ASSESSMENT AND MONITORING OF THE FISHERY RESOURCES
AND ECOSYSTEMS IN THE STRAITS OF SICILY

MiPAF

MedSudMed

GCP/RER/010/ITA

Report of the Expert Consultation on Small Pelagic Fishes: Stock Identification and Oceanographic Processes Influencing their Abundance and Distribution

Salammbô, Tunisia, 1–3 October 2003

MedSudMed Technical Documents No.5
GCP/RER/010/ITA/MSM-TD-05

Mazara del Vallo (Italy), December 2004

Preface

The Regional Project "Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily" (MedSudMed) is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Italian Ministry of Agriculture and Forestry Policies (MiPAF).

MedSudMed promotes scientific cooperation among research institutions of the four participating countries (Italy, Libya, Malta and Tunisia) in the continuous and dynamic assessment and monitoring of the state of the fishery resources and the ecosystems in this area of the Mediterranean.

Research and training are supported to increase and apply knowledge of fishery ecology and ecosystems, and to create a regional network of expertise. Particular attention is given to the technical coordination of the research among the participating countries, which should contribute to the implementation of the Ecosystem Approach to Fisheries. Consideration is also given to the development of an appropriate tool for the management and processing of data related to fisheries and their ecosystems.

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GCP/RER/010/ITA Publications

MedSudMed Project publications are issued as a series of Technical Documents (GCP/RER/010/ITA/MSM-TD-00) related to meetings, missions and research organized by or conducted within the framework of the Project.

Comments on this document are welcome and should be sent to the Project headquarters:

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For bibliographic purposes this document
should be cited as follows:

MedSudMed 2004. Report of the MedSudMed Expert Consultation on Small Pelagic Fishes: Stock Identification and Oceanographic Processes Influencing their Abundance and Distribution. GCP/RER/010/ITA/MSM-TD-05.
MedSudMed Technical Documents, 5: 132 pp.

Preparation of this document

This document is the final version of the Report of the MedSudMed Expert Consultation on Small Pelagic Fishes: Stock Identification and Oceanographic Processes Influencing Their Abundance and Distribution, organized by the FAO–MedSudMed Project (*Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Strait of Sicily)* in Salammbô, Tunisia, 1–3 October 2003.

The document was edited by D. Levi, T. Bahri, G. Basilone, L. Ben Abdallah, A. Bonanno, A. Gaamour, B. Patti and R. Zarrad.

Acknowledgements

The kind hospitality provided by the Institut National des Sciences et Technologies de la Mer through the Director, Dr Amor El Abed, is gratefully acknowledged. The assistance of Mr Ray Griffiths in the technical editing and Anna Lisa Alessi in the preparation of the document is acknowledged.

MedSudMed.
Report of the MedSudMed Expert Consultation on Small Pelagic Fishes: Stock Identification and Oceanographic Processes Influencing their Abundance and Distribution, Salammbô, Tunisia, 1–3 October 2003.
MedSudMed Technical Documents. No. 5. GCP/RER/010/ITA/MSM-TD-05, Mazara del Vallo, 2004. 132 pp.

ABSTRACT

The Expert Consultation on Small Pelagic Fish: Stock Identification and Oceanographic Processes Influencing Their Abundance and Distribution was held from 1 to 3 October 2003 in Salammbô, Tunisia, and was hosted by the Institut National des Sciences et Technologies de la Mer (INSTM). The meeting was attended by 19 experts from 5 institutions in the Project Area, as well as representatives of the FAO Regional Projects AdriaMed and Copemed. Fourteen communications were presented; they covered such issues as results of stock assessment carried out by echo-surveys in the Project area, spatial distribution of the main target species, results of the acoustic identification of small pelagic fish species, reproductive strategy and reproductive biology (reproductive cycle, maturity stages, age and growth), small pelagic fisheries, spatial distribution and modelling of fishing effort, influence of meteorological and hydrographical factors on small pelagic fish. The experience of the AdriaMed Project in promoting international cooperative research on shared small-pelagic fish stocks of the Adriatic Sea was presented, as well as the main results of the Workshop on Environmental Variability and Small-Pelagic Fisheries in the Mediterranean Sea organized by the Copemed Project. The priority list of species that future activities should concentrate on was discussed in the light of the GFCM priority-species list, economic and ecological importance, and taking into account the peculiarities of each country. A short synthesis of gaps in the knowledge of the biotic and abiotic factors and oceanographic processes influencing the distribution and abundance of small pelagic fish species was made. The main gaps identified concern: the migration of adults, transport of eggs and larvae, and the effect of abiotic factors. Many data are presently collected during the echo-surveys, but they remain insufficient to conduct ecosystem-based studies. The lack of interdisciplinary studies in the area remains one of the main gaps. A series of proposals was discussed, dealing with: (i) spatial distribution and stock assessment of small-pelagic-fish populations; (ii) biological and genetic studies; (iii) eggs and larvae; (iv) relationships between biotic and abiotic factors and life-cycles of small pelagic fish species; (v) fishery analysis and catch and effort data. The importance of developing a functional data base for acoustic data resulting from echo-surveys was discussed and agreed upon.

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Report of the Expert Consultation on Small Pelagic Fish: Stock Identification and Oceanographic Processes Influencing their Abundance and Distribution

Salammbô, Tunisia, 1–3 October 2003

1. Background information

The MedSudMed Expert Consultation on Small Pelagic Fish: Stock Identification and Oceanographic Processes Influencing their Abundance and Distribution was held in Salammbô, Tunisia, from 1 to 3 October 2003, and was hosted by the National Institute of Sciences and Technologies of the Sea, (INSTM), Salammbô. The terms of reference of the Expert Consultation are in Annex C and the List of Participants is in Annex A.

The consultation was attended by experts from research institutes in three of the MedSudMed Project participating countries (Tunisia, Malta and Italy). For technical reasons, no experts from Libya were able to attend the consultation. Representatives of FAO Regional Projects (Adriamed and Copemed) were also present.

The consultation was opened by Othman Jarboui, Coordinator of the INSTM Marine Resources Laboratory, who welcomed the participants and thanked the Project for providing the opportunity to organize such a regional consultation.

Fabio Massa, Project Coordinator, thanked the INSTM for hosting the consultation. He recalled the objectives of the MedSudMed Project and gave a summary of the on-going activities. The MedSudMed Project covers six geographical sub-areas (12–northern Tunisia, 13–Gulf of Hammamet, 14–Gulf of Gabès, 15–Malta, 16–southern Sicily and 21–Libya); it has so far launched activities dealing with demersal resources and marine protected areas, and is implementing a regional information system. The Coordinator synthesized the previous Expert Consultations organized by the Project.

The (first) Expert Consultation on Spatial Distribution of Demersal Resources was held in Malta from 10 to 12 December 2002, involving 28 experts representing 11 institutions. Eighteen technical papers were presented by the participating national and international experts on demersal resources in the Project Area, in terms of spatial distribution of the main species, available biological parameters, and characteristics of the biotic and abiotic environment in particular areas. The available knowledge and data were synthesized by four working groups: (i) on spatial distribution of target species; (ii) on biocenoses; (iii) on fishing pressure in the Project Area; (iv) on the abiotic environmental data. Each group produced a short report listing the existing data in each institution as well as the remaining gaps for each issue considered relevant to the spatial distribution of the demersal resources in the MedSudMed Project Area, together with recommendations on how to fill them, and activities to be implemented.

Following the Expert Consultation on Spatial Distribution of Demersal Resources, a Workshop on Standardization of Trawl Survey Protocol in the MedSudMed Project Area was held from 5 to 9 May 2003 at the Istituto per le Risorse Marine e l'Ambiente (IRMA–CNR) in Mazara del Vallo, Italy, with representatives of institutes from all the participating countries attending. The scope of the Workshop was to present existing sampling designs and data-processing procedures adopted in on-going monitoring trawl surveys, compare them and agree on common methods based on existing ones. The format and type of information to be inventoried and collected at national level was then discussed at a technical meeting on a National Data and Information Aggregation Scheme (Rome, 28–30 July 2003). The participants synthesized briefly the availability, format and management of the data in each research institute and gave an overview of the national data bases currently used. The meeting provided the terms of reference for data collection, an agreement on the structure, type and format of the data to be collected, and a general schedule of the activities to be carried out in each institute on this issue.

The (second) Expert Consultation on Marine Protected Areas and Fisheries Management was held from 14 to 16 April 2003 in Salammbô, Tunisia, and was hosted by the Institut National des Sciences et Technologies de la Mer (INSTM). Twenty-eight experts attended the consultation, as well as experts from the FAO–Copemed Project, UNEP RAC/SPA and IUCN. The objective of the consultation was to explore aspects dealing with marine protected areas (MPAs) in the Project Area, in an attempt to synthesize existing knowledge of, and activities dealing with, MPAs, with particular attention to fishery management, and to explore which comparative studies could be conducted in the framework of the MedSudMed Project. Fifteen scientific contributions were presented, touching different issues, among which, an ecological description of protected zones, proposals for future protected areas, socio-economic studies related to fishing closure, and the legal framework for protected areas. Definitions of terms to be used were also discussed. The main recommendations regarded the lack of guidelines on the use of MPAs as a tool for fishery management specific to the Mediterranean, and suggested that MedSudMed could focus on filling this gap, also involving RAC/SPA.

2. State of knowledge of small-pelagic-fish species in the Project Area: contribution of the experts and the regional projects

The experts' contributions covered an array of topics touching the issues proposed in the terms of reference for the consultation.

Echo surveys and stock-assessment results were presented whenever available (i.e. at INSTM and at IRMA–CNR; see papers by Ben Abdallah and Adel Gaamour, and Bonanno *et al.*, in the present Technical Document). Echo-surveys have been conducted for several years by both institutes, resulting in knowledge of the geographical distribution and an estimation of the pelagic biomass along the Tunisian and Sicilian coasts, respectively. Target species differ slightly; INSTM species of interest are: *Sardina pilchardus* (sardine); *Sardinella aurita* (round sardine); *Engraulis encrasicolus* (anchovy); *Trachurus trachurus* (Atlantic horse mackerel); *T. mediterraneus* (Mediterranean horse mackerel); *T. picturatus* (blue jack mackerel); *Scomber japonicus* (chub mackerel); *S. scombrus* (Atlantic mackerel); *Boops boops* (bogue). IRMA–CNR focuses on sardine and anchovy. Experts from both institutions presented the equipment and research vessels used, the adopted sampling design and data-processing software used on board. Biomass estimation and spatial distribution of the pelagic biomass were available by year and season, from 1998 to date. Historical data were also commented on (e.g. results of surveys conducted in 1972, 1981, 1994 and 1995 in Tunisian waters. The programme of both institutions includes the coupling of physical phenomena with biological data in order to understand better the influence of hydrographical features on the spatial distribution of the pelagic biomass. For future studies to be conducted, it was also suggested to take into account the predatory behaviour of epipelagic species, such as *T. trachurus*, *T. mediterraneus* and *Spicara flexuosa*, in view of their predation on other small pelagic species, particularly sardine and anchovy (see paper by Ragonese *et al.* in the present Technical Document).

Still in the framework of the surveys, results on the acoustic identification of small pelagic fish species obtained during INSTM echo-surveys were presented. The goal of such studies is to be able to identify the species of fish from their acoustic signatures (echograms). The direct application provides a better estimation of specific spatio-temporal distributions of each species, and therefore a selective targeting for fisheries. The study presented (see paper by Hannachi *et al.* herein) showed the results of the application of neural networks to the automatic identification rate of three species (anchovy, sardine and horse mackerel), as well as the equation relating Target Strength (TS) to sardine length. The possible application of this method to other parts of the Project Area was discussed and it was agreed that these results could be taken as a springboard for future activities at the regional level.

Issues related to the reproductive strategy and reproductive biology were addressed, with a presentation of available knowledge and on-going activities in the various institutions. A programme on eggs and larvae was launched in 2002 by INSTM, in order to study the spatial distribution of spawning and nursery areas, the effect of environmental factors on eggs and larvae, as well as trophic relationships, growth and mortality (see the paper by Zarrad and Bedoui herein). The methodology was presented for the seasonal and monthly surveys that are currently performed, resulting in the recording of a set of abiotic and biotic parameter values. The same issues are dealt with in the framework of the on-going surveys conducted by IRMA–CNR since 1998 and which produced results on the advection of eggs and larvae along the southern Sicilian coast, using biological and hydrographical measurements (see paper by Patti *et al.* herein). Spawning and nursery areas were mapped for many years, but several hypotheses still remain to be tested, in particular regarding retention zones and relationships with frontal areas.

Moreover, reproductive cycle, maturity stages and age and growth studies were carried out in both the above-mentioned institutions (see papers of Basilone *et al.* and Gaamour *et al.* herein). Indications of reproduction periods are available for the different species, as well as information on the regional variability of individual size. The main methods and results of age and growth studies were presented, showing the calcified structures chosen, the processing and finally the growth curves, age structure and length–age keys that were calculated. Regarding, the reproductive strategy, the length at first maturity was given for the species that have been studied so far, as well as the reproductive periods (winter and early spring for sardine and bogue in Tunisia, and spring to autumn for anchovy and round sardine in Tunisia and in Italy), determined by macroscopic and microscopic studies.

In accordance with the terms of reference of the consultation, information on small-pelagic fisheries was also presented. When available, information on inventories of active units, and their period of activity, as well as on the target species, was given. Moreover, in some places, there are indications of the spatial variability in the species composition of the catches. An interesting comparison between actual catches and biomass estimations for the Tunisian waters (see paper by Gaamour *et al.* herein) was presented. A good example of a national fishery statistical system was presented, with an application in Maltese harbours, developed with the support of the FAO–Copemed Project. Sheets used for the data collection (effort and catch data) were shown, as well as examples of possible outputs, such as summary statistics resulting from direct observation, for boats and gears, for species caught by gear, monthly landings and effort estimates for the different types of gear, mapping of the number of vessels operating on the different fishing grounds, etc. (see paper by Muscat herein). The performance of such a system was underlined by the consultation which fully agreed on the relevance of such an initiative to future studies on fishing effort.

Examples of spatial representation and modelling of fishing effort in Maltese and Tunisian waters were presented. Both were based on information collected from fishermen and used GIS for the presentation of the results. The necessity of carrying on with such studies in order to fill existing gaps was underlined by all the participants.

Finally, a general synthesis was provided on the influence of meteorological factors on small pelagic fish species, giving worldwide examples, such as the effects of El Niño on south-eastern Pacific populations of small pelagic fish species, or studies conducted in the Gulf of California on the Pacific sardine. A list of meteorological parameters relevant to studies on small pelagic fish species was presented, as well as those that are presently under investigation in the Project Area, in Malta in particular.

The representative of the FAO–Copemed Project recalled the main results of the Workshop on Environmental Variability and Small-Pelagic Fisheries in the Mediterranean Sea organized by Copemed in June 2001, in Mallorca, Spain. A Copemed publication summarizing the Workshop is available on the Copemed web site[1], as well as an extended summary included in the present Technical Document. The presentations focused on the objectives of the Workshop, which assembled international experts to determine the possible ways of studying the variability of small-pelagic-fish populations in relation to physical phenomena. One objective was to produce an inventory of existing data on the issue, and identify a future project that could be carried out. The main results of the Workshop were conceptual diagrams summarizing the biological and physical forcing on small-pelagic-fish abundance and spatial distribution, and a set of indicators that could be used for the monitoring of these populations. Methodological indications were also given on the analysis and monitoring of marine ecosystems. Finally, short-terms actions that the Copemed Project could conduct were identified.

The experience of the AdriaMed Project in promoting international cooperative research on shared small-pelagic stocks of the Adriatic Sea was presented. The main geomorphological and hydrographical characteristics of the Adriatic Sea were shown. Evidence, based on available data, of the shared nature of some of the most important demersal and small-pelagic stocks was illustrated and the need for international cooperation on fishery research and management was highlighted. The analysis and comparison of historical landing trends in both the eastern and western Adriatic outlined the production patterns of Adriatic small-pelagic fisheries; the main factors behind the observed trends were commented on. The four main small-pelagic stocks that are regarded as shared in the Adriatic are: *Engraulis encrasicolus*, *Sardina pilchardus, Scomber scomber* and *Sprattus sprattus*. Coherently with the AdriaMed mandate to promote joint research for fishery management, the Project promoted and carried out the programme Joint Echosurvey and Environmental Parameter Monitoring in the Northern Adriatic Sea, which resulted in a cooperative acoustic stock assessment at the regional level (Croatia, Slovenia and Italy), the mapping of pelagic-biomass

[1] http://www.fao.org./docrep/FIELD/003/AD105E/AD105E00.HTM

distribution and a preliminary analysis of environmental parameters in relation to the observed occurrence of the target species. The main results were shown and discussed. A second relevant programme entitled Data Collection and Biological Sampling System on Small Pelagics in the Adriatic Sea was presented. It is based on the establishment of a port sampling network around the Adriatic Sea, in all the four countries participating in AdriaMed (Albania, Croatia, Italy and Slovenia), where full, standardized fishery statistics and biological data collection is performed and which has led to the first regional stock assessment workshop. Results of VPA-based stock assessment were presented together with their implications for fishery management. With reference to both AdriaMed programmes, the implementation strategy adopted (preparatory phase, sampling-design identification, on-the-job training sessions, data collection and analysis workshops, etc) was described. Lastly, the activities of the AdriaMed Project that address small-pelagic fisheries were placed in a management context, by commenting on the relationships between conventional management schemes and a sustainable-development reference system.

3. List of small-pelagic-fish species considered relevant in the Project Area

The list of priority species that future activities should concentrate on was discussed, taking into account the GFCM priority species list (updated at the last GFCM/SAC meeting in Thessaloniki, Greece, 30 June–3 July 2003; see FAO Fisheries Report No. 714) and their economic and ecological importance. Participants underlined the necessity of taking into account the peculiarities of each country, since the economic importance of some species varies drastically from one country to another. For example, anchovy has a predominant value in Italy, whereas it represents only 0.7% of the small-pelagic-fish catches in Tunisia, where mackerel has the highest economic value, which is not the case in Italy. Moreover, participants mentioned that some of the pelagic species on the GFCM priority list are not present in the Project Area; for example, *Sprattus sprattus*., And some others are absent but are of economic or ecological importance for some countries; for example, *Boops boops* and *Scomber* spp. in Tunisia. However, it was strongly suggested that the priority list should be adopted on ecological criteria rather than on economic ones. Therefore, the list agreed includes:

- *Engraulis encrasicolus*
- *Sardina pilchardus*
- *Sardinella aurita*
- *Scomber japonicus*
- *Scomber scombrus*
- *Trachurus trachurus*
- *Boops boops*
- *Trachurus mediterraneus*

It was agreed that *Engraulis encrasicolus* and *Sardina pilchardus* would be considered as the priority species. However, it was emphasized that the activities that could be conducted at regional level cannot exclusively concentrate on these two species. Therefore, when discussing the activities to be launched, it was agreed to mention species concerned.

4. Review of existing gaps and proposed future activities

A short synthesis of gaps in the knowledge of the biotic and abiotic parameters and oceanographic processes influencing the distribution and abundance of small pelagic species was made. Tunisian participants recalled that biological data are available for almost all the species in Tunisia, and that genetic studies of sardine began this year, in order to identify the stock unit by testing the hypothesis of three distinct populations along the northern, southern and central coasts. The main gaps regard the migration of adults, transport of eggs and larvae, and the effect of abiotic factors. Many data are presently collected during the echo-surveys, but they remain insufficient to conduct ecosystem-based studies.

