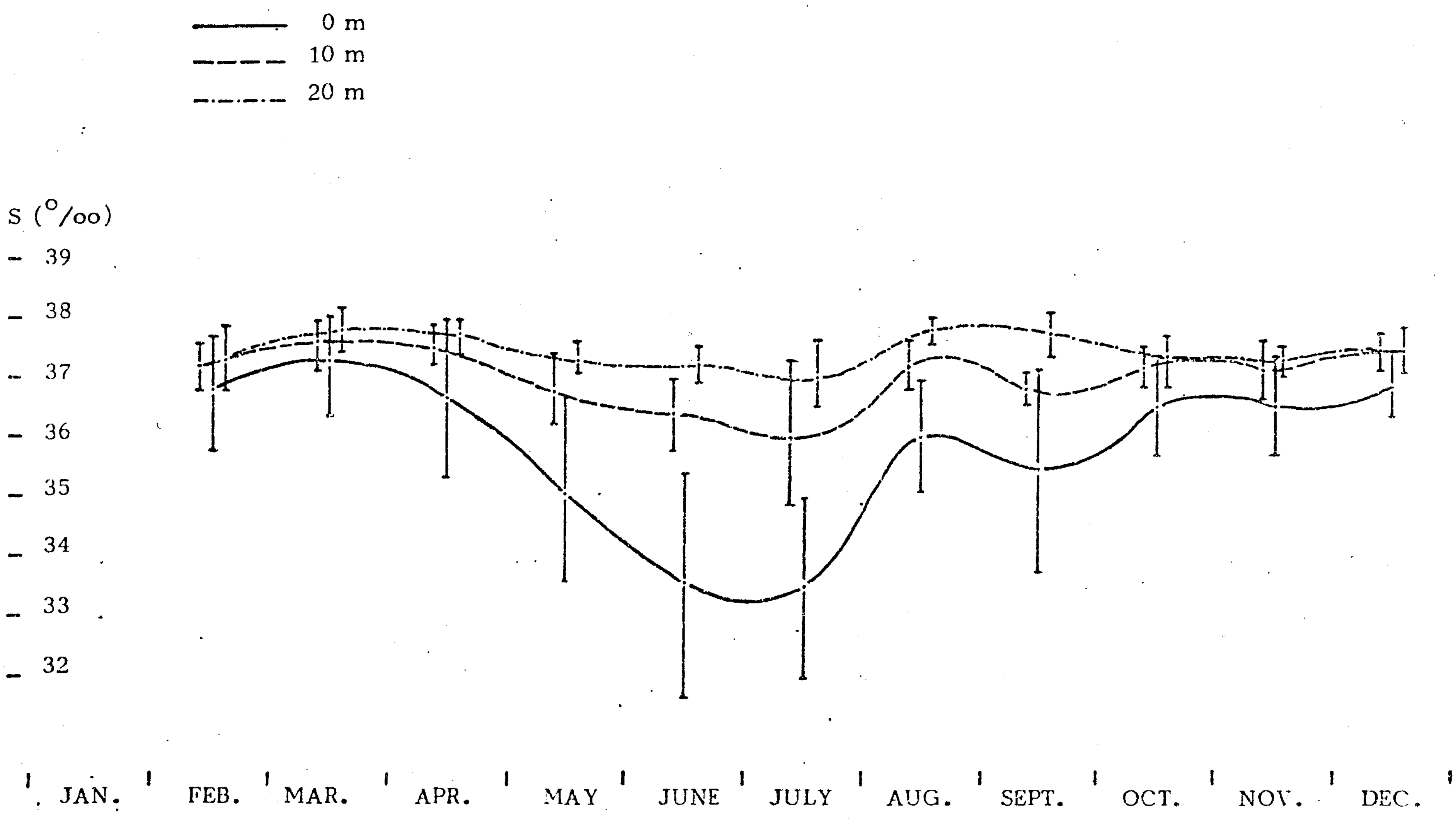
Normally, fishermen work in pairs two to three times daily from Monday to Friday with boats of 800 HP, with a pelagic trawl 150 m long and an 8 m mouth opening. In 1983, up to 15 October, they had to throw away all the catch about 30 times and their gear was smashed three times (Hamersek, pers. comm.).

Table 1. Seasonal temperature variations in the Gulf of Trieste (from Tusnik, 1976)

Depth (m)	Winter (°C)	Spring	Summer	Autumn
0	8.3-10.9	12.8-23.5	19.7-26.2	10.0-19.7
10	7.9-10.4	11.0-18.9	18.5-24.2	11.0-19.2
20	7.5-10.4	10.1-16.4	14.9-21.0	9.8-19.1

Table 2. Occurrence of *Pelagia noctiluca* ephyrae and some data on environmental conditions at stations where ephyrae were found (ephyrae separated from zooplankton vertical hauls)

Month	Diameter (mm)	Depth	Temperature (°C)	Salinity (°/oo)	Oxygen (ml/l)
May	0.5	0	22.2	32.8	5.99
		bottom	13.7	36.8	5.59
June	0.5-2.3	0	20.2	35.1	5.76
		bottom	17.7	37.5	5.43
July	0.6-1.1	0	21.6-22.3	33.6-33.7	5.77-5.79
		bottom	16.6-17.8	37.3-37.4	4.61-4.89
August	0.4-1.1	0	22.0-25.1	34.5-35.9	5.10-6.31
		bottom	18.3-22.7	36.8-38.3	4.27-6.28
September	0.5-3.2	0	21.0-22.2	35.3-36.8	5.03-5.39
		bottom	18.4-20.8	35.7-37.5	3.45-5.39
October	1.0-4.5	0	19.2-21.0	35.0-35.9	5.61-
		bottom	18.4-18.8	35.9-37.5	4.37-
November	0.5	0	15.7	38.1	5.45
		bottom	13.2	37.4	4.29



Variations of salinity in the Gulf of Trieste (from Tusnik 1976, four years survey)

References

Babic, K., (1913). - Planktonicki celenterati iz Jadranskoga mora. *Rad. Jugosl. akad. Zagreb* *200*, 186-202.

Fraser, J.H., (1969). - Observations on the experimental feeding of some medusae and Chaetognata. *J. Fish. Res. Bd. Can.* *26*, 1743-1762.

Issel, R., (1922). - Nuove indagini sul plancton nelle acque di Rovigno. *Mem. Com. Talass. Ital.* 202.

Kolar, G., Stergar, S. and Logar, P., (1982). - Lezija oka zbog meduze. Porocilo na Intersekcijskem sestanku oftalmologa Hrvatske in Slovenije, Split, Oktober 1982.

Purcell, J.E. and Kremer, P., (1983). - Feeding and metabolism of the siphonophora *Sphaeronectes gracilis*. *J. Plank. Res.* *5/1*, 95-106.

Stiasny, G., (1912). - Beobachtungen über die marine Fauna des Triester Golfes während des Jahres 1911. *Zool. Anz. Bd.* 34.

Tusnik, P., (1976). - Osnovne znacilnosti fizicnega okolja v obalnem morju Slovenskega Primorja. *Sci. Rep.* *MBP* *10*, 1-64.

ON SKIN INJURIES PROVOKED BY COELENTERATA AND ECHINODERMATA

by

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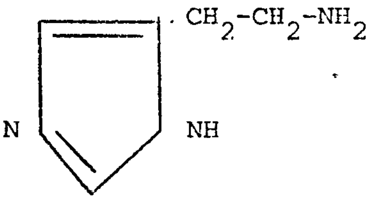
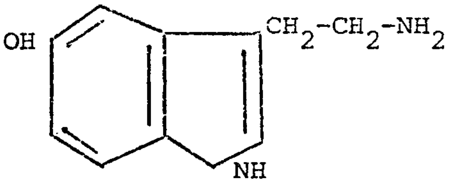


Histamine



Serotonine or
hydroxytriptamine

Acute dermatitis resulting from Coelenterata stings looks like dermatitis striata pratensis.

Erythema, swelling, purpuric whip lashes, wealing, necrolytic bullosis, all signs slowly subsiding in seven to ten days, leaving hyperpigmentation and sometimes scarring, are usually seen.

Histaminergic substances (see formulae) are injected into the skin, which irritate and injure the tissue, including the capillary network and the basal membrane. Serum leakage takes place and presses against the superficial layers. Something similar happens in urticaria bullosa et haemorragica.

Generally speaking, variations in individual reactivity to the host are more pronounced than variations in zoological species. Later on, lesions show deepening in the fat tissue, thus becoming soft nodes and slowly fading away.

Suitable treatment can be summarized as follows: do not wash the injured skin with fresh water and do not remove little tentacles or cnidoblasts with towels wet with fresh water. It is better to use sea-water or dry sand for this purpose. Little tentacles carried on the hands can irritate the face and other sites: so do not rub your hands on your face.

Bromelin 5% ointment or cream can be applied on injured sites with bandaging. Papain ointment is also recommended, though unavailable in Italy up to now. Oral or parenteral antihistamines can be employed if necessary.

Sea-urchin lesions look as nodular, appearing mainly on the knees, hands or feet of divers and underwater fishermen. Nodules can be more or less large, more or less hard and are due to pieces of spines being retained in the tissue.

They remain unchanged for years or spontaneously regress after elimination of the central foreign body.

Corticosteroid local infiltration is perhaps the best treatment. Alternatively, surgical removal or nitrogen criotherapy can be used.

SKIN AND SYSTEMIC SYMPTOMS FROM JELLYFISH STINGS IN THE BAY OF TRIESTE

Toxins of venomous jellyfish

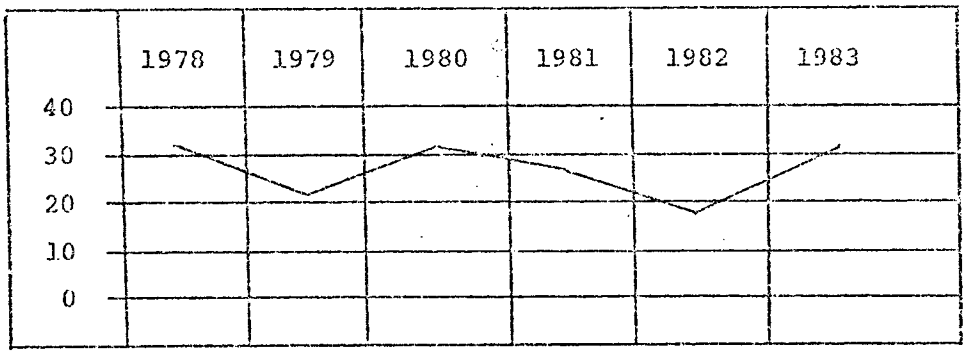
The coelenterate poison produced and discharged by nematocysts of some jellyfish, appears to be a dermo- and neurotoxin, non-dialyzable, separable into biologically active component peptides, provided with low molecular weight (under 500 daltons). They are synthetized from the capsule of the nematocyst and can inhibit succinoxydase.

Tetramethylammonium hydroxyde or chloride (m.w.91) having curare-like properties and 5-hydroxytriptamine, a known histamine release, have been isolated.

The presence of heavy protein (which is anaphylactogenic) is doubtful and is probably biased by the presence of protein impurities extracted from the jellyfish tissues. In our opinion it should not be taken into consideration.

Clinical observations

We observed in our University Skin Clinic (Trieste) 127 subjects altogether (74 males) who had come into contact with Pelagia noctiluca and had been stung with resulting skin and systemic injuries. Thirty-two patients were observed in 1978, 21 in 1979, 33 in 1980, 27 in 1981, 15 in 1982 and 31 in 1983.



General symptoms appearing after the stings were of histamine-like type: headache, pallor or cyanosis, weakness, slight fever on the following day. Atopy could be ascertained through family and personal history in five patients out of 127. They had more severe general symptoms, not reaching the climax of severe anaphylactic reaction.

Recurrent stings from venomous jellyfish (mainly Pelagia) never resulted (in our observations) in the development of severe subsequent anaphylaxis, as usually happens in experimental anaphylaxis.

Local symptoms range from an immediate prickly sensation to intense burning pain, followed by a rash. The injured areas become erythematous, swollen, pomphoid, purpuric, and sometimes haemorrhagic blisters appear. Subsequent ulceration is rare (only in three patients) and this was due to inadequate local treatment followed by septic sloughing. Local pigmentation of longer or shorter duration, and sometimes scar, may ensue.

Treatment

General treatment is needed for alleviation of severe and systemic symptoms. Antihistaminics at middle dosage have been used. In some cases glucocorticosteroids of prednisone type, at a dosage of 20 - 30 mg per day, are used for a few days. Epinephrine has never been employed. Only in three instances has the patient been put to bed in our clinic.

Local treatment is aimed at removing the tentacles that are still present on the skin surface and treating locally with anti-inflammatory and mildly antiseptic drugs.

Tentacles have been carefully removed from the wound by using a towel soaked with dilute ammonia or sodium bicarbonate or ethanol. Fresh water and cold sea-water for cleaning the wounds or the surrounding normal skin are to be strictly avoided, as they cause barb ejection from the intact nematocysts.

Bromelin 5% ointment or papain ointment are not yet on sale in Italy and we could not give them a trial.

PROLIFERATION DES MEDUSES ET RISQUES SANITAIRES

par

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Depuis deux ans, plus particulièrement, l'information générale - beaucoup plus que les milieux scientifiques - a fait état de proliférations anormalement élevées de méduses en Méditerranée. Il est difficile scientifiquement de s'assurer du bien-fondé de ces informations et nous savons tous combien facilement les psychoses collectives se créent et nous savons aussi combien les médias peuvent être responsables de leur diffusion.

Néanmoins puisque le problème est ainsi posé nous devons le prendre en compte et essayer d'en cerner les contours car à côté du phénomène biologique prend place un problème sanitaire.

Nous avons connaissance que depuis toujours il y a une grande variation dans le nombre de méduses rencontrées dans les eaux côtières selon les années et qu'il y a certaines périodes où elles furent nombreuses sur les côtes de Provence, ainsi pendant l'année 1958.

Depuis deux ans il semblerait que leur nombre soit particulièrement élevé. Aussi est-il intéressant de rechercher les causes qui peuvent être à l'origine de ce phénomène.

Parmi toutes les causes invoquées les processus environnementaux apparaissent comme les plus fréquemment cités:

- causes naturelles d'abord: conditions climatiques, régime de vents entraînant des régimes de courants horizontaux ou verticaux avec conditions de température des eaux ayant favorisé la libération de méduses à partir des bourgeons polypoïdes;

- causes anthropogènes ensuite, en particulier la pollution favorisant une croissance anormale de ces organismes filtreurs.

Il peut être intéressant de rechercher les mécanismes plus fins qui peuvent être à la base de ces processus. Pour cela il est possible de mettre en évidence par la voie expérimentale ce qui peut accroître la prolifération des méduses.

Un travail effectué par Tusov et Davis (1971) à l'Université de Californie, a montré, sur Bougainvillia sp., que des colonies de polypes développent des gonophores et produisent des méduses quand ils ne sont pas alimentés régulièrement et que les milieux de cultures ne sont pas changés fréquemment alors qu'aucune colonie ne développe de gonophores quand elles sont maintenues dans des conditions de vie normales.

Ces faits permettent de faire la remarque suivante: les conditions hostiles, comme le manque de nourriture ou l'accumulation des produits de déchets de métabolismes, induisent, vis-à-vis des colonies de polypes, une tendance à la survie de l'espèce en fabriquant des gonophores et de ce fait des jeunes méduses qui, en étant dispersées au loin, ont toutes chances de maintenir la stabilité de l'espèce puisque c'est à partir d'elles et de leurs organes de reproduction sexuée que de nouvelles colonies, forme stable, pourront se développer loin des conditions hostiles.

Il est donc possible que l'accumulation des polluants organiques dans certaines zones de la Méditerranée, favorisées par de longues périodes de conditions météorologiques anticycloniques telles que nous avons eues ces dernières années, ait constitué des conditions biochimiques que les colonies de polypes ont perçu comme hostiles et qu'elles aient de ce fait libéré un grand nombre de méduses.

Il est possible aussi, en analysant les résultats des expériences de Tusov et Davis que l'insuffisance nutritionnelle soit à l'origine de cette libération anormale de méduses; mais il est peu probable que ces organismes filtreurs aient été carencés en micro-organismes planctoniques et bactériens étant donné que la Méditerranée, du fait des apports terrigènes de plus en plus importants, est, en certaines zones côtières, le siège d'une eutrophisation. Néanmoins, une autre observation faite par Mariscal (1971) de l'Université de Floride sur d'autres coélentérés montre que la nutrition ne peut se faire que si les taux de certains acides aminés spécifiques comme le glutathion et la proline ou bien de l'acide pipecolique sont suffisants. On peut avancer avec prudence que les taux de ces acides aminés ont pu baisser dans certaines zones ou bien que la pollution a modifié ou détruit ces composants nécessaires à la nutrition des colonies polypoïdes.

Ces hypothèses biochimiques, répétons-le, ne peuvent être prises en compte que dans la mesure où des résultats analytiques faits "in situ" viendront en confirmer le bien-fondé.

Il a été formulé également d'autres hypothèses plus mécanistes. Ainsi, le prédateur des méduses étant la tortue de mer, celle-ci est trompée par la grande quantité de feuilles de plastique transparentes rejetées en mer comme déchets et les avale, ce qui entraîne, par une obturation du tube digestif, leur mort. La disparition progressive du prédateur entraînerait alors un déséquilibre en faveur des méduses. Là aussi il s'agit d'hypothèses méritant avant d'être adoptées de faire des mesures "in situ" de ces populations.

Il existe donc tout un faisceau de présomptions et il est vraisemblable que tout ou partie de ces facteurs déterminants doivent avoir une part de responsabilités qui reste à déterminer et il n'est pas exclu également qu'ils puissent s'exercer en étroite synergie.

Nous devons maintenant examiner les risques sanitaires en tenant compte d'abord des connaissances classiques et ensuite des faits récemment rapportés.

On sait que les méduses sont capables de sécréter une substance toxique leur permettant non seulement de paralyser la proie qu'ils désirent capturer, mais de provoquer chez l'homme, par simple contact ou effleurement, des brûlures extrêmement vives.

Les baigneurs et les plongeurs connaissent cette sensation extrêmement désagrable provoquée par le contact avec une méduse: une violente douleur, suivie de brûlures, se manifeste sur la peau au point de contact, laissant souvent une cicatrice pigmentée pendant plusieurs mois, voire plusieurs années.

Ces animaux ont la propriété de posséder, réparties dans leur ectoderme, de véritables cellules urticantes, les nematoblastes, petites vésicules microscopiques pourvues de parois propres, remplies de liquide et contenant à l'intérieur un long filament très fin enroulé sur lui-même, comprenant un noyau à la surface duquel se trouve un prolongement, le cnidocil; le fonctionnement est simple: la cellule porte un appendice en liaison avec les terminaisons nerveuses de l'animal; lorsque l'appendice entre en contact avec un corps étranger, l'ensemble du système explose; la paroi du nématocyste se contracte brusquement, le filament se déroule brutalement, se projette en dehors et pénètre dans les tissus de l'animal qui a effleuré le cnidocil et inocule le liquide toxique qui paralyse les proies ou qui, chez l'homme, occasionne des brûlures. Ces cellules, plus ou moins réparties un peu partout sur le corps de l'animal, peuvent être aussi concentrées dans les filaments pêcheurs comme chez les Siphonophores.

Mais il faut rappeler également que les méduses ont été à l'origine de la découverte du phénomène de l'anaphylaxie.

"L'anaphylaxie signifie le contraire de la protection. Ce mot désigne la curieuse propriété que possèdent certains poisons d'augmenter, au lieu de diminuer, la sensibilité de l'organisme à leur action". C'est ainsi que Charles Richet a défini en 1902 ce phénomène. Les circonstances et les différentes étapes de cette découverte nous est narrée en détail par Charles Richet lui-même dans son livre sur l'anaphylaxie. En voici l'essentiel:

> "Dans le cours d'une croisière faite par le yacht du Prince Albert de Monaco, le Prince et G. Richard conseillèrent à P. Portier et à moi-même d'étudier les propriétés toxiques des Physalies qu'on recontre dans les mers australes. Alors, sur le yacht même du Prince, nous fîmes quelques expériences qui prouvèrent que l'extrait aqueux ou glycériné des filaments de la Physalie est extrêmement toxique (pour les canards et les lapins). Revenu en France, et ne pouvant me procurer des Physalies, je pensai à étudier comparativement les tentacules des Actinies qu'on peut se procurer en abondance (Coélentérés qui, à certains égards, se rapprochent des Physalies). Grâce à l'obligeance de Y. Delage, je pus avoir une grande quantité d'Actinies venant de Roscoff; les tentacules coupées au ras du corps étaient mises dans la glycérine, et nous pouvions ainsi avoir à Paris plusieurs litres d'un liquide extrêmement toxique, la glycérine ayant dissous les principes actifs des tentacules de l'Actinie. En cherchant à déterminer la dose toxique de ce liquide, nous vîmes tout de suite qu'il faût attendre quelques jours pour conclure, car beaucoup de chiens ne meurent que le 4e et le 5e jour, ou même plus tard. Nous gardâmes donc des chiens qui avaient été injectés par une dose insuffisante et par conséquent n'étaient pas morts, car nous voulions les faire servir à une seconde expérience après qu'ils seraient complètement rétablies. C'est alors que se présenta un fait imprévu. Ces chiens guéris étaient d'une sensibilité extraordinaire et succombaient à des dose faibles en quelques minutes. L'expérience caractéristique, celle qui m'a présenté le phénomène dans toute son indiscutable netteté, a été faite

sur le chien Neptune. C'était un chien exceptionnellement vigoureux et bien portant. Il avait d'abord reçu 0,1 de liquide glycériné sans être malade; 22 jours après, comme il était en excellente santé, je lui injecte la méme dose de 0,1. Alors aussitôt, quelques secondes après que l'injection a été terminée, il est extrémement malade; la respiration devient angoissée, haletante. Il peut à peine se traîner, se couche sur le flanc, est pris de diarrhée et vomissements sanguinolents. La sensibilité est abolie et il meurt en 25 minutes."

Alors que jusqu'à présent, on ne connaissait qu'un phénomène succédant à une injection toxique: l'immunité, ici on assiste au phénomène inverse. Cette hypersensibilité, c'est l'anaphylaxie, dont l'agent responsable est une toxine.

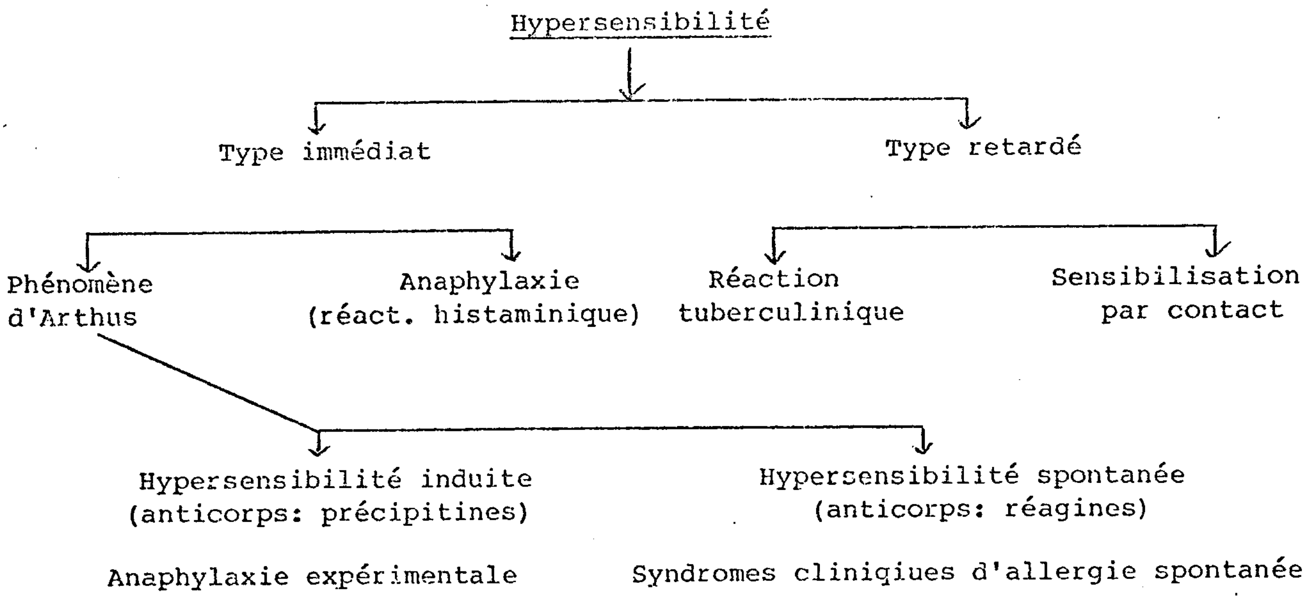
Le phénomène est donc caractérisé par deux éléments conditionnels:

- une sensibilité plus grande à un poison par l'injection antérieure de ce même poison (injection préparante et injection déchaînante);
- une période d'incubation nécessaire pour que cet état d'hypersensibilité puisse se manifester. C'est en somme l'inverse de la mithridatisation.

La suite de cette expérimentation permettait de préciser non seulement les caractères du phénomène anaphylactique, mais aussi d'en déterminer la symptologie. Ainsi, pendant que les expérimentateurs, reproduisant ces phénomènes, en montraient les conditions d'apparition, les cliniciens généralisaient ces faits à la pathologie humaine et en montraient la fréquence.

Il démontraient non seulement les accidents anaphylactiques dus aux toxines, mais ils étaient amenés à considérer comme substances anaphylactisantes des substances étrangères, généralement protéiniques, capables de créer, lors d'une deuxième injection, une réaction différente: ainsi s'ébauchait déjà le concept d'allergie, créé dès 1907 par Von Priquet. L'allergie n'est en somme qu'une variante de l'anaphylaxie: dans les deux cas, le choc est dû à la rencontre de l'allergène avec les anticorps qui se trouvent dans le sang, les humeurs ou les tissus.

Le schéma suivant, que nous propose Halpern et Domine (1962), résume, avec beaucoup de clarté, la parenté de ces phénomènes pathologiques.



Si l'anaphylaxie et l'allergie ont de nombreux points communs, elles présentent des différences; l'une s'établit peu à peu et se fortifie en vieillissant; d'autre part, dans la réaction allergique, l'antigène déchaînant peut ne pas être identique à l'antigène préparant; enfin, les réactions histologiques des réactions allergiques et des réactions anaphylactiques ont chacune leurs caractères particuliers.

Ces faits étant connus, examinons les observations que nous avons pu recueillir sur notre côte au cours de la dernière saison balnéaire. Ces observations sont de deux types.

D'abord compte tenu de la grande quantité de méduses présentes dans nos eaux, un nombre important de baigneurs subirent des brûlures classiquement connues et consécutives au contact avec les méduses. Celles-ci appartenaient principalement à deux espèces: Pelagia noctiluca et Cotylorhiza ruberculata.

leur abondance, certains jours, était suffisante pour que les pouvoirs publics interdisent la baignade.

Néanmoins les atteintes cutané-muqueuses ont entraîné de nombreuses consultations médicales et même quelques hospitalisations.

Si l'origine des troubles observés était indéniable du fait de la collision avec une méduse bien visible par sa taille, il n'en a pas été de même pour un deuxième type de troubles cutané-muqueux que nous voudrions décrire parce qu'ils ont été également présents dans nos eaux.

Ces faits se sont déroulés les 25 et 26 juin 1983 à la plage de Saint-Jean-Cap-Ferrat, près de Nice.

Il s'agit de baigneurs qui, quelques heures après être sortis de l'eau, ont ressenti une sensation de brûlures en plusieurs endroits du corps, sur des zones relativement étendues intéressant partiellement le thorax, les membres et même le visage. Les zones atteintes sont devenues rapidement érythémateuses, puis au cours du lendemain elles ont évolué vers l'apparition de phlyctènes qui se sont transformées en une desquamation suintante.

L'examen des victimes de ces accidents, que nous avons pratiqué quelques jours après, a montré soit de larges traînées brun-rouge avec de grosses phlyctènes, soit des ulcérations rougeâtres et suintantes comme s'il s'agissait de séquelles de brûlures en cours d'évolution.

Nous avons vu six cas, mais il nous en a été signalé d'avantage. Tous les malades que nous avons pu interroger ont affirmé l'absence de méduses dans les eaux où ils se sont baignés et d'ailleurs ce type de blessure ne ressemblait pas aux atteintes attribuables classiquement aux méduses.

Par contre, un des cas concernait un garçon de 12 ans qui présentait sur la face postérieure des jambes et sur les pieds une plaque rougeâtre desquamante. Ce garçon a indiqué que l'apparition de ces sypmtômes avait succédé à un contact prolongé contre un "rocher recouvert d'algues humides" et émergeant d'un fond de posidonies, rocher sur lequel il s'était appuyé pour se reposer. Il avait d'ailleurs vérifié qu'il n'y avait pas d'actinies.

Peut-on rapprocher ces manifestations pathologiques des méduses? Nous pensons que c'est possible dans la mesure où nous pouvons rechercher leur cause dans la présence éventuelle d'organismes microscopiques dans ces eaux et dans cette zone de faible profondeur.

Il existe, en effet, indépendamment de micro-organismes toxiques comme certaines variétés de péridiniens, des méduses de très petites tailles, de diamètre de 1 à 3 mm de l'ordre des lepto-méduses ou de celui des narco-méduses , invisibles pour les baigneurs mais douées de propriétés urticantes. On peut les trouver durant la saison chaude dans des zones relativement fermées comme certaines baies de faibles profondeur favorisant des processus d'eutrophisation.

Notre collègue Henri Augier, de l'Université de Marseille, m'a fait part récemment d'une observation personnelle concernant l'atteinte qu'il avait subi dans le fond de la baie de Port-Cros, zone qui est le siège de phénomènes d'eutrophisation, où il avait été victime, ainsi que l'un de ses assistants, de phénomènes urticants analogues à ceux que nous venons de décrire avec de plus atteinte des muqueuses conjonctivales. Il a attribué ces troubles à ce type de méduses microscopiques de l'ordre des narco-méduses ou des lepto-méduses. D'ailleurs il est signalé dans la littérature que certains de ces organismes se trouvent au voisinage des feuilles de posidonies et viennent s'y reposer en dehors des moments de motilité et d'activité nutritive. C'est d'ailleurs dans cet herbier que ces processus pathologiques sont apparus.

Cette dernière observation nous incite à attribuer une même origine aux manifestations pathologiques que nous avons pu observer à Sain-Jean-Cap-Ferrat. Malheureusement il s'est écoulé quatre jours entre le moment où ces malades ont été atteints et le moment où ils ont été montrés. Et les prélèvements que nous avons faits ne nous ont montré qu'une flore planctonique normale sans présence de ces méduses microscopiques, mais les conditions météorologiques, et de ce fait hydrologiques, étaient totalement différentes.

De l'ensemble de ces observations et de réflexions il est trés possible de penser que les phénomènes de pollution et d'eutrophisation si fréquents maintenant en Méditerranée ne sont pas sans influence sur le comportement de ces coélentérés et que des recherches plus spécifiques doivent être faites dans ce domaine.

Références

Aubert, M. et Aubert, J., (1969). - *Océanographie Médicale*, Edit. Gauthier - Villars, Chapître II, 221-237.

Augier, H., Gonzales, G. et Astier, H., (1983). - La vie sur les fonds marins. *Centr. Nat. Doc. Pedag.*, Edit. Paris.

Halpern, B.N. et Domine, E., (1962). - Problèmes essentiels de l'hypersensibilité et de l'allergie. *La Revue du Praticien*, *XII*, 47-53.

Mariscal, R.N., (1971). - The chemical control of the feeding behaviour in some Hawaiian cords. *Experimental Coelenterate Biology*, University of Hawaï Press, Honolulu, Chapître 10, 100-117.

Meglitsch, P.A., (1973). - *Zoologie des Invertébrés. Protistes et Métazoaires primitifs*. Edit. Doin, 121-176.

Portier, P., (1936). - *Physiologie des Animaux Marins*.

Richet, Ch., (1913). - *L'anaphylaxie*.

Romer, A.S. - *L'évolution animale*, Edit. La Grande Encyclopédie de la Nature, *1* (2 : 64-77.

Tusov, J. et Davis, L.V., (1971). - Influence of Environmental Factors on the Cross of *Bougainvillia* sp. *Experimental Coelenterate Biology*, Honolulu, University of Hawaï Press, Chapître 5, 52-65.

SESSION II a

ASSESSMENT OF BIOLOGICAL CONDITIONS LEADING TO JELLYFISH BLOOMS

EVALUATION DES CONDITIONS BIOLOGIQUES ENTRAINANT DES PROLIFERATIONS ANORMALES DE MEDUSES

LES CONCENTRATIONS DE MEDUSES EN MER LIGURE

par

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Peu d'espèces de méduses manifestent une poussée brutale du nombre d'individus. Ce phénomène, véritable prolifération, est en général très éphémère chez les méduses d'hydraires et très localisé. Les espèces holoplanctoniques ont tendance à maintenir une densité de population élevée tant que durent des conditions hydrologiques ou trophiques favorables. En revanche, Pelagia noctiluca cumule prolifération, densité élevée pendant plusieurs mois, voire plusieurs années, sans que des raisons réelles se dégagent des observations. Le problème est si complexe que cette étude se limite volontairement à la région de Villefranche-sur-mer.

La prolifération des méduses dans la rade de Villefranche-sur-mer

De mai 1963 à mai 1964, la population d'hydroméduses de la rade de Villefranche a été suivie sur cinq stations: deux au fond de la rade, deux à l'entrée de la rade et une au large, par des pêches horizontales à 3, 20 et 50 m de profondeur et par des pêches verticales par paliers de 0 à 600 m.

Sur les 67 espèces recensées, soit un peu plus de la moitié des hydroméduses méditerranéennes connues, 12 présentent une augmentation rapide du nombre d'individus.

Anthoméduses: Cinq espèces prolifèrent au printemps et constituent alors 25 % du total des méduses.

Sarsia gemmifera et Dipurena ophiogaster: le maximum d'individus apparaît en avril 1964. Cette présence massive est éphémère et affecte surtout le fond de la rade.

Podocoryne minima est abondante en mars, à l'ouvert de la rade et jusqu'au large dans la couche d'eaux superficielles.

Podocoryne minuta présente la plus forte densité de population également en mars mais sa localisation se réduit à l'entrée de la rade et sur toute l'épaisseur d'eau.

Lizzia blondina prolifère également en mars depuis le fond de la rade jusqu'au large.

Leptoméduses: Seuls les deux genres Phialidium et Obelia, avec leurs nombreuses espèces, présentent suffisamment d'individus pour dessiner un fort maximum en automne et au printemps pour le premier et pendant tout le printemps pour le second avec une concentration à l'entrée de la rade.

Limnoméduses: La seule espèce abondante, *Scolionema suvaense*, vit sur les herbiers de posidonies. Les méduses y pullulent après les pluies de printemps et jusqu'à l'automne, avec des maxima marqués à chaque lunaison.

Trachyméduses: elles peuplent aussi bien les eaux de la rade que les eaux du large. *Liriope tetraphylla* constitue plus du tiers de la population d'hydroméduses récoltées en un an dans la rade de mai à septembre, dans les 50 premiers mètres. Parmi les autres espèces, *Aglaura hemistoma* et *Rhopalonema velatum* sont présentes toute l'année avec une plus forte densité en été.

Narcoméduses: Le phénomène n'est pas exactement de même nature en ce qui concerne la seule espèce susceptible de manifester une accumulation.

En effet, *Solmissus albescens* est une espèce à rythme migratoire très prononcé, bien mis en évidence par Benovic (1973). En hiver, elle parvient la nuit dans la couche très superficielle; en été, elle ne franchit pas cette sorte de barrière thermique que constitue la thermocline. On assiste alors, dans les pêches horizontales au filet fermant pratiquées juste en dessous de la profondeur correspondant à la chute de température, à une concentration très spectaculaire d'animaux.