In Italy, the species for which most topics have been considered is anchovy (migration of adults, transport of eggs and larvae, biological data). Some data exist for other species, collected during the echo-surveys, but to date, no similar information is available for sardine and round sardinella, mainly because of the lack of spatial data. The available samples for these species are collected in Sciacca, and do not mention the spatial distribution of the hauls. Genetic studies are planned to be started shortly, but no preliminary information is available.

Maltese participants recalled that, in Malta, only studies of the catches are conducted, and no biological or genetic study is on-going; therefore, many fields are still open and to be developed, provided that data and samples are collected.

No synthesis is available for Libya (no Libyan participant). However, it was agreed that an update of the information would be asked of experts from the Marine Biology Research Centre, Tajura, Libya, after the consultation.

Participants stressed the lack of interdisciplinary studies in the area, and the fact that data on physical phenomena of the sea are available and can be collected, but that they are not necessarily applicable to fisheries.Yet, it is of utmost importance to understand the processes driving the production of pelagic biomass, but this is not free of experimental and theoretical difficulties; these can be overcome, however, as proven by existing studies on the coupling amongst several phenomena.

Therefore, all participants agreed on the importance of collecting oceanographic and eco-biological data simultaneously, and the MedSudMed Project was recognized as an opportunity for conducting interdisciplinary activities and publishing results. Nevertheless, beyond the interdisciplinary aspect, standardization of data dealing with different topics (eggs and larvae, biomass assessment etc.) remains an important prerequisite for activities at the regional level.

The definition of joint pilot experiments optimizing the use of past information was suggested, and five topics that could give rise to regional activities in the framework of the MedSudMed Project were discussed:

a. Spatial distribution and stock assessment of small-pelagic-fish populations
b. Biological and genetic studies
c. Eggs and larvae
d. Relationships amongst biotic and abiotic factors and life-cycles of small pelagic species

e. Fishery analysis/catch and effort data

It was agreed that more detailed protocols would be written after the consultation, and persons were nominated to take charge of the different issues. Results of the discussions are summarized below for each topic.

a. Spatial distribution and stock assessment of small-pelagic-fish populations

Data from echo-surveys in the Project Area are available since 1998; the surveys were conducted by Tunisian and Italian institutions, with slight differences in the sampling design (Italian surveys are not interrupted during the night, and four hauls are systematically performed for each transect, whereas the Tunisian surveys are interrupted during the night and hauls are performed only if there are enough fish schools that are deemed interesting) and in the software used (Movies^{+} in Tunisia; Echoview in Italy).

Therefore, the possibility of conducting joint echo-surveys was suggested, as well as the extension of such surveys to include all the GSAs of the MedSudMed Project Area (e.g. add transects so that INSTM could cover the Libyan waters, and IRMA, the Maltese waters). The possibility of conducting surveys in different zones at the same time or of closing zones at different periods was discussed; this would be set up according to the availability of the vessels and to the timetable of the institutions involved. These surveys would also be used to improve acoustic methods, such as target-strength calculations and measurements and automatic school identification.

Final decisions regarding this topic are:

- to conduct a survey covering all the MedSudMed GSAs, in order to have a regional biomass estimation, as well as an idea of the distribution of the stock at regional level
- to calculate common TS relationships to be used in the near future in the region.

Lotfi Ben Abdallah, Angelo Bonanno and Skander Hannachi were nominated to draft a protocol for this task.

b. Biological and genetic studies

Three issues were discussed under this topic.

- *Genetic studies:* To date, no genetic information is available for the Project Area. The only on-going study is in Tunisia, on sardine, but it has not been completed. In Italy, samples are being collected, but no result is available yet. Species that were considered to be a priority for such studies are anchovy, sardine and round sardinella. The conduct of these studies is justified by observations showing that samples of fish from different sites have different morphological and biological characteristics. All institutions represented at the present consultation recognized the importance of conducting such activities, even though in certain zones, such as Maltese waters, small pelagics are targeted only 2 or 3 months of the year and therefore have a limited economic importance.

- *Growth and age determination:* In the framework of methodological standardization, it was agreed that age and growth should be determined using the same tools and scales at the regional level. This issue had already been discussed during the first Expert Consultation on demersal resources (Malta, December 2002). A training course and an intercalibration workshop were proposed. It was agreed to draft a proposal that could also be discussed with the Copemed Project for the co-organization of the event.
- *Reproduction strategy:* The importance of standardizing methods, in particular for macroscopic maturity stages, and the length–frequency distribution of the samples was discussed. Data should be compared at regional level and among zones with different environmental characteristics and/or exploitation rates, as these probably influence the age and length at first sexual maturity. The present debate within the GFCM/SAC on this issue was recalled, as the length at first sexual maturity varies greatly from one area to another, making difficult the adoption of a unique value valid for all Mediterranean areas. MedSudMed could help by providing more accurate information, based on the relevant scientific results, to the SAC Working Groups concerned. Analysis at regional level would lead to conclusions that would either correct the present data or tentatively explain the reasons for the considerable variability.

The final agreements include:

- The organization of a training course on growth and age determination, in collaboration with the FAO–Copemed Project. The training course should include issues discussed during the EC on demersal resources (Malta, December 2002). Jarboui and Ragonese will draft a proposal.
- Genetic studies focusing on sardine and anchovy, and based on the use of microsatellites. Advantage will be taken of the experience and publications of the Adriamed Project on this topic. Ragonese will write a proposal to be circulated and discussed.
- The standardization of methods used to study reproduction strategy, especially the length at first sexual maturity and the partial and/or annual fecundity will be calculated/determined jointly, in order to have valid values at regional level. Gaamour and Patti are in charge of these matters.

c. Eggs and larvae

The conduct of an interdisciplinary activity at regional level was suggested, in order to get information on physical processes that influence the abundance and distribution of early-life stages. Contemporaneous surveys could be conducted in different areas, with mixed research teams on board, in order to confirm the localization of spawning areas (using concentration of eggs as an indicator, but also catches of spawning adults). The amount of information that could be collected and exchanged between countries by contemporaeous surveys was stressed.

The objectives of the surveys would be to test hypotheses on the localization of spawning and nursery areas and to study the relationships with physical processes. A suggestion was also made to measure the TS of juveniles, in order to predict the recruitment success. The working scale for the study of the reproductive strategy should be determined, as well as the set of parameters to be taken into account/measured, and the length and best period for the surveys, which should cover spawning and recruitment of the target species.

A suggestion was also made to organize a workshop on the standardization of methods applied to the sampling and study of eggs and larvae. The Copemed Project will study the possibility of co-sponsoring the meeting, provided that it includes a training component.

The final agreements were therefore to:

- Establish a Working Group on Standardization and Planning supported by MedSudMed and possibly by Copemed
- Organize joint surveys mixing researchers from different institutions on board
- Produce a protocol to identify spawning and nursery areas, estimate the recruitment by using daily egg production and mortality
- Adopt the following target species: sardine, anchovy and round sardinella.

Bedoui, Bonanno, Mazzola, Patti and Zarrad accepted the task of drafting protocols and proposals on this topic.

d. Fishery analysis/catch and effort data

It was stressed that this issue had not treated fully enough during the consultation, despite its importance and the continuing lack of information in all institutions. It was suggested that each country prepare a national profile with the relevant information, mentioning the available time-series of catch and effort data.

The importance of sharing the same statistical system on fishing effort and pressure at regional level was also stressed. In this respect, the MedSudMed Information System that is being developed will be a relevant tool for the standardization of data collection and storage.

Finally, the extension of the study on spatial distribution of fishing effort in Tunisia, to the whole Tunisian coast, and to the whole Project Area was suggested. Ben Rais Lasram, Muscat and Patti will draft a proposal on this matter.

e. Relationships between biotic and abiotic factors and life-cycles of small pelagic species

This issue was already touched on in the preceding topics; there is a need to determine the set of parameters that are relevant to the small-pelagic-species life-cycle, spatial distribution and abundance. Focusing on a few parameters already measured in the framework of on-going studies was suggested; this idea had already been proposed during the first Expert Consultation, on demersal resources. The proposed parameters were:

- temperature
- salinity
- fluorescence
- CTD measurements in general
- wind regime (available in Malta, Tunisia and Italy, at low cost)
- dissolved oxygen

A suggestion was made to couple remote-sensing data with biological data. A calibration could be performed on a specific area (e.g. Gulf of Tunis) to have an estimate of the primary production (by relating it to chlorophyll and/or other phytoplankton measurements when and where available). The overall objectives would be to have real-time observations and enhance knowledge of existing relationships with biological data regarding small pelagics. It was recalled that remote-sensing data are available either from the ICoD in Malta or from IRMA–CNR in Mazara del Vallo, Italy.

5. Update on the MedSudMed Information System

An update on the MedSudMed Information System was presented. One of the expected outputs of the Project is a regional database and information system including a GIS and a web interface, which could be used by all participating countries to share information. This work in progress is being conducted with the help of national experts who suggest specific layouts for the storage and representation of the data. Standardization of the stored data is of utmost importance and conditions the possibility of performing joint data processing at the regional level.

The prototype of the application that is being developed was presented. This software should be used for the input, storage and analysis of data related to demersal resources. Further development of the application should include a module applied to small pelagics and to biocenoses.

The participants agreed on the usefulness of such a system and it was underlined that, to date, there is no functional data base managing acoustic data from echo-surveys. The participants therefore welcomed this initiative. However, acoustic data are not easy to manage and, prior to any storage, agreement on the organization of these data should be reached, particularly the spatio-temporal resolution of the data to be stored. It was agreed to consider this matter more deeply in the near future, and the experts gave their general agreement to collaborate in this initiative.

Annex A: List of participants

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Annex B: Agenda

1. Opening of the consultation
2. Introduction by Project Coordinator and Scientific Coordinator
3. Election of the Chairman and of the Reporting Group
4. Adoption of the agenda and organization of the EC
5. Short synthesis of the previous MedSudMed Expert Consultations
6. Overview of experience and available knowledge in the Project Area (past and on-going key studies, data collection and management, main research topics, available means, characteristics of the fisheries etc.)
7. Experience of other FAO Regional Projects (Adriamed and Copemed)
8. Synthesis of the knowledge and existing data on small pelagic fishes in the MedSudMed study area
9. Discussion and identification of a list of species having particular economic or ecological importance and that will be considered as priority in the Project Area (this list is to be proposed according to the GFCM priority list, but also according to national needs and activities and on-going studies)
10. Identification of gaps and possible improvements and methodological considerations
11. Update on MedSudMed Information System.
12. Identification of possible pilot studies
13. Other matters

Annex C: Terms of reference

1. Introduction

As a consequence of the technical guidelines produced by FAO in support of the implementation of the Code of Conduct for Responsible Fisheries, research to increase knowledge of the ecosystem approach to fisheries is becoming a priority. This was further underlined and strongly recommended by the Declaration of the Reykjavik Conference (1–4 October 2001), which encourages the incorporation of ecosystem considerations into fisheries management, particularly by *"building expertise for collecting and processing the biological, oceanographic, ecological and fisheries data for designing, implementing and upgrading management strategies."* This was recalled during the twenty-fifth session of the FAO Committee on Fisheries (Rome, 24–28 February 2003), by several Member States who underlined the importance of deeper analysis of bioecological issues, and the development of ecosystem-related indicators, reference points and decision rules.

In this context, the FAO Trust Fund Regional Project MedSudMed Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Strait of Sicily is aimed at supporting scientific communities and countries in the development of a monitoring system for the study of fishery resources and ecosystems. The main objectives of the Project are to increase the scientific knowledge of ecosystems in the Project Area, strengthen national and regional expertise, and develop the scientific cooperation for the standardization of the methods used in fishery research.

During the 1st Meeting of the MedSudMed Coordination Committee, a general outline of research and the activities to be implemented by the Project was discussed. A preliminary plan was presented for research aimed at improving the information resources for fishery management, biodiversity protection, and ecosystem preservation in the Project Area. It focused on three main proposals: (i) spatial distribution of demersal resources according to environmental and fishery features; (ii) stock identification of small pelagic fishes and oceanographic processes influencing their abundance and distribution; (iii) marine protected areas and fishery management. Moreover, the implementation of the Project's activities are supported by a regional data base and information system for the storage, analysis and representation of data relative to fish stocks, fisheries and environmental parameters.

The MedSudMed Project, for each of these four topics, decided to organize an Expert Consultation (EC), in order to provide an overview of available knowledge of fishery ecology in the region, and of existing data. The ECs involve regional and extra-regional experts and will provide an overview of available knowledge of the matters addressed. The aims of the ECs are the definition of a work programme of activities to be implemented on the basis of a common methodology and the proposal of pilot study cases. Furthermore, the ECs should also identify needs in national and regional expertise and are an opportunity to define criteria for the data collection and to identify a task leader who will coordinate this programme of work.

The present report is of the EC on Small Pelagic Fishes: Stock Identification and Oceanographic Processes Influencing Their Abundance and Distribution, which is the third Expert Consultation organized by the Project.

2. Background information

The document CC1/02, General Outline of Research, submitted to the 1st meeting of the Coordination Committee (19–20 September 2002), recalled the importance of small pelagic fishes, at commercial and the scientific levels. The latest available FAO statistics show a total capture of 69,094 metric tons for 2001 in the Project Area[2]. Besides, small pelagic fishes represent an intermediate trophic level that can be critical in, for instance, highly productive ecosystems, such as upwelling areas, where they are supposed to exert a control both on the higher and the lower trophic levels.

Relations to oceanographic parameters have been explored and there is considerable evidence that environmental variability plays an important role in controlling abundance and distribution of marine populations. However, despite the existence of models and theories, and despite the important fisheries in the area, little or no information is available on the ecology of small-pelagic-fish populations and stock identification in the central Mediterranean. There is a strong need to identify and describe in detail the processes responsible for enrichment of the water column (circulation, upwelling, frontal zones etc.), describe possible migration patterns in the area and their triggers, identify and monitor factors conditioning spawning patterns, recruitment success and development of early-life stages.

In line with the SAC recommendation[3] to identify more shared stocks in the Mediterranean, a synthesis of the existing knowledge and data in the framework of a MedSudMed component conducted at a regional level should greatly contribute to enhancing knowledge of the stock identification and ecology of small pelagic fishes in the Project Area. Localizing the feeding, reproduction and concentration zones would allow identification of the oceanographic patterns responsible for the spatial distribution and the abundance of small pelagic fishes. Therefore, the objectives of this Project component, as agreed at the 1st meeting of the Coordination Committee, are to provide a synthesis and identify activities to be conducted on the identification of stocks of small pelagics and the influence of oceanographic processes on their abundance and distribution.

3. Objectives of the Expert Consultation

The EC will present and discuss issues concerning small pelagic fishes and their environment in the Project Area, with a view to deriving a synthesis of existing knowledge on the different species and on-going activities. Contributions should provide descriptions of the studies conducted so far on these resources and their environment, as well as the corresponding pelagic fisheries. The synthesis should be based on available fishery, biological, ecological and physical data relative to small pelagic fishes.

The presentation of all available information is essential for the development of future activities (research, training, or management). This would enable the listing of gaps in knowledge and methods, and the consequent drawing-up of work and training programmes agreed upon by all partners.

[2] GFCM landing statistics for sardines, sardinellas, anchovies, mackerels, horse mackerels in 2001 corresponding to geographical sub-areas 12 to16 and 21.

[3] Report of the fourth session of the GFCM Scientific Advisory Committee, Athens, Greece, 4–7 June 2001.

4. Focus of the EC and the issues to be addressed

The focus of the Expert Consultation will be on the stock identification and oceanographic processes influencing the abundance and distribution of small pelagic fishes in the Project Area. Different life stages should be considered (recruits, juveniles, adults). Past and on-going Projects may be presented, as well as tools and methodologies used in the area. Historical data may also be presented.

In the light of the matters discussed at 1st meeting of the MedSudMed Coordination Committee, the types of studies and topics that may be addressed are:

- All available elements in the distribution of small pelagic fishes and their feeding, reproduction, spawning areas.
- Description of the physico-chemical parameters of the region that condition plankton productivity, passive transport, retention and concentration zones: currents, hydrographical patterns (frontal and upwelling zones etc.), bathymetry.
- Interactions between small pelagic fish and biotic and abiotic environmental phenomena. Results of on-going research and bibliographic reviews on small pelagics and their environment in the Project Area may be presented.
- Ecology/biology of the main pelagic species (*Sardina pilchardus*, *Engraulis encrasicolus*, *Trachurus trachurus*, *T. mediterraneus, Scomber japonicus, S. scombrus,* and any other pelagic species that is deemed important from an ecological or economic point of view). Adult and larval ecology should be addressed, as well as any study of growth parameters.
- Migration patterns.
- Description of the fishery: seasonality, quantification and spatial distribution of the fishing effort.
- Methods, equipment, techniques, software for data collection or treatment.
- On-going data surveys.
- Available data that can be exploited for further results.
- Data-management issues.

5. Expected outputs

- Synthesis of the knowledge and data on small pelagic fishes in the MedSudMed Project Area
- Identification of a list of species having particular economic or ecological importance and that will be considered a priority in the Project Area. This list is to be developed according to the GFCM priority list, but also according to national needs and activities and on-going studies.
- Identification of gaps: will give an overview of the information that is still missing, in particular on spatial distribution of the stocks, migration patterns of adults, passive transport of eggs and larvae, factors determining recruitment success.

- A methodology to fill the gaps: this will regard more particularly feasibility studies and/or research to be conducted to improve knowledge of the relationships between the biotic and abiotic environment and distribution, abundance and life-cycles of small pelagic fishes; e.g. data collection may be organized according to the on-going studies in the participating countries (agreement on the type of sampling, calendars, comparative studies).
- Identification of pilot study cases. Advantage will be taken of outputs of previous studies on similar topics. A work plan will be defined and discussed in order to implement the activities that will have been agreed upon.
- Overview of the regional and national expertise.
- Training needs/possibilities: the organization of training will be discussed according to the needs that will have been expressed, in particular regarding exchanges between countries, possible organization of visiting scientists, collective courses for all countries.
- Creation of a regional network of multidisciplinary experts, to be involved in the MedSudMed activities relevant to this EC.

The report of the Expert Consultation will be edited as Technical Document 5 of the MedSudMed Project and will be available as an information paper for the SAC and SAC Sub-Committees on Marine Environment and Ecosystems and on Stock Assessment, as well as for other relevant regional meetings and bodies concerned with the subject addressed.

Before the consultation, participants will be asked to send an abstract of the work they plan to present thereat; this abstract should be consistent with the present Terms of Reference. Authors will then be asked to produce an extended written version to be included in the MedSudMed Technical Document.

Discussions held during this Expert Consultation should not overlap with those of previous Expert Consultations. To date, two MedSudMed ECs have been held, on:

- Spatial distribution of demersal resources in the Strait of Sicily and the influence of environmental factors and fishery characteristics (Gzira, Malta, 10–12 December 2002)
- Marine protected areas and fisheries management (Salammbô, Tunisia, 14–16 April 2003)

Any overlap will be avoided by presenting the main results of the previous ECs. Any available information, data, maps arising from the work of the previous EC will be used as a basis for future activities that will be discussed and decided during the present EC. Therefore, work in progress and available knowledge regarding the previous ECs will be presented.

6. Participation

The Expert Consultation will consist of regional experts. The participants will have a broad disciplinary background; it is of utmost importance that persons with different skills be brought together to share their knowledge and experience.

Discussions will be conducted by the Scientific Coordinator of the Project, Project staff and experts participating in the Expert Consultation. A team leader will be nominated to chair the meeting, help with the preparation of the final document and to coordinate the activities that will be agreed on.
The Expert Consultation will be conducted in English or French.

7. Organization and activities of the Expert Consultation

The Expert Consultation will be convened by the Institut des Sciences et Technologies de la Mer (INSTM), in cooperation with the MedSudMed Project. It will be held in the meeting room of INSTM in Salammbô from 1 to 3 October 2003. Participation is by invitation only.

Coupling between the hydrographic circulation in the Strait of Sicily and the reproductive strategy of the European anchovy *Engraulis encrasicolus*: effects on distribution of spawning grounds

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Abstract

Some aspects of the effects of the hydrographic circulation on the reproductive strategy of the European anchovy (*Engraulis encrasicolus*, L. 1758) population off the southern coast of Sicily are illustrated, using information from satellite SST data and the horizontal distribution of anchovy eggs. Ichthyoplanktonic data used in this study were collected during six summer oceanographic surveys between 1997 and 2002. The general circulation pattern is locally controlled by the motion of the Modified Atlantic Water, the Atlantic–Ionian Stream (AIS). During summer, the water mass advected by the AIS to the south of Sicily is fresher and warmer than the water north of it at the same depth. This characteristic allows the use of temperature as a tracer of the AIS trajectory. The year-to-year variation in the AIS path, inferred from SST data, while confirming the existence of different environmental conditions along the southern coast of Sicily, appeared to be able to affect the anchovy spawning strategy. In fact, the analysis of available information allowed the identification of a correlation between the AIS trajectory and the location of major spawning grounds.

1. Introduction

The main hydrographic feature off the southern Sicilian coast is the Atlantic–Ionian Stream (AIS), a meandering surface current flowing towards the Ionian Sea. Its path and its year-to-year variation have consequences for the predominant hydrographical phenomena in the region, such as the extension of upwelling and the formation of frontal structures. All these hydrographical features have shown their influence on the spawning strategy of the European anchovy, *Engraulis encrasicolus* (Linnaeus, 1758), and the survival of the early-life stages (García Lafuente *et al.*, 2002).

The AIS acts as a transport mechanism for displacing anchovy eggs and larvae from the more important northern spawning grounds towards the southern part of the region (García Lafuente *et al.*, 2002). During summer, the Atlantic water advected by the AIS to the south of Sicily is warmer than the water north of it at the same depth, a fact that is the consequence of the presence of the Adventure Bank Vortex (ABV; Robinson *et al.*, 1991, 1999; Warn-Varnas *et al.*, 1999) and the frequent wind-induced upwelling along the southern shore of the island (Piccioni *et al.*, 1988). The relationship between the meanders of the AIS and the surface thermal structures in the Strait has been stressed in oceanographic papers dealing with this area (Robinson *et al.*, 1999; Lermusiaux, 1999).

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If the AIS path is far offshore, the central-northern coast may have a greater extent of upwelling, thereby producing drastic changes in the temperature regime of the surface water. As a result, the anchovy, which prefers warm water, may refrain from spawning during the peak spawning season (summer). The contrary would occur if the AIS were closer to the coast: the ABV would be reduced in size and water in the coastal zone would increase in temperature because of the AIS's influence.

In this study, the effect of the general surface circulation on the anchovy spawning in the northern part of the Strait of Sicily was investigated. To this end, we analysed data collected in ichthyoplanktonic surveys from 1997 to 2002, during the peak of the anchovy spawning period (Giráldez and Abad, 1995; Cuttitta *et al.*, 1999).

2. Materials and methods

Six annual summer surveys were carried out from 1997 to 2002, aboard the R.V. "Urania", except in 1997 when the F.V. "S. Anna" was used, and in 1999 when the R.V. "Copernaut Franca" was used. Table 1 summarizes information on the surveys used in this study.

Table 1. List of surveys used in this study and related information.

Survey	**Vessel**	**Period**	**Number of stations**
ANSIC97	S. Anna	19 July–2 August 1997	85
BANSIC98	Urania	25 June–11 July 1998	127
BANSIC99B	Copernaut Franca	19–25 June 1999	70
BANSIC2000	Urania	24 June–8 July 2000	131
ANSIC2001	Urania	7–25 July 2001	144
ANSIC2002	Urania	11–31 July 2002	219

Figure 1 shows the map of the study area and the distribution of the plankton stations sampled during the survey series. A total of 776 stations were carried out: 85 in 1997; 127 in 1998; 70 in 1999; 131 in 2000; 144 in 2001; and 219 in 2002 (see Table 1). Sampling stations were based on a step-grid of 4–6 nautical miles on the continental shelf of the southern Sicilian coast, and on a 12-nautical-mile step-grid offshore. Oblique plankton hauls were carried out at a speed of 2 knots targeting at least 100 m depth, where possible, using a Bongo net system with a 40-cm mouth diameter and a mesh size of 0.2 mm for both sides of the frame.

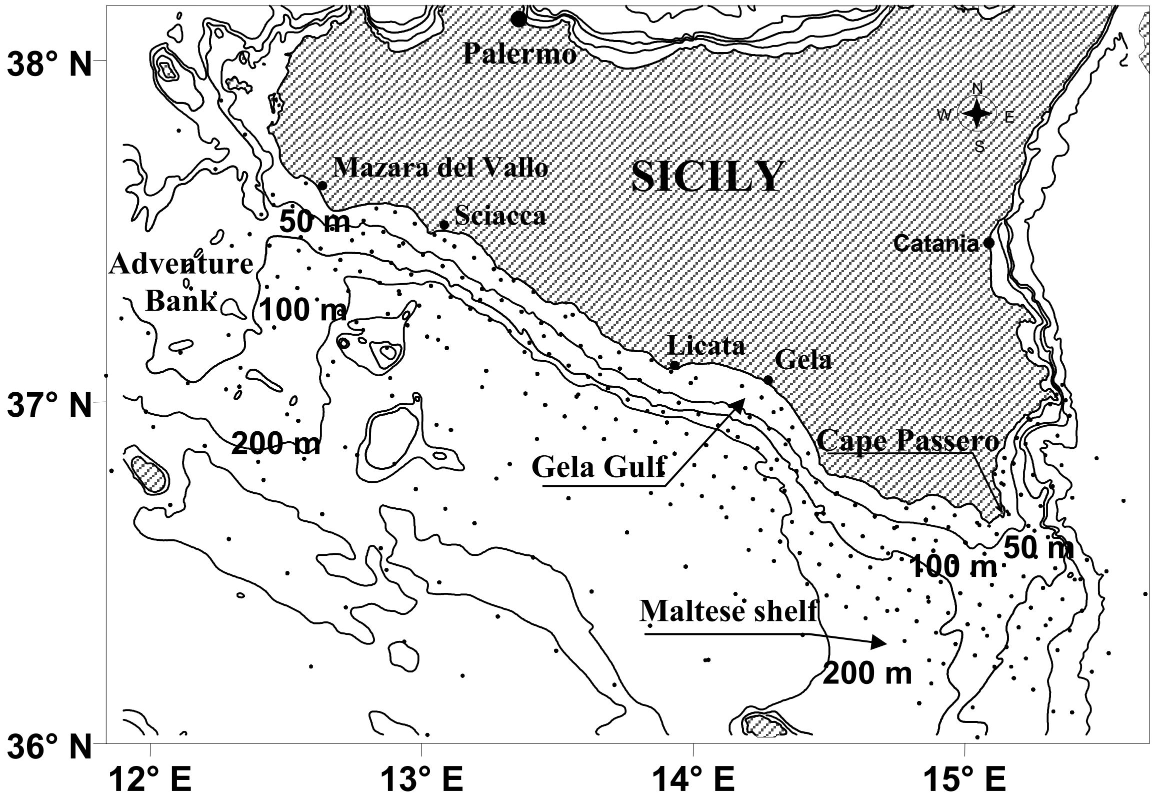

Figure 1. Map of study area including positions (•) of the Bongo-40 hauls and CTD cast stations; surveys 1997–2002.

Samples were preserved in 4% buffered formaldehyde and seawater solution. The sorting of ichthyoplankton samples was performed in the laboratory using a stereobinocular microscope at a magnification of 12×. Anchovy eggs were extracted and counted. Counts were interpolated (kriging method) for drawing purposes by means of Surfer Golden software.

Hydrographical data were acquired during the same cruises by means of CTD probe model SBE 911. CTD casts were analysed using Ocean Data View software, and the path of AIS was initially depicted by the minimum-salinity isohaline.

Temperature and salinity fields in the Strait of Sicily are controlled by the AIS dynamics to a great extent. As a general rule, temperature and salinity are correlated in the sense that the warmer the water, the fresher it is. This is the expected result if the warm water is advected by the AIS, whose main hydrographical characteristic is a salinity minimum. Because of the specific relationship between temperature and salinity that is observed in this area, temperature can serve as a tracer of the AIS trajectory off the southern coast of Sicily. Specifically, the analysis of CTD data suggested that any isotherm whose numerical value were close to 22ºC or 24ºC (depending on whether the SST image was for June or for July) would be indicative of the AIS path in the Strait in June–July, the time of the year when the surveys were carried out (Mazzola *et al.*, 2002).

In this study, in order to infer the AIS trajectory, SST satellite images derived from NOAA/AVHRR (infrared sensor) data were analysed. The spatial resolution of these images, a value-added product of the German Remote Sensing Data Centre (DLR), is 1.1 km. Composite images for the survey periods were produced by averaging the temperature of the corresponding daily images at each pixel.

3. Results

The development from egg to larval stage is temperature-dependent and for anchovy in this area takes 24–36 h (Holden and Raitt, 1975). So, the presence of eggs indicates the location of spawning grounds. Specifically, the analysis of anchovy-egg distribution allowed the identification of three main spawning areas off the southern coast of Sicily (see Figure. 2 a–f): (1) Northern, over the Adventure Bank; (2) Central, in coastal areas from Sciacca to Licata; and (3) Southern, over Gela Gulf and the Maltese shelf. However, the relative importance of these spawning areas underwent wide variations between 1997 and 2002.

Table 2 represents an attempt, based on the presence and abundance of anchovy eggs during the surveys analysed in this study, to qualitatively depict the spawning activity in the known spawning areas. In 1997 and 1998, the most important spawning grounds were the central and southern ones; in 1999, only the southern area appeared to be actively occupied; in 2000 and 2001, anchovy eggs were most abundant in both the northern and southern grounds, but not in the central one; in 2002 very low anchovy-egg densities were detected in all spawning grounds.

Table 2. Spawning activity in the main spawning areas detected off the southern coast of Sicily. “o” = absence of eggs; “+”, “++” = presence of eggs above or well above the average, respectively; “–”, “—” = presence of eggs below or well below the average, respectively.

Survey	**Spawning areas**		
	Northern	Central	Southern
ANSIC97	o	+	+
BANSIC98	–	++	++
BANSIC99B	o	–	+
BANSIC2000	+	–	+
ANSIC2001	++	–	++
ANSIC2002	o	—	—

Observed egg distributions are consistent with the SST maps in Figure 3 a–f. Specifically, the warm AIS water was advected over the central and southern spawning areas in 1997 and 1998, and mainly over southern spawning ground in 1999, 2000 and 2001, though in the last two years even the northern area gained in importance. In 2002, the AIS path was quite far offshore, producing a great general decrease in sea-surface temperature off the southern coast of Sicily.

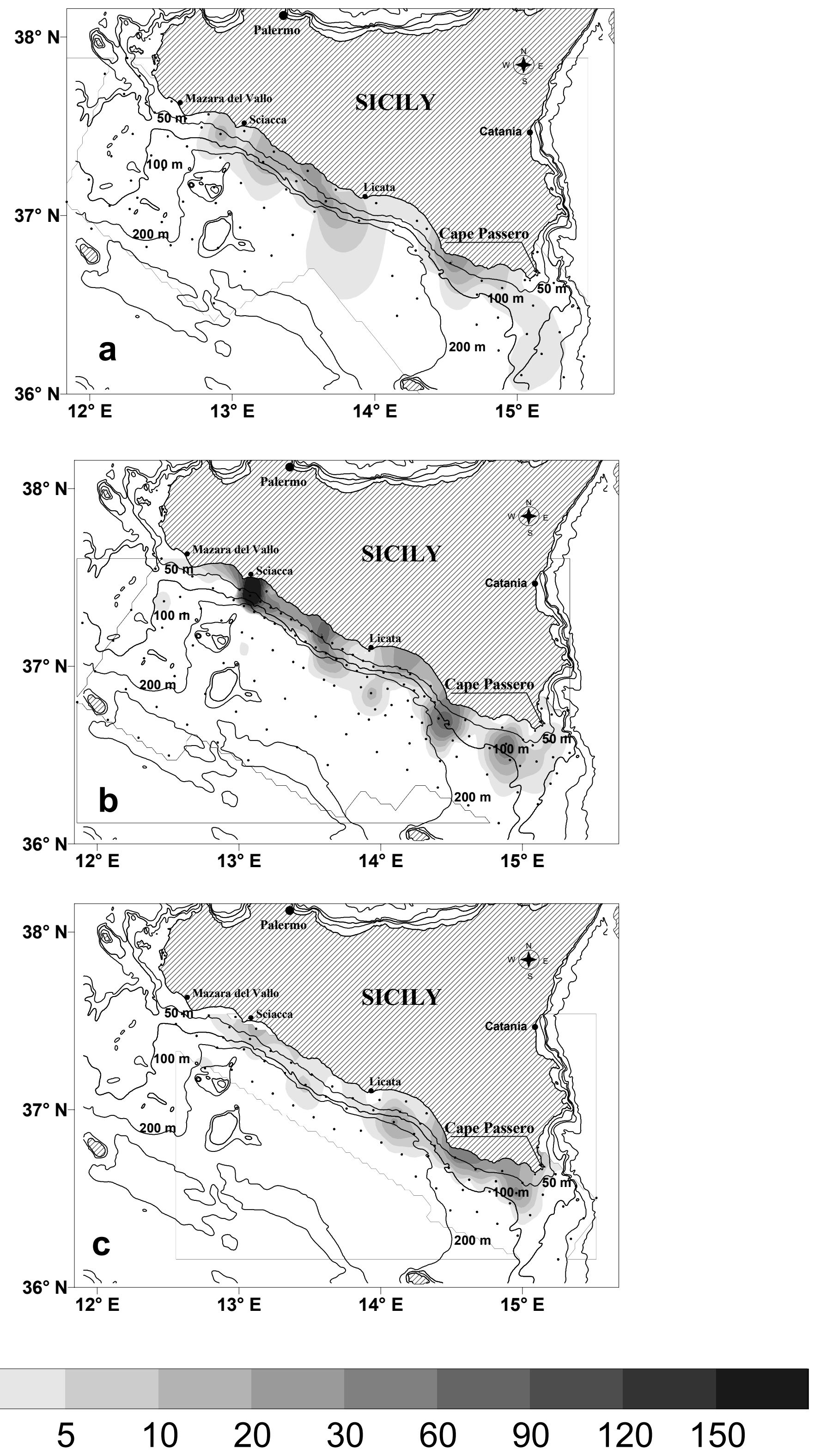

Figure 2. Distribution of anchovy eggs (counts per haul) during surveys carried out along the Sicilian coast in 1997 (**a**), 1998 (**b**), 1999 (**c**), 2000 (**d**), 2001 (**e**) and 2002 (**f**).
(continued)

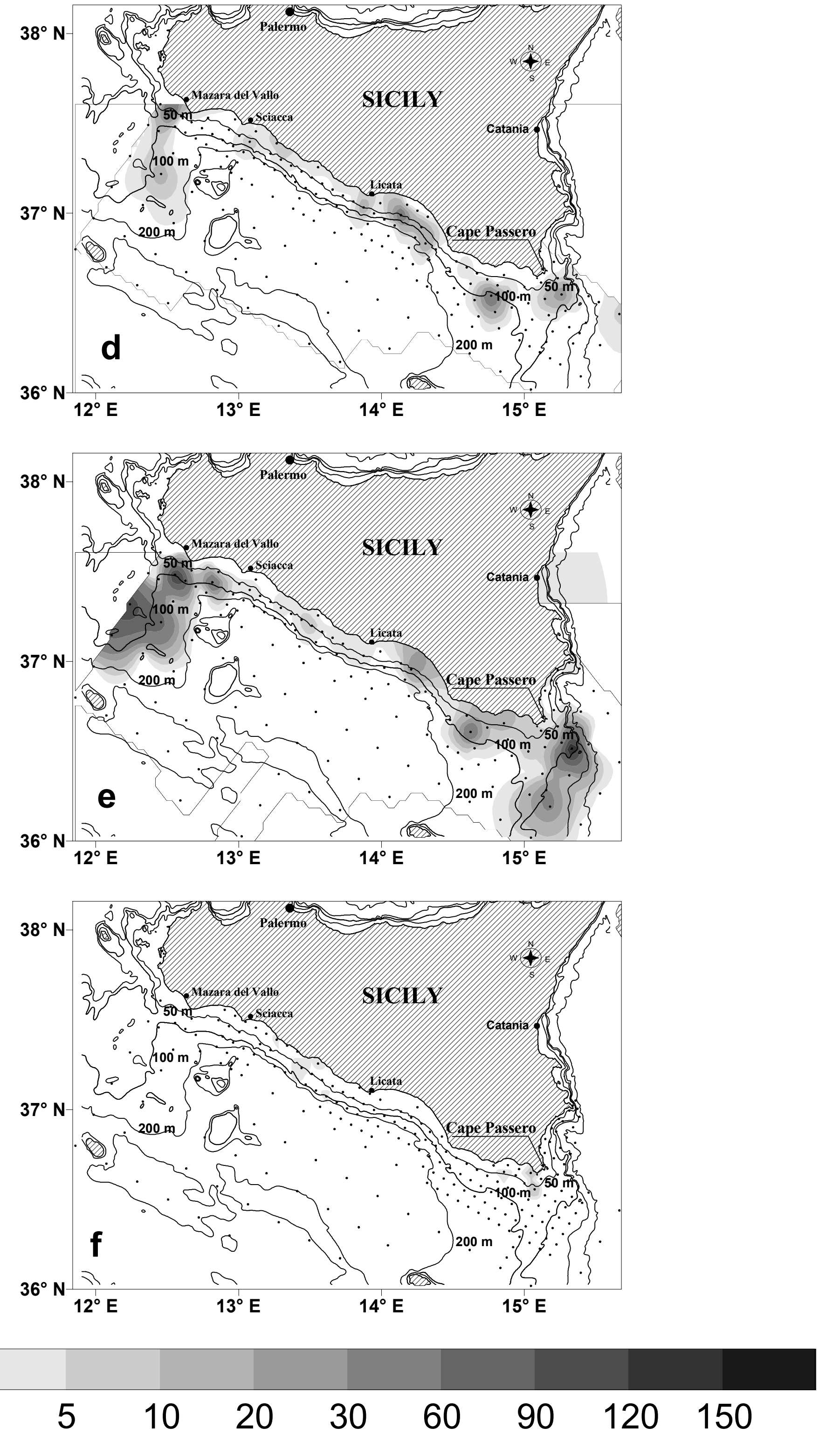

Figure 2 (continued).