Discussion

Les causes possibles de ces proliférations de méduses sont nombreuses. Tout d'abord, certaines causes sont liées au cycle de vie même de l'espèce: les méduses ne sont alors que le résultat de l'activité bourgeonnante de l'hydraire. C'est le cas des anthoméduses, des leptoméduses et des limnoméduses dont l'hydraire réagit aux modifications du milieu extérieur:

- l'augmentation de la température de l'eau en mars déclenche l'émission des anthoméduses;

- la diminution de la salinité, après les pluies diluviennes du printemps, déclenche l'émission de *Scolionema*;

- la durée d'éclairement des jours, presque identique au printemps et en automne, peut expliquer les deux périodes d'abondance des *Phialidium*;

- la pleine lune est connue pour favoriser les bourgeonnements des hydraires d'*Obelia* et également de *Scolionema* (Elmhirst, 1925; Goy, 1973).

Ces causes sont aussi liées à la capacité bourgeonnante des espèces, au niveau de l'hydraire d'une part: tous les hydraires ne sont pas aussi prolifiques que ceux des 8 espèces citées; au niveau des méduses d'autre part: car ces proliférations s'observent souvent chez des espèces à méduses bourgeonnantes: *Sarsia gemmifera*, *Podocoryne minuta*, *Lizzia blondina*, *Phialidium mccradyi*. On peut y ajouter *Eucheilota paradoxica* rencontrée avec une telle densité en mer d'Alboran qu'elle dessinait un véritable bloom. Ces proliférations sont en général très localisées et très éphémères.

Une troisième cause peut être l'aboutissement du développement de la chaîne alimentaire dont le déclenchement est favorisé par une modification bénéfique du milieu. Par exemple, l'effet fertilisant des upwellings peut se résumer ainsi:

upwelling → phytoplancton → herbivores → carnivores

C'est ce type de relations qui semble régir la répartition de Liriope que l'on rencontre toujours dans les zones à forte productivité planctonique (Furnestin, 1959; Goy, 1973), et sans doute celle d'Eucheilota paradoxica qui, en mer d'Alboran, s'accumule juste au niveau où s'affrontent les eaux atlantiques et les eaux méditerranéennes favorisant le développement du phytoplancton et du zooplancton (Médiprod IV).

Une dernière cause, enfin, n'a pas une incidence directe sur la biologie de l'espèce mais la gêne plutôt dans son trajet migratoire. C'est la présence de la thermocline en été sous laquelle viennent "buter" les Solmissus.

Toutes ces proliférations, dues à des causes pourtant très diverses, ont une caractéristique commune: c'est d'être reproductibles d'année en année, avec des modulations certes, mais assez de régularité pour que l'on puisse dresser un "calendrier planctonique".

Tel n'est pas le cas des blooms à Pelagia noctiluca.

Les blooms à Pelagia

Pour tenter une analyse du phénomène, il faut reprendre les données historiques.

Les premières découvertes de Pelagia noctiluca.

C'est en Méditerranée même, près de Majorque, que Forsskål récolte Pelagia noctiluca lors de la traversée qui le conduit en Egypte et qu'il relate en 1775 avec des détails sur la phosphorescence. Forster la trouve ensuite dans le Golfe de Guinée (1778) puis Schwartz (1791) dans l'Atlantique nord-ouest au mois de septembre. Ce dernier auteur précise: "la lueur qu'elle participe à la mer est plus ou moins forte, elle augmente toujours au toucher et dans les nuits sombres et orageuses où ces méduses paraissent en quantité à la surface de l'eau".

Au tout début du XIX° siècle, Bosc en observe "des millions" entre l'Europe et l'Amérique (1802-1803) et Péron et Lesueur la dessine si merveilleusement lors de leur périple aux Terres Australes (1807-1810). Dans le manuscrit de Péron, on peut lire ses observations: "La Pélagie rose habite au milieu des flots paisibles de l'Océan Atlantique équatorial où nous la rencontrâmes en troupe innombrable, accumulée par million autour du navire... la température de l'eau étant de 25°".

Ainsi, les premiers observateurs s'entendent tous sur la répartition: Méditerranée et Atlantique tempéré et chaud; et sur l'aspect chaque fois noté de cette densité étonnante: "par million, en troupe innombrable". La notion de bloom n'est donc par récente, elle ne peut en aucun cas être reliée à une pollution industrielle.

C'est le premier point essentiel que met bien en valeur cette revue historique: les Pelagia apparaissent par blooms spectaculaires. Ces premières observations scientifiques, dès la fin du XVIII° siècle, le montre bien et il n'est pas invraisemblable de penser que Pelagia est l'Acalèphe d'Aristote.

Les *Pelagia* à Villefranche

Dans les archiver de la Station Zoologique sont conservées des fiches établies pour une cinquantaine d'espèces macroscopiques, jour par jour et mois par mois de 1898 à 1916. Ce travail, précieux en ce qui concerne *Pelagia*, montre les fluctuations d'une année à l'autre du nombre de spécimens observés.

- De 1898 à 1903: l'espèce apparaît surtout pendant les mois froids;
- de 1904 à 1907: elle disparaît;
- de 1908 à 1912: elle réapparaît et s'installe dans la rade pendant cinq années consécutives, hiver comme été; puis elle se raréfie de nouveau de 1913 à 1916.

L'abondance, déjà notée par les auteurs anciens se vérifie, mais c'est surtout la première fois que sont notées, sur presque 20 ans, les variations journalières du nombre d'individus. Le dépouillement, avec analyse de variance et de corrélations entre espèces, sera entrepris prochainement, pour toutes les espèces observées d'ailleurs.

Pour ce qui concerne *Pelagia*, ces archives mettent bien en évidence ce deuxième point important: il existe des irrégularités dans les apparitions annuelles avec "des années à méduses" et des "années sans méduses".

Dans ces mêmes archives sont inscrites les températures de l'eau devant la Station Zoologique, de 1905 à 1911. Malgré les imperfections des méthodes de l'époque, il est intéressant de constater que les années à *Pelagia* (1908 à 1911) sont celles où se manifeste le plus faible écart de température entre l'hiver et l'été: 10° à 11,5° contre 12° à 13° pour les années sans *Pelagia*.

Ces hivers doux, dont la température ne s'abaisse pas en dessous de 13° seraient-ils responsables de la prolifération massive des *Pelagia* en Méditerranée? Le lien serait alors à rechercher plus vers une analyse de la météorologie que des modifications des couches d'eaux typiques de la Méditerranée.

Le bloom de 1982

Depuis 1982, on entre dans un nouveau cycle à *Pelagia*. Aucun programme de travail n'a été véritablement mis sur pied; toutefois, on dispose de relevés d'observations mensuelles des adultes en surface, sur une radiale de 35 milles au large de Villefranche, et du comptage des éphyrules sur une station verticale 75-0 m à l'entrée de la rade, pendant l'année 1982, soit 401 pêches.

Les premières méduses apparaissent en mai au large. En juillet, elles sont présentes sur toute la radiale mêlées à des formes jeunes particulièrement abondantes. De novembre à janvier, on observe encore beaucoup de *Pelagia* adultes; plus rares en février, elles redeviennent plus abondantes et plus côtières au printemps 1983.

Les éphyrules sont présentes d'avril à août avec une forte densité en juin. Ceci n'est évidemment pas une étude fine. Toutefois, on constate les déplacements des bancs du large vers la côte, les fluctuations de la densité au cours d'une année et la présence des stades jeunes pendant les mois chauds.

Malgré l'imperfection de ces observations, il se dégage quelques évidences: la présence tout au long d'une année de *Pelagia noctiluca* montre son indépendance par rapport à la température de l'eau qui passe à Villefranche de 13° à 26°; et également par rapport à la salinité. C'est ce qui a déjà été noté en Adriatique où l'espèce supporte des écarts de 6°/oo (Malej, 1982). Une autre observation, faite au cours de la mission Trophos en mai 1982, est l'état de la mer particulièrement calme, mer d'huile pendant quinze jours. Dans ces conditions les oeufs ont pu se développer sans perte occasionnée par le brassage dû aux vagues, d'où le bloom à *Pelagia* jeunes enregistré en juillet sur la radiale.

Les années à *Pelagia*

Une chronologie des années à *Pelagia* a été dressée à partir des données bibliographiques, des archives de la Station Zoologique et des collections conservées au Muséum d'Histoire naturelle de Paris.

Pour tenter une vérification de la liaison "années à *Pelagia* et années à [illegible]ivers doux" trouvée au début du siècle et également en 1982, (température de l'eau en janvier-février 13,5°), on a établi un parallèle avec les périodes de réchauffement mesurées par les décrues des glaciers alpins (Vivian, 1975). Sans être parfait, le synchronisme est assez parlant. Une autre méduse d'eau douce, *Craspedacusta sowerbii*, a aussi une périodicité calquée à la fois sur celle de *Pelagia* et sur celle de ces époques relativement chaudes. Enfin, le fameux El Niño péruvien participe également à ce même cycle.

L'explication de la répartition de *Pelagia* ne doit peut-être plus être recherchée à l'échelon local de la mer Ligure ni même de la Méditerranée mais peut-être plutôt à l'échelle des grandes fluctuations thermiques de la planète.

Un mystère persiste toutefois: c'est le sort des individus lors des années où l'espèce disparaît.

En conclusion, on ne peut que reprendre cette très belle phrase de la mythologie grecque: "Méduse est bien la plus rusée des trois Gorgones".

[illegible]emerciements

Cette étude doit beaucoup à trois chercheurs de la Station Zoologique: Catherine Delabigne, Serge Dallot et Jean-Claude Braconnot.

Chronologie des observations

Pelagia	Recul des glaciers	Craspedacusta	El Niño
1766 à 1778	1770		
1788			
1791			
1802			
1804	1810		
	1830		
1846			
1853			
1876	1876 à 1890		
1885			1891
1895 à 1897			
1898 à 1903	1901		
1908 à 1912	1910 à 1920		
1913			
1914			
1919			
1921			
1922			1925
1926 à 1930	1929 à 1942	1929	
		1933	
		1943	1942
1946	1947 à 1953	1949	
1951			
1952			
1954			1953
1957 à 1960	1957		1957
	1958		1958
	1959	1959	
		1960	
	1962		
1966	1967 à 1970		
1969			
1970		1970	
	1973		1972
1982			

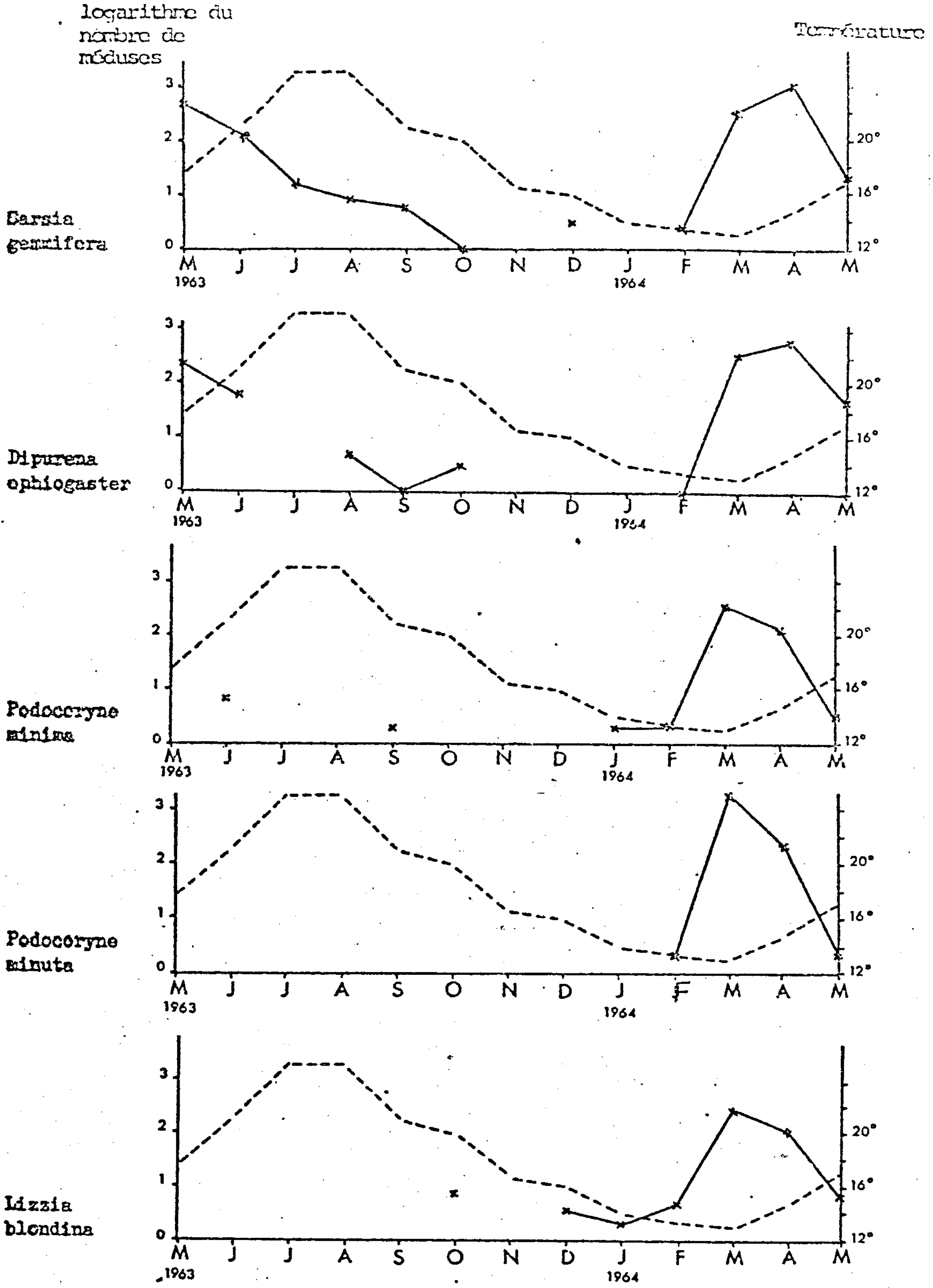

Figure I. Variations, en valeurs logarithmiques, du nombre d'Anthoméduses dans la rade. 1: Sarsia gemmifera; 2: Dipurena ophiogaster; 3: Podocoryne minima: 4: P. minuta; 5: Lizzia blondina. En pointillé: courbe de temp. moyenne au point B. à 0m.

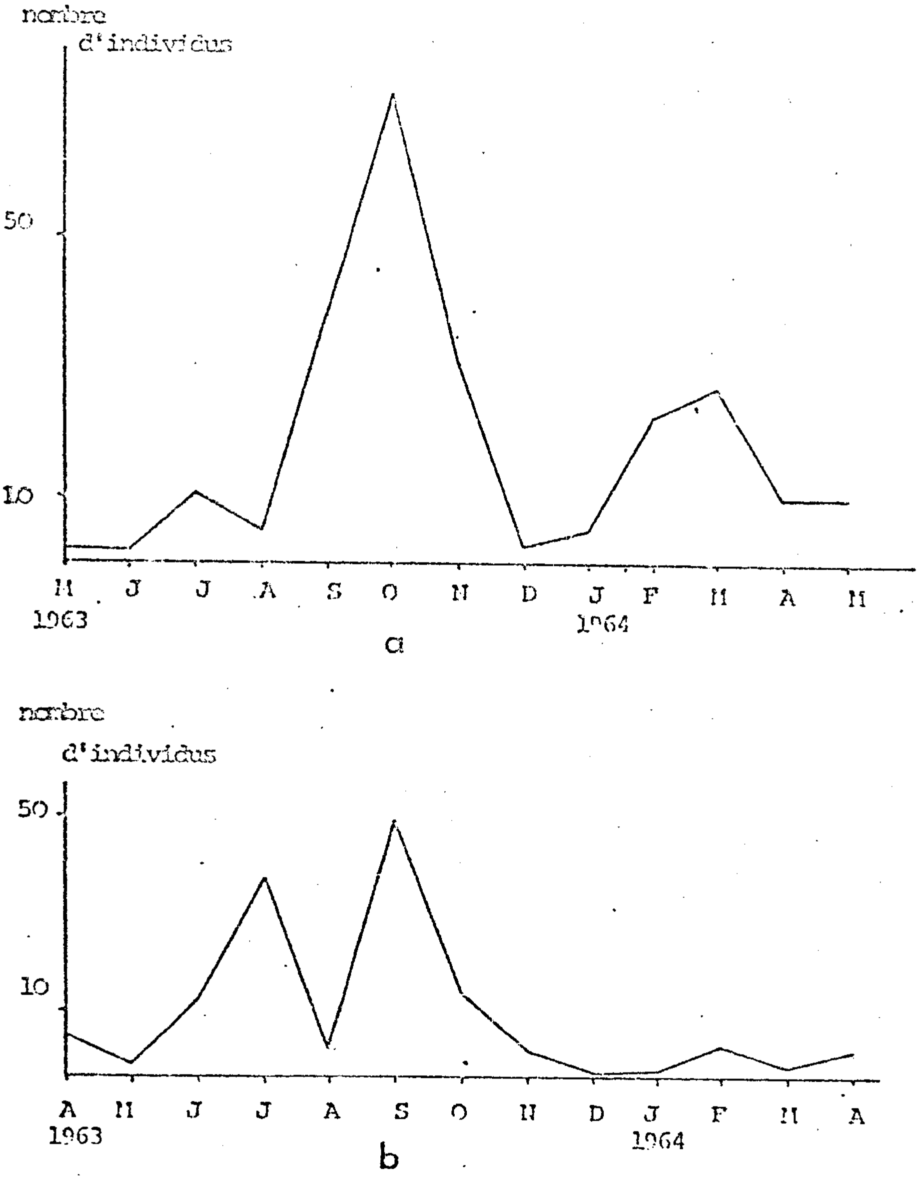

Figure II. Phialidium sp.
a: Variations de la moyenne mensuelle dans la rade.
b: Variations de la moyenne mensuelle dans les 50 premiers mètres au point A.

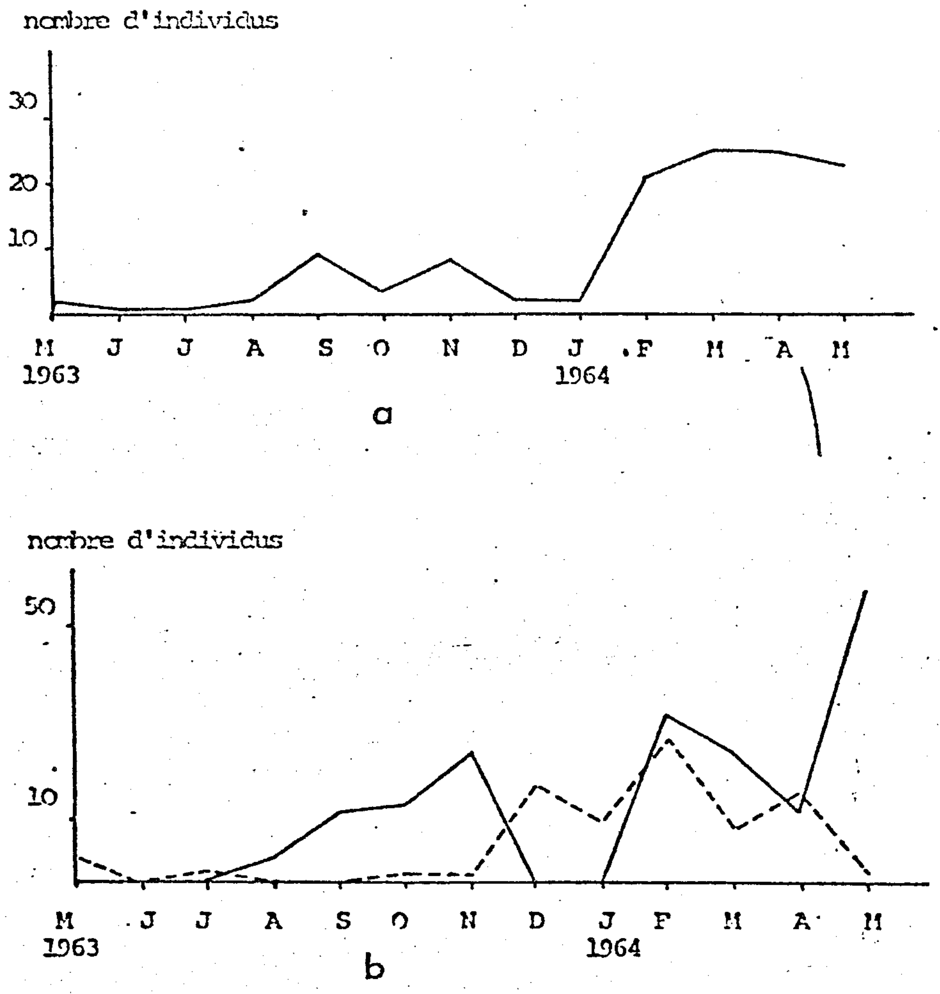

Figure III. Obelia sp.
a: Variations de la moyenne mensuelle d'Obelia sp. dans la rade.
b: Comparaison entre les variations moyennes mensuelles à 3 m aux points S (trait plein) et M (pointillé).

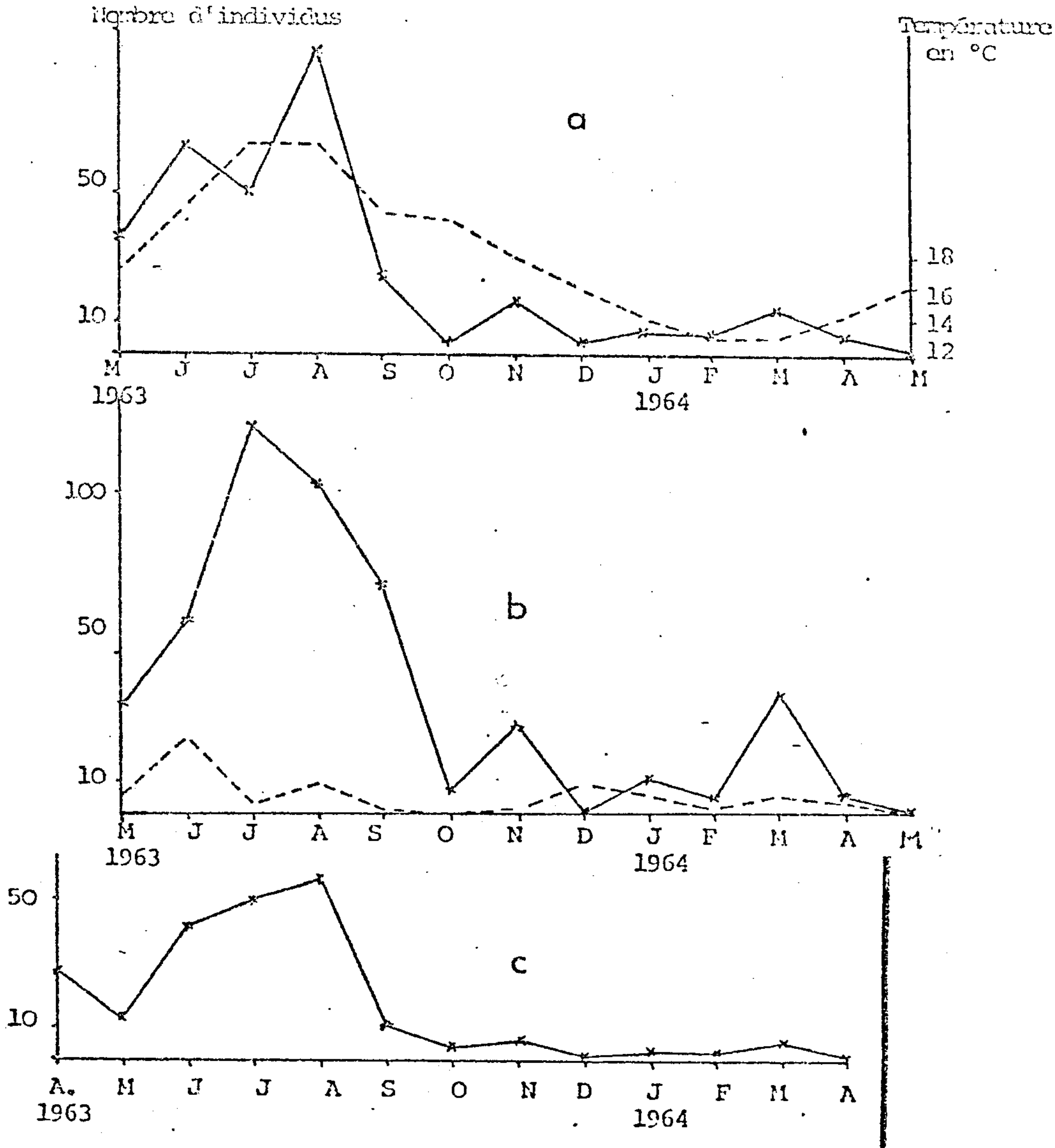

Figure IV. Liriope tetraphylla.
a: Variations de la moyenne mensuelle dans la rade.
b: Comparaison entre les variations moyennes mensuelles à 3 m aux points S (trait plein) et M (pointillé).
c: Variations de la moyenne mensuelle dans les 50 premiers mètres au point A.

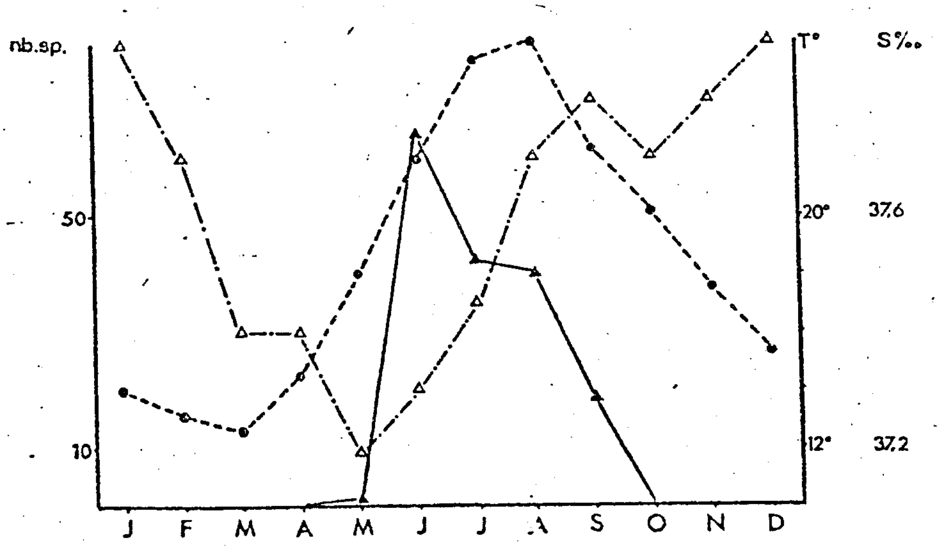

Figure V. Variations mensuelles du nombre de méduses de *Scolionema suvaense* en relation avec la température et la salinité
▲ medusae; ● T°; △ S^o/oo

Références

Benovic, A., (1973). - Diurnal vertical migration of Solmissus albescens (Hydromedusae) in the Southern Adriatic. Mar. Biol., 18, 298-301.

Bosc, (1802). - Supplément à Buffon, Vers, Tome 2: 139, Pl. 17, Fig. 3.

Elmhirst, R., (1925). - Lunar periodicity in Obelia. Nature, (Lond.), 116, (2914), 358-359.

Furnestin, M.L., (1959). - Les méduses du plancton marocain. Rev. Trav. Inst. (scient. tech.) Pêch. marit., 23/1, 105-124.

Goy, J., (1973). - Note sur les Hydroméduses dans les eaux tropicales et subtropicales. Bull. Mus. nat. Hist. Nat., 165, 333-343.

Goy, J., (1973). - Gonionemus suvaensis: structural characters, developmental stages and ecology. Pub.Seto Mar. Lab., 20, 525-536.

Forsskal, (1775). - Descriptiones animalium.

Forster, (1778). - Deuxième voyage de Cook, Tome 1, 44.

Malej, A., (1982). - Unusual occurrence of Pelagia noctiluca in the Adriatic. I. Some notes on the Biology of Pelagia noctiluca in the Gulf of Trieste. Acta Adr., 23, 97-102.

Péron et Lesueur, (1807). - Voyage aux Terres Australes Pl 31, figure II.
(1810). - Annales du Muséum Paris, 14. 349.
Manuscrit du Muséum du Havre.

Schwartz, (1791). - Kong. Vetenskaps Academ. nya Handl., 12, 188 - 190, Pl. 5.

Vivian, R., (1975). - Les glaciers des Alpes occidentales. Grenoble, Allier, 513 p.

EFFECT OF DECREASING LIGHT INTENSITY ON THE ACTIVITY OF THE SCYPHOMEDUSA, Pelagia noctiluca (Forskal)

by

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Abstract

Preliminary laboratory investigations have been performed on the umbrella activity of Pelagia noctiluca as a function of decreasing light intensity. At 20°C, in a recirculating sea-water system, the mean frequencies of umbrella pulsations increased from 84 pulsations per minute on exposure to a light intensity of 3240 Lux, to 105.6 pulsations per minute at light intensity of 14 Lux or less. After approximately three hours in the dark, the pulsation rate again decreased to 95.6 pulsations per minute. The ecological significance of these results is discussed. Other observations on umbrella activity are recorded.

Introduction

Widespread occurrences of coastal swarming of Pelagia noctiluca in several Mediterranean regions have been recorded since 1977 (Malej, 1980; Rottini-Sandrini et al., 1980; Axiak, 1983). During a monitoring survey of such coastal swarming, it was observed that P. noctiluca formed surface swarms more frequently at night (Axiak, 1983). Franqueville (1971) similarly described how P. noctiluca was observed to move up to the surface layers during the night and occupy the lower layers during the day in the Mediterranean.

Little information is available regarding the environmental factors controlling such diel vertical migrations of this scyphomedusa. Light intensity is a dominant environmental parameter controlling similar behaviour in other planktonic species. In the present study, the effects of decreasing light intensity, simulating light conditions during sunset, on the umbrella activity of P. noctiluca were investigated.

Materials and Methods

Pelagia noctiluca were collected from Marfa Bay, Malta, during the month of July, 1983. Animals were gently dipped from the surface layers (sea-water temperature 25°C) and immediately transferred to an insulated container. Twelve medusae were chosen which had intact marginal tentacles and exhibited normal umbrella behaviour. Their extended umbrella diameter ranged from 33 to 40 mm. Within an hour of capture, these medusae were introduced into a glass aquarium measuring 100 cm by 60 cm and 50 cm high. This aquarium was part of a closed recirculating sea-water system kept at 20°C and 37.5‰ salinity with diffuse artificial overhead lighting with a 12 h photoperiod. The medusae were acclimatized in this system for 24 hours prior to use in experiment. During acclimatization and experiment, the medusae were kept unfed.

During the experiment proper, the medusae were kept in the same aquarium at the same acclimatization conditions to ensure the least interference with their activity. Two tungsten bulbs with frosted glass were suspended over this aquarium so as to give as much homogeneous illumination over the aquarium's open surface as possible. Illumination could be changed by varying the voltage supply to the bulbs. At each level of illumination, the light intensity just above the water surface at various points was measured using an Eel photometer and then the overall mean light intensity was recorded. Recirculation of the sea-water ensured a homogeneous water temperature throughout the aquarium. The umbrella activities, expressed as the mean number of umbrella pulsations per minute, on exposure to decreasing light intensity, were then recorded. Eight levels of illumination were chosen, ranging from 3240 to 0 Lux. In the latter case, medusae were observed under red light.

Results and conclusions

Umbrella activity prior to capture could not be investigated. Within an hour of being introduced into the laboratory, the mean frequency of umbrella pulsations per minute, was found to be 87.6 ± 12. This was quite similar to the values measured at the initial phase of the experiment 24 h after, indicatng that animals were well acclimatized to the laboratory experimental conditions as could be observed from their umbrella activity.

All the relevant experimental data and results are presented in table 1 and figure I. The variability in frequencies of umbrella puslations, though appreciably high, were similar on exposure to all levels of light intensities. The experimental rate of decrease in light intensity was lower than that which is normally encountered in the field at sunset. This allowed enough time to measure umbrella pulsations for all the medusae as accurately as possible. Under the given experimental conditions, there is an apparent increase in the mean frequencies of umbrella pulsations with a decrease in light intensity.

To analyse this relationship further, the final mean frequencies of umbrella pulsations obtained on exposure to each level of illumination were plotted against light intensity in Lux. The resultant graph is presented in figure II. Statistical analysis to test for significance of this relationship is presented in table 2 (ANOVA with regression Model 1, according to Sokal and Rohlf, 1981). This indicates a significant difference ($P < 0.01$) in frequencies of umbrella pulsations on exposure to different light intensitites. Moreover, a significant ($P < 0.01$) linear regression exits between these two variables.

During the experiment, all medusae exhibited normal motility, moving randomly throughout the aquarium. Moreover, in many cases it was observed that on exposure to lower light intensities, umbrella pulsations became more vigorous, each contraction being more rapid. This effect could not however be quantified.

Discussion

Several reports reviewed by Yasuda (1973) indicate that several species of medusae move towards the surface at sunset. Franqueville (1971) described the vertical migration of P. noctiluca as observed during a June survey in the Mediterranean. Most of the medusae were at lower levels during the day, but began to occupy the upper layers at and after sunset, being found at the surface at about midnight. During the early dark hours of the morning and before sunrise, they again descended to the lower layers. A more complex pattern of diel vertical migrations was reported for Aurelia aurita (Yasuda, 1973). Yasuda believes that the major factor controlling this migration is illumination. He suggested that an increase in umbrella pulsations of medusae may bring them to the surface on exposure to decreasing light intensity.

Most laboratory physiological experiments regarding umbrella pulsations of scyphomedusae, reported so far, mostly involve the effects of changes in temperatures or salinities. According to Russell (1970) Horstmann found that increasing light intensity raised the pulsation rate of Aurelia aurita, while according to Yasuda (1973), Irisawa et al. reported that Aurelia aurita is very sensitive to a decrease in light intensity, reacting to it by a conspicuous umbrella pulsation.

The present study indicates that on decreasing light intensity, umbrella pulsations of Pelagia noctiluca became significantly more frequent. Admittedly, results from simulated laboratory experiments may not fully explain the real behaviour in the field where the medusa is responding to a number of interacting stimuli. However, results from the present study support the idea that a decreasing light intensity is the major environmental factor causing Pelagia to surface at and after sunset. Moreover, the reported subsequent decrease in umbrella pulsations on prolonged exposure to the dark, correlates well with field observations (Franqueville, 1971) indicating that during the dark early morning hours and well before sunrise, Pelagia noctiluca again sinks to the lower layers. Further investigations will determine whether this behaviour will change with different seasons or at different environmental temperatures.

Acknowledgements

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Table 1. *Pelagia noctiluca*. Mean frequencies of umbrella contractions at decreasing light intensities.