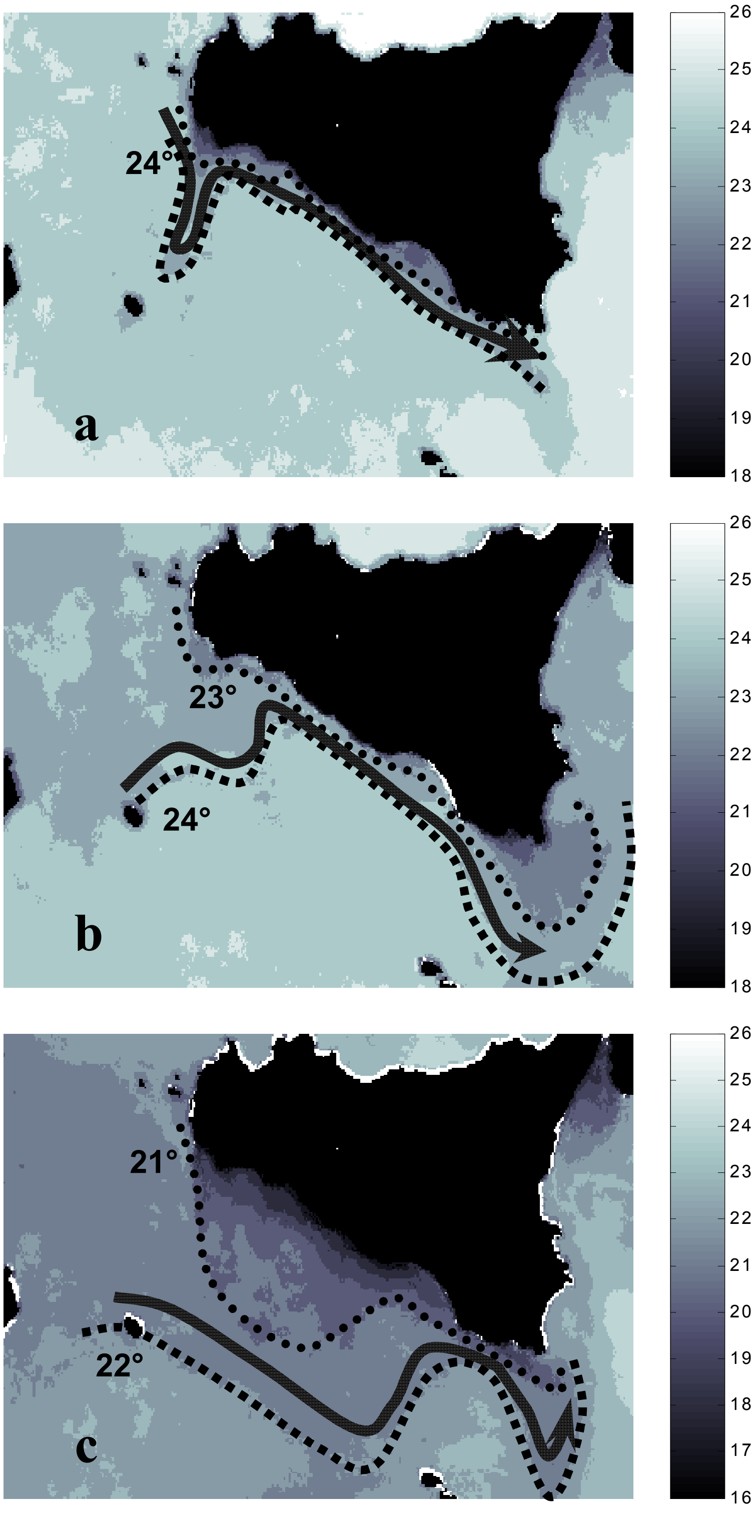

Figure 3. Composite images of daily sea-surface temperature during the surveys ANSIC97 (**a**), BANSIC98 (**b**), BANSIC99B (**c**), BANSIC00 (**d**), ANSIC01 (**e**) and ANSIC02 (**f**). The 23ºC and 24ºC isotherms (for 1999: 21°C and 22°C) have been labelled. The meandering arrows are tentative representations of the AIS, taking those two isotherms as being indicative of its trajectory. (continued)

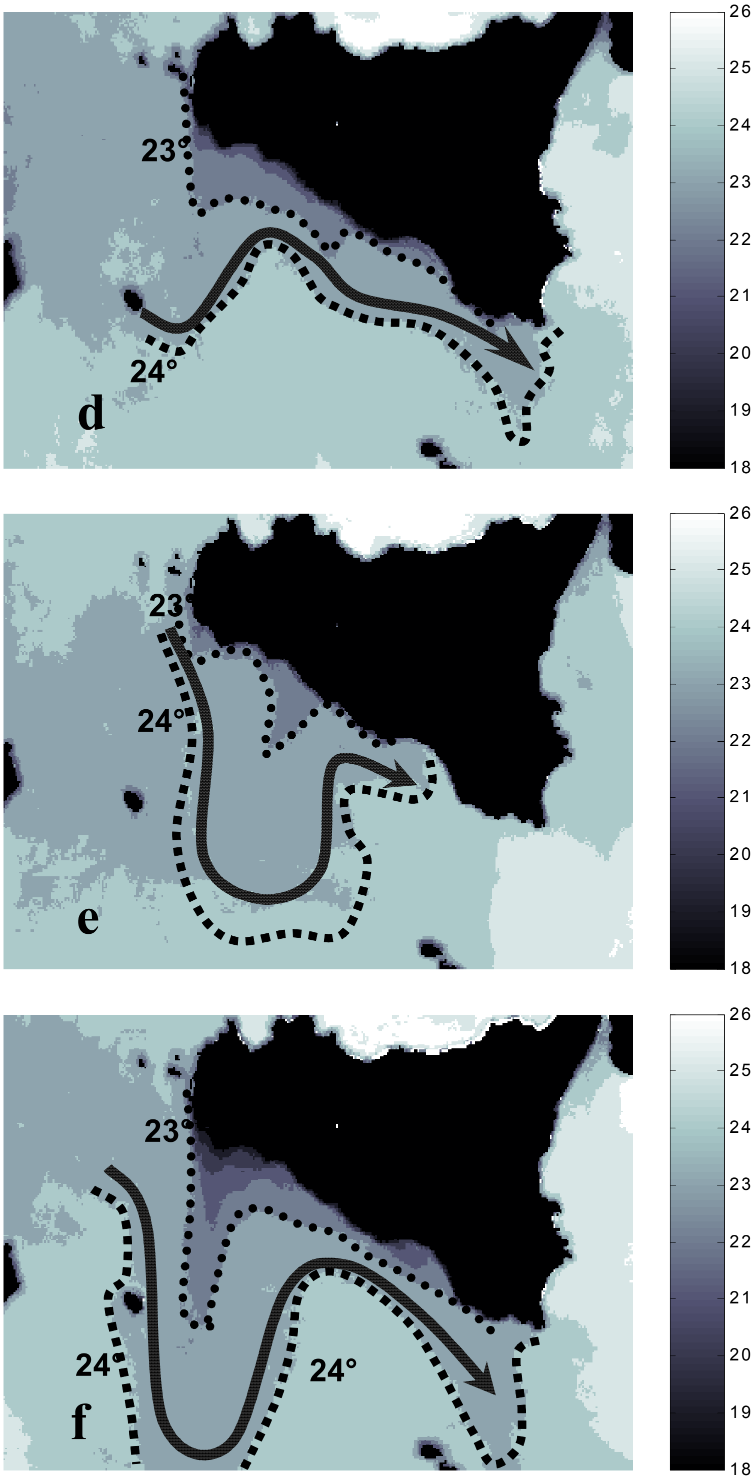

Figure 3 (continued).

4. Discussion and conclusion

The analysis of ichthyoplanktonic samples allowed the identification of a correlation between the horizontal distribution of anchovy eggs and the AIS trajectory; the latter is quite variable from one year to the next, may produce changes in the temperature range and in the extent of the upwelling in the northern part of the area. This in turn may reflect upon the distribution of the anchovy spawning grounds, since a low-temperature regime may inhibit spawning. The preference of the anchovy in the Strait of Sicily for spawning in warmer water, proposed by Mazzola *et al.* (2002) and García Lafuente *et al.* (2002), were confirmed by the results of the present study, showing that surface thermal features due to the AIS, in terms of its distance from the coast, may be successfully used as an indicator of anchovy spawning.

This work was carried out under the auspices of: two European Commission Study Projects – Distribution Biology and Biomass Estimates of the Sicilian Channel Anchovy (MED96-052) and The Sicilian Channel Anchovy Fishery and the Underlying Oceanographic and Biological Processes Conditioning Their Interannual Fluctuations (MED98-070); and the Italian Ministry of Scientific Research project ASTAMAR. We are grateful to the captain and crew of the R.V. "Urania" for their help in data acquisition. We are also grateful to the DFD (Deutsches Fernerkundungs Datenzentrum) for making the sea-surface temperature images available.

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Répartition géographique et estimation de la biomasse des petits pélagiques des côtes tunisiennes

L. Ben Abdallah* et A. Gaamour

Résumé

L'un des thèmes de recherches de l'INSTM est la gestion durable des ressources marines nationales. A cet effet, l'INSTM accorde un intérêt particulier pour les petits pélagiques (sardine, anchois, sardinelle, bogue, etc.) qui représentent 40% de la production nationale et offrent de vastes opportunités pour le développement et la pérennité de l'activité de pêche dans notre pays. La méthode acoustique et la pêche expérimentale sont employées pour l'évaluation de la biomasse et l'identification d'espèces. D'autant plus que cette méthode nous permet d'établir leur répartition géographique dans l'espace et dans le temps. Des fluctuations entre les saisons et les régions sont observées.

Mots clés : *Acoustique, petits pélagiques, Tunisie.*

Abstract

Geographical distribution and estimation of the biomass of small-pelagic fishes along the Tunisian coast

One of the research themes at INSTM is the sustainable management of the national marine resources. To this end, INSTM has a particular interest in small-pelagic fishes (sardine, anchovy, sardinella, bogue, etc.) which represent 40% of the national fish catch and provide a great opportunity for pursuing the sustainable development of Tunisia's marine fisheries. Acoustics and experimental fishing are used in the evaluation of the biomass and in the identification of the species. These methods also enable us to determine their spatial and temporal distribution. Fluctuations from season to season and from area to area are observed.

Keywords: *acoustics, small pelagics, Tunisia.*

1. Introduction

En Tunisie, le terme « petits pélagiques » est synonyme de poissons bleus. Les petits pélagiques cibles regroupent neuves espèces appartenant à cinq familles (Tableau 1). Ces espèces sont totalement libres à l'égard du fond et sont indépendantes de la nature du substrat. Ce sont donc les paramètres physico-chimiques et hydrographiques du milieu qui déterminent leur répartition spatio-temporelle. De plus, ces espèces vivent généralement en bancs et effectuent des déplacements à la recherche des conditions optimales (Fréon, 1988 ; Cury, 1995 ; Gascuel, 1995 ; Pauly, 1997)

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Dans le but d'évaluer la biomasse d'un groupe de poissons de grande importance économique et sociale, l'INSTM a élaboré un programme à long terme d'évaluation directe, par prospection acoustique et pêche expérimentale, et de suivi régulier de la biomasse des petits pélagiques peuplant les eaux tunisiennes. Les campagnes de prospection hydroacoustique présentent un double avantage. Elles permettent d'estimer la biomasse instantanée des stocks des poissons (par échointégration) et de suivre l'évolution de leur abondance relative dans le temps et dans l'espace. Dans la présente étude on expose les résultats des campagnes de prospection hydroacoustique, OASIS 2 et 4.

Tableau 1. Taxonomie des principales espèces des petits pélagiques des eaux tunisiennes.

Familles	Noms communs français	Noms communs tunisiens	Noms scientifiques
Clupéidae	Sardine Sardinelle ronde, allache	Sardina Latcha	*Sardina pilchardus* *Sardinella aurita*
Engraulidae	Anchois	Anchoua	*Engraulis encrasicolus*
Carangidae	Chinchard d'Europe Chinchard à queue jaune Chinchard bleu	Chourou Abiadh Chourou Asfar Chourou Azrak	*Trachurus trachurus* *Trachurus mediterraneus* *Trachurus picturatus*
Scombridae	Maquereau commun Maquereau espagnol	Makrou bou richa Makrou bou ain	*Scomber scombrus* *Scomber japonicus*
Sparidae	Bogue	Bouga	*Boops boops*

2. Matériels et méthode

(a) *Zone d'étude* (Figure. 1)

Tenant compte de la morphologie de la côte et des caractéristiques physiques des fonds marins qui lui sont attribués, nous avons distingué cinq zones :

- La zone sud qui comprend le golfe de Gabès.
- La zone du Sahel qui s'étend du plateau des îles Kerkennah jusqu'à Sousse.
- La zone du golfe de Hammamet qui s'étale de Sousse jusqu'à la pointe du Cap Bon.
- La zone du golfe de Tunis qui se prolonge du Cap Bon jusqu'à Bizerte y compris les hauts fonds des Esquerquis.
- La zone Nord qui correspond à la région de Tabarka et le plateau de la Galite.

(b) *Matériel*

Pour la campagne OASIS 2, le sondeur OSSIAN 1500, en fréquence 38 kHz, est utilisé pour l'échointégration, couplé au système INES-MOVIES pour la numérisation. Cependant, pour la campagne OASIS 4, le sondeur utilisé est de type SIMRAD EK–500 en 38 kHz. Dans les deux cas, le matériel est doté aussi d'un système informatique de traitement du signal et des ports de communication permettant d'intégrer les diverses informations issues du système de navigation (GPS, etc.).

Pour la pêche expérimentale, le chalut 4FF (chalut de fond à quatre faces) dont l'ouverture verticale est de 7 m est employé dans la plupart des cas.

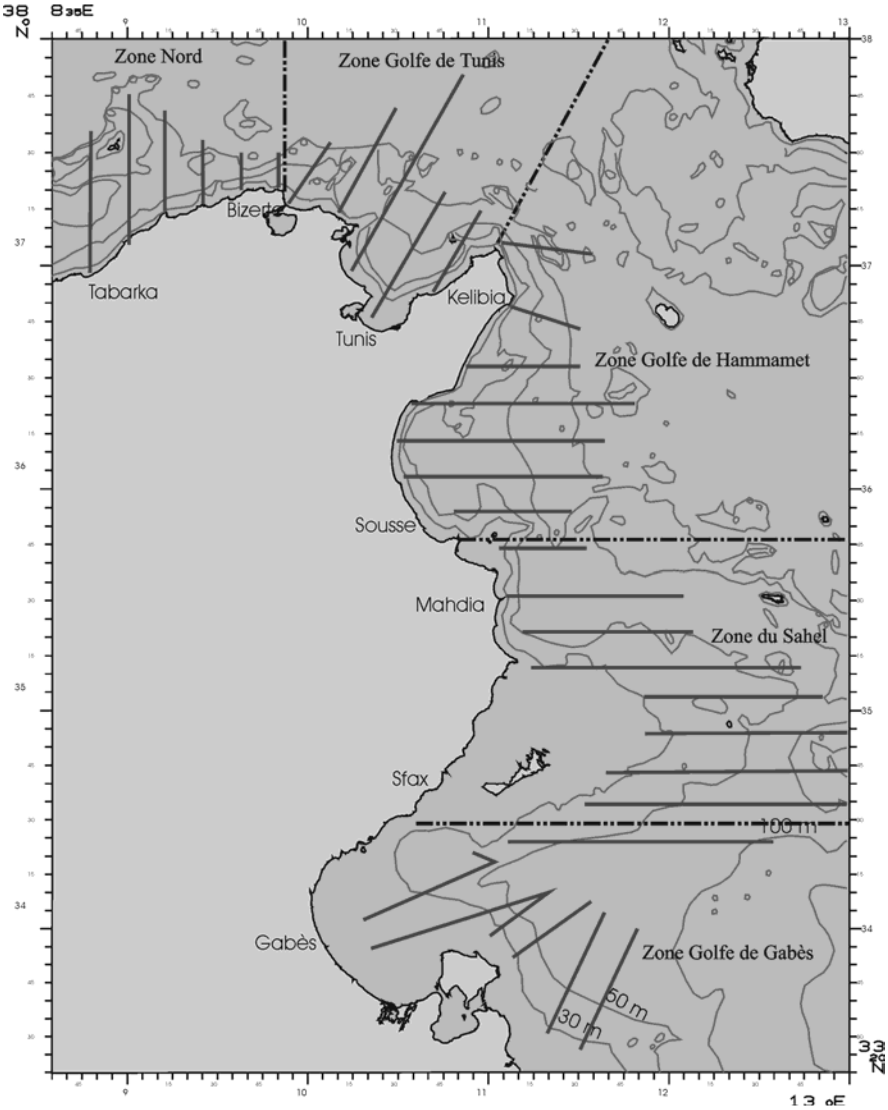


Figure 1. Plan des radiales de prospection acoustique et délimitation des zones géographiques.

Approche scientifique

(a) Prospection acoustique et pêche expérimentale

Lors de chaque campagne, les zones à prospecter sont couvertes suivant un réseau de radiales parallèles adaptées à la topographie (Figure. 1). La vitesse du navire est stabilisée à 8 nœuds, pour une unité de distance en échointégration (ESDU) de un mille nautique. Les radiales sont espacées au maximum de 10 milles nautiques (MacLennan et Simmonds, 1992). La prospection est faite de jour (lorsque les petites pélagiques sont regroupés en bancs) de la côte vers le large entre 20 et 200 m de profondeur.

Chaque fois qu'une détection importante est observée et/ou chaque fois que les structures de détection varient, la prospection est interrompue pour la réalisation de l'opération de chalutage expérimental. Les opérations de chalutage durent entre 30 et 60 minutes à une vitesse de 3 nœuds. Après chaque trait, on établit la composition en taille et en poids ainsi que les relations taille–poids pour chaque espèce.

(b) Échointégration

L'échointégration permet d'avoir une estimation de la biomasse présente dans un volume insonifié par un échosondeur (Massé, 1996). Il est à signaler qu'il y a deux méthodes d'échointégration : l'échointégration par couche et l'échointégration par banc de poisson. C'est la première méthode qui sera utilisée dans ce travail et les résultats sont obtenus par le logiciel Movies+. Dans l'échointégration par couches, la colonne d'eau est divisée dans un certain nombre de couches, certaines sont référencées à la surface et d'autres au fond de la mer (Figure. 2). Pour chaque couche et pour toute la colonne analysée, le logiciel Movies+ donne: Ni, NT, sA et Sv. (Diner *et al.*, 2001) Avec :

Ni : le nombre d'échantillons intégrés, c'est-à-dire plus grand que le seuil d'intégration.
NT : le nombre total d'échantillons dans la couche.
sA : le coefficient de dispersion nautique de secteur dans la couche.
Sv : l'index de réverbération de volume de la couche

C'est le paramètre (sA) qui sera analysé dans cette étude. C'est une grandeur indépendante de la vitesse de navire et du taux d'échantillonnage du sondeur. Une pondération par la distance traversée entre chaque tire est faite pour définir la section transversale d'agrégat balayée:

$$\sigma_{ag} = k \sum_N d \sum_n U^2$$

Avec :
U = amplitude de chaque échantillon intégré, en volts (référence = 1 volt).
d = la distance

Le logiciel Movies+ effectue l'échointégration sur des amplitudes absolues U qui sont livrés directement par le sondeur SIMRAD EK500.
Si nous considérons que:

$$d = S.T$$

Avec :
S = vitesse de bateau en mps.
T = durée des pings en secondes.

Alors nous finissons avec:

$$\sigma_{ag} = \frac{1}{\varepsilon} \sum_N S.T \sum_n U^2$$

Avec: ε= nombre d'échantillons par mètre

σ_{ag} ainsi calculé est donc mesuré en "mètre carré".
La relation suivante définit sA comme coefficient de dispersion nautique de secteur

$$s_A = 23270 \frac{\sigma_{ag}}{D_E}$$ en m^2/mille nautique^2

Avec : D_E = longueur de l'ESDU en mille nautique

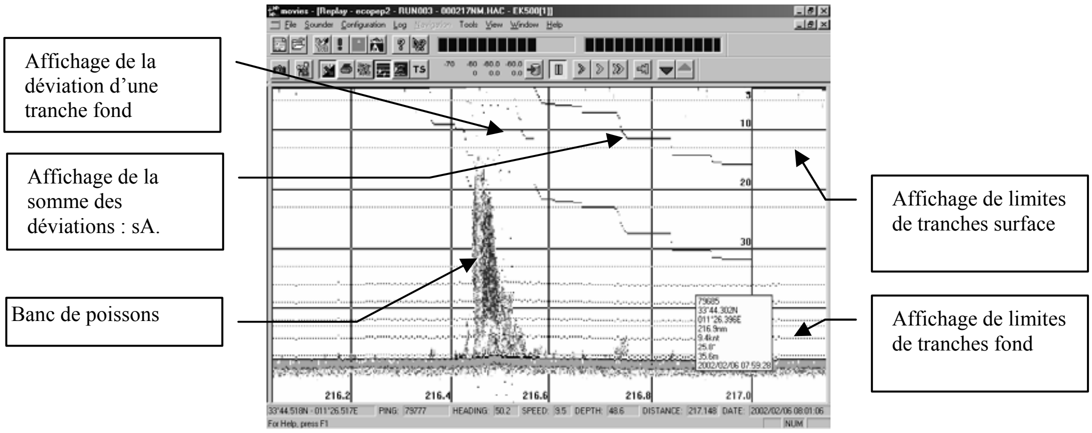


Figure 2 : Illustration de l'échointégration par couche

(c) Pré-traitement des données

Les valeurs brutes de sA ainsi livrées par le logiciel Movies+ vont subir un pré-traitement pour éliminer les sources d'erreur tel que les couche de plancton et les prises de fond. En effet, Movies+ prend parfois pour bancs de poissons des écho-traces de plancton suffisamment denses pour être échointégrés. Les corrections de fond se font manuellement (le logiciel le permet) ; les écho-traces de bancs qui étaient suffisamment denses pour qu'une partie soit confondue avec le fond marin. Le cas contraire peut aussi se présenter, où une partie du fond peut être intégrée avec un banc. On peut déceler ces phénomènes chaque fois qu'il y a une augmentation aberrante de l'énergie échointégrées sur la couche d'eau correspondante au fond.

(d) Traitement des données

Les valeurs de sA obtenues pour chaque mille nautique sur les radiales parcourues, vont servir pour une interpolation sur toutes les eaux tunisiennes. Un model de type « voisin naturel » est appliqué. Ces opérations sont exécutées par le logiciel SURFER.

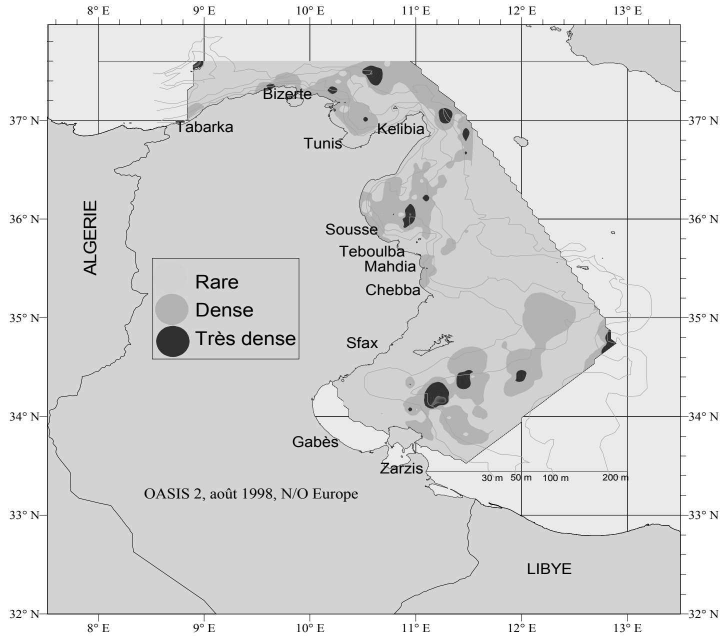
3. Résultats et discussion

3.1 Répartition géographique

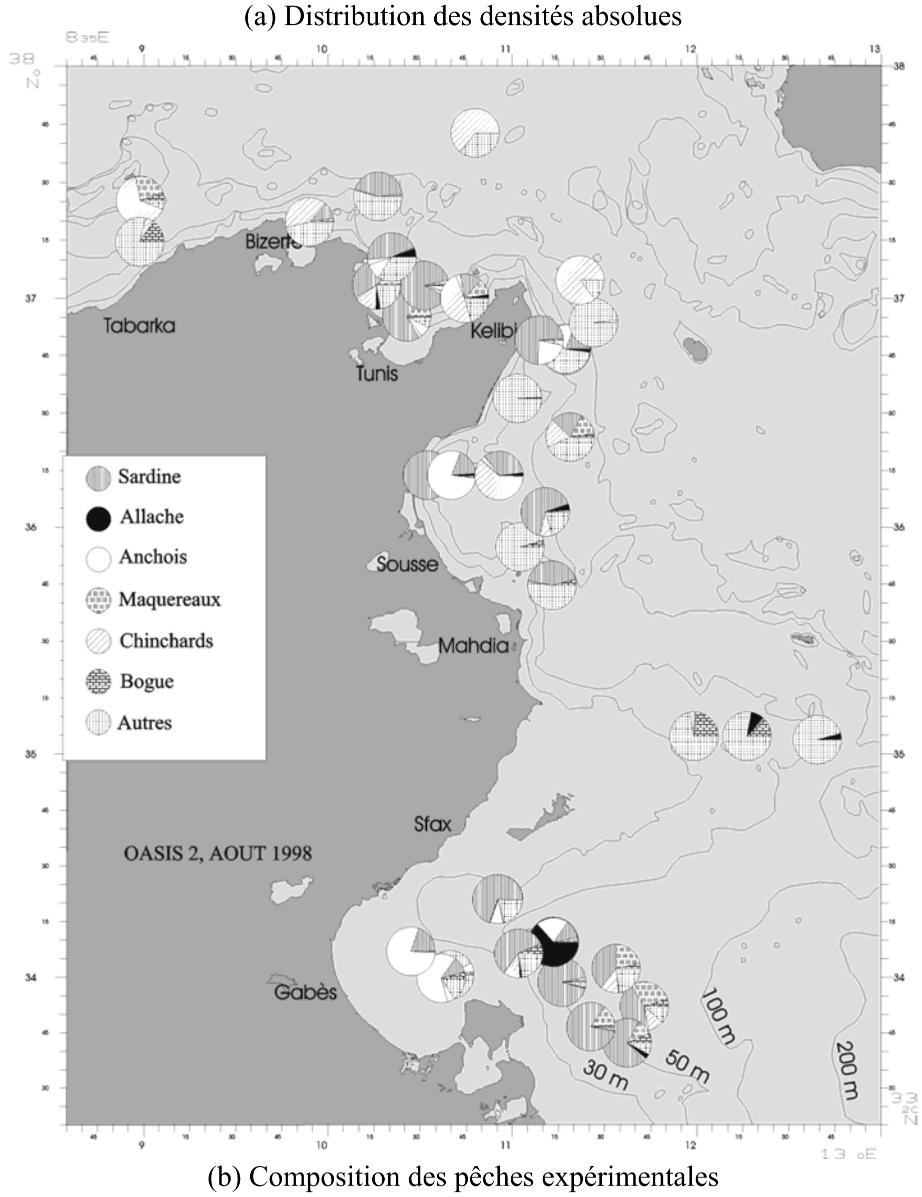
(a) Campagne OASIS 2 : Août 1998

Les densités les plus fortes sont rencontrées dans les golfes. La densité la plus faible est enregistrée dans la zone Nord (Figure. 3.a).

La sardine est la plus abondante dans la zone Sud. Elle est absente dans la zone Nord. La sardinelle est absente dans le golfe de Hammamet et est la moins abondante dans la zone Nord. La densité la plus importante des maquereaux est trouvée dans la zone Sud. Pour la bogue, la densité la plus importante est rencontrée dans la zone du Sahel. L'anchois est absent dans la zone Nord et il est plus abondant dans la zone Sud. Les chinchards sont plus abondants dans le golfe de Hammamet et moins abondants dans la zone Nord (Figure. 3.b).



(a) Distribution des densités absolues



(b) Composition des pêches expérimentales

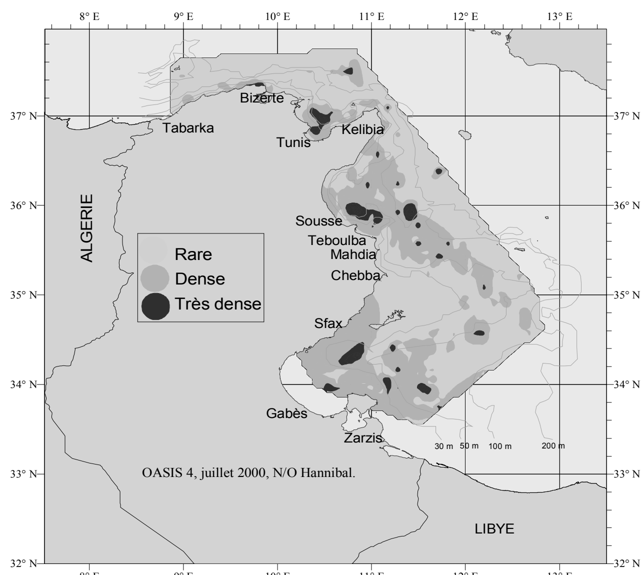
Figure 3. Résultats de la campagne OASIS 2, août 1998.

(b) Campagne OASIS 4 :juillet 2000

Cette campagne s'est déroulée en saison estivale comme celle de OASIS 2, cependant la distribution des densités est différente sauf pour la zone Nord. En effet, les franges denses ont augmenté de surface pour toute la partie Est (le golfe de Gabès, la zone du Sahel et le golfe de Hammamet). L'espace caractérisé par les fortes densités observées lors de la campagne OASIS 2 s'est déplacé par rapport à la campagne OASIS 4. On note toute fois l'apparition de plusieurs nouveaux petits noyaux pour la même zone Est (Figure. 4.a).
La variation des densités relatives entre les deux campagnes pour les différentes régions peut être attribuée à un recrutement et/ou un déplacement des stocks de l'une et/ou l'autre des espèces entre les zones adjacentes.

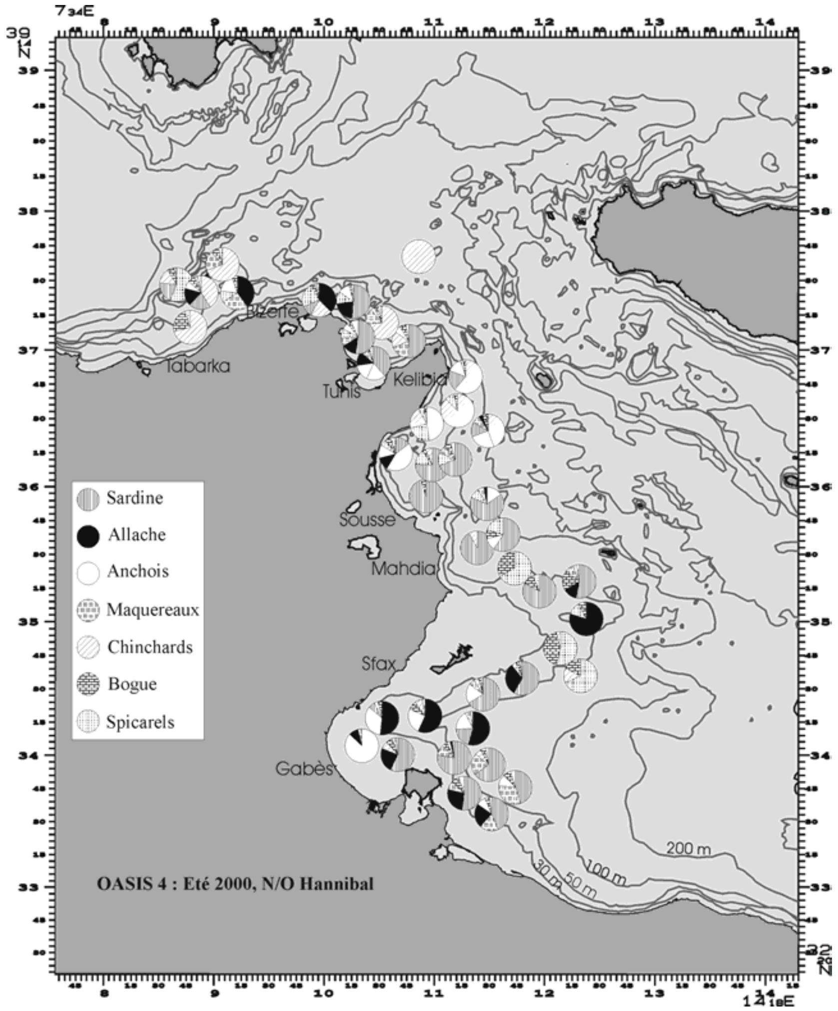
Pour la campagne OASIS 4, dans toutes les zones, si on exclut l'anchois pour la zone du Sahel, on constate que la totalité des espèces des petits pélagiques est représentée dans les captures des chalutages expérimentaux, mais avec des proportions variables d'une strate à l'autre (Figure. 4.b).

- Au fond du golfe de Gabès, les captures des chalutages expérimentaux sont composées principalement d'anchois et d'allache, la sardine domine dans le reste de la région Sud.
- Dans la frange de transition entre la zone Sud et la zone du Sahel, on trouve de la bogue, de l'allache, des picarels et des chinchards. Un peu plus au Nord les autres espèces réapparaissent, particulièrement la sardine.
- Dans le golfe de Hammamet la sardine est l'espèce la plus capturée pour des profondeurs supérieures à 50 m, elle est remplacée par l'anchois et les chinchards pour la partie restante du golfe.
- Dans le golfe de Tunis, les captures des pêches expérimentales sont composées essentiellement de sardine. L'allache n'est présente que pour des profondeurs inférieures à 50 m.
- Pour la zone Nord, les chinchards ont la part la plus élevée dans la quasi-totalité des traits de chalut, l'allache et la sardine sont présentes aux alentours de la Galite.



(a) Distribution des densités absolues

Figure 4. Résultats de la campagne OASIS 4, juillet 2000



(b) Composition des pêches expérimentales

Figure 4. Résultats de la campagne OASIS 4, juillet 2000

3.2 Biomasses exploitables

(a) Campagne OASIS 2 : Août 1998

Pour la campagne OASIS 2 (août 1998) le potentiel exploitable en petits pélagiques dans les eaux tunisiennes a été de l'ordre de 83.200 tonnes, l'espèce la plus représentée est la sardine (Tableau 2). Conformément aux densités, le golfe de Gabès abrite la majeure partie de la biomasse exploitable.

Pour la campagne OASIS 4 le potentiel exploitable a atteint 101.519 tonnes, soit une augmentation de l'ordre de 18% par rapport à l'année 1998, la sardine est également la plus représentée. Si on exclut l'allache, on peut conclure que l'augmentation a touché toutes les espèces avec des proportions variables. Les biomasses exploitables des petits pélagiques ont augmenté, dans les zones Nord (+609%), du Sahel (+72%) et Sud (27%), par contre elles ont diminué dans les golfes de Hammamet (–10%) et de Tunis (–18%) (Tableaux 2 et 3).

Les variations du potentiel exploitable par zone entre les deux campagnes ont les mêmes origines que les variations des densités relatives, ce qui est bien détaillées dans le paragraphe précédent.

Tableau 1. Potentiel exploitable (en tonnes) par espèce et par zone, campagne OASIS 2.

	Golfe de Gabès	Sahel	Golfe de Hammamet	Golfe de Tunis	Nord	TOTAL	%
Sardines	12.000	4.400	8.300	6.300		31.000	37
Allaches	12.250	3.500	0	2.850	100	18.700	22
Anchois	3500	30	950	270		4.750	6
Chinchards	1350	2.250	8.300	1.250	50	13.200	16
Maquereaux	3220	890	400	300	40	4.850	6
Bogue	5	4.075	2.970	595	55	7.700	9
Autres	1	900	950	1.000	150	3.000	4
Total	32.326	16.056	21.880	12.569	394	83.200	100
%	39	19	26	15	1	100	

(b) Campagne OASIS 4 : Juillet 2000

Tableau 2. Potentiel exploitable (en tonnes) par espèce et par zone, campagne OASIS 4.

	Golfe de Gabès	Sahel	Golfe de Hammamet	Golfe de Tunis	Nord	TOTAL	%
Sardine	19.118	11.153	5.801	1.764	238	38.074	38
Allache	6.752	3.530	1.563	571	187	12.602	12
Anchois	2.379	0	2.850	728	19	5.976	6
Chinchards	4.725	2.725	5.135	4.368	841	17.793	18
Maquereaux	4.060	223	1.937	671	806	7.697	8
Bogue	3.945	5.590	712	250	544	11.041	11
Autres	150	4.473	1.609	1.940	162	8.334	8
Total	41.128	27.695	19.607	10.293	2.795	101.519	100
%	41	27	19	10	3	100	

Pour l'année 2000, le potentiel exploitable le plus élevé (41%) est enregistré dans la région Sud, viennent ensuite respectivement les zones du Sahel, du golfe de Hammamet, du golfe de Tunis et Nord (Tableau 3). Au niveau spécifique, les clupéidés ont la part la plus importante du potentiel exploitable (50%). On remarque que pour les zones du golfe de Gabès, du Sahel et du golfe de Hammamet, les potentiels exploitables de la sardine et ceux de l'allache et de l'anchois ont évolué en sens inverses entre les deux campagnes. Dans une zone donnée une augmentation du potentiel de la sardine est accompagnée par une diminution des potentiels de l'allache et de l'anchois et inversement. Ceci, en dehors des erreurs qui peuvent être liées à l'échantillonnage, est probablement sous l'effet d'une variabilité du milieu entre les deux campagnes, car les périodes de reproduction et de recrutement et par suite de déplacement de l'allache et de l'anchois se couvrent et elles sont décalées par rapport à celles de la sardine.