Time	Light intensity (Lux)	Mean contractions per minute	Standard deviation
0 min	3240	-	-
15 min	3240	90.0	12.4
30 min	3240	92.0	13.6
45 min	3240	84.0	12.0
55 min	2293	-	-
1 h 20 min	2293	88.0	12.0
1 h 40 min	2293	88.8	10.0
1 h 45 min	1728	-	-
2 h 10 min	1728	98.0	12.0
2 h 15 min	881	-	-
2 h 30 min	881	94.8	11.6
2 h 40 min	881	98.0	11.6
2 h 45 min	274	-	-
3 h	274	100.0	12.0
3 h 12 min	274	102.4	9.2
3 h 15 min	27	-	-
3 h 30 min	27	104.0	12.0
3 h 40 min	27	104.8	7.6
3 h 48 min	14	-	-
3 h 55 min	14	102.8	8.8
4 h	0	-	-
4 h 15 min	0	105.6	10.4
7 h	0	95.6	13.6

Table 2. ANOVA with regression (Model 1)

Source of variation	df	SS	MS	F
$\bar{y}-\bar{\bar{y}}$ Among groups *	7	341.800	48.83	7.23 **
$\hat{y}-\bar{\bar{y}}$ Linear regression	1	320.868	320.868	91.922 **
$\bar{y}-\hat{y}$ Deviations from regression	6	20.932	3.488	1 ns
$y-\bar{y}$ Within groups *	88	594.100	6.750	
$y-\bar{\bar{y}}$ Total	95	935.900		

* groups exposed to different light intensities

y = umbrella pulsations

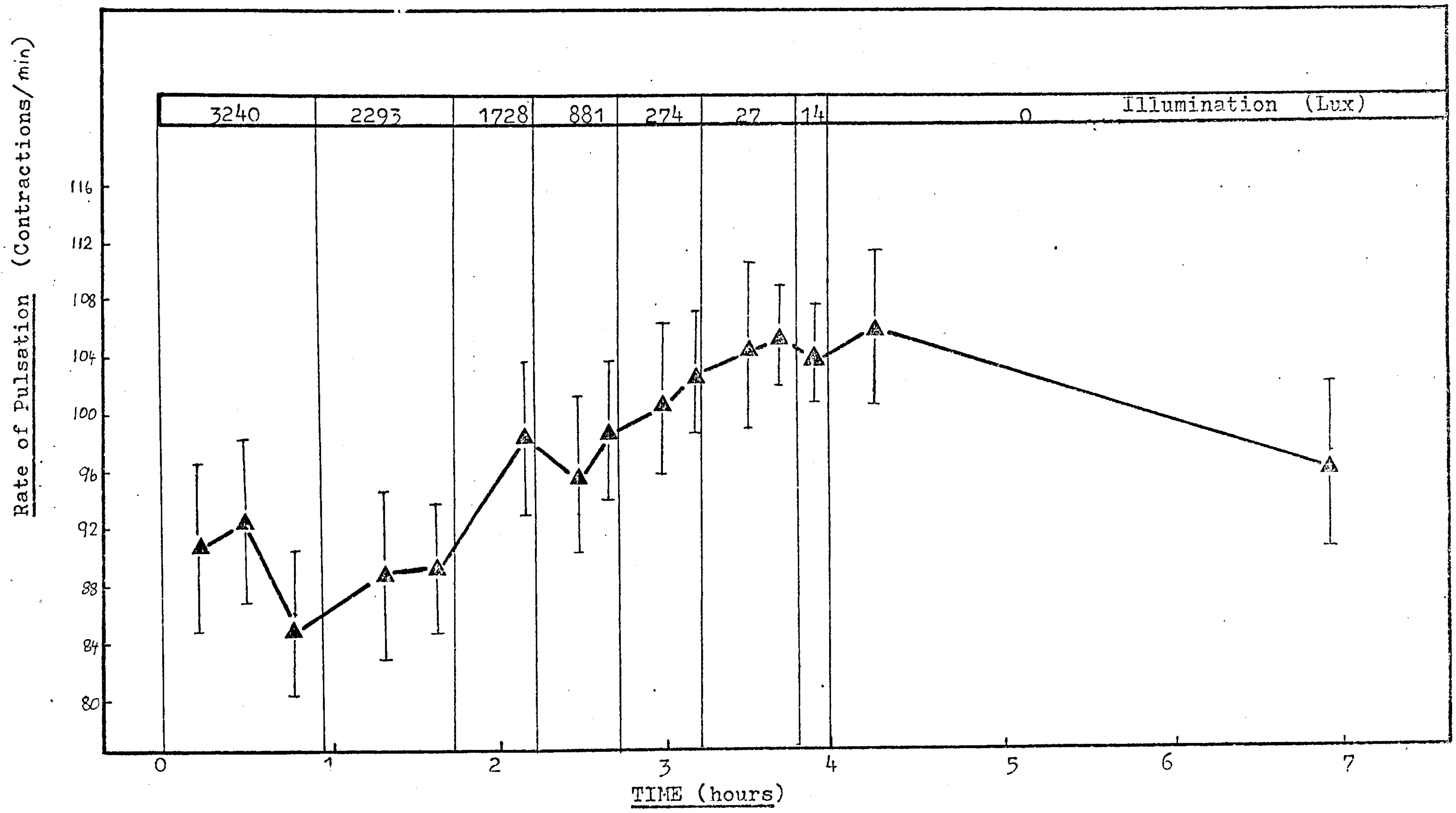

Figure I. Effect of decreasing light intensity on the rate of umbrella pulsations in *Pelagia noctiluca*. Means ± Standard deviation

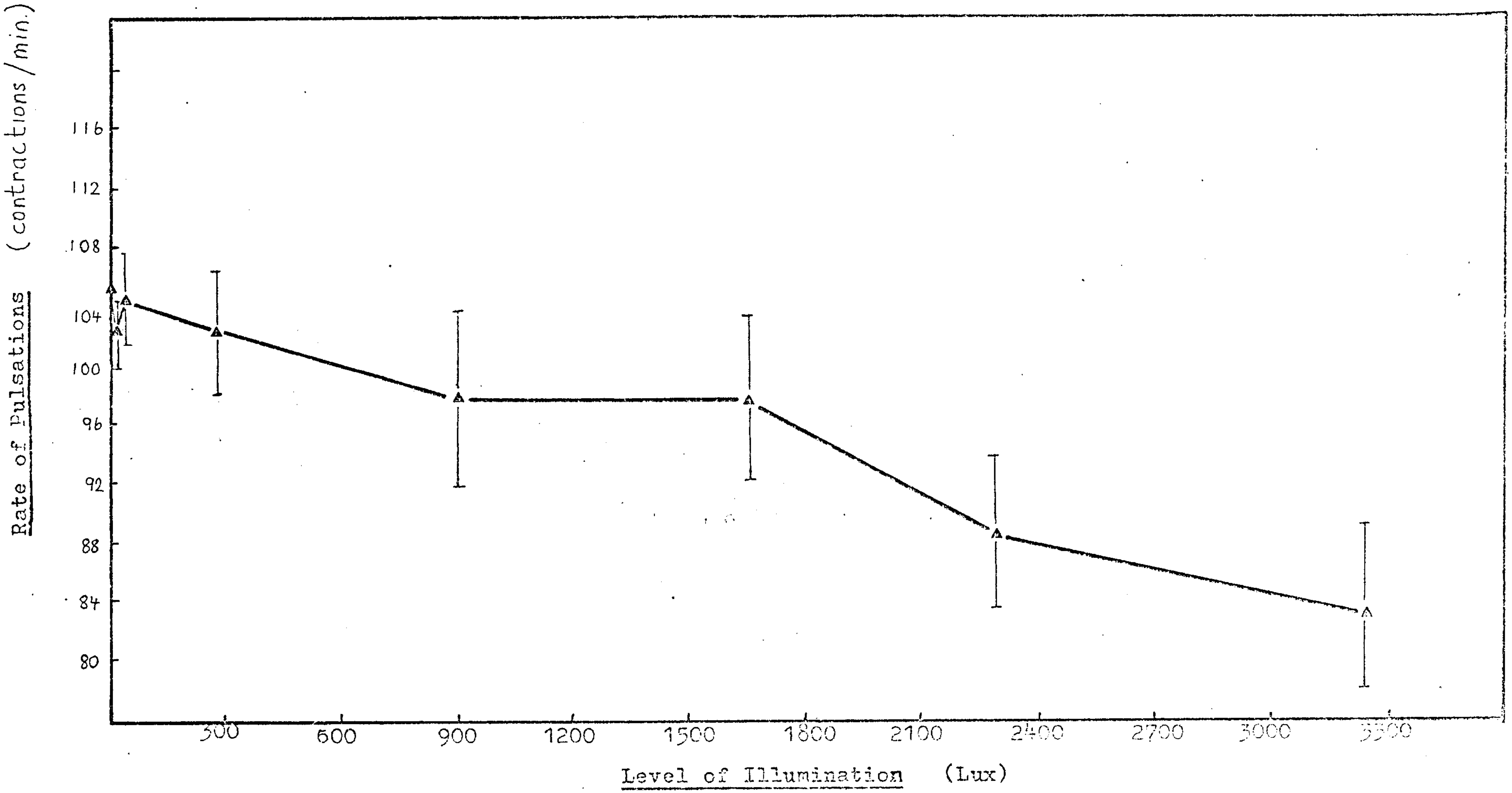

Figure II. Effect of decreasing light intensity on the rate of umbrella pulsations of Pelagia noctiluca
Means ± Standard Deviation

References

Axiak, V., (1983). - Preliminary report on the occurrence of coastal swarming of Pelagia noctiluca (Forskal) around the Maltese islands. Proceedings of Workshop on Medusae in the Mediterranean, Athens, June 1983.

Franqueville, C., (1971). - Macroplancton profond de la Méditerranée, Téthys. 3/1.

Malej, A., (1980). - Preliminary report on the ephyrae of Pelagia noctiluca (Forskal) from the bay of Trieste, North Adriatic, C.I.E.S.M., Cagliari.

Rottini-Sandrini, L., Stravisi, F. and Pieri, G., (1980). - A recent shift in the wind distribution and the appearance of unusual planktonic organisms in the Gulf of Tieste, Boll, Soc, Adriatica Sc., LXIV, 77-84.

Russell, F.S., (1970). - The medusae of the British Isles, Vol. II. Pelagic scyphozoa with a supplement to the first volume on Hydromedusae, Cambridge University Press, 284 p.

Sokal, R.R. and Rohlf, F.J., (1981). - Biometry, San Francisco, W.H. Freeman and Co., 859 p.

Yasuda, T., (1973). - Ecological studies on the jellyfish, Aurelia aurita (Linne') in Urazoko Bay, Fukui Prefecture - VII, Diel Vertical migrations of the medusa in early fall, 1969. Publications of the Seto Marine Biological Laboratory 20, 491-499.

SOME LABORATORY TECHNIQUES FOR THE CULTURE OF SCYPHOZOA

by

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Culture Methods for Jellyfish

Introduction

The recent advent of a problem with noxious coelenterates in the eastern Mediterranean has aroused considerable interest in the scientific community charged with studying and recommending solutions to the problem. The problem is not exclusive to this area. Many other locations in the world have also been affected. Indeed, some have a situation which is worse (Australia) or more frequent (Chesapeake Bay). But in the eastern Mediterranean the problem is more recent. Statements made by my colleagues in June (Anon., 1983) indicate that, for the most part, only since 1977 has the abundance of Pelagia noctiluca become a real problem. There have been some recent papers in the literature which indicate that this type of problem may not be limited to medusae but may include attached or sessile cnidaria as well (Maretic and Russell, 1983). The prospect of widespread studies on this group of animals suggests that some of the techniques and methods that we have found useful in the Chesapeake Bay area would be of some assistance in this area too.

The culture of scyphozoans did not receive much attention until the 1960s, although one early paper by Delap (1906), considered both Aurelia and Pelagia. The group is of little commercial value although its negative impact on tourism is often quite large. Other invertebrate groups, especially crustaceans and molluscs, have received much attention but in the case of the scyphozoans, most studies, at least before 1960, dealt mainly with taxonomic descriptions and distributional occurrences. But there has been increased interest recently, throughout the world, in developing methods of culturing the various life stages in the laboratory, defining techniques for manipulating the more difficult stages to spawn, strobilate, asexually reproduce, and making comparisons between the responses of different species and, in some cases, between the same species from different localities.

There are apparently six medusal species of concern in the Mediterranean (UNEP, 1983), some of which may be of minor significance. In the Chesapeake there are three species abundant enough to cause a problem and one of these occurs only during the winter. (Most of these remarks were originally given at a symposium on the Culture of Invertebrate Animals, Greenport, New York in 1972 and subsequently published (Cargo, 1974)). My comments will be primarily limited to these local species. Distributional data on scyphozoans throught the world have been adequately summarized by Kramp (1961), Mayer (1910) and Russell (1964, 1970).

Much of the recent culture work during the last twenty years has been motivated by a need to understand certain life-cycle phenomena. Most of the available published information deals with the Semaeostomes, a group to which the more familiar jellyfish belong, including Pelagia. The Rhizostomes have been examined in the western Pacific and in Europe (Hofmann et al., 1978), and in eastern North America. More recently, work has been pursued in Australia, with cultivation techniques being developed to aid in defining the life history of Chironex fleckeri (Hartwick, Callanan and Williamson, 1980; Barnes, 1966).

Methods for inducing reproduction vary. Where sexual methods are needed, the mature sperm is usually easily obtained, but some inducement of the females is often required. Some of these methods have been developed for Chrysaora quinquecirrha, the sea nettle, in the Chesapeake and this species will be treated rather fully and then used for comparison when considering other species.

Chrysaora quinquecirrha

Medusae

There is usually no trouble capturing medusae with a fine mesh dip net or by towing a plankton net. They are quite happy in aerated conditions, and if fed, will survive for several months. Acceptable food includes a variety of invertebrates, especially zooplankters, polychaetes, and Ctenophora. The sea nettle survives best at temperatures between 15°C and 30°C and at salinities of 5 to 25^{o}/oo.

Circulating water presents something of a problem. The medusae are continuously swept towards the drain. This can be partly solved by the use of an "under gravel" filter, or by deploying the input and outflow on the same side of a perforated screen dividing the aquarium containing the medusae (see figure).

Medusae may be kept in aerated aquaria for several weeks at 20°C without feeding. They will, however, consume their body resources and become smaller, though remain lively.

Inducing spawning

Female sea nettles indicate sexual maturity by a dusky grey or brown colour in the gonads, gradually darkening as the eggs develop. We have succeeded in inducing spawning in two ways. One involves keeping the medusae in an aerated container and inserting pieces of mature male gonads into the gastric cavity of the female. Larvae are usually present within 48 h. A second method used by the author for some larval preference studies involved placing a number of mature female medusae with several males in an aerated, darkened aquarium. After 24 h, the tank was illuminated from above with a "prolux" fluorescent lamp, and the aeration stopped. The medusae were removed after 3 h and attached planulae were present 24 h later (Cargo, 1979). The production of larvae seems to be most prevalent after sunrise in the case of wild medusae we have examined.

Planulae

Planulae in this species are relatively short-lived. In aquaria and probably in the wild, the settlement and attachment takes place in less than 48 h. No feeding is required. Clean substrate of a rough, craggy nature is apparently preferred, and should be located between 5 and 20 mm above the bottom. They will also attach to the side walls of an aquarium to a lesser extent and at times utilize the hyponeuston as a settlement surface. This habit has also been reported for other species and may be of importance in the case of P. noctiluca where there is no attached stage, but direct development from the planula to the medusa (Brewer, 1976a; Russell, 1970; Benovic, pers. comm., 1983).

Scyphistomae maintenance

The scyphistomae of sea nettles settle on a variety of substrata, especially on the undersides (Cargo, 1979). This is the stage easiest to maintain. The food requirements and water quality are not especially stringent. These polyps exist at temperatures between 10°C and 32°C. They encyst at 34°C but only cease feeding as the temperature falls below 8°C. They remain quiescent down to 4°C, but may encyst at temperatures below that level. Salinities are somewhat more defined. They encyst at salinities below 5^{o}/oo and above 33^{o}/oo.

They feed on a variety of small organisms: protozoans, rotifers, larvae of many types, small crustaceans, planulae of their own and other species and can be cultured indefinitely on Artemia nauplii. Artificial sea salts are satisfactory for the long-term maintenance of scyphistoma. The addition of wild planktonic organisms to the diet may be important since polyps held for long periods on an exclusive diet of Artemia have an abnormal appearance. They are gross and fleshy and quite pink in contrast to polyps from the wild.

Under natural conditions, polyps which have set in the summer, produce large numbers of reddish-brown podocysts at their base. They do this also in culture, particularly if they are provided with an abundance of food and the temperature is lowered to 20°C. A continued lowering will result in a cessation of feeding at 8°-10°C and encystment of the polyp frequently occurs at 2°-4°C.

Strobilation customarily occurs in late spring when the water temperature reaches 22°C. Polyps held in cultures at temperatures above 22°C frequently cease strobilating. We can usually induce strobilation by lowering the temperature to 15°C for a period of four to six weeks. A diapause relationship is suggested here. Upon returning the scyphistomae slowly to above 22°C over a period of a week, strobilation ensues. Strobilation can be completed within two to four days although more time is usually required. If encystment has occurred,excystment can be expected at 15°C-18°C. Podocysts will also excyst at this temperature.

Chrysaora polyps exhibit what N.J. Berrill (1949a) calls "an almost unbelievable protean plasticity". Regeneration is rampant, particularly for the tentacles. They can be fully reformed after loss in three to five days. The stalk is also capable of rapid repair and growth. Excised tentacles round into near-planulae and Hérouard (1913) states that the tentacles of C. hysoscella can set and bud new polyps in this fashion. Aurelia aurita has demonstrated this remarkable ability too. (Lesh Laurie and Corriel, 1973). Several attempts to repeat this with C. quinquecirrha have failed but it is not necessarily impossible.

In culture, these polyps are sessile, moving only very slightly by means of stolons and producing podocysts. If dislodged mechanically, they can easily reattach within a short time. They have never been seen to swim as Haven (pers. comm.) has observed in Aurelia. Their feeding is mostly accidental although some apparent recognition of the passage of small organisms such as barnacle nauplii has been observed. Capture and feeding are quite rapid, the contacted tentacle quickly recoiling into the mouth which gapes open to receive the food organism.

During the warmer part of the year, many polyps alternate strobilation with periods of stolon and podocyst production. The precise activity depends on the recent activity of the polyp and the season (Cargo and Rabenold, 1980). Polyps have been seen to strobilate as many as four times in one twelve-week period and even newly settled polyps can also strobilate within a few weeks of settlement. This latter behavior is not thought, however, to be a customary activity.

Ephyrae

Ephyrae are the most difficult stage to sustain in culture. They feed upon protozoa and other very small organisms, and can be maintained on newly hatched Artemia nauplii or the bodies of ctenophores, Mnemiopsis leidyi strained through a fine mesh and introduced in small quantities (Compton, 1966; Calder, pers. comm.). The addition of salt-water infusorians is suggested by this accepted diet. Calder successfully used Erlenmeyer flasks in a wrist action shaker to provide a gentle agitation.

Aurelia aurita

Spangenberg (1965) has provided us with an account of culture methods for Aurelia. Working in the Gulf of Mexico, she established techniques so that Aurelia could be maintained anywhere and for extended periods of time.

Aurelia medusae are more easily stripped of their embryos than Chrysaora. The fully developed planulae, 250-350 µ in length, are incubated and retained on the oral arms. So planulae may easily be obtained by shaking the mature specimen in a container of natural (NSW) or artificial sea-water (ASW) at a salinity close to that in which the female existed. Merely placing the female in a bowl of water may sometimes result in the release of many planulae. They are commonly available in the Chesapeake area from August to December. Brewer (1980) has presented an account of some of his larval preference studies for this species too. He found that Aurelia likewise chose the undersides of the offered substrate more than 80 per cent of the time. The selection was highly significant.

The larvae usually set within two days on shells or other suitable substrata. The polyps feed avidly on newly hatched Artemia. Spangenberg (1965) fed her polyps twice weekly, changing the water after each feeding. Most cultures can be kept at 21°-27°C. Her ASW formula contained the following C.P. chemicals.

Sodium chloride	23.47 g/l
Magnesium chloride	4.98 g/l
Sodium sulphate	3.91 g/l
Calcium chloride	1.10 g/l
Potassium chloride	.664 g/l
Sodium bicarbonate	.192 g/l
Potassium bromide	.096 g/l
Boric acid	.026 g/l

These chemicals were first dissolved separately in de-ionized water and then mixed. The initial pH is 7.8 and the specific gravity is 1.025 (33.7^{o}/oo). Standard commercial salts compounded for ASW are also satisfactory. Strobilation in *Aurelia* is easily induced at modest temperatures. Spangenberg reports strobilation occurring more or less continuously at 21°C-24°C but mass strobilation occurred only sporadically. Both ASW and NSW suffice, and raising the temperature to 28°C generally causes an immediate initiation of strobilation. She also reported in 1967 that cultures held in ASW for extended periods were reluctant to strobilate. By lowering the temperature to 19° C for 30 days, she caused a large number of these reluctant polyps to strobilate upon return to the higher temperature. This phenomenon is similar to that observed for *Chrysaora*.

Ms. Spangenberg (1967) provided us with a valuable insight on how the element, iodine, influences strobilation. Either free iodine or iodine bound in a soluble compound seem to be satisfactory. She thought that it may act in a hormonal way since thyoxin (C_{15}, H_{11}, I_4, NO_4) also induces strobilation. Loeb (1975) has provided us with additional understanding on this aspect with respect to *Chrysaora*.

Within reasonable limits, *Aurelia* polyps, like those of *Chrysaora*, can be held in crowded conditions if adequate food and water volume is maintained. Keeping ephyrae and medusae is more difficult. In her experiments Spangenberg (1965) successfully maintained 10 to 50 ephyrae in 13 litres of water. These were fed 10 cc of concentrated living *Artemia* daily. She noted a difference in survival of ephyrae from polyps held in ASW as opposed to NSW. In ASW, only 10 per cent of the ephyrae reached maturity whereas 50-75 per cent matured from polyps maintained in NSW.

After reaching 25 mm in diameter, young *Aurelia* were transferred to larger containers, maintaining about 4 litres/medusa. Growth was slow. After 42 to 105 days, her stage "9" animals had reached only 30 - 50 mm in diameter but were sexually mature. Since much larger adults are commonly seen, it appears that it is as difficult to satisfy the nutritional requirements of *Aurelia* medusae as it is for *Chrysaora* (Cargo and Schultz, 1966, 1967). Calder, (pers. comm.) found that *Aurelia* medusae will take strained ctenophores and show some growth on that diet.

Maintenance of the polyp stage of *Aurelia* follows the same pattern already described for *Chrysaora*. They have nearly the same temperature requirements, slightly higher salinity preferences and can utilize the same food. *Aurelia* polyps show one habit which makes their culture more difficult. They cannot be held for any length of time in running water since they frequently detach from the substrate and swim away, using their cilia (Haven, pers. comm.). Neither *Cyanea* nor *Chrysaora* have displayed this habit. The polyps are exceptionally long-lived, many existing in cultures for nearly three years (Spangenberg, 1965).

Cyanea capillata

This species is ubiquitous and nearly as well known as Aurelia. Many of the features of its life cycle and culture are similar to those already discussed. It differs in several ways, particularly with respect to the mid-Atlantic area.

Cyanea is a cold-weather form in the Chesapeake area. Mature females carrying fertilized eggs in their gonads can be found from February to May, and the planulae can be removed from the medusae or the medusa can be allowed to shed them into the receiving container. Planulae are frequently found on the oral arms of the medusae.

Brewer (1976a, 1976b) has provided us with tremendous insight in his landmark studies on larval preferences. The minute stage is apparently able to sense several influences, including gravity, surface character, and light. He likewise documented an ability for some behavioural activities so that the planulae first seek the bottom of the water column and then search upwards for an overhanging surface where they can settle in a suspended position. Protection against smothering is one obvious advantage.

The planulae in the Chesapeake, about 250 µ long, swim for several days and usually set on the bottom of the container as shiny, convex, larval cysts. Chrysaora and Aurelia have never displayed this larval cyst stage. The cysts are translucent to pearly, circular, and about 1 mm in diameter and are frequently found on substrata in deeper water in the upper half of the Chesapeake Bay. Polyps may bud from these cysts in several days or the cysts may remain quiescent for six months or more. Calder (pers. comm.) found in Virginia that most planulae set as cysts at 9°C. They soon produced polyps which began forming stolons and yellow- green podocysts at 15°C. At 25°C, these polyps begin encysting under the impact of higher summer temperatures.

Salinities for these cultures should be higher than for Chrysaora or Aurelia. Polyps have not been found in natural waters where the salinities are much below 20°/oo. Calder, (pers. comm.) stated that their optimum is 20°/oo and that the temperature should be maintained between 5° and 17°C. Budding from larval cysts and podocysts can be expected at salinities up to 35°/oo.

Encysted polyps, podocysts, and larval cysts begin excysting in October as the temperature falls below 20°C. At 15°C, they initiate strobilation. They are unusually small in comparison to Chrysaora prior to strobilation and utilize much of their body materials in the manufacture of monodisk or polydisk strobila (Berrill, 1949b). The strobila closely resemble those of Cassiopea and Rhopilema, causing some doubt about their rightful taxonomic classification. After strobilation, the polyps can be handled like other species providing space, food such as Artemia and other organisms of a similar size.

The ephyrae are robust and can be cultured on small plankton organisms or Artemia or strained ctenophore material. They even ingest and seem to derive some benefit from the diatomaceous scrapings from shells. We have raised them to 18 mm diameter. At this size, they are easily identified.

Cyanea is probably the easiest of the semaeostomes to culture, mostly because the low water temperatures make it a simple matter to provide life's requirements. Its toxin in the smaller sizes is relatively innocuous to most people and it can be handled with impunity.

Rhopilema verrilli

This Rhizostome is never very abundant in the Chesapeake but its relationship to three medusae common in the Mediterranean demands its inclusion in this discussion. R. pulmo, C. tuberculata, and N. punctata have all been mentioned as being of possible concern in the Mediterranean. Until recently only the medusa of R. verrilli was known. Investigators in the Chesapeake have succeeded in describing various stages and developing cultural techniques.

The medusae are large and the females frequently carry fertilized embryos and planulae within the gonadal tissue. They do not appear to carry them on the oral arms as do other species. The planuale are 165-310 µ long, white, and quite active (Calder, 1973). They metamorphose into polyps after 7-10 days at 12°C. Budding of polyps can also occur directly from the gonadal tissue without passing through the motile planula stage (personal observations). The polyps, small and white, survive and feed actively down to 5°C. They can be fed Artemia successfully. Salinities of 18-20^{o}/oo are satisfactory.

Polyps held at 10° and 12°C grew slowly in cultures at the Virginia Institute of Marine Science. When raised to room temperature of about 20°C, growth was more rapid and the polyps appeared to be healthier. They can be fed Artemia or other suitably sized organisms. When held under unsatisfactory conditions, the polyps make small, golden podocysts, 280-350 µ in diameter.

We were able to induce strobilation in early spring by allowing the temperature to rise slowly from 9° to 20°C. We raised the salinity from 13.5 ^{o}/oo to 19.5^{o}/oo over a period of six days by adding one g of "Rila Marine Mix"* artificial sea salts daily to 500 ml of tank water (Cargo, 1971). Strobilae of the monodisk type were present within seven days. Strobilae closely resembled published descriptions of Cassiopea in Mayer (1910) with some minor differences.

Calder (1973) has established additional laboratory techniques for this species and has also described the ephyral stages (Calder, 1977). R. verrillii is more common to the south of the Chesapeake Bay, so that warmer temperatures for all stages seem to be indicated.

Acknowledgements

Many people have contributed generously to the information embodied in this account. I have leaned on unpublished information in many cases. Particular thanks go to Dr. Dale R. Calder of the Royal Ontario Museum, Toronto, and Messrs Dexter Haven and Reinaldo Morales of the Virginia Institute of Marine Science, Gloucester Point, Virginia for their help. I also owe a debt to my colleagues at the Chesapeake Biological Laboratory: Dr. Leonard P. Schultz, Mr. Michael J. Reber, Ms. Rosalie Cumbee, for allowing me access to many of their unpublished reports.

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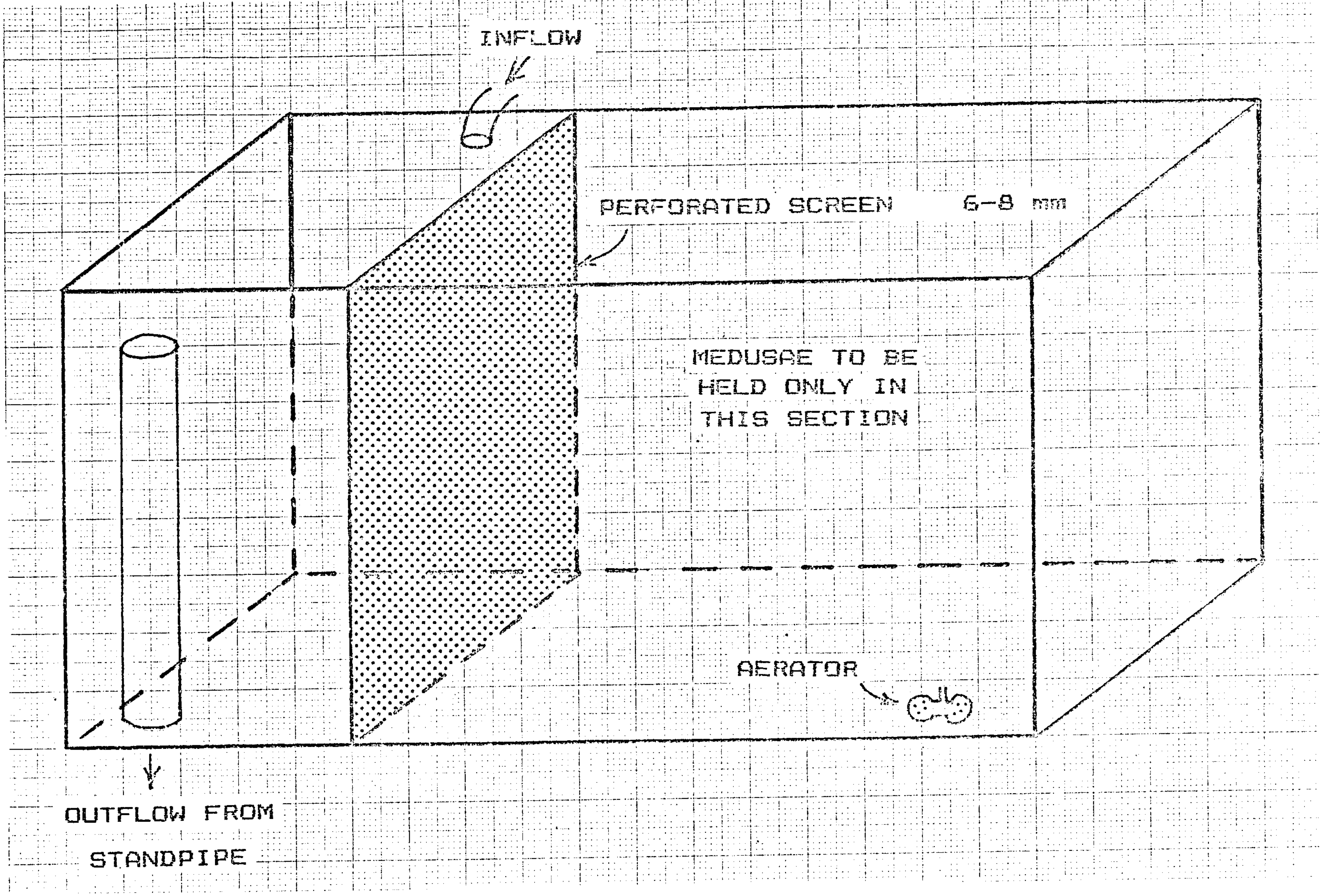

Arrangement for holding medusae

References

Anon., (1983). - Workshop on the medusa in the Mediterranean, Athens, 6-9 June 1983. Ministry of Physical Planning, Housing and the Environment.

Barnes, J.H., (1966). - Studies on three venomous cubomedusae, Symp. Zool. Soc. London. In: The Cnidaria and their Evolution, London and New York, Academic Press, pp. 307-332.

Berrill, N.J., (1949a). - Developmental analysis of scyphomedusae. Biol. Rev. 24, 393-410.

Berrill, N.J., (1949b). - Form and growth in the development of scyphomedusae. Biol. Bull. 96, 283-292.

Brewer, R.H., (1976a). - Larval settling behavior in Cyanea capillata (Cnidaria Scyphozoa). Biol. Bull. 150, 183-199.

Brewer, R.H., (1976b). - Some microenvironmental influences on attachment behavior of the planula of Cyanea capillata (Cnidaria: Scyphozoa). In: Coelenterate Ecology and Behavior, Plenum Publ. Co. pp. 347-354.

Brewer, R.H., (1978). - Larval settlement behavior in the jellyfish, Aurelia aurita (Linnaeus) (Scyphozoa: Semaeostomeae), Estuaries 1/2, 120-122.

Calder, D.R., (1973). - Laboratory observations on the life history of Rhipilema verrilli (Scyphozoa: Rhizostomeae). Mar. Biol. 21, 109-114.

Calder, D.R., (1977). - Nematocysts of the ephyral stage of Aurelia, Chrysaora, Cyanea, and Rhopilema (Cnidaria: Schyphozoa). Trans. Amer. Micros. Soc. 96/1, 13-19.

Cargo, D.G., (1971). - The sessile stages of a scyphozoan identified as Rhopilema verrilli. Tul. Stud. Zool. 17/2, 31-34.

Cargo, D.G., (1974). - Comments on the laboratory culture of scyphozoa. In: Culture of marine invertebrate animals, Smith and Chanley, Eds. pp. 145-154.

Cargo, D.G., (1979). - Observations on the settling behavior of planular larvae of Chrysaora quinquecirrha. Int. Jour. Invert. Reprod. 1, 279-287.

Cargo, D.G. and Rabenold, G.E., (1980). - Observations on the asexual reproductive activities of the sessile stages of the sea nettle Chrysaora quinquecirrha (Scyphozoa). Estuaries 3/1, 20-27.

Cargo, D.G. and Schultz, L.P. (1966). - Notes on the biology of the sea nettle, Chrysaora quinquecirrha in Chesapeake Bay. Ches. Sci. 7/2, 95-100.

Cargo, D.G. and Schultz, L.P., (1967). - Further observations on the biology of the sea nettle and jellyfishes in Chesapeake Bay. Ches. Sci. 8/4, 209-220.

Chuin, T.T., (1930). - Le cycle évolutif du scyphistome de Chrysaora. Trav. Sta. Biol. Roscoff. 8, 1-179.

Compton, Ann M., (1966). - Mnemiopsis leidyi as a food for the cultivation of Chrysaora quinquecirrha under controlled conditions. Unpub. ms. Ref. No. 66 - 49., Ches. Biol. Lab. Solomons, Md. 11 pp.

Delap, Mary J., (1906). - Notes on rearing in an aquarium, of Aurelia aurita L. and Pelagia perla (Slabber). Rep. Sea Inland Fish., Ire. 1, 22-26.

Hartwick, R.F., Callanan, V. and Williamson, J., (1980). - Disarming the box jellyfish. Nematocyst inhibition in Chironex fleckeri, Med. J. Aust. 1, 15-20.

Herouard, E., (1913). - Relations entre la dépression et la formation de pseudoplanula tentaculaires chez le scyphistome. C.R. Acad. Sci. 156, 1093-1095.

Hofmann, D.K., Neumann, R. and Henne, K., (1978). - Strobilation, budding, and initiation of scyphistoma morphogenesis in the Rhizostome, Cassiopea andromeda (Cnidaria: Scyphozoa). Mar. Biol. 47, 167-176.

Kramp, P.L., (1961). - Synopsis of the medusae of the world. J. Mar. Biol. Assoc. U.K. 40, 469 pp.

Lesh-Laurie, Georgia, E. and Corriel, R., (1973). - Scyphistoma regeneration from isolated tentacles in Aurelia aurita. Journ. Mar. Biol. Assn., UK 53, 885-894.

Littleford, R.A., (1939). - The life cycle of Dactylometra quinquecirrha L. Agassiz in the Chesapeak Bay. Biol. Bull. 77, 368-381.

Loeb, M.J. and Gordon, C.M., (1975). - Strobilation in the Chesapeake Bay sea nettle, Chrysaora quinquecirrha - IV. Tissue levels of iodinated high molecular weight component and "NIF" in relation to temperature change-induced behavior. Comp Biochem. Physiol. 51A, 37-42.

Maretic, Z. and Russell, F.E., (1983). - Stings by the sea anemone Anemonia sulcata in the Adriatic Sea. J. Trop. Med. Hyg. 32/4, 891-896.

Mayer, A.G., (1910). - Medusae of the world. Pub. Carnegie Inst. Wash., No. 109: 499-735.

Russell, F.S., (1964). - On scyphomedusae of the genus Pelagia. J. Mar. Biol. Assoc. U.K. 44/1, 133-136.

Russell, F.S., (1970). - The medusae of the British Isles. II Pelagic Scyphozoa. Cambridge Univ. Press. 284 pp.

Spangenberg, D.B., (1965). - Cultivation of the life stages of Aurelia aurita under controlled conditions. J. Exp. Zool. 159/3, 303-318.

Spangenberg, D.B., (1967). - Iodine induction of metamorphosis in Aurelia. J. Exp. Zool. 165/3, 441-449.

UNEP, (1983). - Monitoring of swarming by Scyphomedusae. UNEP. 23 pp. and App.

OCCURRENCE OF THE PHOSPHONOCOMPOUNDS IN THE MEDUSA *Pelagia noctiluca* AND THEIR POSSIBLE RELATION WITH THE BLOOMS OF JELLYFISH

by

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The ultimate purpose of our research programme is to contribute to answering the question: How may naturally occurring phosphonolipids affect the nutrition of an organism?

During the last few years a considerable increase in knowledge about phosphonolipids has been achieved. It was proved that phosphonolipids are, indeed, natural components of many organisms, mainly protozoa, molluscs and cnidaria, even of mammalian tissues at lower concentrations (1, 2, 3, 26). This is important because for a long time it was believed that living tissues were not able to synthesize such compounds. What are phosphonolipids?

These lipids contain a C-P carbon-to-phosphorus bond (also called a phosphono bond) (figure I).

The physical and most of the chemical properties of the phosphonolipids are very similar to those of the more common phospholipids which have an oxygen atom between carbon and phosphorus. This similarity is the reason why phosphonolipids were discovered so late.

However, the C-P bond is extremely resistant to prolonged vigorous hydrolysis, being also resistant to enzymic attack by phospholipases (4).

Because of this resistance an important biological advantage might be conferred by the presence of these phosphonolipids in the biological membranes of the organisms which are able to synthesize such compounds. In the gastrovascular cavity of sea anemones, into which many hydrolytic enzymes are released, cell membranes may benefit from this stability (6).

Likewise, the presence of aminoethylphosphonate in proteolytic enzymes of the sea anemone suggests that substances with phosphono-bonds may provide groups which closely resemble the phosphate group in their "dissociation constants" but which are more stable to the action of other enzymes in the gastrovascular cavity. Similar reasoning may be applicable in the case of ciliates which are found in the rumen stomach, which is an environment rich in phosphatases (5).

Many glycero-, sphingo- and glycosphingo- phosphonolipids have been characterized, but unfortunately the phosphono proteins have not been investigated to the same extent (7). The concentration and distribution of phosphonolipids in the living organisms are shown in table 1 (2).

We must note that glycerophosphonolipids are present in small amounts in the heart muscles, the liver and the brain of humans, in the milk, liver and brain of cows and goats, and in bovine bile (8-14).

Because of the small quantities of phosphonolipids found in the higher animals, several investigators have suggested that some incorporation of external phosphono-compounds goes on.

There has so far been no report* in the literature concerning the occurrence of phosphonolipids in the Scyphomedusae (17), especially Pelagia noctiluca, which has been found in blooms in the Mediterranean during the last few years. On the other hand, we knew from the literature that a high percentage of sphingophosphonolipids is present in other organisms of the same phylum (Cnidania) (6, 17).

For the above reasons we chose Pelagia noctiluca as a one of our research subjects three years ago.

Experimental

The bodies of 21 live scyphomedusae Pelagia noctiluca (captured in May 1982) were extracted whole according to Bligh-Dyer's method, by homogenizing them with a triple volume of $CHCl_3$/MeOH (1:2). One vol $CHCl_3$ was added to the homogenate and the solvents were separated.

One vol $CHCl_3$/MeOH (1:1) was added to the residual material and it was rehomogenized. One vol H_2O and 1 vol $CHCl_3$ were added to the extract and it was left (12 h) for phase separation. The total lipids were obtained from the chloroform phase (19).

A partial analysis of every single part of the body was impossible for the following reasons:

1) The presence of large amounts of water in their bodies;

2) The existence of a small quantity of lipids;

3) The existence of enzymes like phospholipases, phosphodiesterases and proteolytic toxines, leads to the destruction of the body shortly after it has been taken out of sea-water.

Also the possibility of analysing this organism after lyophilization involves the risk of changes in the results due to the breaking down of the fatty acids from the polar lipids.

A portion of total lipids was preliminarily studied by Thin Layer Chromatography (TLC), see figure II. The results showed the presence of glycerolipids (Cardiolipin (Car), phosphatidyl ethanolamine (PE), phosphatidyl choline (PC), etc.) and of several sphingophosphonolipids.

Another portion of total lipids was fractionated by column chromatography on silicic acid as shown in table 3. The column fractions were examined by TLC accompanied by quantitative analysis of total phoshorus (20), as well as of phosphonate/phosphorus percentage (21). It is well known that by mild alkaline hydrolysis (0,1N NaOH, 35° C, 2-3 h) only the glycerolipids are hydrolysed, whereas the sphingolipids remain stable (MAS).

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* Only the fatty acids of "scyphomedusae" have been studied. These are composed of highly complex mixtures with 70-80 per cent unsaturated fatty acids (table 2).

The fractions 2, 3, 4 and 5 were hydrolysed under the above alkaline conditions. The main component of Fr. 2 was completely hydrolysed (Car), but those of the other fractions were partially hydrolysed.

The mild alkaline stable lipids of each fraction were analysed for phosphonate (phosphorus percentage) by a conventional method, as well as by a method devised in our laboratory (4, 21, 22). The data are: 24 per cent of total phosphorus belongs to sphingophosphonolipids, which seem to be of several molecular structures. Another 12 per cent belongs to PE and 35 per cent to PC.

Moreover, a portion of MAS lipids of Fr. 4 was further purified by preparative TLC and the purified lipids were completely hydrolysed by acid catalysed methanolysis (2NHCl, 80° C, 5 h) in order to characterize the molecular species of this sphingophosphonolipid (23, 24, 25).

The fatty acid methyl esters of the acidic hydrolysis products were further purified by preparative TLC and are now being studied by gas chromatography analysis.

Table 1. Content of sphingophosphonolipids in Protozoa, Mollusca and Coelenterata (as % of phospholipid)

	SPnL*	CAEPn**	CMAEPn***
Protozoa			
T. pyriformis W	11[a]	+	++
T. pyriformis WH-14	5[a]	++	+
Mollusca			
Liolophira japonica	37.4	++	+
Trubo cornutus			
muscle	10.6	-	+++
viscera	8.2	-	+++
Monodonta labio	16.2	-	+++
Tegula lischkei	33.1	+	++
Conomurex luhuanus	20.7	+++	-
Celluna eucosmia	14.5	+++	-
Ostrea gigas			
adductor	45.2	+++	-
gills	22.2	+++	-
mantle	21.0	+++	-
viscera	19.2	+++	-
Mytilus edulis	25.6	+++	-
Hyriopsis schlegelii			
ova	16[a]	++	+
spermatozoa	7[a]	++	+
Scallop			
H. giganteum	17	+++	-
Pink abalone			
H. corrugata	9	++	?
Coelenterata			
A. elegantissima	19.9[b]	+++	-
M. senile	10[b]	++	+

[a] As % of alkali-stable lipid fraction

[b] As % of total lipid

* SPnL : sphingophosphonolipid

** CAEPn : ceramide aminoethylphosphonate

*** CMAEPn : ceramide-N-methyl-aminoethylphosphonate

Table 2. Major fatty acids of representative scyphozoan medusae

Species	*C. capillata*	*A. aurita*	*S. meleagris*	*C. quinquecirrha*
F.A.	%	%	%	%
14:0	1.5	3.3	1.7	0.7
16:0	14.1	16.0	12.1	10.0
18:0	7.1	6.4	8.7	10.9
20:0	2.0	1.2	0.5	1.9
16:1	5.2	4.7	2.9	3.2
18:1	7.0	11.8	3.4	3.9
20:1	12.2	13.7	0.4	0.7
22:1	2.0	4.5	0.1	0.4
18:2	0.2	0.8	0.9	0.5
18:3	0.4	0.4	0.5	0.4
18:4	0.2	0.1	1.1	0.1
20:4	6.2	6.7	15.5	22.4
22:4	2.0	0.6	2.6	6.3
20:5	9.8	8.5	19.1	7.6
22:5	5.8	1.9	17.3	10.3
22:6	13.3	7.0	15.9	11.9
Total unsaturated fatty acids	75%	73%	77%	76.5%

Table 3. Elution of medusa lipid from silicic acid column

Fraction no.	Bed volume	Solvent system	Intact column fraction	After mild alkaline hydrolysis column fraction							
				Mild alkaline stable components (MAS)					Water methanol soluble component		
			% total lipid P	P % of column fraction	% Total-P	Phosphonate % of MAS	Phosphonate % of total-P	Main components	P % of column fraction	% total-P	Main component
1	8	C/M 98:2	0.8								
2	1.5	C/M 9:1	6.7	4.6	0.3	-	-	-	95.4	6.4	Car
3	3.5	C/M 9:1	30	60	18	60	10.8	sphingo-phosphono-lipids	40	12	PE
4	4	C/M 4:1	26	50	13	95	12.3		50	13	PC
5	4	C/M 4:1	33	25	8.25	8	0.66		75	24.75	PC
6	5	EtA_c/M 3:2	1								
7 8	8 3	C/M 1:9 CH_3OH	0.8								
						Total	$\simeq$ 24				

C: Chloroform
M: Methanol

Et.Ac: Ethylacetate
P: Phosphorus

Car: Cardiolipin
PC: Phosphatidyl choline

PE: phosphatidyl-ethanolamine

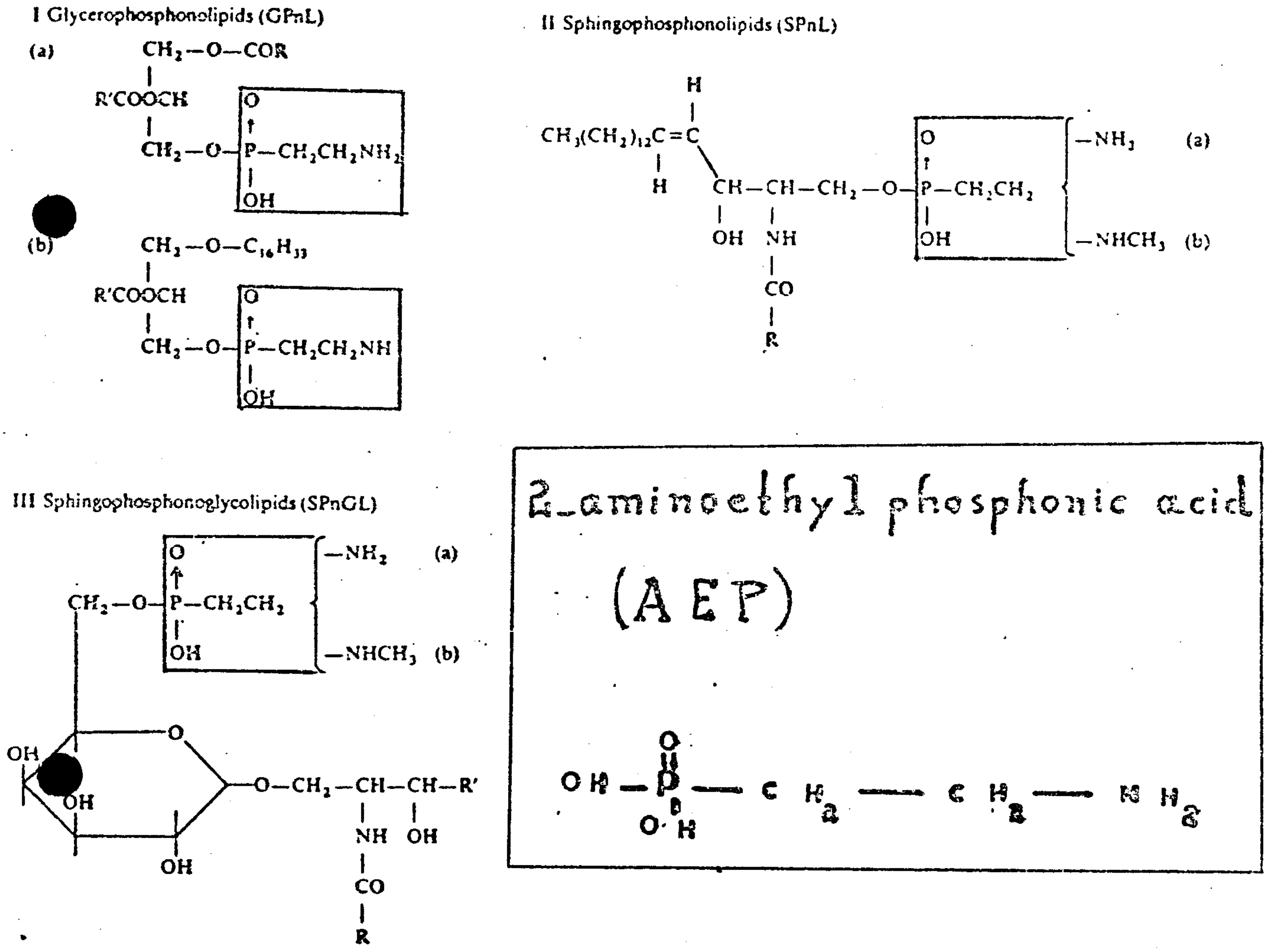
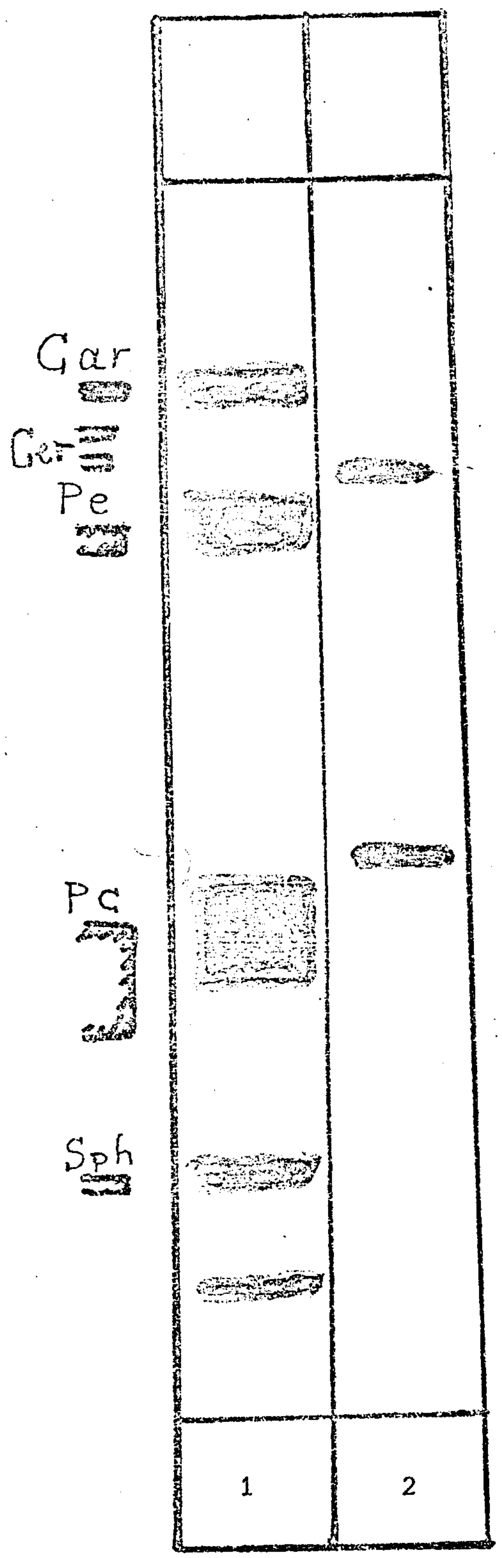


Figure I. Chemical structures of some phosphonolipids



1. ▨ Phospholipids
2. ▨ Glycolipids

Development system C/M/W. (65:25:4)

Figure II. TLC of crude lipids

References

1. Horiguchi, M. and Kandatsu, M., (1959). - Nature (Lond.), 184, 901.
2. Hori, T. and Nozawa, Y., (1982). - In: Phospholipids (Hawthorne/Ansell. eds), 4, 95. Elsevier Biochemical Press.
3. Mastronicolis, S.K. and Kapoulas, V.M., (1983). - Chim. Chron., "New Series", 12, 119.
4. Kapoulas, V.M., (1969). - Biochim. Biophys. Acta, 176, 324.
5. Kittredge, J. and Roberts, E., (1969). - Science, 164, 37.
6. Rouser, G., Kritchevsky, G., Heller, D. and Lieber, E., (1963). - J.A.O.C.S 40, 425.
7. Smith, J.D. and Lepak, N.K., (1982). - Archives of Biochemistry and Biophysics, 213, 565.
8. Alhadeff, J.A. and Doyle Daves, G., (1970). - Biochemistry, 9, 4866.
9. Alhadeff, J.A. and Doyle Daves, G., (1971). - Biochim. Biophys. Acta, 244 211.
10. Kandatsu, M. and Horiguchi, M., (1965). - Agr. Biol. Chem., 29, 781.
11. Shimizu, H., Kakimoto, Y., Nakajima, T., Kanazawa, A. and Sano, I., (1965). - Nature (Lond.) 207, 1197
12. Hasegawa, S., Masato, T. and Masao, K., (1976). - Agr. Biol. Chem., 40/10, 2097.
13. Tamari, M. and Kametaka, M., (1973). - Agric. Biol. Chem., 37/4, 933.
14. Tamari, M., Ogawa, M., Hasegawa, S. and Kametaka, M., (1977). - Agr. Biol. Chem., 40/10, 2057.
15. Ataki, S., Komai, Y. and Satake, M., (1980). - J. Biochem., 87, 503.
16. Ataki, S. and Satake, M., (1981). - Neuroscience Letters, 22, 179.
17. Jeanne, J.D., (1979). - Prog. Lipid Res., 18/1, 1.
18. Mason, W.T., (1972). - B.B.A.,280, 538.
19. Bligh, E.G. and Dyer, W.J., (1959). - Can. J. Biochem., 37, 911.
20. Long-Staples, (1961). - Biochem. J., 78, 179.
21. Aalbers, J.A. and Bieber, L.L., (1968). - Analytical Biochem. 24, 443.
22. Kapoulas, V.M., Mastronicolis, S.K., Nakhel, I.G. and Stavrakakis, H.J., (1984). - Z. Naturforsch., 39c, 249.
23. Mastronicolis, S.K., Nakhel, I.C., Kapoulas, V.M. and Galanos, D.S., (1983) 15th FEBS Meeting Brussels 24-29 July.
24. Mastronicolis, S.K., Nakhel, I.C., Kapoulas, V.M. and Galanos, D.S., (1983) Chim. Chron., "New Series", in press.
25. Sweeley, C.C. and Moscatelli, E.A., (1959). - J. Lipid Res., 1/40.
26. Mastronicolis, S.K., Stavrakakis, H.J. and Kapoulas, V.M., (1983). - 5th Balkan Biochemical and Biophysical Days, Thessaloniki, Greece, 11-13 May

SUR QUELQUES TRAVAUX RELATIFS AUX MEDUSES ACALEPHES DE MEDITERRANEE

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Résumé

58 travaux s'échelonnant de 1839 à 1979, relatifs aux méduses scyphozoaires séméostomes, Aurelia aurita (L.), Chrysaora hysoscella (L.), Pelagia noctiluca (Forskål) et Cyanea capillata (L.), sont analysés. Les connaissances acquises sur les cycles de reproduction et le rôle des facteurs physiques ou chimiques sur la strobilation et les autres formes de gemmiparité sont présentées et commentées ainsi que quelques aspects de l'action des toxines.

Summary

Fifty-eight works dealing with scyphomedusae semeostomae and especially the species Aurelia aurita (L.), Chrysaora hysoscella (L.), Pelagia noctiluca (Forskål) and Cyanea capillata (L.), are reviewed and annotated in this note with emphasis on the biology and the reproduction cycles. A few comments are given on the effects of the nematoblast toxins.

La prolifération sporadique des méduses acalèphes n'est pas un phénomène nouveau et des rassemblements monospécifiques ont fréquemment été observés en mer ou échoués sur les plages.

Ces essaims spectaculaires ont récemment pris en Méditerranée un relief d'autant plus prononcé qu'ils n'avaient jamais été aussi nombreux et généralisés avant ces trois dernières années. En effet, c'est à partir de 1980 que l'on a pu assister à des arrivées par vagues régulières et massives de méduses sur les plages et dans les ports entre le début avril et la fin septembre avec un maximum en période estivale.

La multiplication intensive des méduses acalèphes et l'apparition des essaims n'ont pas encore à ce jour été expliquées d'un manière satisfaisante. Les observations in-situ, les élevages et les expériences en laboratoire ont permis de souligner l'importance de certains facteurs externes tels que la température ou l'abondance de nourriture à certaines époques du cycle de reproduction mais les mécanismes sont loin d'être élucidés.

Cette communication a pour objet de présenter les résultats d'un certain nombre de travaux relatifs à la reproduction des scyphoméduses séméostomes, à l'action des facteurs externes physico-chimiques et aux effets vulnérants des nématoblastes.

Les publications analysées sont pour la plupart consacrées à des espèces communes en Méditerranée: Aurelia aurita Linné, de la famille des Ulmaridae; Chrysaora hysoscella Linné et Pelagia noctiluca (Forskål) de la famille des Pelagiidae.

Une quatrième espèce Cyanea capillata Linné, est considérée comme peu fréquente en Méditerranée mais sa distribution est cependant controversée et son cycle présente des aspects particuliers qui méritent d'être soulignés. Elle a été retenue pour ces raisons.

Généralités

Le synopsis sur les méduses, accompagné d'une bibliographie exhaustive, publié par Kramp en 1961 et l'ouvrage de F.S. Russell "The Medusae of the British Isles" réédité en 1970 permettent d'avoir rapidement accès aux très nombreuses références parmi lesquelles les noms de Bigelow, Claus, Kramp, M.E. Thiel et Hj. Thiel, Uchida et bien d'autres sont fréquemment rencontrés.

D'une manière classique on sait que les scyphoméduses séméostomes sont gonochoriques, à l'exception de Chrysaora qui est hermaphrodite protandre. On admet généralement que les ovocytes sont fécondés sur l'individu femelle, que l'oeuf se segmente dans les ovaires ou dans des poches incubatrices, que les modalités de la gastrulation varient avec les espèces avec parfois l'apparence d'une viviparité.

Aux termes des différentes étapes du développement embryonnaire, une planula, caractéristique des cnidaires, est constituée. On y distingue les extrémités orale et aborale, cette dernière étant à l'origine de la sole pédieuse lors de la fixation de la larve sur un substrat convenable.

Peu après la fixation de la planula un disque buccal se différencie avec 4 ou 8 puis 16 - parfois plus-tentacules. Cette forme polypoïde benthique est le scyphistome qui, par un processus de strobilation conduit à la différenciation et à la libération d'éphyrules par l'extrémité supérieure.

Quelle que soit l'espèce considérée, la morphologie des éphyrules est identique, seule l'anatomie permet de les différencier. Ce sont de petites formes préfigurant la méduse où l'on reconnaît 8 expansions périphériques bi-lobées aplaties. On distingue une cavité sous-ombrellaire, un manubrium, les canaux radiaires et inter-radiaires ainsi que la cavité gastrique. La strobilation peut, dans certaines circonstances, donner naissance à plus d'une trentaine d'éphyrules.

Avec des exceptions cependant, ce schéma se retrouve dans tous les cycles de reproduction des méduses acalèphes. Il se complique toutefois chez certaines espèces de phénomènes de bourgeonnement, de stolonisation, d'enkystement, et de régénération.

Aurelia aurita Linné

C'est une espèce cosmopolite d'eaux tempérées et tempérée-froides. En ce qui concerne plus particulièrement la Méditerranée, elle existe probablement, selon Kramp (1924), sur toutes les côtes; Carus (1884) l'ayant auparavant rencontrée à Nice, à Naples, en Sicile, à Trieste et en Méditerranée orientale. En mer Noire elle a été pêchée au cours de l'expédition du Thor en 1910 et elle est fréquente dans le golfe d'Aqaba, en mer Rouge (Van Der Maaden, 1959) où je l'ai moi-même souvent observée en plongée, formant des essaims de 10 à 20 m d'épaisseur en nappes de plusieurs dizaines de m^2.

Reproduction

Elle a été très étudiée. On sait que le gonochorisme est la règle (Siebold, 1839) et que la maturité des produits sexuels est le plus souvent atteinte quand la méduse a un diamètre d'environ 40 mm (Claus, 1883). Après la fécondation dans l'ovaire ou dans le sinus génital, les oeufs sont conduits par des mouvements ciliaires dans des poches incubatrices situées à l'extrémité des bras buccaux. Les poches incubatrices ont été décrites par plusieurs auteurs dont Minchin (1889) et M.E. Thiel (1959) a précisé qu'elles apparaissent sur des individus dont le diamètre a atteint 65 mm. On pense qu'une méduse peut se reproduire deux fois dans sa vie.

Les planulas une fois constituées s'échappent des poches incubatrices et, après un temps plus ou moins long, vont se fixer pour donner naissance au scyphistome. C'est alors que les phases du cycle peuvent présenter différentes modalités:

1) La métamorphose en éphyrule est directe sans strobilation, le stade polype peut même ne pas apparaitre (Yasuda, 1975);

2) Des polypes peuvent se développer sur le polype fondateur, sur la colonne ou à sa base;

3) Une stolonisation se manifeste parfois et donne naissance par bourgeonnement à de nouveaux polypes (H. Thiel, 1962);

4) Des formes résistantes, les podocystes ont été fréquemment trouvées et bien décrites par Chapman (1966, 1968).

Ces divers modes de reproduction: sexués, par strobilation et par stolonisation avec de nouveaux bourgeonnements suivis de strobilation permettent de comprendre que des conditions de milieu particulièrement favorables puissent entraîner une prolifération intense des méduses.

Cycle annuel et action des facteurs

Le cycle annuel d'A. aurita avec l'incidence possible de différents facteurs a été reconstitué à partir de différents travaux.

Les éphyrules sont libérées en janvier et l'on compte environ 4 à 5 mois de croissance avant l'apparition des produits sexuels. Entre avril et septembre on rencontre des individus à tous les stades, de juvénile à adulte, avec cependant une décroissance progressive du nombre des organismes matures et leur quasi-disparition au début de l'automne.

Pendant toute cette période, la coexistence de différentes classes d'âge paraît possible étant donné la capacité de métamorphose directe des planulas en éphyrules (Yasuda, 1975). Ce même auteur a également observé qu'en mer du Japon, tout au moins dans la région d'Urazoko Bay, la strobilation n'est pas le mode le plus fréquent de formation des méduses, mais lorsqu'il se manifeste il intervient un mois après la fixation de la planula.

En général, les méduses libèrent les planulas vers la mi-août et les polypes fondateurs se développent en 2 à 3 semaines. La multiplication asexuée intervient de septembre à décembre et la strobilation qui peut se manifester dès la formation du polype devient alors intense et il arrive qu'elle dure toute l'année.

Au-delà du mois de septembre, il est admis que les méduses migrent en profondeur et s'y maintiennent au moins jusqu'en décembre.

De nombreuses incertitudes demeurent cependant quant aux facteurs responsables de l'apparition des différentes phases ou de l'existence simultanée des diverses modalités de reproduction.

Il est certain que la température joue un rôle primordial car on a pu observer, vers les hautes latitudes, des apparitions plus tardives d'éphyrules et une période de croissance et de maturation des méduses plus longue (Verwey, 1942; M.E. Thiel, 1959b).

Les températures limites compatibles avec la présence d'A. aurita sont -0,5°C et 30°C, ce qui explique leur migration en eau plus profonde dès l'apparition des grands froids surtout dans les régions les plus septentrionales avec le gel des eaux de surface. Dans les eaux sub-tropicales où la température de surface peut parfois dépasser 30°C les animaux se maintiennent dans les eaux sub-superficielles (Yasuda, 1974).

En ce qui concerne la strobilation elle intervient entre 6° et 27°C avec semble-t-il un optimum à 15°C tant pour le nombre d'éphyrules que pour le temps d'apparition des 6 stades caractéristiques reconnus de croissance (Kato, Aochi, Ozato, 1973). Quant à la libération des éphyrules dans des conditions expérimentales, elle intervient 3 à 4 jours après la fixation de la planula à 20°-28°C; à 15°-21°C il faut 5 jours, 8 jours à 12°-15°C et 8 à 11 jours pour des températures de 6° à 12°C (Yasuda, 1975).

Les résultats de ces travaux, accomplis en mer du Japon concordent assez bien avec les observations de Verwey (1942). Selon ce dernier auteur la strobilation se manifeste entre 4° et 8°C. En laboratoire elle peut être déclenchée en soumettant le polype pendant quelques heures à une température de l'ordre de 5°C.

Il est probable que le stimulus déclencheur n'est pas uniquement la température. En effet, un même polype peut présenter des strobilations 4 fois par an, deux d'entre elles sont considérées comme principales (décembre et mars) les deux autres en avril et en mai sont moins importantes. Enfin, on sait que certains individus produisent des éphyrules toute l'année (H. Thiel, 1962).

La salinité ne semble pas jouer un rôle important de même que la lumière bien que cette dernière soit à l'origine de migrations verticales journalières de méduses et qu'indirectement, par l'intermédiaire de zooxanthelles associées au scyphistome, elle puisse avoir un rôle au moment de la strobilation.

Enfin, il a été montré que des substances chimiques comme l'iodure de potassium induisent des strobilations, ou encore la thyroxine, sur des scyphistomes préconditionnnés par une température de 19° C (Spangenberg, 1968).

On sait également que l'ectoderme du scyphistome possède un grand pouvoir de régénération.

En résumé, les origines des proliférations d'A. aurita paraissent multiples. Les organismes matures peuvent avoir une forte production d'oocytes et il arrive que cette capacité se manifeste au moins 2 fois dans l'année. C'est donc une quantité considérable de planulas qui, malgré la mortalité et la prédation, donnera naissance à un très grand nombre d'éphyrules soit par métamorphose directe soit par l'intermédiaire des scyphistomes avec les potentialités de strobilation que l'on connaît.

Par ailleurs, on observe fréquemment d'autres formes de gemmiparité, bourgeonnements multiples (polydisques), accompagnés de stolonisations qui accroissent énormément les potentialités de multiplications.

Enfin, la formation de podocystes limite les risques de disparition de l'espèce et favorise sa dissémination.

En ce qui concerne l'induction de ces divers modes de gemmiparité par des facteurs externes, on est certain que la température intervient ainsi que certaines substances chimiques mais on en ignore les mécanismes précis.

Chrysaora hysoscella Linné

C'est une méduse fréquente en Méditerranée et citée dans de nombreux ouvrages dont les références seront trouvées dans le travail exhaustif de Kramp en 1961. Il semble également que ce soit une espèce relativement confinée aux mers tempérée-froides. En Europe sa limite se situe aux environs de 58° N mais elle a également été signalée en hémisphère sud en Terre de Feu, à l'île Melchior en Antarctique et sur les côtes d'Afrique Occidentale. Elle apparaît le plus souvent en essaims. D'après Schaeffer (1921) les limites de températures sont 4°C pour la plus basse et 28°C pour la plus haute.

Reproduction

L'hermaphrodisme protandrique de C. hysoscella a été découvert par Claus (1877) en Adriatique. Les individus jusqu'à 5 cm ne présentent que des cellules germinales mâles alors qu'au-delà jusqu'à environ 25 cm de diamètre les éléments sexuels mâle et femelle coexistent. Au-delà de cette taille les individus sont tous femelles (Claus, 1883).

Les éléments génitaux mâles se développent dans diverses régions de l'animal - tel l'épithélium endodermique des lobes buccaux ou dans l'épithélium sous-ombrellaire de la cavité gastro-vasculaire (Haeckel, 1880) - et apparaissent dans des follicules de filaments génitaux dans la cavité gastrique (Widersten, 1965).

Les ovaires se trouvent fréquemment à proximité des filaments génitaux mâles mais on ignore si les fécondations sont croisées étant donné l'hermaphrodisme protandrique ou bien s'il existe une auto-fécondation.

Il faut également souligner la particularité de la segmentation qui conduit à une gastrula capable d'une croissance aux dépens de la méduse mère, puis une fermeture du blastopore au moment de la constitution de la planula nageuse dont la taille peut être variable (Teissier, 1929). Ces phases complexes de la segmentation jusqu'à la planula permettent de qualifier C. hysoscella de vivipare.

Comme chez A. aurita le polype peut vivre longtemps mais apparemment le bourgeonnement et la stolonisation sont beaucoup plus fréquents.

Il existe également des phénomènes de régénération et des petits fragments de stolon se réorganisent en forme de planula qui se métamorphose en polype. Enfin, il est fréquent d'observer des podocystes (Tcheou-Tai-Chuin, 1930).

Cycle et facteurs externes

Selon Claus (1877) et Graeffe (1884), les éphyrules en Adriatique sont produites en septembre et octobre et les méduses arrivent à maturité en mars et avril. Des observations analogues avaient été faites auparavant par Derbes (1850) à Marseille. Divers auteurs ont signalé l'apparition de gros adultes, donc probablement de sexe femelle, en Mer du Nord, en juillet, en août et septembre (Hartlaub, 1913; Russell, 1970) et Van der Maaden (1942) a trouvé les derniers individus en décembre sur les côtes hollandaises.

La fixation des planulas et la métamorphose en scyphistomes s'accomplissent à partir du mois de mars avec une strobilation particulièrement intense de juin à octobre, accompagnée d'une stolonisation et complétée en hiver par un bourgeonnement et la formation de podocystes; ceci tout au moins dans la région de Roscoff (Tcheou-Tai-Chuin, 1930) car Widersten (1968) pense que la strobilation ne s'effectue pas sur les côtes suédoises de la Mer du Nord. Pour Tcheou-Tai-Chuin le polype peut vivre longtemps et le bourgeonnement interviendrait toute l'année. En hiver il serait à l'origine des sexués.

Les facteurs à l'origine des apparitions massives d'éphyrules et de l'accentuation des modes asexués de reproduction sont mal connus. C'est ainsi que l'on a constaté qu'un scyphistome riche en substances de réserve avant la strobilation est l'indice de la formation de 4 à 16 étranglements le long de l'ephyrulum. Il est certain que l'abondance alimentaire - se traduisant par une richesse de l'endoderme en substances de réserves - favorise le bourgeonnement et la régénération. En contrepartie, une carence inhibe partiellement les processus de gemmiparité.

On constate également que la souche d'un scyphistome strobilé réacquiert après la libération de la dernière éphyrule la couronne labiale et les tentacules d'un scyphistome.

Les températures les plus favorables se situent entre 7° et 10°C.

Quant à la longévité, il semble qu'elle soit grande puisque Claus (1891) a conservé 14 ans un scyphistome.

Selon Tcheou-Tai-Chuin (1930): "L'apparition et la persistance de tel ou tel mode de bourgeonnement sont des phénomènes si instables qu'il est difficile de préciser quelle en est la cause déterminante".

Pelagia noctiluca Forskål

Distribution

Largement distribuée dans les eaux chaudes et tempérées P. noctiluca se trouve fréquemment en Méditerranée et Carus (1884) la signale à Majorque, Nice, Gênes, Naples, Messine. Au cours de l'expédition du Thor, elle est également trouvée à Alger, en mer Ionienne, en Crète du sud, en mer Egée. Haefelfinger (1975) décrit des arrivées en masse à Villefranche-sur-mer en France où les pêcheurs les ramassaient par seaux entiers à la fin de l'année 1959 et où l'on a pu observer des milliers d'organismes échoués formant des couches de plusieurs dizaines de centimètres d'épaisseur à la laisse des eaux. On la connaît d'Afrique Occidentale et dans l'Atlantique européen ainsi qu'en Mer du Nord où les invasions sont fréquentes.

Reproduction cycle, action des facteurs

L'une des particularités de cette méduse acalèphe est l'absence du stade scyphistome dans son cycle. Krohn (1855) fut le premier à observer la métamorphose directe de la planula en éphyrule. Les descriptions des oeufs, de leur segmentation et des stades ont été parfaitement faites par Delap (1907).

D'après les observations de Lo Bianco (1905) et celles de Franqueville (1971) les individus matures se reproduisent à la fin de l'automne et les éphyrules apparaissent en hiver. En mars, les jeunes méduses d'environ 2 cm de diamètre se rencontrent et leur croissance se poursuit (4 à 6 cm en avril-mai; 6 à 8 cm en juin) pour atteindre leur taille maximum, 8 à 10 cm, et leur maturité sexuelle en été et jusqu'à la fin de l'automne. La mort intervient immédiatement après la reproduction.

Il semble cependant que ce cycle puisse se compliquer par une reproduction en toutes saisons ainsi que Kramp (1968) le signale pour les régions tropicales, considérant que la Méditerranée et a fortiori l'Atlantique (golfe de Biscaye) sont des zones de reproduction restreintes. Lo Bianco (1888) par ailleurs, avait indiqué la présence de spécimens matures toute l'année dans le golfe de Naples avec un nombre accru en hiver et un nombre considérable d'éphyrules de novembre à mars.

Probablement que la température joue un rôle important dans la reproduction de P. noctiluca de même que la nutrition mais apparemment aucune observation n'a été faite sur l'action de ces facteurs.