L'effet de la variation des conditions du milieu sur la répartition des petits pélagiques dans les eaux tunisiennes, peut être appuyé par l'augmentation de la biomasse de la sardine et la raréfaction de l'allache dans le golfe de Gabès d'une année à l'autre. La sardine est probablement en train de remplacer l'allache dans le golfe de Gabès.

Des études poussées de la variation spatio-temporelle des conditions morphologiques et hydrographiques le long des côtes tunisiennes devraient être combinées avec des campagnes saisonnières de prospection et les statistiques des pêches professionnelles permettraient d'apporter des éléments de réponse à toutes les hypothèses.

4. Conclusion

Les densités des petits pélagiques dans les eaux tunisiennes sont variables d'une part entre les zones au cours des années de l'étude et d'autre part pour la même zone d'une espèce à l'autre : elles sont donc saisonnières. Cette saisonnalité peut être le résultat d'un et/ou de plusieurs facteurs. Dans la limite actuelle des connaissances, il est très difficile de définir avec certitude les causes de cette variabilité, car les pêcheries tunisiennes sont multispécifiques et les exigences écologiques sont différentes entre les espèces. En effet, la sardinelle et les chinchards sont des espèces à affinité intertropicale (Marchal, 1991) alors que la sardine et les maquereaux ont une affinité septentrionale (Nédélec, 1958 ; Belvèze, 1984). Aussi, en plus des fluctuations des conditions physico-chimiques et hydrographiques des eaux tunisiennes, la recherche des frayères peut également jouer un rôle dans cette variabilité. Les différentes espèces étudiées sont connues par leurs déplacements à la recherche des zones de reproduction (Fréon, 1988 ; Pauly, 1997). De ce fait, l'époque de recrutement de l'une des espèces se chevauche avec le départ de ses adultes et l'arrivée des adultes d'une autre espèce et pour une espèce donnée uniquement une fraction du stock migre.

Ce qui est sure c'est la richesse des zones dont les profondeurs sont supérieures à 50 m, car pour les deux campagnes les densités les plus importantes sont enregistrées dans ces zones.

Avec un taux d'exploitation de l'ordre de 45% du potentiel disponible (Ben Abdallah *et al.*, 2000), les petits pélagiques constitueront sans aucun doute, les solutions de rechange et les créneaux de développement du secteur de la pêche en Tunisie. Cependant, un suivi régulier de ces ressources s'impose dans le but d'une exploitation rationnelle. A cet effet, une campagne annuelle de prospection acoustique est organisée régulièrement.

La méthode directe reste indispensable. Cependant, l'utilisation d'algorithmes plus performants (Marrakchi, 1999; Scalabrin, 1996) améliorera le pouvoir de discrimination entre les différentes espèces afin de mieux estimer leurs biomasses et délimiter leurs aires de répartition et de migration. Aussi, la prise en compte des facteurs du milieu permettra d'élucider les variations observées et faire des projections pour le futur.

5. Remerciements

Nous adressons nos vifs remerciements à :

M. Amor El Abed en tant qu'ex-directeur général et coordinateur de ce projet,
M. Othman Jarboui en tant que directeur de Laboratoire,
Tous les membres du groupe de travail sur les petits pélagiques de l'INSTM,
L'équipage du N.O. « Hannibal »,

Pour la coordination et l'aide si précieuse pour la réalisation de ce travail.

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Fluctuation of sardine and anchovy abundance in the Strait of Sicily investigated by acoustic surveys

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Abstract

This study assembles the main results of the research carried out during the last several years on the application of hydro-acoustic technology to the evaluation of biomass and distribution of small-pelagic-fish species off the southern coast of Sicily. The biomass estimates and the population-density charts presented concern the two main species: sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*). Six acoustic surveys were carried out from 1998: in June 1998, October 1999, July and September 2000, October 2001 and July 2002. For biomass-evaluation purposes and for the study of distribution, hydro-acoustic data acquired at 38 kHz were used. Large inter-annual fluctuations were observed both for sardine and anchovy populations: sardine biomass estimates ranged from 6,000 metric tons in July 2002 to over 36,000 metric tons in July 2000; anchovy evaluations ranged from about 7,000 metric tons in June 1998 to 23,000 metric tons in October 2001. Such fluctuations suggest the importance of yearly recruitment success, which is affected by environmental variation. Acoustic estimates are largely consistent with the landings recorded in Sciacca (the main fishing port on the southern coast of Sicily for small-pelagic-fish species) during the year following the evaluation surveys, emphasizing their relevance not only to monitoring but also to managing such resources.

Keywords: Small pelagic fish, sardine, *Sardina pilchardus*, anchovy, *Engraulis encrasicolus*, fish biomass evaluation, population density charts.

1. Introduction

The sustainable exploitation of the marine biological resources should follow an accurate estimation of abundance and distribution of the target species. The acoustic method (Johannesson and Mitson, 1983) is widely acknowledged to be one of the most efficient methods to evaluate the state of certain renewable resources, such as small-pelagic-fish species (sardine, anchovy, etc.). For these species, hydro-acoustic surveys on research vessels are opportunely designed also taking into account information from the biology and ecology of the species.

Anchovy and sardine jointly represent more than 90% of the commercial small-pelagic-fish landings in Sciacca, the main port for this fishery on the southern coast of Sicily (Mazzola *et al*., 2002). There is general agreement that, for this kind of living resource, the main driving factors influencing fluctuations are to be found in the environment.

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The Strait of Sicily has a very complex bottom topography characterized by a quite narrow continental shelf (the preferred habitat for the target populations), with the slope at about 15 nautical miles from the coast from Mazara del Vallo to Marina di Ragusa, though the shelf widens to more than 50 nautical miles over the Adventure Bank and the Malta shelf (Figure 1).

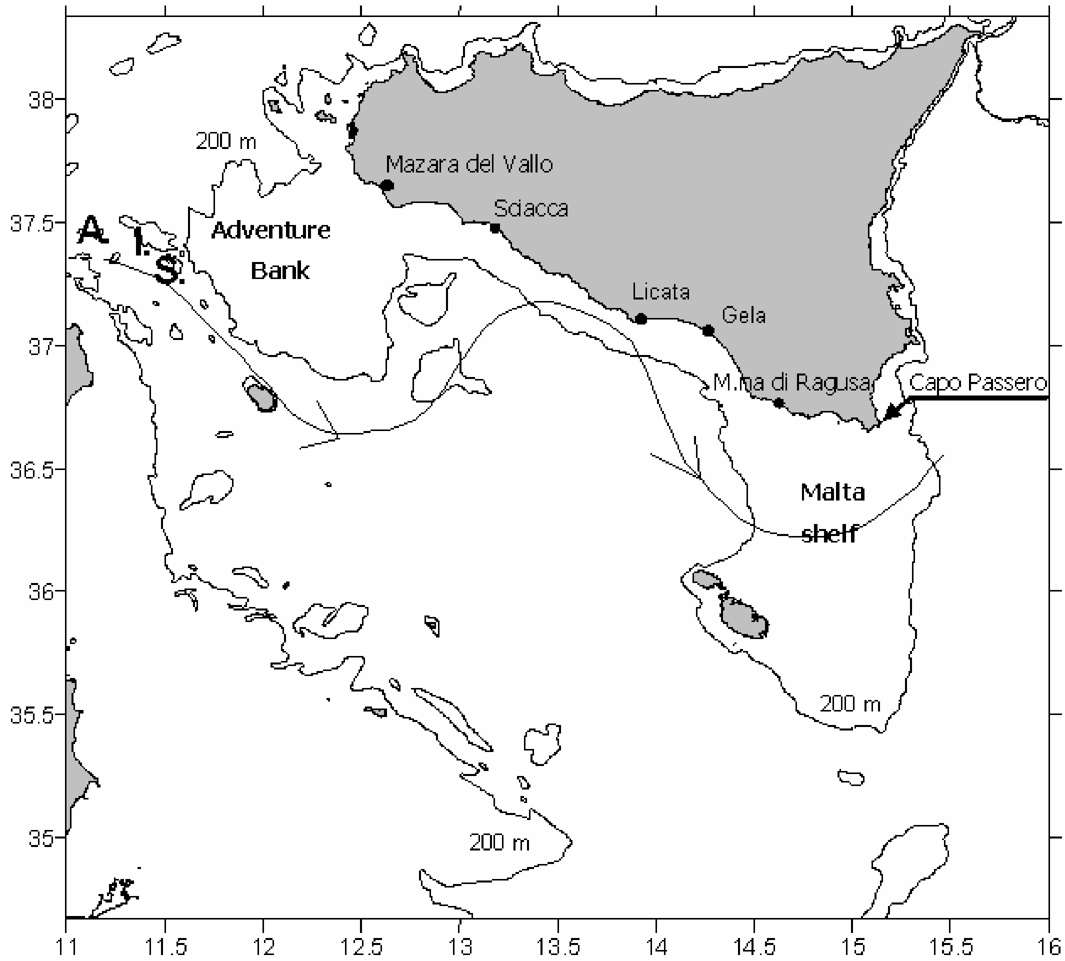

Figure 1. The Strait of Sicily and the mean current of incoming Modified Atlantic Water, the so-called Atlantic–Ionian Stream (AIS).

The Modified Atlantic Water (MAW) current, the so-called Atlantic–Ionian Stream (AIS; Robinson *et al*., 1991) (Figure. 1), controls the surface circulation. During the stratified period, it enters the Strait of Sicily at its western end, meanders, owing to topographic effects, internal baroclinic processes or strong atmospheric forcing, and diverges from the coast when it encounters the Malta shelf. Along this path, the AIS goes around two large cyclonic vortexes; the first one lies over the Adventure Bank and the second, over the Malta shelf, off Cape Passero (see Figure. 1). The circulation favours the establishment of "permanent" upwelling to the left of the Stream at certain places, possibly reinforced by wind-induced upwelling, which may sharpen the density front due to the offshore Ekman transport. The main source of nutrient pumping in the area is associated with coastal upwelling (García Lafuente *et al*., 2002). The AIS path is characterized by significant year-to-year variation, with consequences for other predominant hydrographical phenomena in the region; for example, the extension of upwelling and the formation of fronts. In intermediate and deep layers, the modified Levantine Intermediate Water (LIW) flows from east to west. Additional intrusions of water from the Ionian Sea, mostly with properties intermediate between those of the MAW and LIW, also occur.

In the present paper, general results of six hydro-acoustic evaluation surveys, carried out from 1998 to 2002, are presented. Data concern both abundance and distribution of the two target species: sardine and anchovy.

2. Materials and methods

The acoustic surveys on the continental shelf off the southern coast of Sicily were carried out in two different periods: June–July in 1998, 2000 and 2002 and September–October in 1999, 2000 and 2001. Sampling periods were chosen taking into account life cycles of target species. In particular, estimates from surveys carried out in the autumn may include the first sign of recruitment for the year, whereas summer surveys provided information on the adult fraction of the anchovy population.

Biomass evaluations were carried out using a standard method and the following equipment:

- SIMRAD EK500 two-frequency (38 and 120 kHz) split-beam echo sounder;
- pelagic trawl net for experimental hauls (horizontal opening 13–15 m, vertical opening 6–8 m, mesh size in the cod-end 10 mm);
- trawl monitoring system based on a SIMRAD ITI sensor.

Before or after each cruise, a calibration procedure was carried out on board using a standard sphere.

During the surveys (1998–2002), 102 control hauls were made, about 75% of which confirmed the presence of sardine and anchovy (Table 1). The vessel speed during surveys was 6–10 knots, whereas during the fishing hauls it was 3–4 knots.

Table 1. Fishing hauls by survey, with the corresponding frequency of occurrence of sardine and anchovy (percentage frequency of occurrence in brackets).

Survey date	**Total number of hauls**	**Number of hauls containing sardine**	**Number of hauls containing anchovy**
19–22 June 1998	12	10	6
14–29 October 1999	11	10	11
6–16 July 2000	18	15	12
11–16 September 2000	18	11	12
4–17 October 2001	22	15	20
4–15 July 2002	21	15	14
Total	102	76 (75%)	75 (74%)

The acoustic sampling design, originally planned with systematic parallel transects, was sometimes discarded in favour of a zigzag scheme which also depended on sea weather conditions.

Only data acquired by the 38-kHz transducer were used to calculate the NASC (Nautical area scattering coefficient, m^2 per square nautical mile) (MacLennan *et al*., 2002) and to estimate the biomass. The echo-integration interval was constant, i.e. 1 nautical mile (1,852 m). For data acquisition and data analysis, the following software was used: EP500 (Simrad), BI500 (Simrad) and EchoView (Sonar Data). Distributions were obtained by interpolating fish surface density (tons per square nautical mile), taking into account the species composition in the control hauls and applying, for each species, the appropriate relationship between Target Strength (TS) and the length of a single specimen. As no TS–length relationship has been definitely established in this area for the two species, in this study we adopted the TS–length relationships proposed by Barange *et al*. (1996). For interpolating surface density, the Kriging geostatistical method (Goovaerts, 1997; Cressie, 1991) was adopted.

The acoustic biomass estimates were compared with small-pelagic-fish landing data collected in Sciacca, the main port for this fishery on the southern coast of Sicily (Mazzola *et al*., 2002).

3. Results and discussion

Sardine biomass appears to be quite uniformly distributed along the southern coast of Sicily, though large differences occurred in both distribution and biomass among surveys (Figure 2).

The anchovy population exhibited a more patchy distribution than that of sardine (Figure. 3). During the peak spawning period for anchovy (echo-surveys in July 1998 and 2000), the main concentrations were observed in the central part of the study area, from Sciacca to Licata, whereas, in the surveys conducted in the autumn, two main concentrations were detected, one north of Sciacca and the other in the Gulf of Gela (south of Licata). During July 2002, sardine and anchovy populations appeared quite segregated, with sardines in the northern region and anchovy in the southern part of the study area.

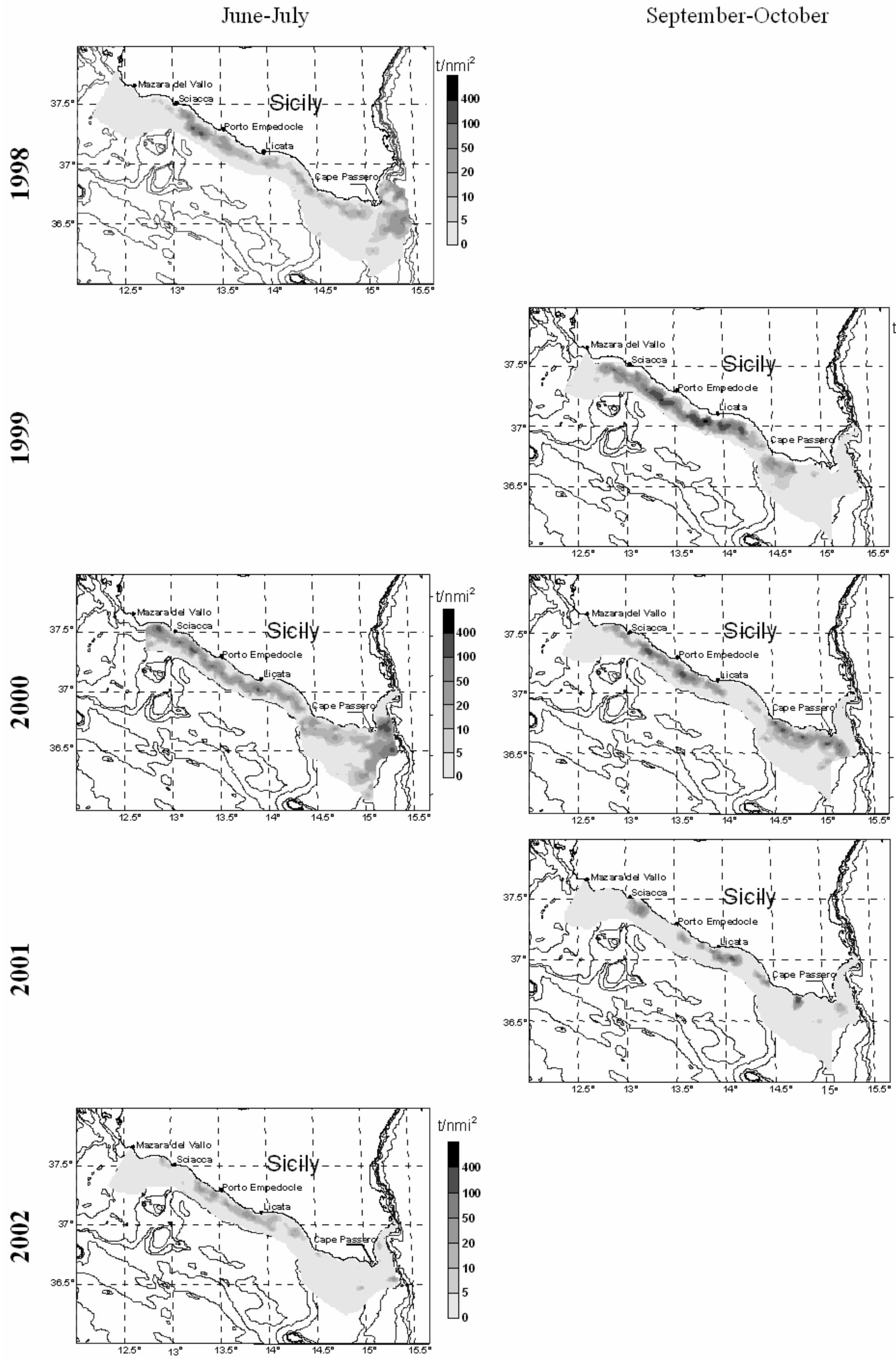

Figure 2. Sardine biomass distributions for the period 1998–2002.