Cyanea capillata Linné

Distribution

C. capillata est une méduse de l'hémisphère boréal dont la distribution est circumpolaire et elle est très commune en mer du Nord dans le Skagerak et le Kattegat. En Baltique elle est liée aux coups de pistons qui plus ou moins régulièrement introduisent des eaux plus salées, elle se rencontre alors jusqu'au golfe de Riga. Au Japon elle est fréquente à Hokkaido et semble liée au cours du courant froid "Oyashio" (Yachida, 1954).

Kramp l'a cependant signalée en 1959 au large des côtes occidentales africaines et en 1965 dans les eaux australiennes. Selon lui cette présence indiquerait une distribution cosmopolite, ce que tendraient à confirmer les captures faites en Méditerranée près des côtes.

Cycles et action des facteurs

Le cycle C. capillata est classique avec scyphistome et strobilation.

La période de maturité et de reproduction se situe d'août à septembre et la planula nage librement pendant 4 semaines avant sa fixation et sa métamorphose. Les strobiles apparaissent en novembre-décembre. Ils se maintiennent souvent jusqu'au mois de février de l'année suivante (Hagmeier, 1933) et Le Danois (1913) en a trouvé à l'île de Ré en mai. Selon Loomis (1961) les scyphistomes peuvent bourgeonner indéfiniment s'ils sont bien nourris dans de l'eau changée régulièrement.

La métamorphose de la planula se fait en 6 jours à 16° C (Korn, 1966). Les éphyrules apparaissent aux environs de février en mer du Nord et mer d'Irlande, et les petites méduses en avril et mai, les tailles adultes sont trouvées en juin, surtout en juillet et dès septembre leur nombre diminue progressivement. Le diamètre de 1,9 cm en avril passe à 16,9 cm en août (M.E. Thiel, 1960) en baie de Kiel.

L'un des aspects particulièrement intéressant chez cette espèce est la capacité de bourgeonnement de la planula (Widersten, 1968) et le bourgeonnement à partir de stolon s'accompagne de l'enkystement des polypes à des températures relativement hautes comprises entre 25° et 29°C. Lorsque la température décroît vers 23° C les kystes bourgeonnent pour donner des polypes dont la strobilation apparaît à 15° C (Cargo et Schultz, 1967).

La méduse est moins résistante que les formes asexuées et meurt à 27°C (Mayer, 1914).

Action des nématoblastes

Avec les travaux de Richet et Portier accomplis sur le navire océanographique Princesse Alice du Prince Albert Ier de Monaco au cours des campagnes de juillet - septembre 1901, étaient découvertes l'action des toxines de Physalia pelagica cnidaire siphonophore et les réactions anaphylactiques qui s'ensuivaient. Les résultats des recherches de ces deux auteurs sont parfaitement regroupés dans un mémoire rédigé par Portier, après la mort de Richet en 1935, à partir des cahiers d'expériences et publiés dans les Résultats des Campagnes Scientifiques du Prince de Monaco (1936).

En ce qui concerne les 4 espèces citées ici, seule A. aurita est considérée comme quasi-inoffensive bien que les tentacules, courts par ailleurs, de même que la région périphérique de l'ombrelle soient fortement garnis de nématoblastes disposés en anneaux de batteries. Les tentacules buccaux sont également trés riches. Les toxines sont faiblement ressenties et on ne connaît pas la réponse physiologique des organismes déjà sensibilisés.

Chez P. noctiluca, l'ombrelle est couverte de boursouflures formées par un nombre considérable de nématoblastes. La taille du manubrium est environ 1,5 fois celle de l'ombrelle et ses bras sont également couverts de batteries de nématoblastes. Les tentacules marginaux également riches en cellules urticantes peuvent atteindre étendus 30 à 40 cm.

Cette méduse est citée par Halstead (1978) comme présentant des conséquences peu graves bien que, selon les individus, les contacts puissent être ressentis comme des brûlures intenses et un choc douloureux. L'inoculation des toxines pouvant être suivie d'érythème, d'urticaire, d'inflammation, d'engourdissement, d'ecchymoses, le tout accompagné de sueurs, de pleurs, éventuellement de toux et de réactions de type asthmatique.

Personnellement j'en ai eu une expérience douloureuse. C'était dans la région d'Alger au cours de l'été 1955. Les méduses étaient nombreuses mais jamais rassemblées en essaim, je fus touché à la cuisse probablement par le manubrium de l'une d'entre elles.

La sensation de brûlure fut telle que je bondis hors de l'eau; j'avais sur la cuisse une trace de 6 à 7 cm de long sur environ 1 cm de large, violacée. Dans les heures qui suivirent outre la turgescence et l'ecchymose la peau se mit à suinter un plasma comme aurait pu en produire une brûlure. En même temps, j'étais fiévreux avec des phases de tachycardie. 24 heures après, la peau s'ouvrit laissant une ulcération suintante qui dura 2 semaines. Après la cicatrisation la trace violacée persista longtemps avec réapparition de l'ulcération tous les ans pendant 3 années successives à la même époque et pour quelques jours.

Chrysaora hysoscella et surtout Cyanea capillata sont considérées comme réellement dangereuses.

Chrysaora possède un manubrium dont la taille représente plusieurs fois le diamètre de l'ombrelle et les tentacules, dont le nombre peut être très élevé - on en a compté jusqu'à 40 - atteignent 30 à 40 cm de long. La surface vulnérante est donc considérable.

Cyanea présente une ombrelle couverte de nématoblastes avec des batteries marginales. Le manubrium et le bord des tentacules buccaux sont très largement garnis de batteries; quant aux tentacules marginaux, au nombre d'une centaine, ils en sont entièrement couverts et ils présentent en outre la capacité de s'allonger de plusieurs mètres.

Chez l'homme, les contacts peuvent se traduire par des crampes musculaires, une hyperesthésie, des évanouissements. Lorsque la cornée de l'oeil est touchée les lésions sont graves. Enfin, le coeur et l'activité respiratoire sont souvent affectés (Kramp, 1937; Mitchell, 1962).

Conclusion

L'apparition brutale de peuplements denses de scyphoméduses séméostomes pose de nombreux problèmes quant à la nature des facteurs externes et internes qui en sont à l'origine et qui interviennent au cours des différentes phases du cycle biologique de ces cnidaires.

Ces facteurs peuvent induire plus ou moins précocement la maturité sexuelle des méduses, favoriser la multiplication intensive des cellules germinales et ainsi entraîner un accroissement important du nombre de planulas, d'autant mieux que les individus présentent parfois 2 périodes annuelles de pontes et que la longévité des adultes paraît être de 2 ans, tout au moins dans certaines circonstances.

En outre, les manifestations de gemmiparité sont multiples. Elles se rencontrent déjà chez les planulas; les polypes bourgeonnent fréquemment par la base et sont polydisques ce qui, à la suite de strobilations souvent intenses, conduit à une production considérable d'éphyrules.

A ces phénomènes s'ajoutent les potentialités de stolonisation, sources de nouveaux scyphistomes, qui s'accompagnent aussi de régénération à partir de fragments de stolon et d'une capacité de donner naissance à des podocystes, formes de résistance à des conditions de milieu défavorables et sources de nouveaux polypes lorsque les conditions redeviennent plus clémentes.

Quant aux scyphistomes, ils peuvent donner naissance à des éphyrules plusieurs années de suite et leur longévité semble grande.

Deux facteurs, la température et la quantité de nourriture, paraissent avoir une action prépondérante dans le déclenchement des mécanismes de reproduction.

Au cours du cycle normal, la strobilation intervenant en hiver, on comprend que la saison froide sensibilise le polype au moins dans les couches superficielles d'abord puis de plus en plus profondément au fur et à mesure de l'homogénéisation thermique de la colonne d'eau.

En ce qui concerne les strobilations tout au long de l'année et en particulier quand les eaux sont stratifiées, on peut supposer qu'elles sont liées à des changements de profondeur de la thermocline et/ou à des remontées d'eaux froides. Les modifications de position de la thermocline et les upwellings sont les conséquences sur les côtes septentrionales méditerranéennes de coups de vents de secteur nord (Mistral, Bora ...). L'analyse des conditions météorologiques et hydrographiques de ces dernières années permettrait peut-être d'établir une relation éventuelle avec le grand nombre d'essaims observés.

Il a été parfaitement montré que si la privation de nourriture n'empêche pas la strobilation - bien que le polype soit petit et le nombre d'éphyrules réduit - une longue préparation nutritive est nécessaire et favorise une production intense d'éphyrules. Par la suite, ces dernières doivent trouver une nourriture abondante pour assurer leur croissance jusqu'à la méduse et sa maturation. L'éthologie alimentaire n'est que très superficiellement connue. Une espèce comme Chrysaora hysoscella par exemple est un prédateur de Tomopteris et de Sagitta mais l'animal est également omnivore (Delap, 1901; Lebour, 1923).

Le facteur quantité de nourriture doit très certainement agir d'une manière plus intense au moins à deux époques clés du cycle:

- au moment de la strobilation - hormis la prédation éventuelle - il est probable que les déchets organiques entrent dans le régime alimentaire directement ou indirectement car certains détritivores sont aussi des proies potentielles pour le polype;

- lorsque les éphyrules apparaissent, la nourriture est constituée par du micro-zooplancton et peut-être aussi des débris organiques. L'abondance du micro-zooplancton est en étroite relation avec les "blooms" phytoplanctoniques et en conséquence un problème de synchronisation entre l'abondance de nourriture et le nombre d'éphyrules, puis de jeunes méduses, se pose. Cette synchronisation est étroitement liée aux conditions climatiques et océanographiques des saisons antérieures et du moment.

En dehors de ces deux facteurs, température et abondance de nourriture, la lumière pourrait éventuellement avoir une action par l'intermédiaire des zooxanthelles associées au scyphistome. Une eau turbide provoquerait la disparition des symbiontes ce qui aurait pour conséquence d'empêcher la strobilation sans pour autant faire disparaître le polype.

Il est probable que certains produits chimiques ont la propriété d'induire les strobilations comme le fait l'iode ionique mais aucune observation n'est rapportée sauf pour la thyroxine.

En ce qui concerne Pelagia noctiluca bien des aspects de sa biologie et de sa physiologie demeurent dans l'ombre et aucune hypothèse ne permet d'expliquer son apparition en abondance certaines années. Il est évident comme le dit Plessis (1958) que "dans l'évolution d'une méduse la multiplication gemmipare est probablement le mode de prolifération le plus important: c'est lui qui donne le plus grand nombre d'individus". Dans le cas de P. noctiluca la reproduction asexuée ne semble pas avoir été observée.

Enfin, un travail considérable est encore à accomplir sur les effets vulnérants des nématoblastes, sur la nature des toxines et des réponses des organismes sensibilisés surtout à une époque où les cas d'anaphylaxie et d'allergie paraissent se multiplier.

Références

Cargo, D.G. and Schultz, L.P., (1967). - Further observations on the biology of the sea nettle and jellyfishes in Chesapeake Bay. Chesapeake Sci., 8, 4, 209-220.

Carus, J.V., (1884). - Prodromus faunae mediteraneae. Vol. 1.

Chapman, D.M., (1966). - Evolution of the scyphistoma. In: The Cnidarian and their evolution. Symp. Zool. Soc. London, 16, 51-75.

Chapman, D.M., (1968). - Structure, histochemistry and formation of the podocyst and cuticle of Aurelia aurita (L.). J. Mar. Biol. Assoc. U.K., 48, 187-208.

Claus, C., (1877). - Studien über Polypen and Quallen der Adria. I. Acalephen (Discomedusen). Denkschr, Akad. Wiss. Wien, 38, 64, 1-11.

Claus, C., (1883). - Untersuchungen über die Organisation und Entwicklung der Medusen. Prague und Leipzig, pp. 1-96.

Claus, C., (1891). - Ueber die Entwicklung des Scyphostoma von Cotylorhiza, Aurelia und Chrysaora, Savie über die Systematische Stellung der Scyphomedusen. Arb. Zool. Inst. Univ. Wien, 9, 85-128.

Cleland, J.B. and Southcott, R.V., (1965). - Injuries to man from marine inverterbrates in the Australian region. National Health and Medical Research Council, Spec. Rep. Ser., 2, 282 p.

Custance, D.R.N., (1964). - Light as an inhibitor of strobilation in Aurelia aurita. Nature, Lond., 204, 1219-1220.

Delap, M.J., (1901). - Notes on the rearing of *Chrysaora isosceles* in an aquarium. *Ir. Nat.*, *10*, 25-28.

Delap, M.J., (1907). - Notes on the rearing, in an aquarium of *Aurelia aurita* L. and *Pelagia perla* (Slabber). *Rep. Sea Inld. Fish. Ire.* (1905), pt II, Sci. Invest. 160-164.

Derbes, A., (1850). - Note sur les organes reproducteurs et l'embryogénie de *Cyanea chrysaora*. *Annls. Sci. nat.* *sér. 3*, *13*, 377-382.

Franqueville, C., (1971). - Macroplancton profond (Invertébrés) de la Méditerranée nord-occidentale. *Téthys*, *3*, 1, 11-56.

Graeffe, E., (1884). - Ueber der Seethierfauna des Golfes von Triest Notizen über Vorkommen, Lebensweise, Erscheinungs - und Fortpflanzungszeit der Einzelnen Arten. *Arb. Zool. Inst. Univ. Wien*, *5*, 333-362.

Haeckel, E., (1880). - *System der Acraspeden. Zweite Hälfte des Systems der Medusen*, pp. 361-672. Jena.

Haefelfinger, H.R., (1975). - In: *Le Monde Animal*, T.1 pp. 215-225, Zurich, Stauffacher Ed.

Hagmeier, A., (1933). - *Die Züchtung Verschiedener Wirbbelloser Meerestiere. Abderhalden's Handbuch der biologischen Arbeitsmethoden*. Abt. IX, Teil 5, 465-598.

Halstead, B.W., (1978). - *Poisonous and venomous marine animals of the world*. Princeton, N.J., Darwin Press.

Hartlaub, C., (1913). - Craspedote Medusen. Teil I. Lief *3*. Tiaridae. *Nord. Plankt.*, Lief *17*, XII, 237-263.

Kato, K., Aochi, M. and Ozato, K., (1973). - Developmental aspects of strobilation in *Aurelia aurita*. *Pub. Seto·Mar. Biol. Lab.*, *20*, 179-194.

Korn, H., (1966). - Zur ontogenetischen Differenzierung der Coelenteratengewebe (Polypstadium) under besonderer Berücksichtigung der Nervensystems. *Z. Morph. Okol. Tiere*, Berlin, *57*, 1-118.

Kramp, P.L., (1924). - Medusae. *Rep. Dan. Oceanogr. Exp. 1908 - 1910*. Mediterranean and adjacent seas, *2*, Biology, H 1. pp. 1-67.

Kramp, P.L., (1937). - Polypdyr (Coelenterata) II. Gopler. *Danm. Fauna*, *43*, 1-223.

Kramp, P.L., (1959). - Medusae. Mainly from the west coast of Africa. *Expedit. océanogr. Belge eaux côtières afric. Atlant. sud. Rés. sci.*, *3*, 6, 33 p.

Kramp, P.L., (1961). - Synopsis of the Medusae of the world. *J. Mar. Biol. Assoc. U.K.*, *40*, 1-469.

Kramp, P.L., (1965). - Some Medusae (mainly Scyphomedusae) from Australian coastal waters. *Trans. R. Soc. S. Aust.*, *89*, 257-278.

Kramp, P.L., (1968). - The Scyphomedusae collected by the Galathea Expedition 1950 - 1952. *Vidensk. medd. dansk naturh. Foren.*, *131*, pp. 67-98.

Krohn, A., (1855). - Ueber die frühesten Entwicklungsstufen der *Pelagia noctiluca*. *Arch. Anat. Physiol.*, pp. 491-497.

Lebour, M.V., (1923). - The food of plankton organisms. II. *J. Mar. Biol. Assoc. U.K.*, *13*, 70-92.

Le Danois, E., (1913). - Coelentérés du plankton recueillis pendant la croisière d'été 1913 par le yacht *Pourquoi-Pas?*. *Bull. Soc. Zool. Fr.*, *38*, 282-288.

Lo Bianco, S., (1888). - Notizie biologiche riguardanti specialmente il periodo di maturita sessuele degli animali del golfo di Napoli. *Mitt. Zool. Stn. Neapel*, *8*, 385-440.

Lo Bianco, S., (1903). - Le pesche abissali eseguite da F.A. Krupp col Yacht "Puritan" nelle adiacenze di Capri ed in altre localita del Mediterraneo. *Mitt. zool. Stn. Neapel*, *16*, 109-278.

Loomis, W.F., (1961). - In: *The Biology of Hydra*, Univ. Miami Press. Ed. H.M. Lenhoff & W.F. Loomis. pp. 335-336.

Maaden, H. Van der, (1942). - Beobachtungen über Medusen am Strande von Katwijk aan Zee (Holland) in den Jahren 1933 - 1937. *Archs. néerl. Zool.*, *6*, 347-362.

Maaden, H. Van der (1959). - Notes on *Aurelia aurita* (L.) Lamarck and *Cassiopea andromeda* Eschscholtz from the Gulf of Aqaba. *Bull. Sea Fish. Res. Sta., Haifa*, *20*, 12, 5-10.

Mayer, A.G., (1914). - The effects of temperature upon tropical marine animals. *Publs. Carnegie Instn.*, *183*, 1-24.

Minchin, E.A., (1889). - Note on the mode of attachment of the embryos to the oral arms of *Aurelia aurita*. *Proc. Zool. Soc. London*, *59*, 583-585.

Mitchell, J.H., (1962). - Eye injuries due to jellyfish (*Cyanea annaskala*). *Med. J. Aust.*, *3*, 303-305.

Plessis, Y., (1958). - Quelques observations sur le cycle de Méduses acalèphes. *Bull. Mus. Hist. Nat.*, 2ème sér., *30*, 4, 379-386.

Richet, C. and Portier, P.,(1936). - Recherches sur les toxines des Coelentérés et les phénomènes d'anaphylaxie. *Résult. Camp. Sci. Prince Albert ler, Monaco*, *95*. 22 p.

Russell, F.S., (1970). - *The Medusae of the British Isles*. Vol. II. *Pelagic Scyphozoa*. Cambridge University Press.

Schaeffer, J.G., (1921). - Untersuchungen an Medusen. I. Teil. *Pflügers Arch. ges. Physiol.*, *188*, 49-59.

Siebold, C.T. Von, (1839). - *Beiträge zur Naturgeschichte der Wirbellosen Thiere.* *Ueber Medusa, Cyclops, Loligo, Gregarina und Xenos*. 94 p.

Spangenberg, D.B., (1968). - Recent studies of strobilation in jellyfish. *Oceanogr. Mar. Biol.*, *6*, 231-247.

Sugiura, Y., (1965). - On the life history of rhizostome medusae. III. On the effects of temperature on the strobilatin of *Mastigas papua*. *Biol. Bull, Mar. Biol. Lab. Woods Hole*, *128*, 493-496.

Tcheou-Tai-Chun, (1930). - Le cycle évolutif du Scyphistome de *Chrysaora*: étude histophysiologique. *Trav. Sta. Biol. Roscoff*, *8*, 1-179.

Teissier, G.,(1929). - La croissance embryonnaire de *Chrysaora hysoscella* (L.). *Arch. Zool. exp. gén.*, *69*, 2, 137-178.

Thiel, H., (1962). - Untersuchungen über di Strobilisation von *Aurelia aurita* (L.) Lam. an einer Population der Kieler Förde. *Kieler Meeresforsch.*, *18*, 198-230.

Thiel, M.E., (1959a). - Beiträge zur Kenntnis der Wachstums-und Fortpflanzungs - Verhältnisse von *Aurelia aurita* L. *Abhandl. Verh. Naturw. Ver. Hamburg*. N.F. *3*, 13-26.

Thiel, M.E., (1959b). - Scyphomedusae, Semaeostomae, Physiologie. *Bronn's Kl. Ordn. Tierreichs*, *2*, Abt II, Buch 2, Lief 6, 840-1072.

Thiel, M.E.,(1960). - Beobachtungen über Wachstum, Variationen und Abnormitäten bei *Cyanea capillata* der Ostsee. *Abhandl. Verh. naturw. Ver. Hamburg*, N.F. 4, 89-108.

Uchida, T.,(1954). - Distribution of Scyphomedusae in Japanese and its adjacent waters. *J. Fac. Sci. Hokkaido Univ.*, Ser. VI, (Zool.), *12*, 209-219.

Verwey, J.,(1942). - Die Periodizität im Auftreten und die activen und passiven Bewegungen der Quallen. *Archs. néerl. Zool.* *6*, 4, 363-468.

Widersten, B., (1965). - Genital organs and fertilization in some *Scyphozoa.* *Zool. Bidr. Uppsala*, *37*, 1, 45-61.

Widersten, B., (1968). - On the morphology and development in some Cnidarian larvae. *Zool. Bidr. Uppsala*, *37*, 2, 139-179.

Yasuda, T., (1974). - Ecological studies on the jellyfish *Aurelia aurita* L. in Urazoko Bay, Fukui Prefecture. X - Diel vertical migration of the Medusa in summer 1970. *Bull. Jap. Soc. Sci. Fish.*, *40*, 10, 971-975.

Yasuda, T., (1975). - Ecological studies on the jellyfish *Aurelia aurita* L. in Urazoko Bay, Fukui Prefecture. XI - An observation on Ephyra formation. *Publ. Seto Mar. Biol. Lab.*, *22*, 1/4, 75-80.

ANALYSIS OF TRACE METALS IN JELLYFISH BY XRF

by

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Abstract

X-ray emission spectroscopy was used for analysis of trace elements in the jellyfish Pelagia noctiluca. Mean values of concentrations for 14 elements with the minimum detection limits of several ppm for most elements were determined.

Introduction

Elemental composition of scyphomedusae (jellyfish) can be of great interest in the search for a successful method of preventing their spreading. X-ray emission spectroscopy enables fast and simultaneous detection of all elements in the sample with atomic number above 15; further, it is non-destructive and the necessary sample mass can be of the order of 1 mg. The method was used for analysis of a species of scyphomedusae common in the Adriatic Sea, Pelagia noctiluca.

Sample preparation

Scyphomedusae Pelagia noctiluca were caught near Rovinj, in the Northern Adriatic. They were dried, ground and sent to our laboratory in a plastic box.

Grains were inhomogeneous in size and colour, so they were powdered to dust in ceramic plates. After drying, the tissue was put into clean polyethene phials and dissolved in redistilled nitric acid (5 mg of dry tissue in 100 μl of one-molar HNO_3). Dissolving continued at room temperature for 48 hours.

Twenty microlitres of solution from each phial was put on mylar foil stretched on a plastic holder. The rest of the solution from each phial (80 μl) was mixed with 20 μl of nickel chloride (6 mg Ni/ml) so that the final Ni concentration was about 2000 ppm in total weight. Nickel was chosen for the internal standard because of its low concentration in tissue. Targets were prepared in the same way as before.

Irradiation

Samples were put in a vacuum chamber and irradiated with photons obtained from an X-ray tube with Mo anode. Working conditions for Philips roentgen apparatus were 26 kV, 22 mA, with X-ray beam passing through Zr and Mo filters to reduce its intensity. The Si(Li) detector used enabled detection of K_a characteristic lines of all elements with atomic numbers between 15 and 39 and L characteristic lines of all heavier elements. All characteristic lines are detected simultaneously with detector and multichannel analysing system. Irradiation time was 2^{11}s.

Results

One of the spectra obtained from irradiation of a prepared target of scyphomedusae is shown in the figure. The same elements were observed on all spectra with few variations in intensities of their characteristic lines.

Elemental concentrations were determined from intensities of their characteristic X-ray lines obtained by the computer program. Targets were thin (less than 10^{-3} g/cm^2) and the absorption effects can be neglected. Therefore concentrations are calculated from the relation

$$C_i = \frac{I_i}{\varepsilon_i} \frac{\varepsilon_{Ni}}{I_{Ni}} C_{Ni}$$

where I denotes intensities and relative efficiences for i-th element and nickel, respectively.

The table shows values of concentrations for 14 detected elements obtained from five separate measurements, their mean statistical errors, mean values and relative standard deviation.

Conclusion

An energy-dispervise X-ray system was used for determination of concentrations of the following 14 elements in jellyfish: S, Cl, K, Ca, Cr, Mn, Fe, Cu, Zn, As, Se, Br, Rb and Sr. It would be of interest to analyse sea-water simultaneously. In future investigations we propose to cultivate jellyfish in a controlled medium in varied physical and chemical conditions. A complete picture of correlations of elemental concentrations in jellyfish and its medium would thus be obtained.

Acknowledgement

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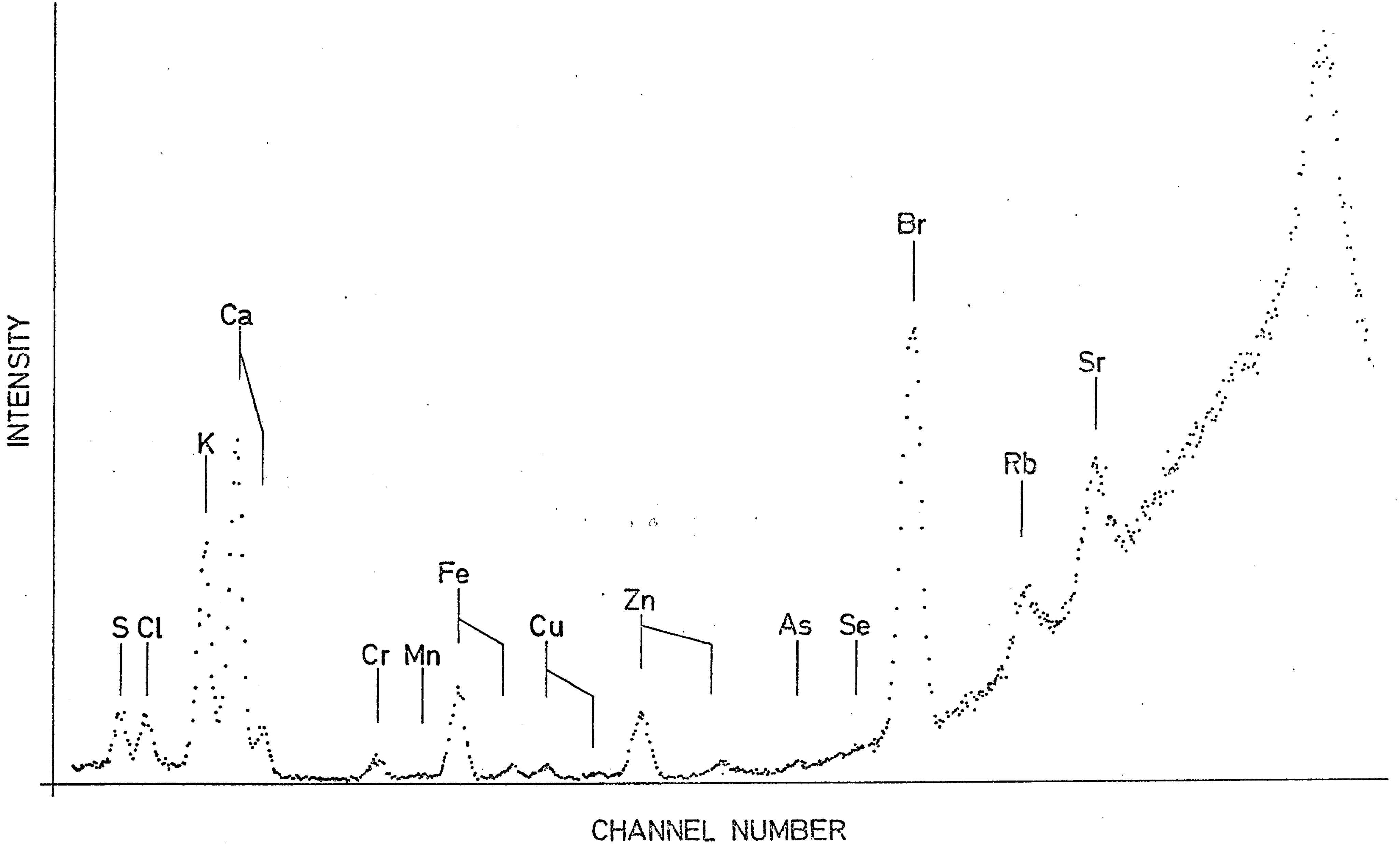
References

Bowen, J.H.M., (1966). - Trace Elements in Biochemistry, New York and London Academic Press.

Valkovic, V., (1980). - Analysis of Biological Material for Trace Elements Using X-ray Spectroscopy, Boca Raton, Florida, CRC Press.

Concentration in dry matter (ppm)

Target No.	S	Cl	K	Ca	Cr	Mn	Fe	Cu	Zn	As	Se	Br	Rb	Sr
1	10 202	8 676	20 765	11 974	-	21	146	9	53	9	177	1 080	130	98
2	10 117	9 003	20 387	20 200	16	15	242	5	29	7	180	1 188	146	110
3	9 428	7 839	20 250	12 078	-	13	143	15	64	7	182	1 070	132	116
4	10 589	7 473	27 200	12 262	44	12	262	40	37	17	-	1 050	131	200
5	8 035	5 500	19 691	16 205	32	7	133	5	76	5	-	844	98	214
Mean statistical error (%)	5.0	4.5	3.0	2.5	30.0	35.0	6.5	6.5	3.5	30.0	3.0	1.0	9.0	5.8
Mean value (ppm)	9 674	7 698	21 659	14 544	31	14	185	15	52	9	180	1 040	127	148
Standard deviation (%)	10	18	14	25	46	37	33	99	37	52	1.4	12	14	37



XRF spectrum of Pelagia noctiluca

SOME CAUSES OF THE BLOOMS AND UNUSUAL DISTRIBUTION OF THE JELLYFISH *Pelagia noctiluca* IN THE MEDITERRANEAN (ADRIATIC)

by

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Summary

Some causes of the blooms and unusual distribution of the jellyfish *Pelagia noctiluca*, since 1977, in correlation with hydrography changes in the region are discussed.

For the last 50 years the jellyfish *Pelagia noctiluca* have apparently been relatively uncommon along the northern and central Adriatic coasts. Rottini-Sandrini (1982) wrote that "for the first time in 1977-1980 many swarms of *Pelagia noctiluca* have been noticed in the northern Adriatic with maximum intensity along the coast of Istria and in the Gulf of Trieste from April - May to October - November". Previous records in the North Adriatic are scattered but include findings near Trieste (Neppi, 1922), along the Istrian coast near the island of Brioni, in summer 1913 (Stiasny, 1921) and south near Senj in July, 1895 (Babic, 1913). The most detailed information for the whole Adriatic and especially for the central part or south Dalmatia came from Babic (1913). He noted that *Pelagia noctiluca* was a species of the deep sea, found often only in deep Adriatic pits. He observed many in June 1910 and May 1911 after periods of southerly winds in the waters surrounding the island of Vis.

After the above findings in the period from 1895 to 1914, *Pelagia* was not mentioned in any paper on plankton until 1977. Since 1977 enormous quantities of adults have been seen from Otranto up to the Bay of Trieste as well as young stages - especially from May to September (Malej, 1982; Rottini-Sandrini, 1982; Vucetic, 1982; Rottini-Sandrini and Vucetic, 1983).

The appearance of *Pelagia noctiluca* in the Adriatic in earlier years (before 1977) never presented a problem to the human population. During the 1900-1920 period, bathing in the sea was probably less popular and bathers were more protected by clothing. However the absence of any earlier mention of stinging may indicate that: a) the medusae did not appear in such dense swarms, b) medusae have become more "stinging", or c) humans have become more sensitive. Answers to the questions: are we seeing a) fluctuations in the distribution or b) fluctuations in the population density are perhaps the key to understanding this phenomenon.

The irregular appearance of *Pelagia* in the Adriatic has been repeated along the other coastal areas of the Mediterranean and the Atlantic. In connection with this we have tried to answer the following questions. Where is this species permanently present? Does it show strong periodic fluctuations in its "autochthonous" or "native" place? Does it regularly respond to some cyclic fluctuations in the environment (hydrographic or biological) or some intrinsic (physiological) factor?

Comparing all density data reviewed for Pelagia the "native" zone or "autochthonous" place for this species in the Atlantic may be around the Azores (Vucetic, 1982). This region appears to be an area under the influence of Meditteranean-type water with higher salinity and temperature than in other parts of the Atlantic (Wüst, 1978). From this "native" zone Pelagia may spread to the north (and south) and the fluctuations in dynamics of these water masses reflect both the distribution of the species and its population density.

High population densities may result from enhanced reproduction in the "native" place before transport to the north, or from increases in population density after transport to these northern areas. The second hypothesis is that after arriving in the north, at an interface area between unfavourable northern water conditions and the favourable southern waters, Pelagia, after undergoing one kind of "stress" invests much energy in reproductive cells in response to reduced salinity and other linked conditions in the area adjoining the polluted coastal water.

In the Mediterranean Sea there is probably a permanent "native" place over deep water (Broch, 1933) off the east coast of Sicily taking in the complete south Sicilian sea around the Pelagian islands. Some nuclei may also exist in the Tyrrhenian and the Ionian Seas (Piccinetti, in press). Since there have been no systematic surveys of zooplankton in this area, it is difficult to speak about fluctuations in population density for this "native" area except by quoting personal communications by fishermen in Catania, Siracusa and data for the Maltese islands, (Axiak, in press).

The "intermediate Levantine" water circulation must play a very important role in the distribution of this species in the central part of the Mediterranean and Adriatic (Vucetic, 1983; Axiak, in press) and perhaps the Atlantic surface current too.

Is it possible that the deep or "intermediate Mediterranean" waters carry adult medusae to the Atlantic (through the Strait of Gibraltar) and that with the surface inflow of Atlantic waters the ephyrae stages return to the Mediterranean, as Pelagia were often registered around the Balearic Islands (Kramp, 1924; Vives, personal communication)? According to Goy (1983) this cannot be possible since neither young nor adult Pelagia have been found in the Strait of Gibraltar. The stronger fluctuations have in many cases been registered in the North Atlantic, North Sea, Golfe du Lion, Bay of Naples, North Adriatic, where they are not permanently present. These fluctuations may be connected with movements of water masses (Le Danois, 1934; Taylor-Stephens, 1980), sea surface temperature (SST) changes (Fieux, 1979; figure I a, b), water quality changes, (Cushing, 1982) or some cyclical phenomenon (Le Danois, 1934; Russell, 1967; Buljan, 1953; Southward et al., 1975).

Reviewing the Mediterranean hydrographic data for the period of Franqueville's (1971) findings of Pelagia near Marseilles, they arrived during an upwelling of the intermediate Levantine water, which was especially noticeable in spring to late autumn in 1969 (figure V in Sankey, 1973). Bougis (1968) reviewed hydrographic data at Villefranche and was inclined to doubt the "upwelling" and preferred to call this "une hypothèse de travail".

It is worth paying attention to the fact the Pelagia was found in abundance in April 1911 by the R/V Pangan in the Ionian Sea (Kramp, 1924) and later in May in the Central Adriatic by Babic (1913) and that was in the period of stronger "ingression" of the Mediterranean water in the Adriatic (Buljan, 1976), (figure II a, b).

Since many data have been published on the biological response to environmental changes (cycles, periodicity, etc.) for the Adriatic ecosystem particularly in relation to the hydrographic characteristics of this almost land-locked sea, we have tried to explain the distribution of Pelagia in relation to these fluctuations in the distribution of water masses (Vucetic, 1982, 1983).

In the advection years there is an "ingression" to the north in winter of warmer (14°-15°C) and saltier (up to 38.9°/oo) partly Mediterranean water with intermediate and surface water. This influx was especially strong in 1876, 1910-1914, 1930, 1939, 1948-1949, 1968-1969, 1976-1977. During the years 1911 to 1914 the maximum winter temperature in the South Adriatic Pit was to be found near the surface or even on (figure III) the surface itself (Buljan, 1957). These conditions may have allowed Pelagia to be active rather than sink to the bottom with the cooled (10°-11°C) water in the winter as they do in years without ingression. In these warmer upper layers (14°C) they can continue their biological cycles as Rottini-Sandrini (1982) has shown experimentally.