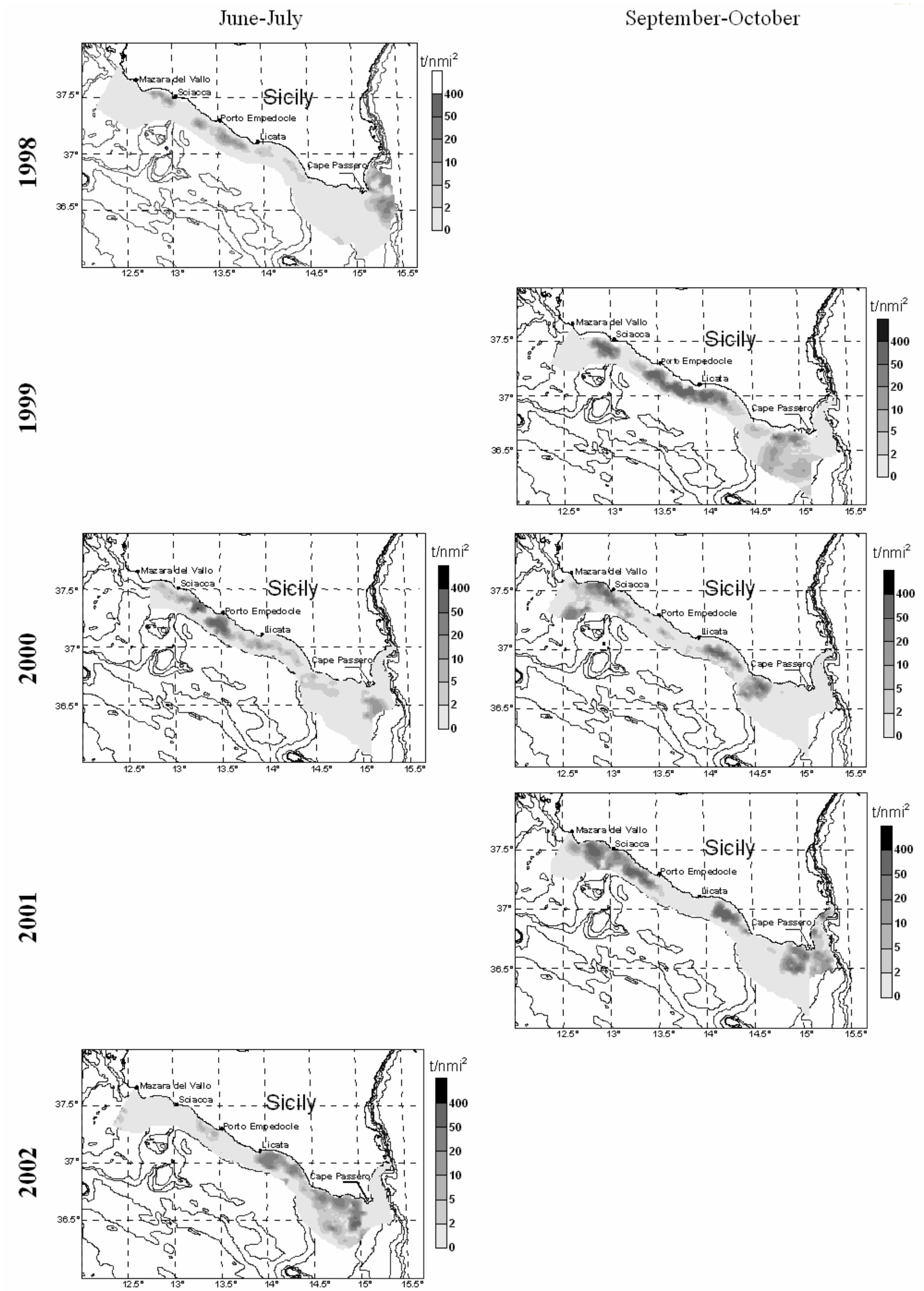

Figure 3. Anchovy biomass distributions for the period 1998–2002.

Estimated biomass, by year and by species, is given in Table 2.

Table 2. Biomass estimates (in metric tons) for sardine and anchovy populations off the southern coast of Sicily, by survey. Investigated area covers approximately 2,400 square nautical miles (8,232 km^2).

Survey	Sardine	Anchovy	Total
June 1998	20,000	7,100	27,100
October 1999	33,700	20,200	53,900
July 2000	36,370	11,000	47,370
September 2000	24,800	11,050	35,850
October 2001	10,054	22,950	33,004
July 2002	6,000	11,500	17,500

Both sardine and anchovy populations experienced quite large inter-annual fluctuations during the period 1998–2002. Sardine biomass estimates ranged from 6,000 metric tons in July 2002 to over 36,000 metric tons in July 2000; anchovy estimations ranged from about 7,100 metric tons in June 1998 to 23,000 metric tons in October 2001.

The sardine population has decreased steadily during the last few years, from 36,000 metric tons in 2000 to just 6,000 metric tons in 2002, so that, from 2001 onwards, the anchovy biomass started to exceed the sardine biomass.

It may be hypothesized that some process of compensation permitted the total biomass to vary moderately, at least up to 2001. For instance, in one year, from September 2000 to October 2001, sardine biomass dropped by 60% and the anchovy biomass increased by 108%, but the total biomass (sardine + anchovy) declined by only 8%.

The weight of the landings in Sciacca are one order of magnitude lower than the biomass estimates; reported landings have varied from 126 metric tons in 1999 to 2,312 metric tons in 2001, for anchovy, and from 1,233 metric tons in 1999 to 2,080 metric tons in 2000, for sardine (Mazzola *et al*., 2002). Although the total catch along the southern coast of Sicily is unknown, the Sciacca fleet accounts for about one-third of the total effort on small-pelagic-fish species in the study area. Consequently, much of the observed fluctuation in the biomass is believed to be related to the effects of the variability of environmental factors on early-life stages of the populations, which would be able to affect yearly recruitment success and ultimately fishing yields during the following year, when recruitment size is reached.

Data on the reproductive biology of the anchovy in the study area (Basilone *et al*., 2003) showed that anchovy caught during summer between Sciacca and Gela are at the peak of spawning. In addition, it is well known that the nursery area is separate from the spawning area close to Cape Passero (García Lafuente *et al*., 2002) where a retention area is formed by the surface circulation (vortex). These considerations suggest that the anchovy finds better environmental conditions for feeding and spawning in the area between Sciacca and Gela, while the AIS transports anchovy larvae to the nursery area.

For sardine it is not possible, at present, to theorize on similar behaviour, since no survey was carried out during the spawning period of this species.

Preliminary results showed that acoustic estimates, when obtained from surveys carried out in time to be significantly affected by the juvenile or recruitment biomass, are largely consistent with the landings recorded in the port of Sciacca during the year following the evaluation surveys (Figure 4). The main exception is the anchovy biomass evaluation from survey carried out in September 2000. From this biomass estimate, a lower level of anchovy landings than that one recorded in 2001 was expected. However, that survey was probably carried out too early to include a significant effect from recruitment success for a population whose peak spawning period occurs in July. Probably, an accurate analysis of the variability of fishing effort and environmental conditions will provide an explanation of the above-reported exception.

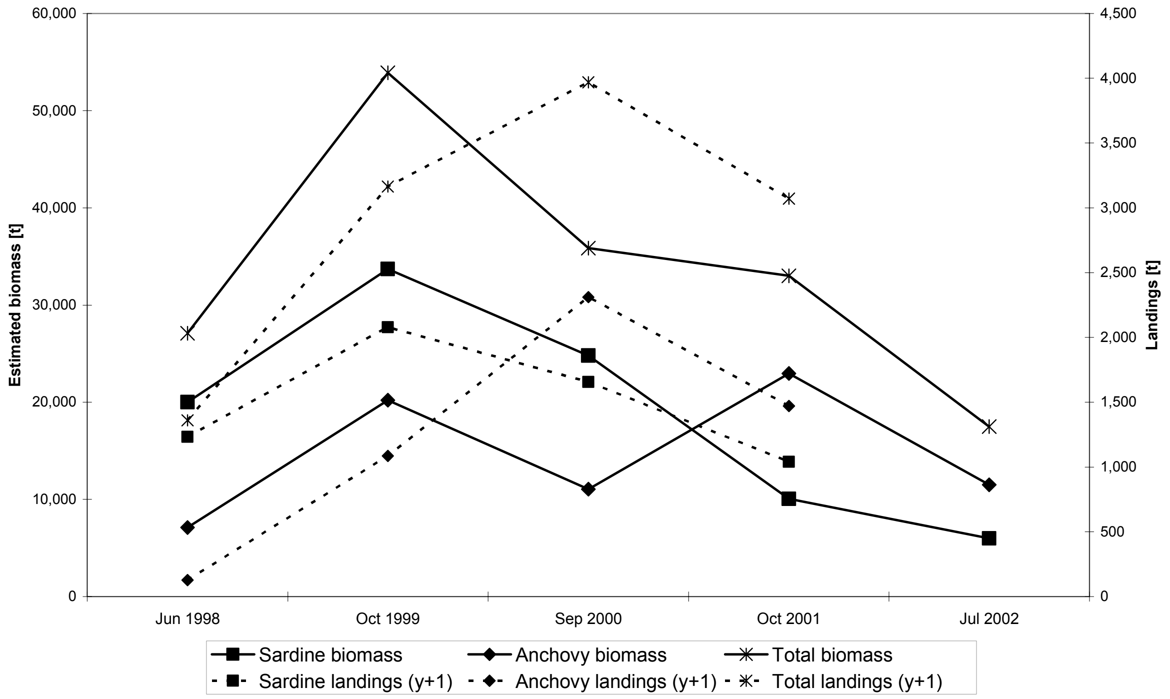

Figure 4. Biomass estimates for sardine and anchovy populations off the southern coast of Sicily and landings in Sciacca during the year following the evaluation surveys (y+1).

4. Conclusions

The study presents the estimates of abundance and distribution of two small-pelagic-fish species (sardine and anchovy), obtained by the hydro-acoustic method in the Strait of Sicily on the Sicilian continental shelf.

The observed fluctuations in the abundance of these species are consistent with the commercial landings in Sciacca. If these preliminary results are confirmed, it would be possible to predict future catch levels from acoustic biomass estimates, thus emphasizing their importance for the management of small-pelagic-fish populations.

5. Acknowledgements

The study was supported by the European Commission under Project MED 96-052 of the DG XIV (Fisheries), by Project 4-A-44 of the Italian Ministero delle Politiche Agricole e Forestali, Direzione Generale della Pesca e dell'Acquacoltura (L. 41/82 - D.M. 9/11/1982) and by Project 1 C10 (ASTAMAR) of the Italian Ministero dell'Istruzione Università e Ricerca – cluster 10 of the Piano Ambiente Marino.

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Etudes de la biologie et de l'exploitation des petits pélagiques en Tunisie

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Résumé

Dans les eaux tunisiennes cohabitent plusieurs espèces de petits pélagiques. Celles qui présentent un intérêt commercial sont la sardine *Sardina pilchardus*, l'allache ou sardinelle ronde *Sardinella aurita*, la bogue *Boops boops* et l'anchois *Engraulis encrasicolus*. Pour assurer une exploitation rationnelle de ces richesses nationales, le Groupe de Travail des Petits Pélagiques du Laboratoire des Ressources Marines Vivantes de l'INSTM, s'est intéressé à l'évaluation de la biomasse exploitable (par la méthode directe), à l'étude de la distribution géographique et à la détermination des principaux paramètres biologiques de ces espèces ainsi qu'à l'analyse de leur exploitation. Dans le présent travail, on expose les méthodes d'études et les principaux résultats relatifs à la biologie et à l'exploitation des petits pélagiques des eaux tunisiennes.

Abstract

Studies of the biology and the exploitation of small-pelagic fish species in Tunisia.

Several small-pelagic species cohabit in Tunisian water. Those of commercial interest are the sardine (*Sardina pilchardus*), the allache or round sardinella (*Sardinella aurita*), the bogue (*Boops boops*) and the anchovy (*Engraulis encrasicolus*). To ensure a rational exploitation of these national resources, the Working Group on Small Pelagics, of the INSTM Laboratory of Marine Living Resources, became interested in the evaluation of the exploitable biomass (by the direct method), in the establishment of the geographical distribution and in the determination of the principal biological parameters of these species, as well as the analysis of their exploitation by the fisheries. In this work, we explain the methods of study and the principal results relating to the biology and the exploitation of small-pelagic fishes of the Tunisian coastal seas.

1. Introduction

Le groupe des petits pélagiques est constitué par l'ensemble des poissons de petite taille qui passent la plus grande partie sinon la quasi-totalité de leur phase adulte en surface ou en pleine eau. Ces espèces sont totalement libres à l'égard du fond et sont indépendantes de la nature du substrat (Laloë et Samba, 1990 ; Collignon, 1991). L'influence de l'environnement sur leur biologie et les fluctuations de leur disponibilité et leur abondance a été mise en évidence dans des nombreuses pêcheries du globe (Belvèze, 1984 ; Cury et Fontana, 1988 ; Fréon, 1988 ; Binet, 1995 ; Csirke, 1995 ; Pauly, 1997). L'analyse de la dynamique des petits pélagiques nécessite donc des programmes de recherche à long terme et pluridisciplinaires

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combinant éco-biologie, halieutique et hydrologie (Gaamour, 1999). Ça n'a pas été le cas en Tunisie, les études antérieures des petits pélagiques sont rares et se sont intéressées soit à la détermination de quelques paramètres biologiques et la description de l'exploitation (Quignard et Kartas, 1976 ; Hattour, 1979 ; Kartas, 1981 ; Anato *et al.*, 1983 ; Turki, 1987 ; Ben Salem, 1990 ; Gharred 1993 ; Missaoui, 1996) soit à l'étude de la distribution spatiale et l'évaluation des biomasses (Rijavec et Zarra, 1974 ; Rijavec et Gueblaoui 1975 ; Rijavec *et al.*, 1977). Pour assurer une exploitation durable et rentable des petits pélagiques, qualifiés de ressources instables, le Groupe de Travail des Petits Pélagiques du Laboratoire des Ressources Marines Vivantes de l'INSTM a élaboré (depuis 1996) un programme de recherche pluridisciplinaire et à long terme. Dans le présent travail on présente les méthodes d'études et les principaux résultats, de ce programme de recherche, relatifs à la biologie et à l'exploitation de la sardine, de la sardinelle ronde, de la bogue ainsi que de l'anchois.

2. Zone d'étude

La Tunisie occupe une position stratégique en Méditerranée en s'ouvrant sur les deux bassins, l'oriental et l'occidental. Par cette position ses 1.300 km de côtes (88.000 km^2 de plateau continental) se caractérisent par une variabilité des biotopes. Les trois régions tunisiennes considérées dans la présente étude, correspondent à celles définies dans le Journal Officiel pour la gestion de l'effort de pêche (Figure. 1):

- la région Nord s'étend de la frontière tuniso-algérienne au parallèle passant par le phare de Borj Kélibia ;
- la région Est s'étend du parallèle passant par le phare de Borj Kélibia au parallèle passant par Ras Kapoudia ;
- la région Sud est limitée au nord par le parallèle passant par Ras Kapoudia et au sud par la frontière tuniso-libyenne.

Un aperçu des conditions climatiques et hydrologiques des côtes tunisiennes met en évidence l'opposition qui existe entre la région Nord, caractérisée par des fonds rocheux et des conditions hydrologiques complexes et les régions Est et Sud dont les conditions climatiques et hydrologiques sont de plus en plus modérées en allant du Nord au Sud (Gaamour, 1999). En effet, d'après les études faites par Lubet et Azzouz (1969), Ben Othman (1971), Ktari-Chakroun et Azzouz (1971), Azzouz (1973), Brandhorst (1977) et Gharbi *et al.* (1986) le long des côtes tunisiennes :

- le plateau continental s'élargit du Nord au Sud : l'isobathe des 200 m situé à 8,5 milles nautiques au niveau de Borj Kélibia s'en écarte de 135 milles nautiques à Gabès ;
- le courant atlantique s'atténue du Nord au Sud tout en s'écartant du littoral ;
- la masse d'eau atlantique a des mouvements variables suivant les saisons : elle est proche des côtes en début d'été, s'en éloigne vers l'Est en septembre et octobre ;
- la distribution de la salinité est zonale et saisonnière : en avril et mai elle est en moyenne de 37 au Nord et 38,3 dans le golfe de Gabès ; en septembre et octobre elle y est respectivement de 37,4 et 39 en moyenne ;
- la température de l'eau en surface présente une distribution zonale et saisonnière, avec généralement des valeurs croissantes du nord-ouest au sud-est. En hiver, elle est de 13,6°C au Nord et de 14,6°C au Sud en moyenne ; en été elle atteint 24,8°C au Nord et 29,1°C au Sud.

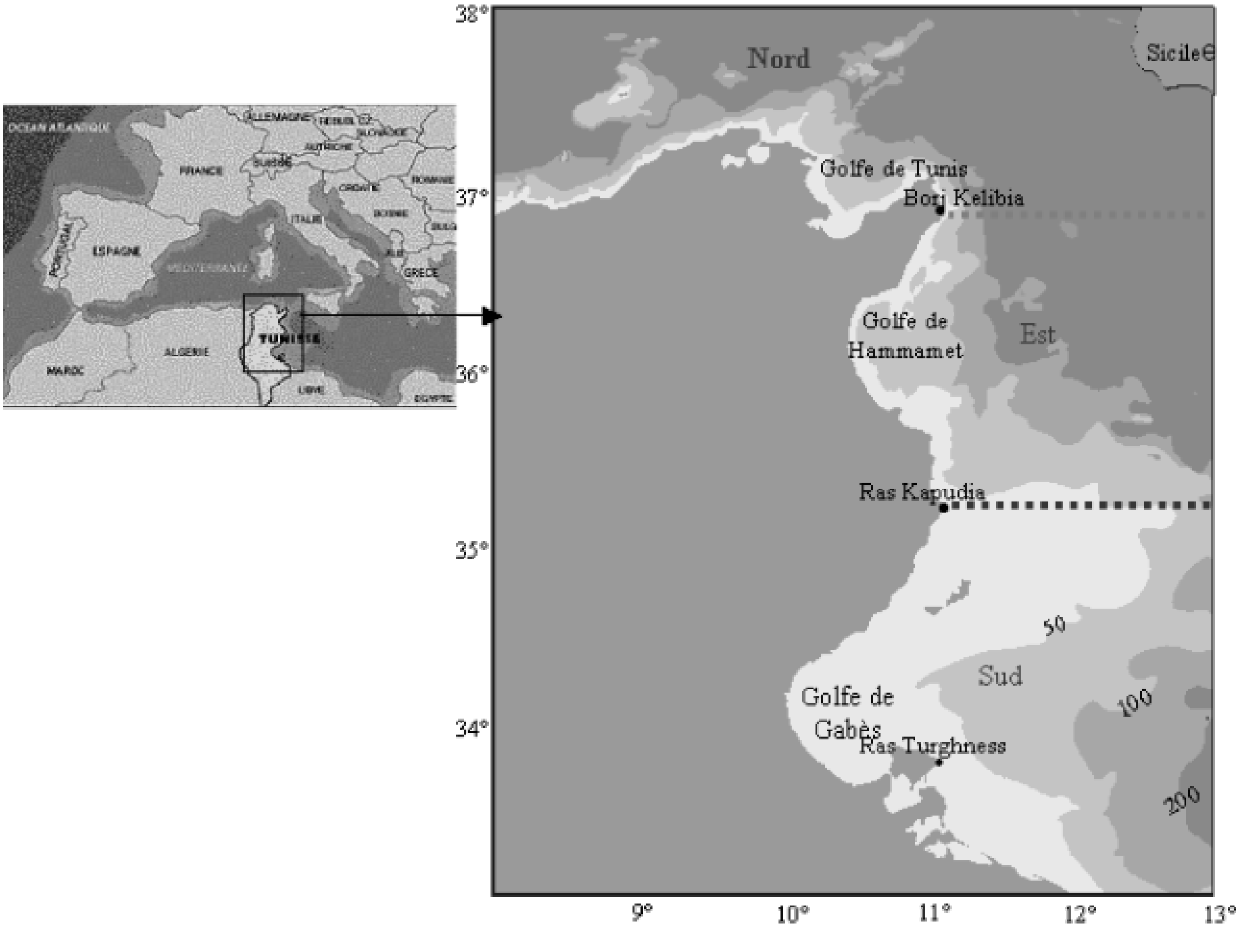


Figure 1. Cadre géographique (les isobathes de 50 m, de 100 m et de 200 m sont indiqués).