Before the recent ingression of Pelagia (1977 onwards) it had been generally absent from the North Adriatic since the advection period 1895 - 1914. Because the recent invasion was associated with the abnormal presence of high saline water in winter, (as in 1914), the presence of the animal may indicate differences in water transport at long intervals of time.

It may well be that the invasion of Pelagia into the Adriatic reflects the long-term periodicities that occur in marine ecosystems. Ottested (1942, 1960) has shown that the variations in cod catches at Lofoten may reflect long-term periodicities. If such periodicities in abundance of Pelagia were real, there would be no need to attribute its appearance in the Adriatic to local pollution. Other evidence of influxes into the Adriatic are: the occurrence of rare fish and cephalopods from the open Mediterranean, and some movements of organisms from the South to the North Adriatic. This ingression is also manifested by a general increase in productivity of the sea and resulting "good" fishery years.

Inflow in the deep southern Adriatic is continuous but there are large differences from year to year in the intensity of the advection; sometimes southern waters of high salinity can be detected in the most northern waters of the Adriatic.

These findings in the Adriatic are similar to conditions in Mediterranean coastal areas (Majorca, Golfe du Lion, Naples, Messina). Both probably depend on changes in water mass dynamics due to the distribution of "deep" intermediate Levantine water (Fieux, 1979; Lacombe, 1981; Garzolli and Maillard, 1977.

After 1966, in the Atlantic, climatic changes may have brought about different water mass dynamics, manifested in particular by the "reversed Russell cycles" in the North Sea (Cushing, 1982; Southward, 1975, 1980; Taylor, 1980). The strong influences of the ingression of southern waters from the Central to the North Atlantic brought Pelagia to the North Atlantic and to the North Sea.

The high population densities may be produced by unsuitable hydrography at the place of arrival or by confrontation with "frontier" coastal water of reduced salinity and increased toxicants. The potential effects of an increase in pollutants have been shown experimentally (Stebbing, 1981 a, b). Stebbing found in a hydroid that gonozoid frequency increased as a response to reduced salinity and other unfavourable changes in the water chemistry and resulting hormesis - stimulation of colony growth by copper, cadmium and other toxicants. In the case of Pelagia, differences in water mass quality may result in a great population density of Pelagia on the "boundary" between two different water bodies. Perhaps this "boundary" could also be called the "frontier" of lower salinity and polluted coastal water.

The increased abundance and the unusual swarming of Pelagia cannot be related to a decrease in numbers of predators. The sudden increase in the catch of tunny fish (figure IV) in the Adriatic and Mediterranean recorded from 1976 onwards seems to coincide with the unusual occurrence of large swarms of Pelagia. However, the maximum catch in the Mediterranean was recorded in 1976 and in the Adriatic in 1978.

All the above explanations do not exclude the one per cent of "new" distributions of different species in the sea including Pelagia. The incidence of such increases in distribution may perhaps be facilitated by the rapidly growing merchant fleet with greater volumes of ballast water which can cause a dissemination of pelagic species, wherever that ballast is discharged.

Conclusions

Fluctuations in the distribution and the population densities of Pelagia have been shown to appear at the same time as the long-term environmental changes in water mass dynamics especially those of the "reversed Russell cycles" in the Atlantic and the intermediate Levantine water in the central Mediterranean and the Adriatic.

Observations here show promise for the prediction of population fluctuations and suggest the relevance of previously proposed periodicity in the ecosystem such as that put foward by Le Danois (1934) regarding Atlantic water "transgressions" and compared by Buljan (1953) with the "ingression" or influx of Levantine intermediate water in the Adriatic.

The greater prevalence of Pelagia seems to have begun in the Atlantic in 1966, in the Mediterranean in 1969 and in the Adriatic in 1977. These dates are significant in the reversal of the Russell cycle in the Atlantic (Cushing, 1982; Southward, 1980).

The changes in population distribution and density of Pelagia could be called natural fluctuations produced by planetary or climatic changes, but it is somewhat unlikely that the anthropogenic influence of sea pollution may also be a contributing factor because the animals appeared earlier in the century. These changes may be observed only in "frontier" zones where Pelagia, arriving from their native place, meet coastal, less salty and polluted water; and by "hormesis" of Pelagia under new conditions which stimulate colony growth and increase reproduction, as Stebbing (1981) found with hydroids.

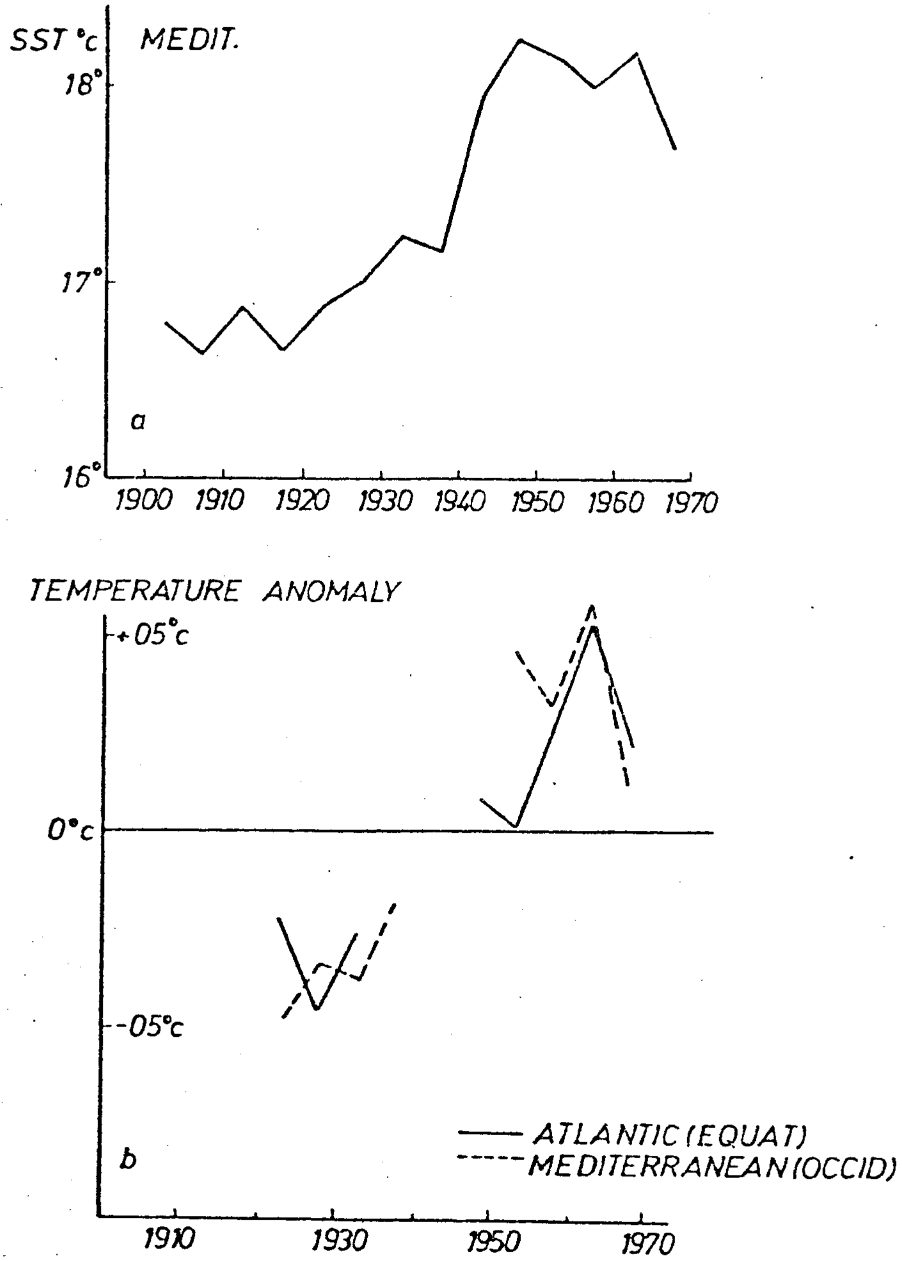

Figure I. Long-term sea surface temperature changes in the Mediterranean 1900 - 1970 (a) and (b) temperature anomaly in west Mediterranean and Central Atlantic (Fieux et al., 1979)

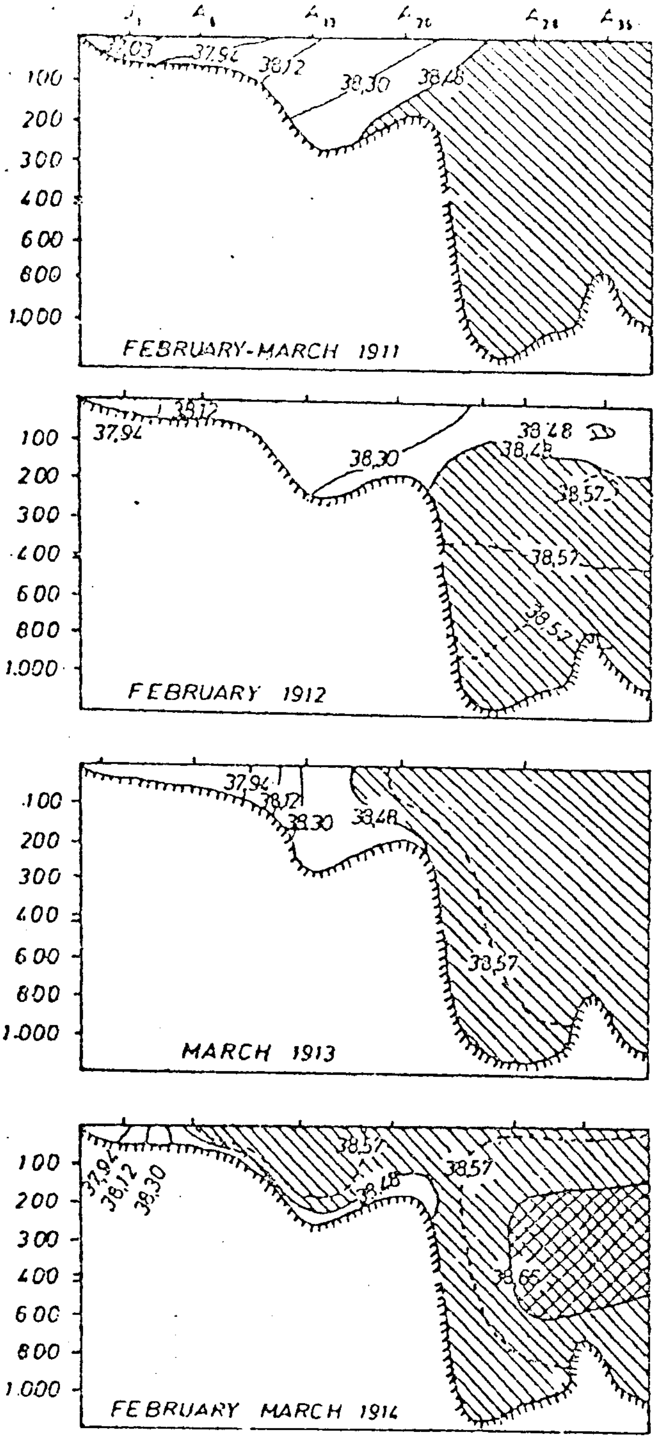

Figure IIa. Increase of salinity (°/oo) in the Adriatic during the ingression period 1911-1914 (Buljan, 1953)

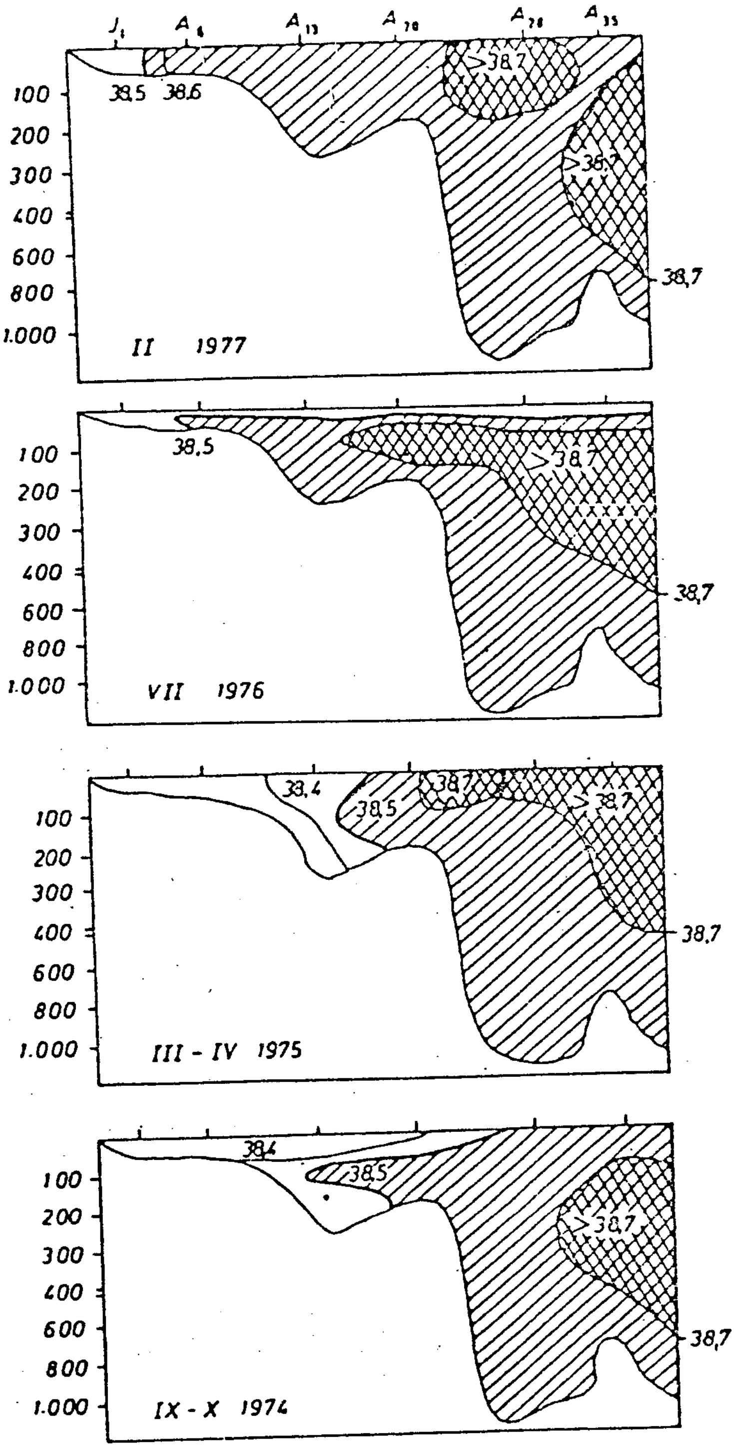

Figure IIb. Salt water advection to the northern Adriatic in the surface layer in the 1974-1977 period

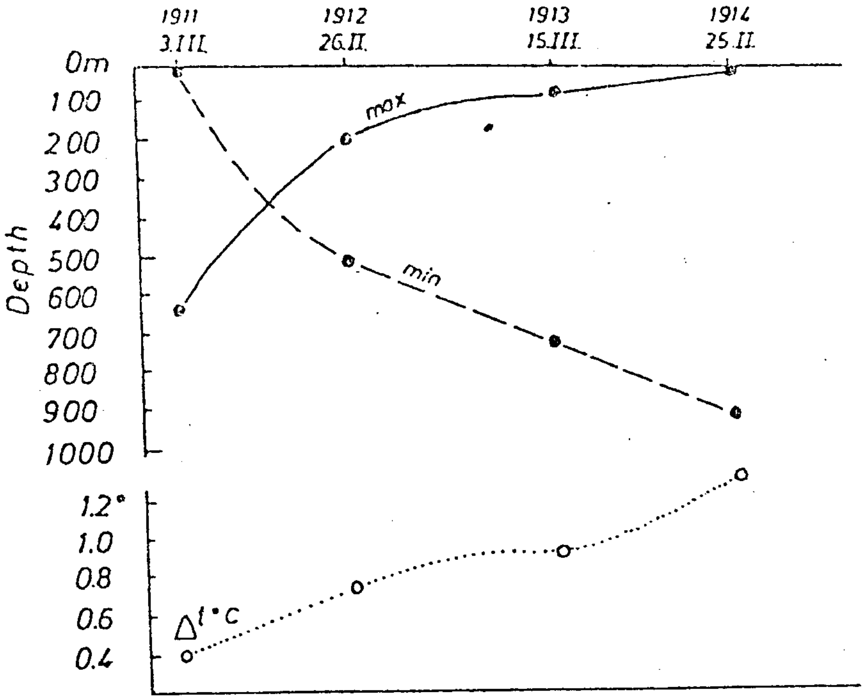

Figure III. During the ingression period changes in the winter position of the maximal (----) and minimal (- - -) temperature in the South Adriatic Pit, and fluctuation of the difference (....) between maximum and minimum water temperature (Buljan, 1957)

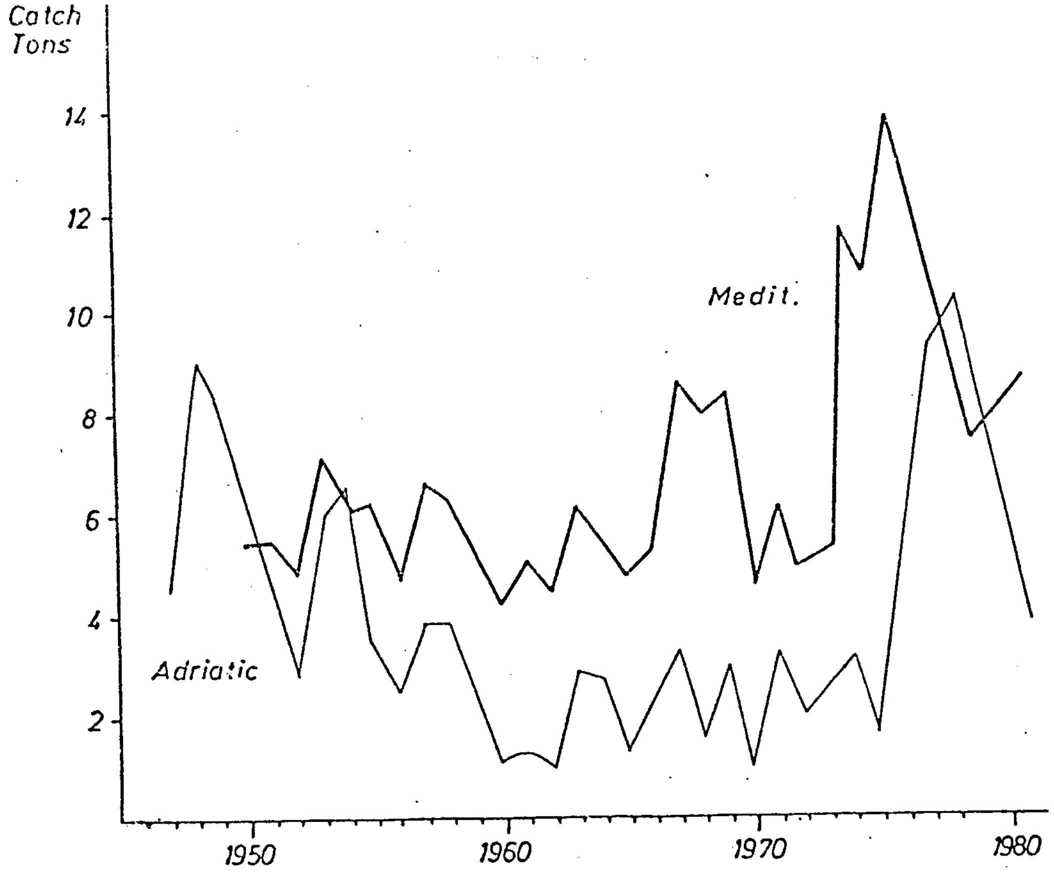

Figure IV. Catch of tunny fish in the Mediterranean and Adriatic

References

Axiak, V., (in press). - A brief note on the occurrence of Pelagia noctiluca around the Maltese islands.

Babic, K., (1913). - Planktonicki celenterati iz Jadranskog mora. "Rad", JAZU, 100, 186-202.

Buljan, M. and Zore-Armanda, M., (1976). - Oceanographical properties of the Adriatic Sea. Oceanogr. Mar. Biol. Ann. Rev., 14, 98 p.

Bougis, P., (1968). - Le problème des remontées d'eaux profondes à Villefranche -sur-mer. Cah. Oceanogr., XX/7, 597-603.

Broch, H., (1933). - Scyphomedusae. Michael Sars, N. Atlantic Deep-Sea. Exp. 1910, 3, 20 p.

Cushing, D., (1982). - Climate and Fisheries. Acad. Press. 339 pp.

Fieux, M., Garzoli, S. and Gonella, J., (1979). - Résultats préliminaries d'une étude statistique sur des paramètres climatiques en Méditerranée occidentale. Rapp. P.-v Reun., C.I.E.S.M., 25/26, 7, 37-45.

Franqueville, C., (1971). - Macroplancton profonde (invertébrés de la Méditerranée Nord-occidentale. Théthys, 3/1, 11-56.

Garzoli, S. and Maillard, C., (1977). - Hydrologie et circulation hivernales dans les canaux de Sicile et de Sardaigne. Rapp. Inter. Lab. Ocean. Physique du Museum, Paris, (unpubl. doc.).

Goy, J., (1983). - Les hydroméduses dans les parages du détroit de Gibraltar. Rapp. Comm. int. Mer Médit., 28/9, 133-134.

Kramp, P.L., (1924). - Medusae. Rap. Danish. Oceanogr. Exped. Medit., 2, Biol. M.I. 67 p.

Le Danois, E., (1934). - Les transgressions océaniques. Rev. des Trav. Off. Pêches Marit., 7/4, 28.

Lacombe, H., Gascard, J.C., Gonella, J. and Bethoux, J.P., (1981). - Response of the Mediterranean to the water and energy fluxes across its surface on seasonal and interannual scales. Oceanol. Acta., 4/2, 247-225.

Malej, A., (1982 b). - Some notes on the biology of Pelagia noctiluca in the Gulf of Trieste. Acta Adri., 23 (1/2), 97-102.

Maretic, Z., Russell, F.E. and Ladavec, J., (1980). - Epidemic of stings by the jellyfish Pelagia noctiluca in the Adriatic. In: Eaher, D. and Wonströn, T. Natural toxins, New York, Pergamon Press, p. 77.

Neppi, V., (1922). - Meduse adriatiche. Mem. R. Comit. Talass. Italiano, 101, 31 p.

Ottestad, P., (1942). - On periodical variations in the yield of the great sea fisheries and the possibility of establishing yield prognoses. Fisherdirekt. Skrift., 7/5.

Piccinetti Manfrin, G. et Piccinetti, C., (sous presse). - Distribution de Pelagia noctiluca en Méditerranée dans l'été 1983.

Rottini-Sandrini, L., (1982). - Effect of water temperature on the motility of Pelagia noctiluca (Forskal). Experimentia, 38, 453-454.

Rottini-Sandrini, L. and Stravisi, F., (1982). - The occurrence of Pelagia noctiluca in the Gulf of Trieste and its correlation with the wind distribution. Acta Adri., 23 (1/2), 103-104.

Rottini-Sandrini, L. et Vucetic, T., (1983). - Données nouvelles sur la présence de planulae et éphyre de Pelagia noctiluca en Adriatique. Rapp. Comm. int. Mer Médit., 28/9, 127.

Russell, F.S., (1970). - The Medusae of the British Isles. II Pelagic scyphozoa Cambridge, (Univ. Press.), 283 p.

Sankey, T., (1973). - The formation of deep water in the north Mediterranean. Progr. in Oceanogr., 6/5, 159-179.

Southward, A.J.,(1980). - The Western English Channel an inconstant ecosystem? Nature, (Lond.), 285, 361-366.

Stebbing, A.R.D., (1981 a). - The effect of reduced salinity on colonial growth and membership in a hydroid. J. Exp. Mar. Biol. Ecol., 55, 233-241.

Stebbing, A.R.D.,(1981).- Hormesis-stimulation of colony growth in Campanularia flexoosa (Hydrozoa) by copper, cadmium, and other toxicants. Aqutic Toxicology, 1, 227-238. Elsevier/ North-Holland Biomed. Press.

Steuer, A., (1902). - Beobachtungen über des Plankton des Trieste golfes im Jahre 1901. Zool. Anz. 25, 671, 371-372.

Stiasny, G., (1921). - Mittheilunger über Scyphomedusen. I Zool. Meded. 6, 109-113.

Vucetic, T., (1970). - Les principales masses d'eau en Adriatique et leur influence sur les communautés pélagiques. Journées Etud. Planctonol., Monaco, C.I.E.S.M., 105-114.

Vucetic, T., (1973). - Zooplankton and the circulation pattern of the water masses in the Adriatic Sea. Neth. J. Sea Res., 7, 112-121.

Vucetic, T.,(1982). - Influence of the water masses dynamic on the distribution of the Pelagia noctiluca in the Adriatic. Acta Adri., 23 (1/2), 105-115.

Vucetic, T., (1983). - Fluctuation in the distribution of Pelagia noctiluca (Forskal) in the Adriatic. Actes 17^{e} Symposium EMBS in Brest 1982. Oceanolog. Acta (in press).

Vucetic, T. et Rottini-Sandrini, L., (1982). - Les hypothèses sur la cause possible de la présence exceptionelle de la méduse Pelagia noctiluca depuis 1977 en Adriatique. Rapp. Comm. int. Mer Médit., 28, 131-132.

Wüst, G., (1978). - The stratosphere of the Atlantic ocean. Sc. Res. Germ. Exp. r/v. Meteor, 1925 - 1927, 6/1, 112 p.

Zore-Armanda, M., (1968). - The system of currents in the Adriatic Sea. Stud. Rev. Gen. Fish. Counc. Mediterr.,-34, 48 p.

UNEP, (1983). - Changes in the distribution and size of the population of Pelagia noctiluca in the Mediterranean. UNEP, (in press).

SESSION II b

ASSESSMENT OF ENVIRONMENTAL CONDITIONS LEADING TO JELLYFISH BLOOMS

EVALUATION DES CONDITIONS DU MILIEU ENTRAINANT DES PROLIFERATIONS ANORMALES DE MEDUSES

METEOCLIMATIC INFLUENCE ON THE BLOOMS OF *Pelagia noctiluca* IN THE NORTHERN ADRIATIC

by

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Abstract

Climatic data of wind frequency and sea-water temperature at Trieste since 1931 have been considered, together with seasonal data on the presence of *Pelagia noctiluca* in the Gulf of Trieste since their appearance in 1977. The winter sea-water temperature is found to be a limiting factor for the survival of *Pelagia*: a 50 per cent mortality can be expected at 7°C. Vice versa, the first arrival of *Pelagia noctiluca* in the northern Adriatic, under highly favourable wind and therefore marine current conditions, followed a 14 year period of warm winter sea-water temperatures.

Introduction

A correct approach to the solution of the problem represented by jellyfish blooms in the sea must necessarily take into account all the possible interactions between these animals, the other organisms and the environment.

Climatic and meteorological conditions, physical and chemical characteristics of sea-water must in particular play some role, at least at some point, perhaps small but effective, in the whole chain. The global understanding of so many different processes represents a stimulating goal for marine biologists and oceanographers; the proper use of numerical models could be convenient to this end.

In recent years (from about 1975) the abundance of *Pelagia noctiluca* in particular began to increase in the Mediterranean Sea; after that time, swarming of this jellyfish occurred here and there, the planktonic organisms behaving like lagrangians driven by the mean surface circulation and by wind currents. An unusual increase in southerly winds, for example, contributed to the arrival of *Pelagia noctiluca* in the northern Adriatic in 1977 (Rottini *et al.*, 1980, 1981, 1982).

In order to gain more insight into the possible correlations between meteoclimatic parameters and the presence of *Pelagia noctiluca*, data collected in the Gulf of Trieste (northern Adriatic) in the last fifty years are considered.

This particular area has been selected since continuous meteorological data have been collected here by the Istituto Talassografico (IT) (C.N.R.) since the 1st century; furthermore, the Gulf of Trieste is small enough for the global abundance there of *Pelagia noctiluca* to be estimated.

Period 1976-1983

Data during this eight-year period are represented in figure I. The seasonal abundance of Pelagia noctiluca (PN), according to arbitrary units, has been estimated by Rottini-Sandrini, on the basis of many direct observations of different origin. Climatic data (Istituto Talassografico di Trieste) are given as seasonal averages as well; winter includes January, February and March, and so on. The following elements have been considered: global solar radiation on the horizontal surface, sea-water temperature at 2 m depth in the harbour of Trieste and the easterly (NE, ENE, E, ESE sectors) and southerly (SE, SSE, S, SSW) winds frequencies. These winds have been chosen because of their role in the water circulation of the northern Adriatic (Rottini et al., 1980), which will be clarified in the following context; wind frequency, instead of distance covered, has been selected because of homogeneity problems in such a long time series. Details on the data acquisition instruments and methods are reported by IT (1980). In order to show any recent change, data are referred to "normal" values: so the ratios of actual total seasonal solar radiations to the 1971-1980 averages (SR), the differences between actual seasonal sea-water temperatures and the 1951-1980 averages (ST), the ratios of seasonal E, S wind frequencies and the 1951-1980 ones (EF, SF) have been considered.

The following comments on figure 1 may be made: (i) The first appearance of Pelagia noctiluca in the Gulf of Treiste in spring 1977 followed a winter with particularly warm sea-water, aacompanied by frequent S and scarce E winds. The wind - Pelagia noctiluca abundance correlation does not of course implicate a cause - effect relation, but just represents in this case a favourable condition for advection, as pointed out by Rottini, Stravisi and Pieri (1980). The scarce solar radiation at Trieste in winter 1977 also indicates that sea-water in the Gulf did not warm locally but through advection from the south. It can therefore be stated that Pelagia noctiluca came into the Gulf of Trieste at that time following the cyclonic circumadriatic current, particularly enhanced by meteorological conditions. (ii) The Pelagia noctiluca abundance increases, on an annual average, almost linearly in the period 1977-1980; the abrupt decrease in winter 1981 is related to the low sea-water temperature in that season (7.4°C average, 5.2°C minimum). The annual total Pelagia abundance in the Gulf of Trieste grows little during 1981, 1982; this is correlated with a second cold sea-water winter temperature (8.1°C average, 7.2°C minimum) in 1982, followed by a period with less southerly winds than usual. Finally, a warm-sea winter and frequent southerlies are correlated with a large bloom of Pelagia in the Gulf in 1983.

Points (i) and (ii) above suggest a direct correlation between winter sea-water temperature and the abundance of Pelagia noctiluca. To be more specific, low water temperatures ($\lesssim 7$°C) drastically reduce the number of Pelagia in this area; this is in accordance with the laboratory experiments performed by Rottini (1981). The obvious conclusion is that, even if normal departures from usual spring-summer-autumn sea-water temperatures apparently do not greatly influence the Pelagia biological cycle, the winter average survival of this animal is, on the contrary, strongly dependent on this parameter. The northern Adriatic, and the Gulf of Trieste in particular, which is a very continental basin (Stravisi, 1983c) where cold winter water is formed (Stravisi, 1983b), can therefore be considered as a winter "sink" for Pelagia noctiluca.

Period 1931-1983

A longer period is now considered, in order to see if there is some climatic change which could explain the recent swarmings of Pelagia noctiluca. Annual data at Trieste are represented in figure II. The yearly total hours of easterly winds EF (which drive surface water out from the Gulf of Trieste) and of southerly winds SF (which increase advection from the south) clearly show, as already pointed out, a shift after 1963, culminating in 1977, just creating the most favourable conditions for the arrival of planktonic organisms in the northern Adriatic. Looking at the sea-water winter temperature ST (average and minimum values are plotted) at 2 m depth, representing the whole water column in this season (Stravisi 1983b), two main periods can be distinguished, before and after 1964. Before 1964, sea-water temperature shows irregular variations. there is only a six-year period (around 1960) with winter averages greater than 8°C and minimum temperatures greater than 6°C, followed by a very cold 1963 winter. After 1964 there are fourteen years with warm winter sea-water that lead to the Pelagia noctiluca bloom. In 1980 the abundance of these animals is so high that the cold 1981 winter can only considerably reduce their numbers. After that reduction, the number of Pelagia again starts to increase at the same rate (or higher) as in the preceding 1976-1980 period.

A linear regression shows that in the years 1951-1980 the sea-water annual mean temperature at Trieste decreased by 0.009°C per year, while the winter mean temperature increased at the rate of 0.019°C per year. The simultaneous wind shift (figure II) cannot account by itself, by advecting warm southern water, for all the winter warming observed; it should then be checked, by looking at sea-water temperature time series in other Adriatic and Mediterranean sites, if the winter warming observed at Trieste is or is not a general trend.

Conclusions

The comparison of meteoclimatic data at Trieste with the abundance of Pelagia noctiluca in that area leads to the followings conclusions: (i) The winter survival of Pelagia noctiluca is strongly influenced by the sea-water temperature. Roughly speaking, a 50 per cent mortality can be expected at 7°C. (ii) One of the environmental conditions favourable to the demographic explosion of Pelagia noctiluca is therefore a warm winter sea-water temperature, extended over a sufficiently long period of years, so that the concentration of these animals can grow from usually low up to observable values.

Further research is however necessary to find data, if any, in order to assess if winter temperature did really rise in the Mediterranean, especially in those seas which can be considered to be the areas of origin of Pelagia noctiluca.

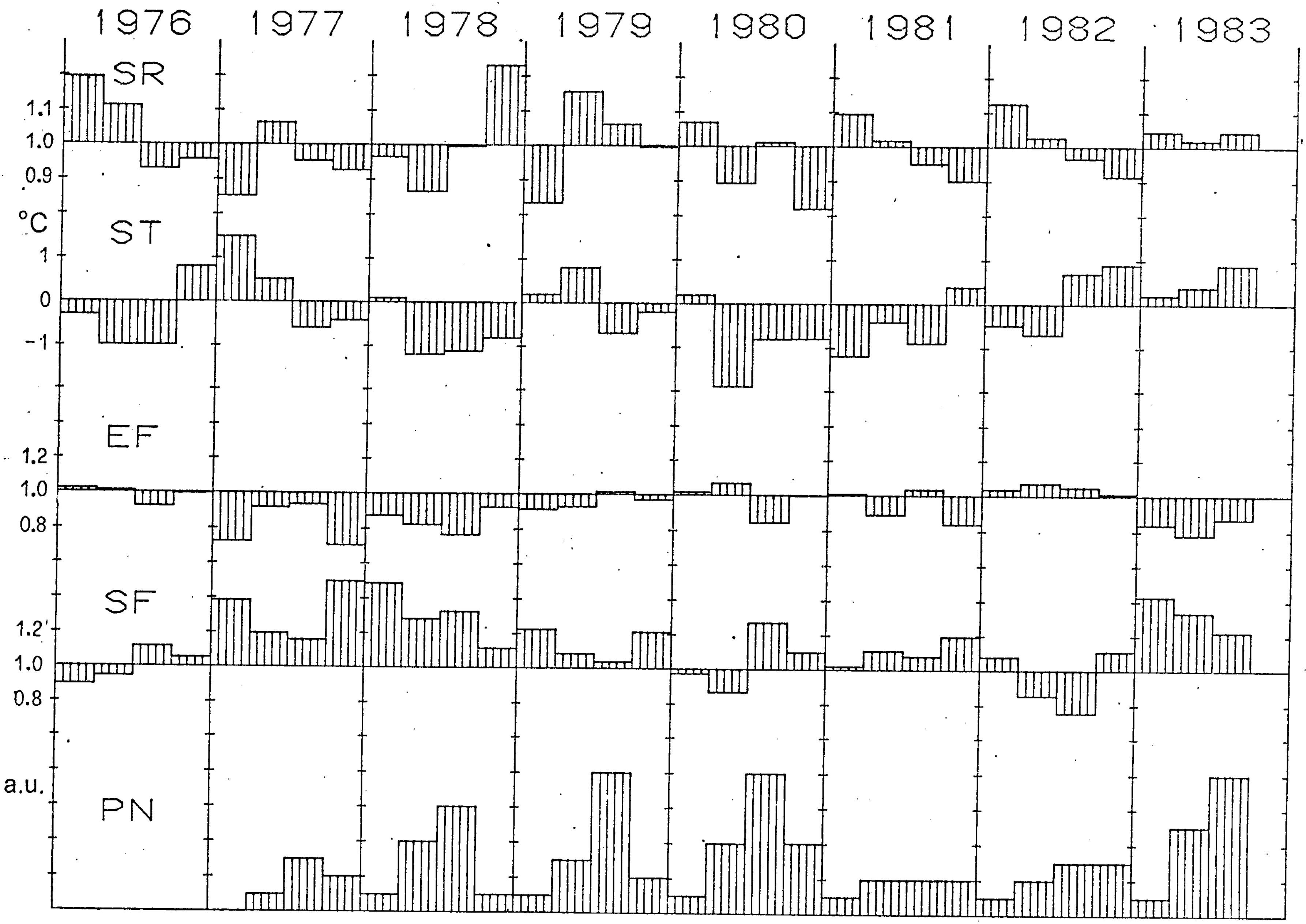

Figure I. Trieste, 1976-1983 seasonal data. SR, global solar radiation (ratio of actual to 1971-1980 averages); ST, sea-water temperature at 2 m depth (difference/C° between actual and 1951-1980 averages); EF/SF, easterly/southerly winds frequency (ratio of actual to 1951-1980 averages); PN, average abundance of <u>Pelagia noctiluca</u> (arbitrary units) in the Gulf of Trieste.

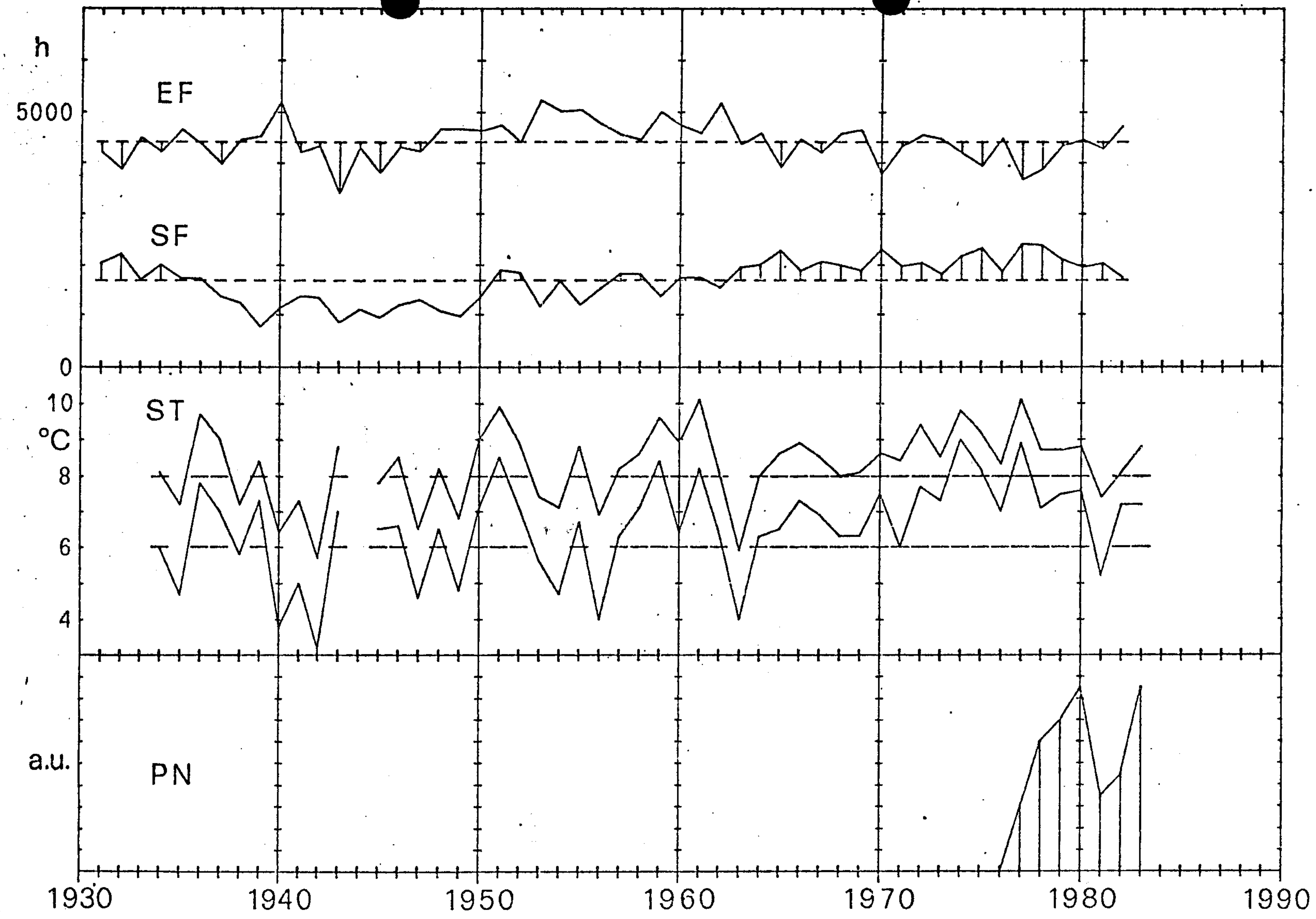

Figure II. Trieste, 1931-1983 annual data. EF/SF, total hours of easterly/southerly winds and related averages; ST, winter (January, February and March) mean and minimum sea-water temperature/C^o at 2 m depth; PN, total abundance of Pelagia noctiluca (Arbitrary units) in the Gulf of Trieste.

References

IT, (1980). - Annuario 1979, C.N.R. Ist. Talassografico Trieste, N. 550, 1-36.

Rottini-Sandrini, L., (1982). - Effect of water temperature on the motility of *Pelagia noctiluca* (Forskal), *Experientia*, 38, 453-454.

Rottini-Sandrini, L. and Stravisi, F., (1981). - Preliminary report on the occurrence of *Pelagia noctiluca* (Semaeostomeae, Pelagiidae) in northern Adriatic, C.I.E.S.M. Rapp. Comm. int. Mer Medit., 27/7, 147-148.

Rottini-Sandrini, L. and Stravisi, F. (1982). - Unusual occurrence of *Pelagia noctiluca* in the Adriatic, Acta Adr., 23, 1/2, 103-104.

Rottini-Sandrini, L., Stravisi, F. and Pieri, G., (1980). - A recent shift in the wind distribution and the appearance of unusual planktonic organisms in the Gulf of Trieste, Boll. Soc. Adriatica Sc., 64, 77-84.

Stravisi, F., Pieri, G. and Berger, P., (1981). - Golfo di Trieste: risultati delle misure correntometriche 1951 - 1954, Boll. Soc. Adriatic Sc., 65, 23-35.

Stravisi, F., (1983a). -.Some characteristics of the circulation in the Gulf of Trieste, Thalassia Jugosl., 19 (1/4), 355-363.

Stravisi, F., (1983b). - The vertical structure annual cycle of the mass field parameters in the Gulf of Trieste, Boll. Oceanol. Teor, Appl., 1/3, 239-250.

Stravisi, F., (1983c). - Normal climatic data for the Adriatic sea, GFCM III Technical Consultation on Stock Assessment in the Adriatic, Fano, Italy, 6/10 June 1983; FAO Fish. Rep., 290, 59-67.

TRANSPORT OF *Pelagia noctiluca* SWARMS IN THE SOUTH ADRIATIC[1/]

by

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Abstract

In view of the unusual occurrence of the jellyfish *Pelagia noctiluca* in the South Adriatic Sea, transport from the Strait of Otranto along the eastern part of the Adriatic Sea is discussed.

The results suggest that along the sea-shores around Dubrovnik one may find more specimens of the medusae immediately after the persistent *Jugo* throughout spring until the end of June. It is less likely to find medusae in summer, but if found, it will be more difficult to find correlations with the *Jugo*. The probability of finding specimens of medusae increases again in September, but only after a strong *Jugo*.

Introduction

The first observations of *Pelagia noctiluca* along the eastern coast of the Adriatic sea were made some seventy years ago (Babic, 1913). Until recently, little has been done to uncover basic facts about its occurrence and spreading.

Since 1977 unusual summer occurrences of swarms in the northern Adriatic have been recorded and have aroused much interest (Maretic, 1979; Malej, 1980; Rottini-Sandrini, 1980; Rottini-Sandrini *et al.*, 1980). The first hypotheses concerning causes of appearances were put forward by Malej, 1980; Rottini-Sandrini and Stravisi, 1980, and Vucetic, 1982. At the same time important ecophysiological studies were published (Rottini-Sandrini and Avian, 1983; Rottini-Sandrini, 1982).

In this paper we shall discuss why and when one expects to find specimens of the medusa close to the east shores of the South Adriatic.

Observations of the medusa

Pelagia noctiluca have been observed, not in large numbers, but repeatedly for several years, along the coasts of Dubrovnik either at the beginning, middle or end of May, depending on the year. However, medusae have not been found in July, August, September or October, the period they have been observed to occur in the northern Adriatic.

[1/] Original scientific paper

Physcial characteristics of the South Adriatic

In order to explain the above observations we need to consider the characteristics of the southern Adriatic. We also assume (and most biologists would agree, too) that the medusa is unable to swim a straight course on the scale of tens of kilometres.

Current regime

The region under discussion is shown in figure I. It is characterized by a relatively smooth shoreline oriented SE/NW. This suggests that the current regime found in the Strait of Otranto would not be significantly distorted along the SE coast.

Below, we describe the current system stating at the Strait of Otranto and going inwards into the Adriatic. The results have been obtained by direct current measurements and calculation of dynamic heights (Vucak and Nozina, 1982).

Winter (February). A strong current field exists in the cross-section of the Strait. The inward current is present in the major part of the cross-section along the eastern coast, forming a wedge which extends to the 800 m depth (figure II). The mean incoming velocity, vertical to the cross-section, is 22.8 cm/s. The outflowing current forms a narrow vertical wedge along the west coast. A temperature of 14.73°C was observed in the incoming water from 0 to 200 m. Salinity varied from 38.51 to 38.66$^{\circ}/oo$; oxygen was almost constant. Recorded wind direction was 340° with the wind speed at 3.9 m/s.

Spring (May). The current field weakens. The eastern (inflow) wedge becomes shallower while the outflow current weakens on the surface, but along the western boundary it increases with depth. The mean velocity of water in the inward direction is 19 cm/s. Temperature range between the 0 and 200 m depths is from 16.5° to 14.8°C. Salinity varies fro 38.75 to 38.82$^{\circ}/oo$. Dissolved oxygen is between 5.5 and 5.79 ml/l. Wind direction of 340° was recorded with a speed of 6.5 m/s.

Summer (July). The current system is very weak with the the outflowing directions prevalent. The cross-section cannot be split into wedges but rather into two zones. The outflowing zone extends almost throughout the whole cross-section with the exception of the small region between the 100 and 300 m depths, along the western part, where the medium or small outflowing current prevails (5-10 cm/s).

Autumn (October). Strong wedges are formed. The first wedge, extending along most of the surface of the strait, has a strong inward direction (mean of the surface currents vertical to the cross-section is over 30 cm/s). The very deep, western wedge is characterized by a small out-going current. The surface temperature (down to 30 m) is almost 22°C, between a depth of 50 to 75 m it decreases to 14°C and finally at the bottom it reaches 13.5°C. Salinity increases with depth from 38$^{\circ}/oo$ at the surface to 38.6$^{\circ}/oo$ close to the bottom.

The circulation system in the Adriatic has been investigated by several authors from the east coast (Zore-Armanda, 1968; Vucak, 1978). By now it is well known that cyclonic circulation exists in autumn, winter and spring (Vucak and Nozina, 1982) and it seems that it is more or less uniform along the same depth. In autumn, water masses passing along the east coast begin to branch off towards the west coast at the Dubrovnik-Bari transect creating a large gyre (figure I). During winter this gyre is moved towards the south-east. From this gyre (let us call it the great gyre since it turns out to be the largest) towards the north-west there is a continuous branching of water masses across the Adriatic with decreasing intensity. At the north-east end, however, during the three seasons, a gyre has not been observed. From winter to summer the first gyre moves north-west so that in July its centre is at the Jabuka Pit. Furthermore, in summer 1977 a gyre in the north-west was observed (Degobbis _et al._, 1979). The great gyre and this last one are probably the only large gyres in the Adriatic (the first being more stable and persisting almost throughout the year) with the exception perhaps of the occurrence of a small vortex during the summer just south of the great gyre.

Surface currents in summer, and especially in July change from cyclonic into outflowing (towards the south-east) (figure III). This generative situation is actually first observed in the South Adriatic where it starts in June (Z. Vucak, pers. comm.). The surface outflowing current is partially balanced by an inflow through a small portion of the middle layer. Interestingly enough, the bottom current in the Strait of Otranto was found to be small but outflowing throughout the year (figure II).

Along the south-east coast off Dubrovnik we have a rather clear nominal surface (i.e. without a strong SW wind) and middle layer current system (up to 150-250 m): in autumn, winter and spring the current is parallel to the coast and directed NW. In July and August the surface current is still parallel to the coast, but now it is a SE/S current.

In case of a strong SW wind, persistent for a week, a deflection of currents towards the coast may be observed. Of course, the strongest effect and thus the largest perturbation causing currents to turn towards the coast, may be expected at the time of a change in the direction of nominal currents, that is in June and beginning of September.

Characteristics of the swarm

The observed size of the swarm in the open sea (in the vicinity of Malta) varies from 2 to 10 km (Axiak, personal comm.). The diameter of this swarm turns out to be of the KISS scale or just below (Kierstead and Slobodkin, 1953; Skellam, 1951). That is to say, for _Pelagia noctiluca_ we may assume that a pair of medusae gives birth to approximately 100 organisms, half of which will, after a month, survive to become adults. The instantaneous growth rate in terms of numbers is then $r = 0.1073$ (1/day). Since the KISS scale is given by:

$$I_o = 2.4 \, (D_h / r)^{1/2} \qquad (1)$$

where D_h = horizontal diffusion (10^4 - 10^5 cm^2/s) and I_o = radius of the swarm, it turns out to be 681 m $\leq I_o \leq$ 2.2 km. However, the calculated I_o is not the upper bound because predation of fishes on medusae is not taken into account. The predation reduces the instantaneous growth rate r and thus increases the critical radius I_o. Nor is the radius the lower bound because the ability of medusae to move towards the swarm will decrease I_o.

Calculation of an analogous vertical KISS scale results in an expression similar to (1), except that 2.4 has to be replaced by $\pi/2$ and D_h should be replaced by D_v - the vertical diffusion coefficient. Taking into account that D_v is four orders of magnitude smaller than D_h, the critical vertical scale, or the thickness of the swarm, is between 4.46 and 14.12 m. The actual observations in the sea (Belamaric, pers. comm.) give a value of about 10 m.

If we take the density of organisms to be between 10 and 25 organisms/m^3 it follows that there are from 65×10^6 to 5.4×10^9 organisms in a swarm of a critical radius.

In case of convergence or the ability of medusae to swim towards the centre, the critical radius of the swarm decreases. If the swimming of medusae is of the order of 1 m/s critical swarm does not exist, hence any swarm is a persisting one.

Transport of Pelagia noctiluca along the South Adriatic

The problem of the transport of a swarm along the South Adriatic may be put into a precise mathematical framework and solved numerically using suitable initial and boundary conditions. Here, however, an intuitive approach will be followed in order to give an idea of the phenomenon.

The first question to ask is: When can a swarm enter the Adriatic Sea from the Mediterranean? According to the discussion in the section on the current system, the swarm, if passing in front of the Strait of Otranto, may enter the Adriatic during any season but summer. The most probable place of entry will be the middle or east side of the strait. During summer the entry conditions are unfavourable due to the outflowing currents in the surface layer and in most of the cross-section of the strait.

Given that the swarm enters the Adriatic, the second question is: How long will it take for the swarm to reach a place close to the Dubrovnik coast? This question is easy to answer since we know the mean current velocities. It turns out that the swarm would need approximately 15 to 20 days if it starts at the strait during autumn, winter or early spring. During May the time necessary increases so that if the swarm enters in June, it will not reach Dubrovnik at all, because of a change in the direction of surface currents towards the south-east.

According to our earlier discussion it appears that a swarm starting at Otranto cannot reach Dubrovnik in July or August either, since the water in front of Dubrovnik is outflowing at that time. More specifically, the surface currents are oriented SE with a tendency to deflect towards the south. This means that if a swarm starts somewhere from the Middle or North Adriatic and passes off Dubrovnik in July or August, it will be closer to the west coast.

The two indications above lead us to conclude that in nominal conditions (without the SW wind) no swarm can reach Dubrovnik shores in July or August.

However, a strong Jugo can affect a swarm in the Adriatic and elsewhere in the Mediterranean in two ways:

1. Deflection of the path of the swarm;

2. Wind-induced strong surface currents may carry specimens away from the edge of the swarm.

The response of a swarm to a strong wind is sinking to rather lower depths. This automatically prevents a high deflection of the path since currents in a deeper water layers are in general more stable. It also prevents high loss due to a tangential stress on the swarm. A swarm which passes off Dubrovnik before summer (in a north-easterly direction) is closer to the coast than one which travel south-east during the summer. Thus we conclude that individual specimens of Pelagia noctiluca are likely to be seen in somewhat larger numbers before summer than during summer itself. Also, the time needed for specimens to reach the coast is shorter before summer.

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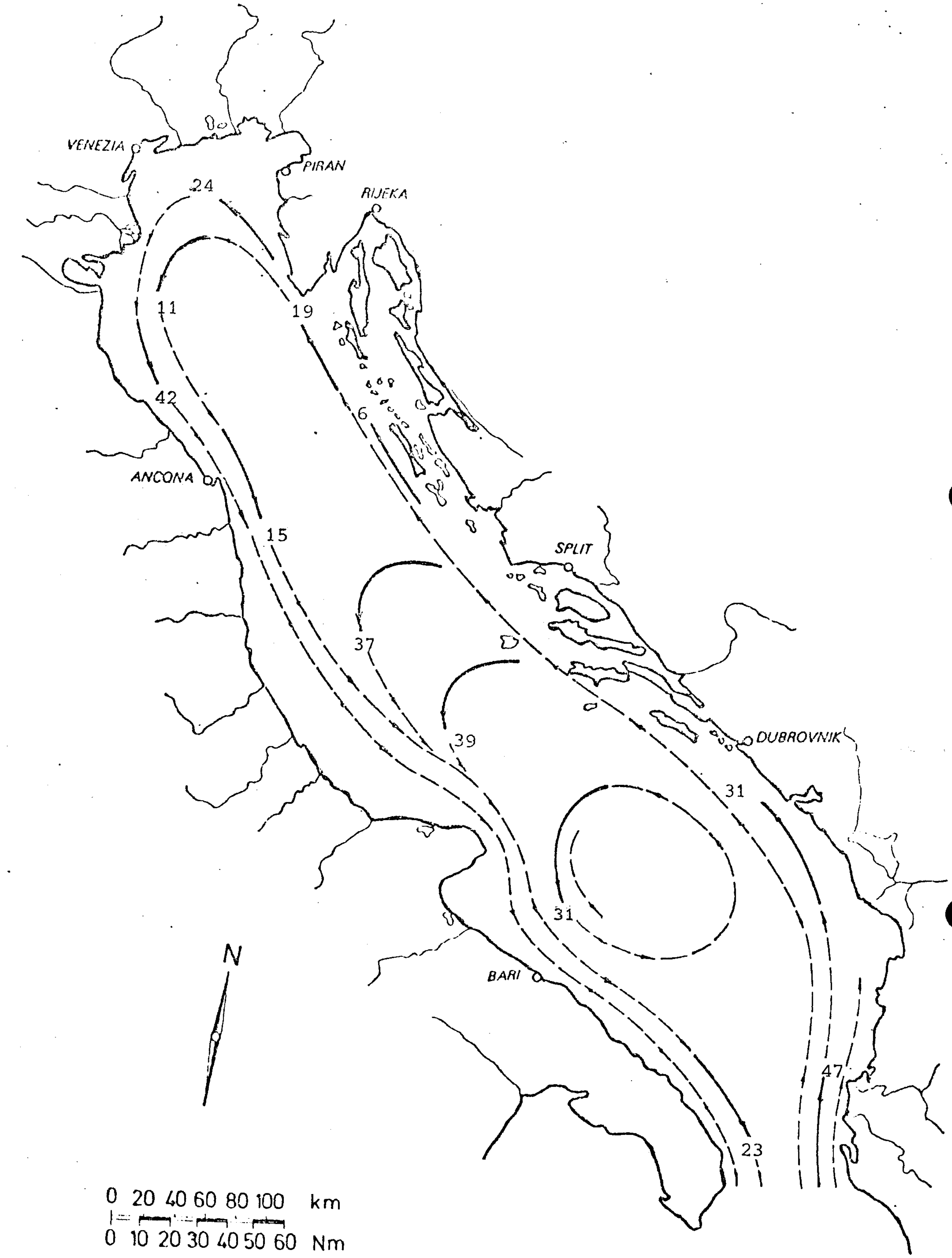

Figure I. Surface currents (0-30 m) in the Adriatic Sea during autumn (September). Values are given in cm/s

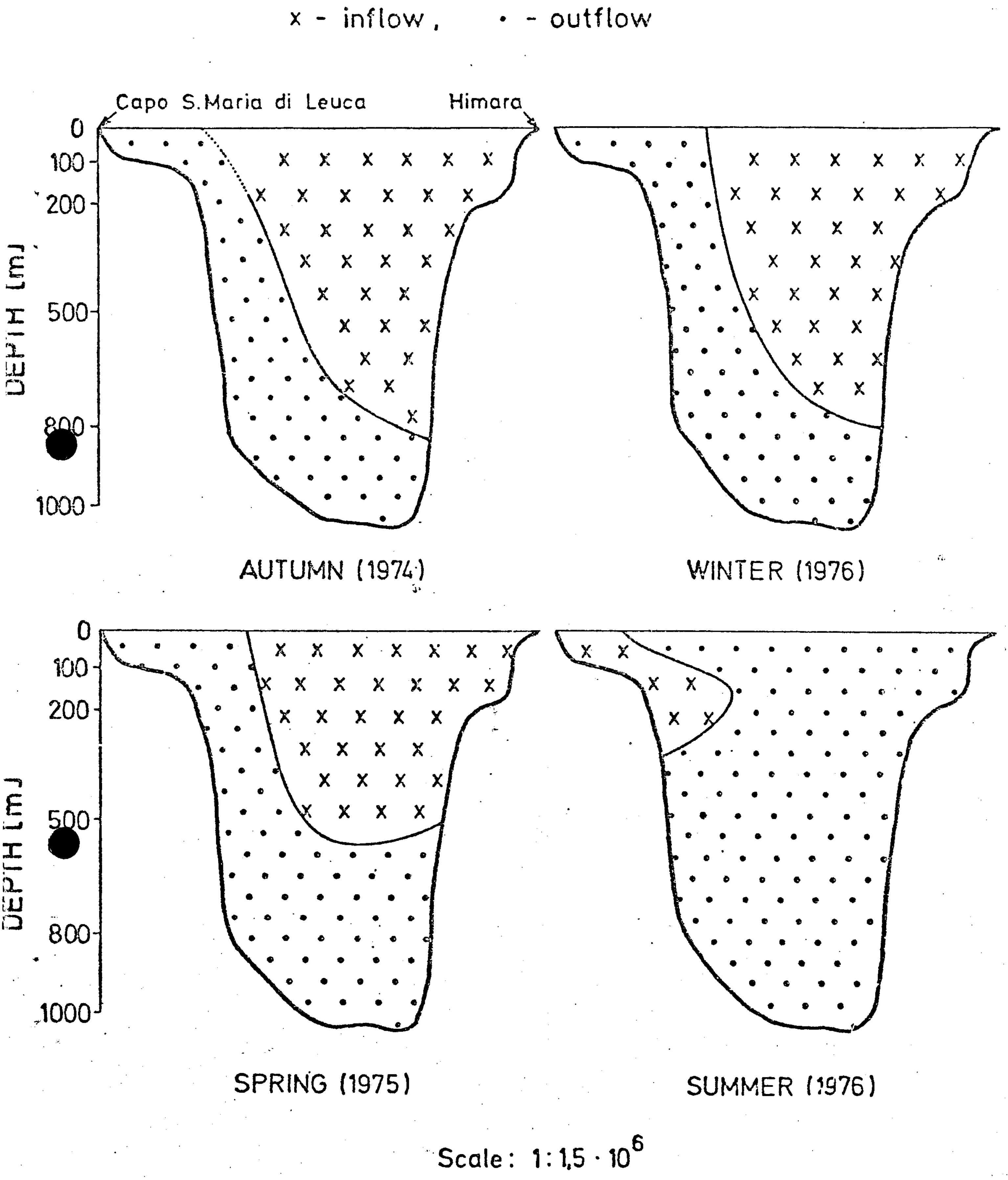

Figure II. Water flow through the Strait of Otranto in four seasons of the year

Figure III. Surface currents (0–30 m) in the Adriatic Sea during summer (July)

References

Andrija Mohorovicic 1974 - 1976, Hydrographic Institute of the Yugoslav Navy, Split, 1982.

Babic, K., (1913). - Planktonicki celenterati iz Jadranskog mora, Rad, *JAZU*, *200*, 186-202.

Degobbis, D., Smodlaka, N., Pojed, I., Skrivanic, A. and Precali, R., (1979). - Increased eutrophication of the Northern Adriatic Sea. *Mar. Pollut. Bull.*, *10*, 298-301.

Malej, A., (1980). - Preliminary report on the ephyrae of *Pelagia noctiluca* from the bay of Trieste, North Adriatic, *C.I.E.S.M., Rapp. et Proc. Verb.*, *27*, 149-150.

Maretic, Z., (1979). - Najezda otrovnih meduza u Jadranu, *Priroda*, *2*/3.

Okubo, A.,(1978). - Advection-diffusion in the presence of surface convergence. In: *Oceanic Fronts in Coastal Processes*. M.J. Bowman, W.E. Esaias, (Eds.), Berlin, Springer, 23-28.

Rottini-Sandrini, L., (1982). - Effect of water temperature on the motility of *Pelagia noctiluca* (Forskal) *Experimentia*, *38*, 453-454.

Rottini-Sandrini, L. and Avian, M., (1983). - Biological cycle of *Pelagia noctiluca*: morphological aspects of the development from planula to ephyra, *Mar. Biol.*, *74*, 169-174.

Rottini-Sandrini, L. and Stravisi, F., (1980). - Preliminary report on the occurrence of *Pelagia noctiluca* in Northern Adriatic, *C.I.E.S.M. Rapp. et Proc. Verb.*, *27*, 147-148.

Rottini-Sandrini, L., Stravisi, F. and Pieri, G., (1980). - A recent shift in the wind distribution and the appearance of unusual planktonic organisms in the Gulf of Trieste, *Boll. Soc. Adriat. Sc.*, *LXIV*.

Vucak, Z., (1978). - Measurements of currents in the Strait of Otranto, (in Serbo-Croatian), M.Sc., School of Oceanography, Univ. Zagreb, 112 p.

Vucak, Z. and Nozina, I., (1982). - A contribution to the understanding of currents in the sea in the region of Strait of Otranto (in Serbo-Croatian) 14 p (in press).

Vucetic, T., (1982). - Influence of water masses dynamics on the distribution of *Pelagia noctiluca* in the Adriatic, *Acta Adr.*, *23*, 105-115.

Zore-Armanda, M., (1968). - The system of currents in the Adriatic Sea. *Stud. Rev. Gen. Fish. Coun. Medit.*, *34*, 48 p.

POSSIBLE CONNECTIONS BETWEEN SEWAGE EFFLUENT, NUTRIENT LEVELS AND JELLYFISH BLOOMS

by

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Abstract

Jellyfish blooms can occur in polluted waters. The ways in which this man-made eutrophication provides inorganic, organic nutrients and zooplanktonic prey for marine consumers is reviewed for the waters of the Saronikos Gulf, Greece.

The attributes of medusae that make them better able to exploit these conditions than crustacean competitors are described.

Finally some avenues for control or amelioration of nuisance jellyfish blooms that may arise from marine waste disposal practices are suggested.

Introduction

Over the last few years, mass occurrences of jellyfish in coastal and neritic waters have been observed (e.g., Adriatic Sea, Rottini-Sandrini, 1983). In these areas, jellyfish are regarded as a nuisance. They sting and scare swimmers, tourists and fishermen, and they hinder fisheries by preying on and competing with the icthyoplankton (Möller, 1980), and by clogging fishing nets. Also, they reduce the efficiency of industries that use these waters in cooling systems by obstructing intake inlets (Matsueda, 1969).

Frequently, these coastal and bay areas are also subject to urban pollution (e.g., Black Sea, Vinogradov and Grinberg, 1979), especially by sewage outfalls. So, significant amounts of nutrients are introduced into seas that are often oligotrophic, resulting in strong eutrophication effects (Dugdale and Hopkins, 1978). Such man-made eutrophication may be responsible for increasing the population size of medusae. The circumstantial evidence leading to this possibility will be reviewed for the Saronikos Gulf waters, and for medusae in general.

Sewage effluent and eutrophication

Eutrophication may result from upwelling near some outfalls due to "surface boils" (Whitledge et al., 1972) as sewage discharged below the thermocline is mixed with nutrient-rich, deeper waters. However, at the shallow Keratsini outfall, effluent mixes primarily with nutrient-impoverished surface waters. Large amounts of nutrients are discharged with the effluent, including high concentrations of nitrogen, such as ammonium (Friligos, 1982).

The effect of the sewage outfall at Keratsini is evident as a nutrient-rich plume of water that extends up to 20 km south of Salamis Island (figure I, taken from Coachman _et al._, 1976). When the wind is north or north-easterly, the water currents are counter-clockwise and the nutrient-rich waters pass down the coast of Salamis. When the winds are south to south-westerly, the currents move clockwise and drive the waters along the Attica coast. As a consequence of this and the shallow sills and breakwaters around Elefsis Bay, the water circulation is limited, leaving the Saronikos Gulf waters enriched in nutrients.

These nutrients, both inorganic and organic, are available to medusae both directly and indirectly (via the food-chain) (figure II).

Direct availability of inorganic nitrogen for jellyfish

Certain jellyfish (e.g., _Mastigias_ sp., _Cassiopea_ sp., _Nausithoe_ sp. and _Cotylorhiza tuberculata_) contain symbiotic dinoflagellate algae that make direct uptake and incorporation of ammonium by the medusae possible. This has been measured by Muscatine and Marian (1982) in _Mastigias_ sp. The ammonium taken up can then be incorporated into amino acids in the algae (Wilkerson and Muscatine, 1984). The algae can release these amino acids along with much of their photosynthate to the animal partner for growth and metabolism (Lewis and Smith, 1971).

Indirect availability of inorganic nitrogen for jellyfish

Since ammonium and nitrate form the principal nitrogen sources for phytoplankton growth, additional amounts will cause nutritional enhancement of higher food-chain elements, resulting in a high production of herbivorous zooplankton; a food source for the jellyfish. Such a prediction was shown to be true for the Saronikos Gulf area. Becacos-Kontos and Dugdale (1971) showed that enhanced chlorophyll concentrations corresponded with high nutrients from the sewage outfall. Dugdale and Hopkins (1978) later showed the distribution of food-chain contributors to closely fit the "plume" of nutrients extending from Keratsini. Such blooms of dinoflagellates and zooplankton increase the energy transfer between successive levels in the marine food-chain, greatly enhancing the provision of food for carnivorous medusae. Medusae are efficient feeders, and will be especially effective when hunting in large groups.

Another study in 1972 (Dugdale _et al._, 1972) showed that concentrations of ammonium and nitrate, and uptake rates of these nutrients by phytoplankton were greater in the effluent-enriched Saronikos populations compared with algae in the unmodified oligotrophic Petalion Gulf. Also, the diversity of dinoflagellates and diatoms was far greater in surface waters of the Saronikos Gulf. The annual primary production calculated in $gmC/m^2/yr$ was 6.5 times higher in the Saronikos and the potential yield almost 18 times higher than that in the Petalion Gulf (Dugdale and Hopkins, 1978). It follows that a richer food-chain will build up in these eutrophicated waters.

Availability of organic nutrients for jellyfish

The dissolved organic matter (DOM) in the effluent-enriched water may be absorbed directly by soft-bodied invertebrates. Most invertebrate epidermal epithelia are specialized in the absorption of dissolved amino acids from sea-water (West et al., 1977). Shick (1975) has shown that dissolved glycine can be used as a supplemental nutritional source for Aurelia aurita scyphistomae and planktonic ephyrae. Energy utilization by this route of DOM is four times more effective than the usual heterotrophic route via bacteria (Sorokin and Wyshkwarzev, 1973). These authors also showed that 10-40 per cent of the total metabolic requirement of jellyfish can be met by DOM uptake. Interestingly, animals with chitinous exoskeletons have a very limited capacity for uptake. Such crustaceans are frequently the planktonic competitors for jellyfish in the marine trophic web. Using this additional mode of nutrition, aided by their suctorial tentacles and mucus coating, the medusae may be more opportunistic than the crustacean consumers.

Jellyfish as exploiters of high nutrient environments

Jellyfish are opportunistic having certain characteristics which enable them to outdo other zooplankton consumers. They can employ a wide range of nutritional strategies that allow them both to absorb dissolved inorganic and organic nutrients and prey on planktonic food. They have a high feeding capacity, e.g., the medusa Chrysaora feeds at a rate directly proportional to prey density, even at high prey density (Clifford and Cargo, 1978). A variety of organisms contribute to the diet of these mostly omnivorous beasts. Gomoiu (1980) reviewed the food of scyphomedusae and found it to contain microphytic species, detritus, planktonic crustaceans, mollusc and polychaete larvae and small jellyfish. Möller (1980) and Purcell (1981) have reported the presence of fish larvae in the gut contents of medusae. A novel feature shown by jellyfish, but not their crustacean competitors, is the capacity to shrink or "degrow" in times of starvation and then regrow when food becomes available (Hamner and Jenssen, 1974). These attributes all make jellyfish very effective consumers, especially when food is abundant in dense patches.

Jellyfish are able to exploit situations in which there are high levels of nutrients. They have higher growth rates than other non-gelatinous zooplankton (Biggs, 1976; Alldredge, 1984) and have high growth efficiences (Fraser, 1969). This ensures a quick response to increased food by increasing medusa biomass. Jellyfish also have reproductive strategies to exploit nutrient-rich situations. They have the potential for short generation times, such as two and a half months, reported for the siphonophore Aglantha digitale (Williams and Conway, 1981). This allows for more than one reproductive cycle per year (e.g., Hamner and Jenssen, 1974). Many medusae also exhibit high fecundity. The leptomedusae Phialidium gregarium produce up to 3,000 eggs per female (see Alldredge, 1984). Asexual reproduction of medusae through schizogamy (Stretch and King, 1980) or budding may also increase the reproductive potential of some species. Consequently, when nutritional resources increase, jellyfish are able to reach high population densities rapidly, enabling them to overwhelm consumers and create blooms.

Conclusions

It appears possible that jellyfish blooms may arise as a consequence of marine waste disposal practices. One way to control these blooms may be to treat the effluent before it is discharged, the appropriate treatment depending upon investigations to determine the nature of the link to the effluent, i.e., whether direct or indirect, etc. Secondly, various biological control techniques, including aquaculture might be employed. Finally, discovery and eradication of scyphistomae stocks in nutrient-rich waters will reduce the reproductive capacities of most medusae, except _Pelagia noctiluca_, that does not have a sessile form in its life cycle.

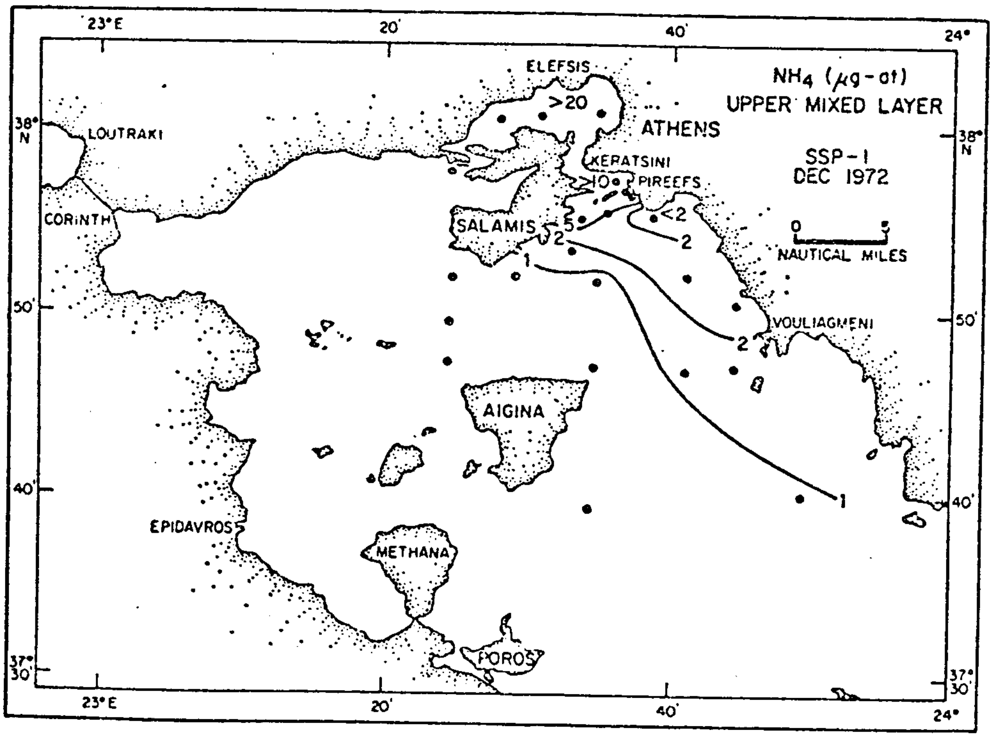

Figure I. Distribution of ammonium in Saronikos Gulf (taken from Coachman _et al._, 1976)

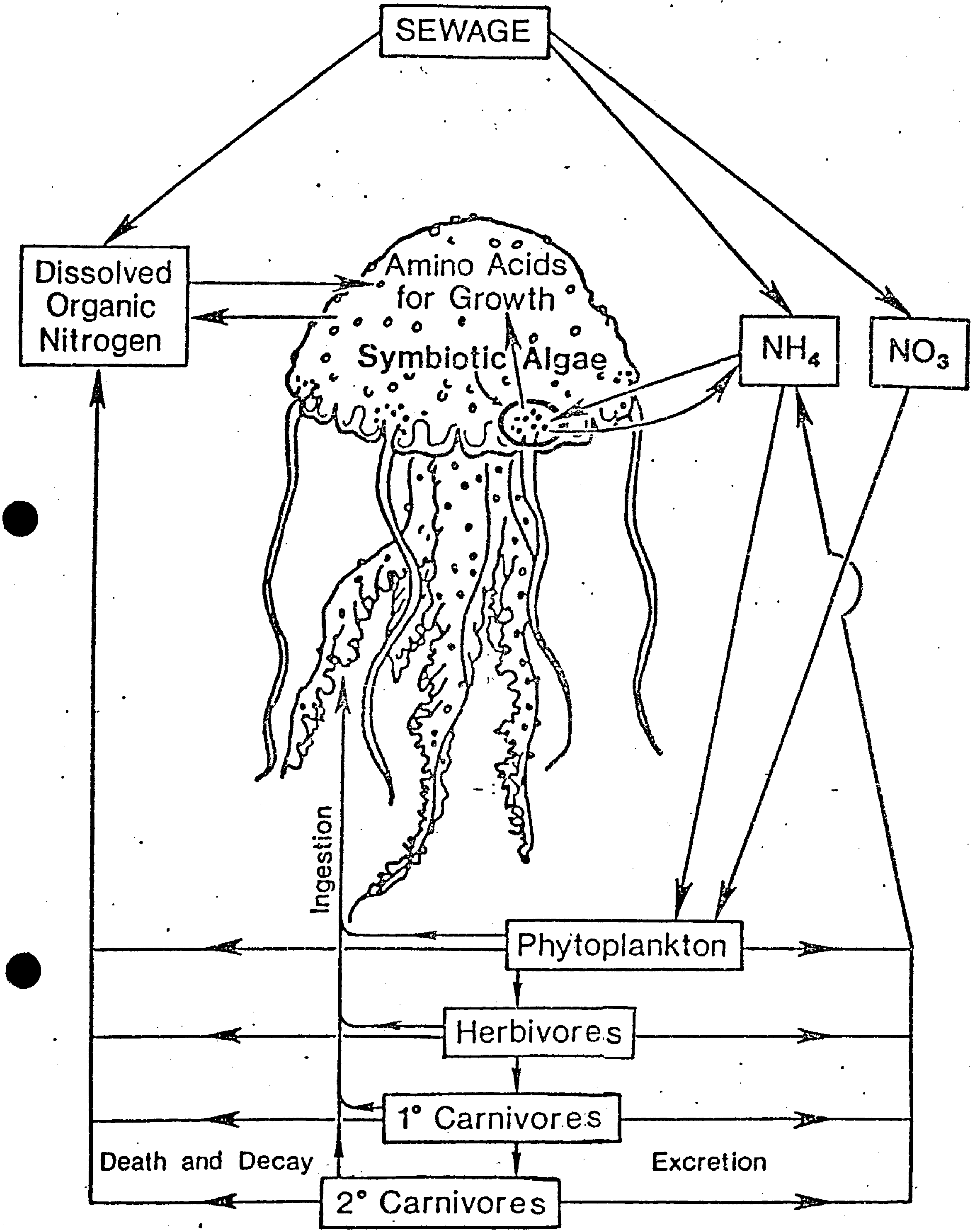

Figure II. Nitrogen cycle linking sewage and jellyfish metabolism

References

Alldredge, A., (1984). - The quantitative significance of gelatinous zooplankton as pelagic consumers. In: *The flow of energy and material in marine ecosystems*. Ed. M. Fashman. NATO Advanced Research Inst., Plenum Press.

Becacos-Kontos, T. and Dugdale, R.C., (1971). - Pollution in Greek waters. *Mar. Pollut. Bull.*, *2*, 158-160.

Biggs, D.C., (1976). - Nutritional ecology of *Aglama okeni*. In: *Coelenterate Ecology and Behaviour*. Ed. G.O. Mackie. New York. Plenum Press, pp. 201-210.

Clifford, H.C. and Cargo, D.G., (1978). - Feeding rates of the sea nettle *Chrysaora quinquecirrha*, under laboratory conditions. *Estuaries* *1*, 58-61.

Coachman, L.K., Hopkins, T.S. and Dugdale, R.C., (1976). - Water masses of the Saronikos Gulf in winter. *Acta Adr.*, *18*, 133-162.

Dugdale, R.C. and Hopkins, T.S.,(1978). - Predicting the structure and dynamics of a pollution-driven marine ecosystem embedded in an oligotrophic sea. *Thalassia Jugosl.*, *14*, 107-126.

Dugdale, R.C., MacIsaac, J. and Blasco, D., (1972). - Nutrient kinetics of algal populations in two gulfs adjoining the Attic Peninsula one receiving effluents. *Journées Etud. Pollutions, Athènes, C.I.E.S.M.*, pp. 163-166.

Fraser, J.H., (1962). - Experimental feeding of some medusae and chaetognaths. *J. Fish. Res. Bd. Can.*, *26*, 1743-.

Friligos, N.,(1982). - Enrichment of inorganic nutrients in the inner Saronikos Gulf (1973 - 76). *Mar. Pollut. Bull.*, *13*, 154-158.

Gomoiu, M.T., (1980). - Ecological observations on the jellyfish *Aurelia aurita* (L.) populations from the Black Sea. *Cercetari Mar.*, *13*, 91-102.

Hamner, W.M. and Jenssen, R.M., (1974). - Growth, degrowth and irreversible cell differentiation in *Aurelia aurita*. *Amer. Zool.*, *14*, 833-849.

Lewis, D.H. and Smith, D.C., (1971). - The autotrophic nutrition of symbiotic marine coelenterates with special reference to hermatypic corals. I. Movement of photosynthetic products between the symbionts. *Proc. Roy. Soc. Lond. B.*, *178*, 111-129.

Matsueda, N.,(1969). - Presentation of *Aurelia aurita* at thermal power station. *Bull. of the Marine Biological Station of Asamushi XIII* (3).

Möller, H., (1980). - Scyphomedusae as predators and food competitors of larval fish. *Meeresforschung* *28*, 90-100.

Muscatine, L. and Marian, R.E., (1982). - Dissolved inorganic nitrogen flux in symbiotic and nonsymbiotic medusae. *Limnol. Oceanogr.*, *27*, 910-918.

Purcell, J.E., (1981). - Feeding ecology of *Rhizophysa eysenhardti*, a siphonophore predator of fish larvae. *Limnol. Oceanogr.*, *26*, 424-432.

Rottini-Sandrini, L., (1982). - Effect of water temperature on the motility of *Pelagia noctiluca* (Forskal). *Experientia*, 38, 453-454.

Shick, J.M., (1975). - Uptake and utilization of dissolved glycine by *Aurelia aurita* scyphistomae: temperature effects on the uptake process; nutritional role of dissolved amino acids. *Biol. Bull*, *148*, 117-140.

Sorokin, Y.I. and Wyshkwarzev, D.I., (1973). - Feeding on dissolved organic matter by some marine animals. *Aquaculture*, *2*, 141-149.

Stretch, J.J. and King, J.M., (1980). - Direct fission: an undescribed reproductive method in hydromedusae. *Bull. Mar. Sci.*, 522-525.

Vinogradov, M.Y. and Grinberg, V.N., (1979). - 64th Cruise of the R/V Vityaz. A study of pelagic ecosystems of the Black Sea. Oceanology, 19, 225-228.

West, B., De Burgh, M. and Jeal, F., (1977). - Dissolved organics in the nutrition of benthic invertebrates. In: Proc. 11th Europ. Mar. Biol. Symp. Eds. B.F. Keegan, P.O. Ceidigh and P.J.S. Boaden. Oxford., Pergamon Press, pp. 587-593.

Whitledge, T., Dugdale, R.C. and Hopkins, T., (1972). - The effect of upwelling on effluents discharged at depth. Journées Etud. Pollutions, Athènes, C.I.E.S.M., p. 115.

Williams, R. and Conway, D.V.P., (1981). - Vertical distribution and seasonal abundance of Aglantha digitale (O.F. Muller) (Coelenterate: Trachymedusae) and other planktonic coelenterates in the north east Atlantic Ocean. J. Plankton Res., 3, 633-643.

Wilkerson, F.P. and Muscatine, L., (1984). - Uptake and assimilation of dissolved inorganic nitrogen by a symbiotic sea anemone. Proc. Roy. Soc. Lond. B., 221, 71-86.

SESSION III

METHODS TO CONTROL AND COMBAT BLOOMS OF JELLYFISH

METHODES DE CONTROLE ET DE LUTTE CONTRE LES PROLIFERATIONS ANORMALES DE MEDUSES

JELLYFISH FLOATATION BY MEANS OF BUBBLE-BARRIERS TO PREVENT BLOCKAGE OF COOLING WATER SUPPLY AND A PROPOSAL FOR A SEMI-MECHANICAL BARRIER TO PROTECT BATHING BEACHES FROM JELLYFISH

by

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Summary

The Ringhals nuclear power station, located on the coast of Sweden, has experienced a number of shut-downs due to blockage of the cooling water screens by jellyfish. In 1975 and 1978 experiments were conducted, together with the Laboratory of the State Power Board, to examine whether air-bubbles released at the bottom of the cooling water intake canal could float jellyfish to the water surface from where they could be removed.

In the 1978 experiments the jellyfish distribution in a depth profile of the canal was measured before and after the airflow distribution systems. With the installation being tested, about 60 per cent of the jellyfish drifting near the bottom of the entry to the canal were lifted to the surface layer and stayed there.

The results also indicated that a higher efficiency could be reached if the installed air-capacity were distributed over a bigger canal area.

A permanent installation was constructed in 1980 and has been operated successfully for three summer seasons. A series of slides shows the effect of the floatation system. For the extension of the power plant with two further units a new cooling water intake canal is under construction. This canal will from the beginning be equipped with a jellyfish floatation system by means of air-bubbling.

Another idea to prevent the drifting of jellyfish, on to bathing beaches for instance, arose from the successful measures to control the chlorination concentration by means of an encircling loop installed on the periphery of the beach comprising the combination of a submerged mechanical skirt with a height of about three quarters of the depth and a bubble barrier. The method can be applied where no complete separation of the bathing zone from the sea is wanted fron an aesthetic point of view but where a controlled exchange of water can take place while still preventing jellyfish from entering.

This method of partial separation of two masses of water has not yet been applied for protection from jellyfish.

Introduction

The floatation of jellyfish was occasionally observed in the early 1970s when operating an Oilspill Protection Bubble Barrier which comprises the release of compressed air through a submerged perforated hose. Several hundreds of jellyfish were brought up to the surface by the waterflow generated. It was also noticed how many of the jellyfish had lost their transparency and become milky in appearance. Most of these milky jellyfish stayed floating on the surface of the water as if they had adsorbed air and become lighter than the water.

These observations were brought up when the jellyfish problems at the Ringhals power plant were discussed in 1975.

The Ringhals nuclear power plant is located on the west coast of Sweden about 80 km south of Gothenburg. The station consists of four units with a total output of 3,400 MW. The first two units, 1,600 MW, were put into operation in 1974. Unit Nr3 is completed and ready to start and unit Nr4 will be completed in 1984. Already during the first year of operation the capacity of the screen house for units 1 and 2 proved to be insufficient. High concentrations of jellyfish in the cooling water drawn from the sea caused several shut-downs of the plant. Parts of the travelling screens have been destroyed on three occasions.

Units 1 and 2 utilize 80 m^3/s of cooling water and are constructed with one 600 m long intake canal through which the cooling water is withdrawn from the sea. At about 150 m from the shoreline a skimmer wall is constructed down to 4 m below sea level. The intake canal ends in the screen house. Each of the five separate lines in the screen house is equipped with two automatically cleaned trash racks and a travelling screen. The cleaning capacity (jellyfish) is a few specimens per m^3 of cooling waters.

Jellyfish distribution observations

Along the west coast of Sweden there is a net flow towards the north in the surface layer and a south net current in the deeper water. Close to the station however there is a weak net flow towards the south.

Three or four different species of jellyfish are regularly observed in the area. The Aurelia (Aurelia aurita L.) dominates in the top layer from where the cooling water is withdrawn. Its reproduction area is Kattegat and in the Baltic Sea. Intake problems due to jellyfish have also been reported from the Swedish nuclear power plant Barsebaeck as well as from Danish and German Federal Republic power stations.

Early observations at Ringhals indicated that jellyfish are normally found in accumulations rather than being uniformly distributed in the water. During the summers of 1977 and 1978 extensive observations were made on the occurrence of jellyfish in the coastal water near the intake. The observations were made from an aeroplane and from a boat. Several accumulations of different size and form were often observed at the same time in the area close to the intake. The size varied from a few m^2 to 3,000 x 500 m^2. Concentrations of up to several hundred specimens per m^3 of water have been measured locally in such accumulations. A maximum mean concentration of 80 specimens per m^3 has been registered in the top layer of 10 m, from where the cooling water is withdrawn. This corresponds to a volume of 30 l per m^3 of water. Measurements in nine fixed positions rarely showed any jellyfish. These observations confirm that jellyfish normally appear in accumulations rather than being uniformly distributed in the water. The collapses of the screens can thus be explained by the intake of such accumulations of jellyfish.

Tests with air-bubbling

The idea of floating jellyfish to the surface by the relase of air was first tested at Ringhals in 1975. The air was released through perforated plastic tubes placed on the bottom of the intake canal where it enters from the sea. The efficiency of the airflow release was not determined by direct measurements but by visual observations of the number of jellyfish on the surface of the water with and without an airflow discharge. The tests showed that jellyfish were floated to the surface by the rising air-bubbles. However for various reasons it was decided at the time to increase the capacity of the screen house instead of installing a permanent air-bubbling system.

Although the capacity of the screen house for units 1 and 2 was considerably increased after 1975, shut-downs still occurred due to the intake of dense jellyfish accumulations. An air-bubbling system was therefore reconsidered and new experiments were decided on for the summer of 1978.

The air-bubbling arrangement installed in 1978 was principally the same as the one tested in 1975 and comprised perforated polythene tubes laid across the 35 m wide intake canal bottom, 15 tubes of 40 mm diameter spaced 2 m apart with anchoring lead wire of 3 kg/m and a tube of 90 mm diameter anchored with concrete blocks, 15 kg/m.

The airflow was delivered by a single-stage oil-free rotary screw compressor giving 573 l/s. The air pressure required is that of the hydrostatic pressure over the tubes plus smaller pressure losses in the air distribution system. For the actual depth of 10 m the operating pressure was about 1.5 bar.

The 15 smaller tubes were perforated with 1.0 mm diameter holes equally spaced to create a homogeneous bubble-mat over a 50 m length of the canal. However by means of valves any combination of tubes could be operated, although the airflow distributon would not then be uniform for all combinations. The airflow discharge for equal distribution to all 15 hoses was thus about 1 l/s and m bubble tube or 0.28 l/s and m^2 canal area. Such an airflow discharge generates a vertical flow of water of 600 l/s m at a depth of 10 m. This waterflow turns to a horizontal outflow at the surface and the maximum surface velocity for the actual airflow discharge is 0.25 m/s in stagnant water.

The 90 mm tube, also perforated with 1.0 mm bubble holes was dimensioned for the release of the full air-capacity in one barrier across the canal. The airflow discharge of almost 1 m^3/min and m tube generates a surface velocity of 0.66 m/s in stagnant water. In the canal this velocity has to be superimposed on to the current caused by the withdrawal of cooling water to achieve the resulting surface velocity.

The aim of these new experiments was to quantify the lifting capacity of rising air-bubbles. Methods to further deflect or by other means take care of the jellyfish brought up to the surface were not studied during these tests.

For each test the jellyfish concentration was measured at 6 m depth in the 10 m deep intake canal from two pontoons anchored about 20 m upstream and 100 m downstream of the bubble-mat section. The jellyfish, drifting at various depths in the cooling water inflow were caught in specially designed netted boxes equipped with a sliding gate covering the 0.5 x 0.5 m^2 opening. These traps were attached to vertical wires suspended from the pontoon with the gates closed. The upper trap was always placed just below the water surface. All gates could be opened and closed simultaneously by pulling a rope. For each test the traps were kept open long enough to catch measurable quantities of jellyfish. As the jellyfish concentration could vary in time the traps at the inner pontoon were opened and closed an interval of time later than the traps at the outer pontoon. The time interval was taken as the floating time between the two pontoons. The jellyfish concentration could also vary across the width of the intake canal. As only two pontoons anchored along the centre line of the canal were used jellyfish accumulations registered at the outer one could pass beside the inner one without being registered. This spacial variation was "eliminated" by taking the average catch of repeated experiments. An average difference of about 10 per cent in total catch of jellyfish at the two pontoons in experiments without air-bubbling seemed to justify this procedure for the tests performed in 1978.

In the table below the results of four series of a total of 31 experiments with air-bubbling are presented.

Dates of tests	Air released through tubes (numeration of tubes)	Number of tests	Air discharge (m^3/s at atm. pressure)	Cooling water discharge (m^3/s)	Lifting efficiency (%)
25/7-1/8	1.15	11	0.42	18 - 35	50
28/7	16	3	0.42	35	45
2/8	4,5,9,10,11,16	3	0.45	25	58
9/8-22/8	1-15	14	0.20-0.30	35	62

During the tests, jellyfish floated to the water surface were observed to drift away in the direction of the wind and were seldom caught in the surface trap at the inner pontoon. The liftng efficiency of the air release was therefore calculated as the ratio of the difference in the total amount of jellyfish caught in the five lower traps at the outer and inner pontoon for one series of experiments to the total amount of jellyfish caught at the outer pontoon.

As shown in the table higher efficiency was reached when the airflow was released through the smaller tubes than through the large tube only.

Visual observations actually indicated that, although the vertical waterflow transported jellyfish towards the surface, not all of them remained there. Many sank directly back in to deeper water in the horizontal outflow of the bubble-mat, frequently in an abnormal way, sometimes upside down, while others lost their transparency and became milky. These latter stayed floating on the surface.

It seemed as if when the jellyfish had trapped too many air-bubbles they easily tilted and got rid of the air without any effect on their floating; compare, for example, air-bubbles under a plate in water, when just a very small oblique angling of the plate makes the air leave.

We interpreted the change in transparency to an air-bubble having been adsorbed on to the softer centre part of the jellyfish and being therefore unable to escape into the water, even when tilted, causing these milky jellyfish to remain afloat.

The conclusions drawn from these observations are that the airflow should be very moderate, almost just single bubbles rising towards the surface through a stagnant watercolumn rather than a bubble-stream generating a vertical waterflow. However, the air-bubbling-mat will then have to have a big area so that each jellyfish is hit by at least one air-bubble.

A new lay-out for the permanent installation was proposed based on these conclusions. Basically the jellyfish should be floated further out in the canal. This would make room for a deflecting barrier, diverting the jellyfish from the intake area. An improved floatation technique was also considered. However for reasons of economy the permanent installation had about the same lay-out as the one used for the test.

Effects of the permanent installation

A series of photos shows the effect of the floatation system and the auxiliary equipment on the deflection and recovery of the jellyfish during a normal late summer operation.

The centre part of the floated jellyfish was lifted above the surface of the water and seemed to dry out. This part acted like a sail and the jellyfish drifted with the wind.

The floated jellyfish were deflected towards a recovery device by means of a standard mechanical oilspill boom, design Troilboom.

The floated jellyfish were pushed together by the wind.

At peak-loads of jellyfish the skirt of the boom was not deep enough for the thick layer of jellyfish so they passed under the boom.

The jellyfish were taken out of the water by means of a transport band and dumped into a pump hopper, design Troil boom.

However a special band with nails had to be arranged to increase the recovery capacity.

Some of the jellyfish were of exceptional size.

The jellyfish were pumped into a special deposition basin together with seaweed and other debris where they disintegrated.

A bigger transport band had to be installed to cope with peak loads.

Several tonnes an hour at peak-loads have been successfully floatated and pumped away with this system.

Pneumatic mechanical barrier

98 per cent of all waste water in Sweden is today treated in three-step treatment plants. This has resulted in a considerably improved quality of the receiving waters. So, for example, as a result of this improved water quality, a public bath Smedsudden was opened in the very centre of Stockholm in the Maelar lake.

However with a certain wind and current direction the water quality deteriorated and moderate chlorination had to be introduced to guarantee the quality.

As the exchange of water at the beach varied considerably the dosage of chlorine became very difficult. Construction means had to be considered to reduce this water exchange.

However the whole idea with this project was to create a natural bathing beach for people who dislike swimming pools and so constructions had to be as imperceptible as possible.

Thus an encircling loop was installed outside the beach comprising the combination of a submerged mechanical skirt with a height of about three quarters of the depth and a bubble barrier. The skirt is of plastic-coated fabric.

This method can be applied where no complete separation of a bathing beach from the sea is wanted from an aesthetic point of view but where a controlled exchange of water can take place.

As the surface outflow generated by a bubble-barrier will prevent jellyfish from entering the surface layer and through the skirt in the deeper layer this method has been proposed for jellyfish protection of bathing beaches.

No project has been realized yet.

References

Billfalk, L. and Gunstad, T., (1979). - Preventing jellyfish from entering a cooling water intake by a pneumatic barrier. International Association for Hydraulic Research.

Blomberg, E., AB Troilboom Systems, Gothenburg, Sweden.

SOME SPECULATIONS ON POSSIBILITIES OF CONTROLLING JELLYFISH BLOOMS

by

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Blooms of certain jellyfish species are a nuisance to fisheries and coastal engineering, a danger to swimmers, and a contributive factor to the mortality of larval fish. Recent attempts to avoid problems caused by jellyfish have been restricted to keeping them away from the inlets of power plants by the use of air-bubble curtains or rotating screens. Some local success has been achieved, but there is as yet no method to combat jellyfish on a larger scale.

Most problems are due to the mass occurrence of the scyphozoan genera _Aurelia_ (Matsueda, 1969; Yasuda, 1979; Möller, 1980 a), _Cyanea_ (Möller, 1984), _Chrysaora_ (Schweigger, 1959; Calder, 1974; Möller, 1980 a) and _Pelagia_ (various contributors to this workshop). The main problem in developing methods to control the mass occurrence of these animals is the fact that their biology, especially their population dynamics, is insufficiently known. The most detailed information actually available deals with _Chrysaora quinquecirrha_ (Cargo and Schultz, 1967; Gatz _et al._, 1973; Calder, 1974; Cargo and Rabenold, 1980) and _Aurelia aurita_ (Thiel, 1962; Yasuda, 1979; Möller, 1980 b).

In seeking methods for combating jellyfish swarms, various ideas should be discussed, although it has to be pointed out that most of them are rather speculative:

(1) Preventing the emergence of jellyfish by destruction of their polyp colonies by:

- (a) mechanical or chemical methods;
- (b) introduction of predators or parasites.

(2) Reduction of existing jellyfish swarms by:

- (a) fishing or other mechanical destruction;
- (b) reduction of their food resources;
- (c) introduction of predators;
- (d) introduction of pathogenic parasites.

(3) Protection of recreational or industrial areas from jellyfish by:

- (a) nets;
- (b) rotating screens;
- (c) air-bubble curtains.

(1) Preventing the emergence of jellyfish by destruction of their polyp colonies

(1.a) The medusae of most scyphozoan species emerge from polyps settling on the bottom. The settling behaviour of the polyps in relation to environmental factors has been studied for various species (Thiel, 1962; Brewer, 1976; Cargo, 1979; Yasuda, 1981). In general the polyp is found upside down on the underside of shells or artificial concrete or wooden constructions. A pre-requisite for any successful reduction of a local polyp population would be that the polyp stages are not scattered all over the area under consideration, but settle in a small number of large colonies. Such an observation has been made in Kiel Bight for the polyps of Aurelia aurita, occurring mostly on the under-sides of docks and other submerged artificial structures. No specific methods to remove polyps on a large scale have been reported yet.

(1.b) No information is available on parasites of scyphopolyps. However, some species are exposed to heavy predation. Thiel (1962) reported that in 1959 large numbers of the nudibranch Facelina drummondi almost obliterated the polyp colonies of Aurelia aurita in certain areas of Kiel Fjord. It might be worth checking whether an artificial propagation of this predator is possible and whether its release would have any significant impact on naturally growing polyp stocks. No such trials have been reported yet.

(2) Reduction of existing jellyfish swarms

(2.a) Any significant removal of jellyfish swarms from the sea by fishing is unrealistic due to insuperable technical problems. No other information on mechanical destruction of jellyfish in the sea is available.

(2.b) From laboratory experiments it is well-known that scyphomedusae shrink considerably within only a few days if the food supply is interrupted (Will, 1927; Hamner and Jenssen, 1974). The emergence of large swarms of scyphomedusae is usually restricted to coastal waters with high primary productivity, providing sufficient food for the medusae. The introduction of human eutrophicating substances into these areas favours this process, although it is usually impossible to differentiate clearly between the effects of natural hydrographical conditions and changes brought about by man. Nevertheless, it seems to be likely that the introduction of anthropogenic wastes contributes to the growth of jellyfish swarms locally. However, the extent of this contribution still remains unknown and therefore no guarantee can be given that a reduction of human waste disposal will result in a significant reduction of local jellyfish populations as well.

(2.c) Jellyfish are not a typical food item for other marine animals. In a few instances crabs have been observed to feed on Chrysaora quinquecirrha (Phillips et al., 1969), Cyanea capillata (Farr, 1978) and other species. Lauckner (1980) reported that on the bottom of the Baltic Sea, adult Carcinus maenas feed very frequently on Aurelia aurita. Hartog (1980) found sea anemones and scyphomedusae in the stomachs of sea turtles. Small fish (particularly of the Carangidae and Gadidae) associated with jellyfish have occasionally been reported to eat parts of the umbrella and the tentacles (Mansueti, 1963). In the North Sea and the western Baltic Sea, the mackerel (Scomber scombrus) has been observed to attack Aurelia aurita, picking out either their eggs from the oral arms or their amphipod parasites from the umbrella. Also the Mediterranean bogue (Boops boops) occasionally feeds on Pelagia noctiluca. However, it may be assumed that predation on jellyfish is not a usual habit but a result of the absence of "normal" food. There is no realistic chance of reducing a jellyfish stock by a propagation of predators.

(2.d) In his review, Lauckner (1980) did not report any viral or bacterial diseases from cnidarians, but claimed, with a considerable degree of probability, that such diseases should be expected to exist. Disease-producing protozoa have not yet been found in scyphomedusae.

Dollfus (1963) and Stunkard (1967) reported various species of larval trematodes from the mesogloea of different groups of scyphomedusae. The occurrence of cestode larvae seems to be restricted to rhizostome medusae. Thiel (1976) listed 51 species of 28 invertebrate genera that are associated with scyphomedusae as parasites, commensals or symbionts.

The amphipod Hyperia galba parasitizes in a large variety of scyphomedusae species in various parts of the ocean with the exception of the lower latitudes (for literature see Lauckner, 1980). It feeds on gonads and on connective tissue as observed by Kramp (1937), Dahl (1959) and Metz (1967) in Aurelia aurita and Cyanea capillata. Young amphipods are found in the gastrovascular system as well as in the connective tissue, while adult stages occur predominantly in the gonads and the subgenital pouches (Möller, 1983), destroying the gonads entirely in massive infestations (Rasmussen, 1973).

In Kiel Fjord, where the mass occurrence of Aurelia starts every year in April, the first Hyperia are found in the middle of August in the medusae. They are adult specimens of about 1 cm in length and 1-3 mg in dry weight. About two weeks later a mass invasion of young amphipods can be observed. In 1979 the average infestation intensity increased from about 5 parasites per 100 ml Aurelia in the first half of October to about 15 in the second half of October and more than 50 in mid-November. The increase of parasite biomass was clearly correlated with the decrease of the host biomass (Möller, 1984). After the annual population has died, the parasites can be observed for a few weeks swimming free in the plankton. Where they spend the winter is not known.

Heavy and repeatedly occurring mass infestations of jellyfish by Hyperia have been reported from various parts of the Baltic Sea (Metz, 1967; Rasmussen, 1973; Möller, 1984) and there is considerable evidence that the parasitation might be a major reason for the elimination of the medusa population in autumn. More detailed quantitative studies on the effects of this predator on the host population would be desirable.

(3) Protection of recreational or industrial areas from jellyfish

(3.a) The protection of swimming areas by nets calls for high maintenance costs and has proved to work unsatisfactorily. All nets tested eventually became clogged and bits of the jellyfish passed into the bathing areas, stinging swimmers (Marks and Cargo, 1974).

(3.b) The use of rotating screens is now a common method to keep debris, fish and jellyfish away from cooling water systems of power plants. However, a rapid occurrence of large jellyfish swarms is able to clog even these systems, as reported e.g. from the power plants of Ringhals, Sweden and Kiel, Federal Republic of Germany (Möller, 1980 a).

(3.c) Air-bubble screens are used nowadays to reduce the number of jellyfish reaching the inlets of power plants. Most power plants along the coast of the Baltic Sea are equipped with such systems. Detailed technical descriptions have been given by Marks and Cargo (1975), Marks (1975) and Verner (this Workshop).

References

Brewer, R.H.,(1976). - Larval settling behaviour in *Cyanea capillata* (cnidaria: scyphozoa). *Biol. Bull.*, 150, 183-199.

Calder, D.R., (1973). - Laboratory observations on the life history of *Rhopilema verrilli* (scyphozoa: rhizostomeae). *Mar. Biol.*, 21, 109-114.

Cargo, D.G., (1979). - Observations on the settling behavior of planula larvae of *Chrysaora quinquecirrha*. *Int. J. Invert. Reprod.*, 1, 279-287.

Cargo, D.G. and Rabenold, G.E., (1980). - Observations on the asexual reproductive activities of the sessile stages of the sea nettle *Chrysaora quinquecirrha* (Scyphozoa). *Estuaries*, 3, 20-27.

Cargo, D.G. and Schultz, L.P., (1967). - Further observations on the biology of the sea nettle and jellyfishes in Cheasapeake Bay. *Cheasapeake Sci.*, 8, 209-220.

Dahl, E., (1959). - The hyperiid amphipod, *Hyperia galba*, a true ecto-parasite on jellyfish. *Univ. Bergen Arbok, nat. rekke*, 9, 1-8.

Dollfus, R.P., (1963). -.Liste des coelentères marins, paléarctiques et indiens où ont été trouvés des trématodes digénétiques. *Bull. Inst. Pêch. Marit. Maroc*, 9/10, 33-57.

Farr, J.A., (1978). - Blue crab predation on jellyfish. *Florida Sci.*, 41, 217-219.

Gatz, A.J., Kennedy, V.S. and Mihursky, J.A., (1973). - Effects of temperature on activity and mortality of the scyphozoan medusa, *Chrysaora quinquecirrha*. *Chesapeake Sci.*, 14, 171-180.

Hamner, W.M. and Jenssen, R.M., (1974). - Growth, degrowth and irreversible cell differentiation in *Aurelia aurita*. *Am.Zool.* 14, 833-849.

Hartog, J.C. den (1980). - Notes on the food of sea turtles: *Eretmochelys imbricata* (Linnaeus) and *Dermochelys coriacea* (Linnaeus). *Neth. J. Zool.*, 30, 595-610.

Kramp, P.L., (1937). - Polypdyr (Coelenterata) II. Gopler. *Danmarks Fauna* 43, 1-223.

Lauckner, G., (1980). - Diseases of cnidaria. In: Kinne, O. (Ed.): *Diseases of marine animals*, Vol. 1, 167-238. Chichester: J. Wiley & Sons.

Mansueti, R., (1963). - Symbiotic behavior between small fishes and jellyfishes with new data on that between the stromateid, *Peprilus alepidotus*, and the scyphomedusa, *Chrysaora quinquecirrha*. *Copeia* 1963, 40-80.

Marks, C.H., (1975). - Preliminary investigation of the use of water jets as a jellyfish barrier. *MTS Journal*, 9, 34-37.

Marks, C.H. and Cargo, D.G., (1974). - Field tests of a bubble screen sea nettle barrier. *MTS Journal*, 8, 33-39.

Matsueda, N., (1969). - Presentation of *Aurelia aurita* at thermal power station. *Bull. Mar. Biol. Stat. Asamushi*, 13, 187-191.

Möller, H., (1980 a). - Scyphomedusae as predators and food competitors of larval fish. *Meeresforschung* 28, 90-100.

Möller, H., (1980 b). - Population dynamics of *Aurelia aurita* medusae in Kiel Bight, Germany (FRG). *Mar.Biol.* 60, 123-128.

Möller, H., (1984). - Okologie der Quallen und Jungfische in der Kieler Bucht. Kiel: H. Möller (in press).

Phillips, J.H., Burke, W.D. and Keener, E.J., (1960). - Observations on the trophic significance of jellyfish in Mississippi - Sound with quantitative data on the association behaviour of small fishes with medusae. *Trans.Am.Fish.Soc.* 98, 703-712.

Rasmussen, F., (1973). - Systematics and ecology of the Isefjord marine fauna (Denmark). *Ophelia*, 11, 1-495.

Schweigger, E., (1959). - *Die Westküste Südamerikas im Bereich des Peru-Stroms.* Heidelberg, Keysersche Verlagsbuchhandlung, 513 pp.

Stunkard, H.W., (1967). - The life-cycle and developmental stages of a digenetic trematode whose unencysted metacercarial stages occur in medusae. Biol. Bull, Mar. Biol. Lab. Woods Hole, 133, 488.

Thiel, H., (1962). - Untersuchungen über die Strobilisation von Aurelia aurita Lam. an einer Population der Kieler Förde. Kieler Meeresforsch., 13, 198-230.

Thiel, M.E., (1976). - Wirbellose Meerestiere als Parasiten, Kommensalen oder Symbionten in oder an Scyphomedusen. Helgol. wiss. Meeresunters. 28, 417-446.

Will, L., (1927). - Ueber Hungerreduktionen bei Aurelia aurita. Stizungsber. Abh. naturforsch. Ges. Rostock, 3, 66-69.

Yasuda, T., (1979). - Studies on reproductive biology of harmful marine animals - the common jellyfish, Aurelia aurita, along coast of Wakasa, Japan Sea. Proc. 7th Japan-Sov. Joint Symp.Aquacult., Tokyo, 185-195.

Yasuda, T., (1981). - The reproductive ground of the common jellyfish, Aurelia aurita, in Urazoko Bay, Fukui Prefecture. Mar. Fouling, 3, 1-8.

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