2. Matériels et méthodes

L’étude couvre toutes les régions tunisiennes. Pour la sardine, la bogue et l’anchois les échantillons sont collectés au cours de la période 2000–2002, ils proviennent aussi bien des captures des pêches expérimentales réalisées lors des campagnes de prospection hydroacoustique que des débarquements de la pêche professionnelle au niveau des principaux ports de la pêche sardinière tunisienne. Pour l’allache, à côté des individus prélevés suivant le même protocole que les trois autres espèces, les spécimens qui ont servis à l’étude de l’âge et de la stratégie de reproduction sont prélevés au cours de la période 1994–1996 à partir des captures des lamparos travaillant dans la région du Cap Bon. Les histogrammes des fréquences des tailles des différents échantillons sont représentés dans l’annexe 1.
Pour chacune des espèces étudiées, les relations entre la longueur totale (Lt en millimètres) et la longueur à la fourche (LF en millimètres) sont établies.

Les paramètres *a* et *b* de la relation taille–poids sont déterminés après transformation logarithmique et application de la méthode des moindres rectangles (Ricker, 1973 ; Do Chi, 1978). L’emploi de la méthode statistique pour la détermination de l’âge des poissons bleus est délicat et hasardeux (Fréon, 1988 ; Gaamour, 1999). La méthode adoptée par le Groupe de Travail des Petits Pélagiques de l’INSTM pour l’estimation de l’âge est la méthode individuelle qui se base sur l’analyse des pièces calcifiées. Le choix parmi plusieurs structures squelettiques de la meilleure pièce minéralisée et de son meilleur mode de préparation constitue une étape préliminaire pour toute étude de l'âge et de la croissance d'une nouvelle espèce (Beamish et McFarlane, 1983 et 1987 ; Castanet *et al*., 1992). Pour les quatre espèces de la présente étude les pièces analysées sont les écailles (*in toto*), les otolithes (*in toto* et en tranche), l'os operculaire (*in toto*) et les rayons de la nageoire dorsale (tranches). Le choix de la meilleure pièce et de son mode de préparation est fondé sur la combinaison de plusieurs critères dont la facilité d'interprétation des marques de croissance, de préparation de la pièce et à l'investissement accordé à l'étude (Panfili et Loubens, 1992). La validation bien qu'ignorée par pas mal d'études (Beamish et McFarlane, 1983), constitue une étape fondamentale pour une estimation d'âge la plus fiable et la plus proche de l'âge réel. La validation consiste essentiellement à déterminer la chronologie de formation des marques de croissance sur la pièce osseuse. Il existe plusieurs méthodes de validation, celle retenue par le Groupe de Travail est la méthode semi-directe basée sur le suivi mensuel de la formation de la marque de croissance marginale Allongement marginal AM et % d'individus ayant une zone hyaline marginale %ZHM. *Avec* $AM=(R_t–R_n)/(R_n–R_{n-1})$ où R_t est le rayon de la pièce calcifiée et *Rn* le rayon de la nième zone hyaline. Les mesures ont été effectuées à l'aide d'un système d'analyse d'image et le logiciel OPTIMAS. Les équations de croissance en longueur selon le modèle de croissance de Von Bertalanffy sont établies. En se basant sur la date de naissance moyenne et le nombre de zones hyalines on a représenté sous forme de tableau une clé âge–longueur pour l'ensemble des individus dont l'âge a pu être déterminé.

La taille de première maturité sexuelle est définie dans la plupart des études comme celle à laquelle 50% des individus sont matures (Lm50). Pour son calcul les individus de chaque espèce échantillonnés pendant la période de reproduction ont été rangés par classe de taille de 10 mm. Dans chaque classe a été calculé le pourcentage des individus dont le stade macroscopique de maturité sexuelle était supérieur ou égal au stade 3, suivant une échelle à six stades (Gaamour, 1999). Les données ont été ajustées par une courbe logistique (King, 1995) dont la formule est la suivante :

$\mathbf{P = 1 / (1 + e^{-r\,(L\,-\,Lm50)})}$ où *P* est la proportion des matures ; *r* est la pente ; *L* est la longueur.

Le rapport gonadosomatique moyen RGS est suivi mensuellement afin d'établir la période moyenne de reproduction des quatre espèces.

RGS = 100* Pg/Pev où *Pg* est le poids des gonades et *Pev* celui du poisson éviscéré

Pour la sardinelle ronde et l'anchois, le suivi du RGS est amélioré par l'étude de l'histologie ovarienne de quelques femelles sélectionnées à différentes périodes de l'année. Les coupes d'ovaires de 5 µm d'épaisseur sont colorées au Trichrome de Masson modifiée (Déniel, 1981). La cinétique de l'ovogenèse qui traduit en terme de fréquence relative la manière dont les ovocytes, suivant une échelle microscopique de développement ovocytaires (Gaamour, 1999), évoluent vers la maturité est étudiée. Celle-ci est complétée par l'analyse de la distribution des diamètres ovocytaires des échantillons d'ovaires fixés dans le liquide de Gilson. La manière dont les ovocytes sont émis ou la stratégie de ponte (Le Duff, 1997 ; Gaamour, 1999) est déterminée. La fécondité par lot qui correspond au nombre d'ovocytes susceptibles d'être émis par acte de ponte est estimée, elle est corrélée à la longueur.

En Tunisie, les petits pélagiques sont débarqués essentiellement par les sardiniers (technique de la pêche au feu et à la petite senne). L'engin de pêche est une senne tournante et coulissante. Une analyse de l'activité de la flottille sardinière, par région, est réalisée. A côté du suivi de l'évolution annuelle et saisonnière des débarquements par région on s'est intéressé à la comparaison des captures annuelles et de la biomasse exploitable par espèce, cette dernière est évaluée par la méthode directe d'hydroacoustique.

3. Résultats et discussion

La relation longueur totale–longueur à la fourche utilisée est de la forme Lt=x+yLF (Lt et LF en millimètres). Les paramètres *x* et *y* obtenus pour chaque région (Nord, Est et Sud) ne montrent pas de différence significative, les valeurs moyennes pour toutes les eaux tunisiennes sont récapitulées dans le Tableau 1.

Tableau 1. Relation longueur totale–longueur à la fourche par espèce.

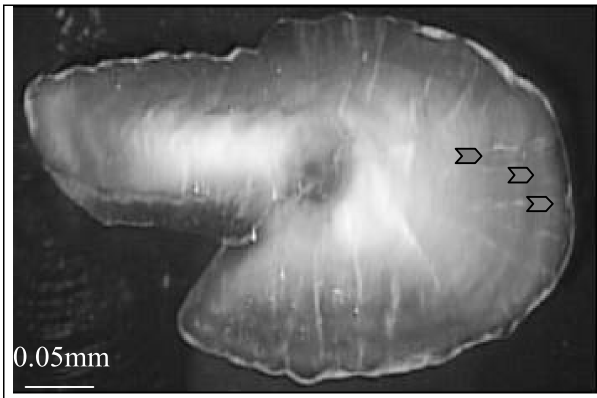
Espèce	Sardine	Allache	Anchois	Bogue
x	0,47	–0,25	0,34	–0,11
y	1,06	1,13	1,05	1,12
Effectif	2.011	2.458	2.503	1.699
Coefficient de corrélation	0.99	0.99	0.99	0.99

Les valeurs des paramètres *a* et *b* de la relation taille–poids par espèce et par région sont récapitulées dans le Tableau 2. Une comparaison statistique entre les relations obtenues dans les différentes régions, pour une même espèce, ne peut être réalisée car les paramètres *a* et *b* sont très sensibles aux nombres d'échantillons mensuels et à la composition en taille de chacun (Fréon, 1988 ; Mouneimne, 1981). Néanmoins, pour l'ensemble des espèces étudiées les nuages des points des courbes Pt = f (Lt) par région se couvrent ce qui permet de conclure que les différences entre les régions ne sont pas significatives. Les valeurs moyennes, pour l'ensemble des eaux tunisiennes, des paramètres *a* et *b* peuvent être utilisées dans les études dynamiques de l'une ou l'autre des espèces pour les différentes régions. Pour la sardine, l'allache et l'anchois l'allométrie est majorante ($b>3$) ; le poids croit proportionnellement plus vite que la longueur. Alors que pour la bogue la croissance peut être considérée comme isométrique car $b \approx 3$.

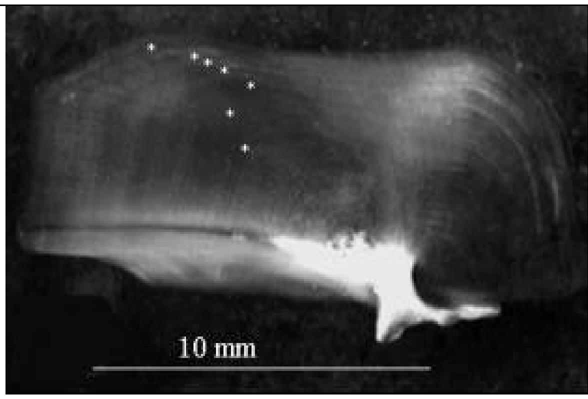
Tableau 2. Paramètres *a* et *b* des relations taille–poids par espèce et par région.

Région	Espèce	Sardine	Allache	Anchois	Bogue
Nord	*a*	0,0029	0,0042	0,003	0,0128
	b	3,44	3,2	3,28	2,92
Est	*a*	0,0047	0,0043	0,0031	0,0076
	b	3,16	3,06	3,27	3,086
Sud	*a*	0,0065	0,0061	0,0042	0,0074
	b	3,056	2,93	3,16	3,11
Tunisie	*a*	0,0036	0,0052	0,0038	0,0078
	b	3,28	3,13	3,19	3,086

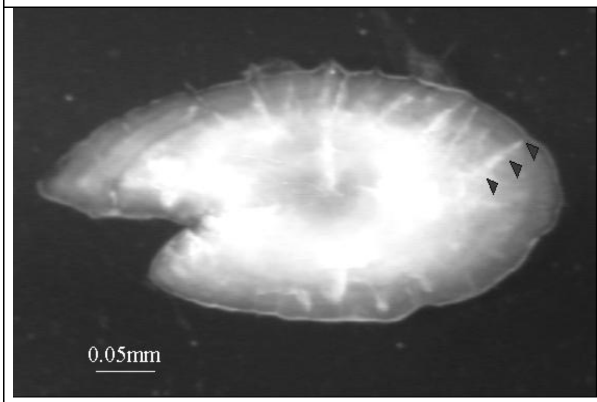
L'étude comparative entre les écailles, les otolithes, l'os operculaire et les rayons de la nageoire dorsale pour l'estimation de l'âge individuel a montré que chez l'allache c'est l'os operculaire qui est susceptible de donner les meilleurs résultats. Pour l'anchois et la sardine l'otolithe *in toto* peut être utilisé pour l'estimation de l'âge individuel de la plupart des individus, chez quelques spécimens on est amené à utiliser des coupes transversales des otolithes. Pour la bogue l'otolithe en coupe transversale est le meilleur mode de préparation pour l'estimation de l'âge (Planche 1). Cette étude comparative, pour chacune des espèces, est réalisée pour la première fois en Tunisie. Chez l'allache, la courbe de l'évolution mensuelle de l'AM moyen montre deux maxima et deux minima dans l'année (Figure. 2A). Chaque année se forme deux zones hyalines, en moyenne en février et août. Pour la bogue, l'évolution mensuelle du %ZHM présente un seul maximum et un seul minimum dans l'année (Figure. 2B). Le cycle de croissance de cette espèce est donc annuel, la période d'arrêt et/ou de ralentissement de croissance est hivernale. Pour l'anchois et la sardine les analyses sont encore en cours.



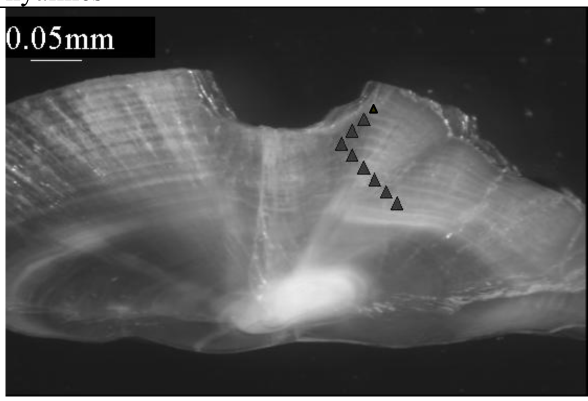
Otolithe de sardine de 16 cm, 3 zones hyalines



Os operculaire d'allache de 23 cm, 7 zones hyalines

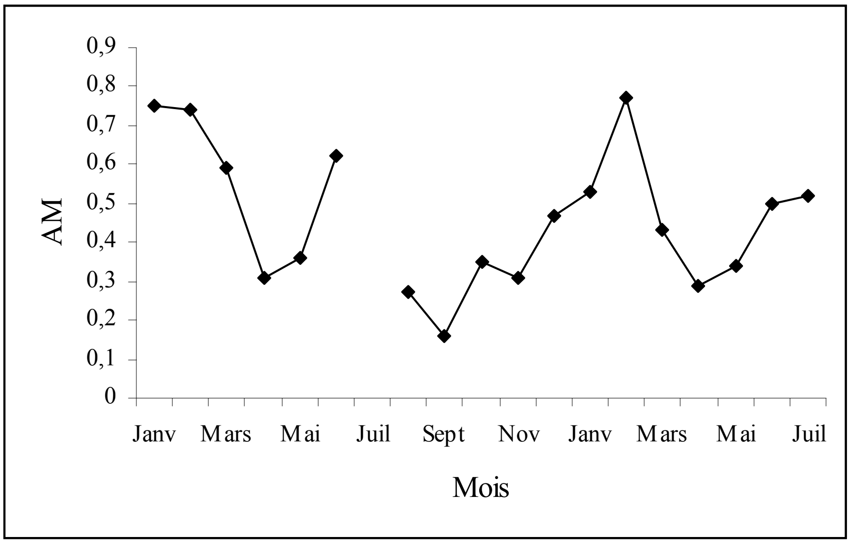


Otolithe d'anchois de 15 cm, 3 zones hyalines

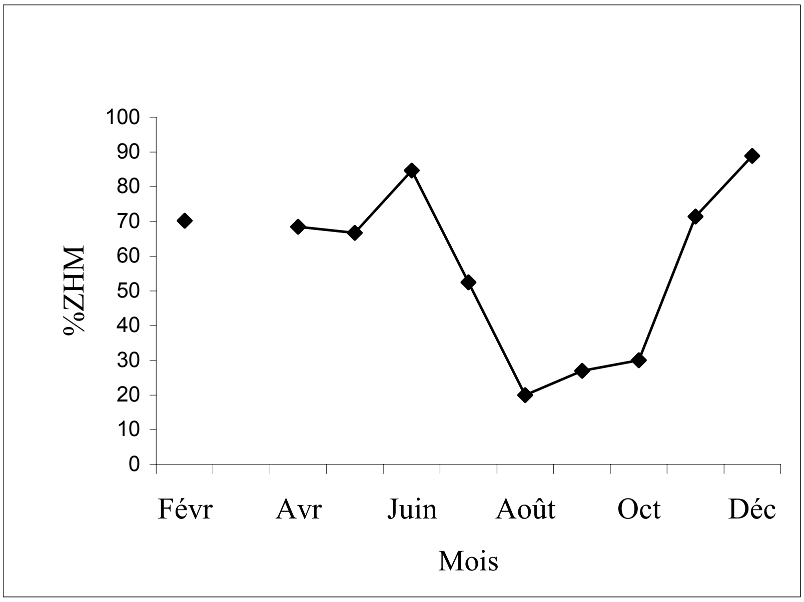


Tranche d'otolithe de bogue de 21 cm, 9 zones hyalines

Planche 1 : Pièce calcifiée et mode de préparation choisie pour l'étude de l'âge individuel.



A : Evolution mensuelle de l'allongement marginale moyen ($AM=(R_t–R_n)/(R_t–R_{n-1})$) chez l'allache.



B : Evolution mensuelle du % d'individus à zone hyaline marginale (%ZHM) chez la bogue

Figure 2. Chronologie d'apparition des marques de croissance chez l'allache (**A**) et la bogue (**B**).

Pour la sardinelle ronde, les équations de croissance en longueur des mâles et des femelles, suivant le modèle de Von Bertalanffy sont :

Mâles : $Lt=234\{1–\exp[–0.295(t+1.9)]\}$
Femelles : $Lt=263\{1–\exp[–0.231(t+2.1)]\}$
Où *Lt* est la longueur à la fourche en millimètres.

La croissance des femelles est plus rapide que celle des mâles. Les différences commencent à apparaître à partir de l'âge de 2,5 ans (Figure. 3). Une nouvelle représentation de la clé âge-longueur est réalisée et adoptée par le Groupe de Travail des Petits Pélagiques de l'INSTM (Annexe 2).

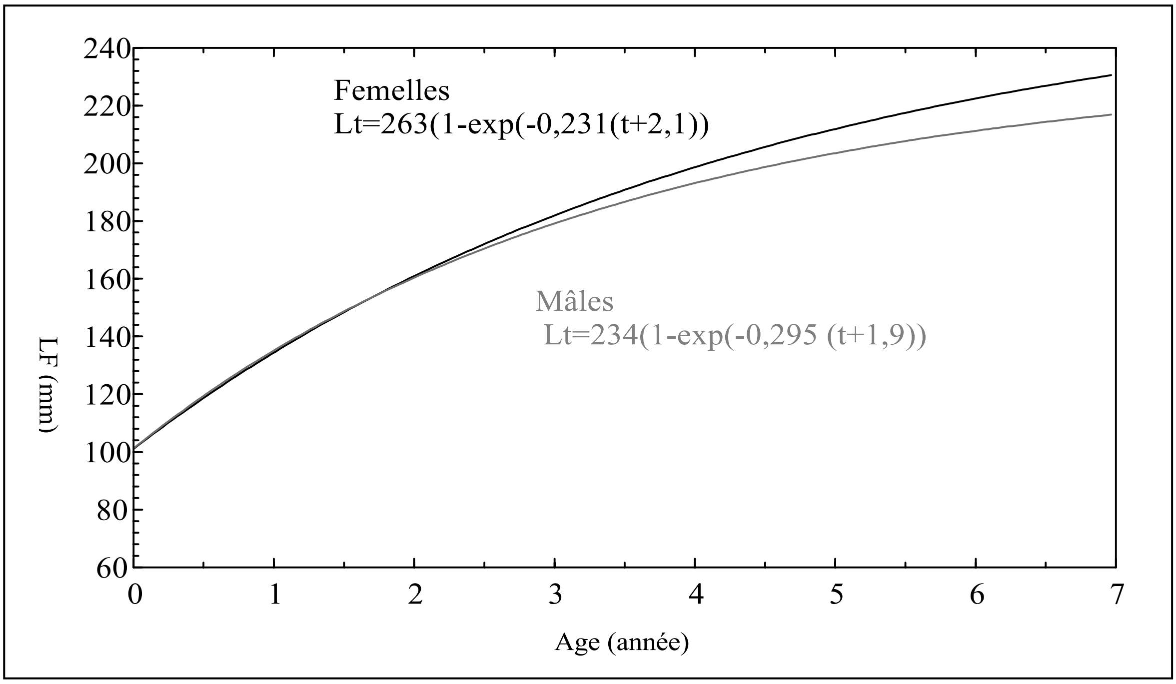


Figure 3. Courbe de croissance en longueur des mâles et des femelles d'allache.

Les tailles de première maturité sexuelle (L50) obtenues pour chaque espèce dans chaque région (Nord, Est et Sud) ne présentent pas de différence significative. On signale que pour la plupart des espèces les L50 relatives à la région Est sont légèrement supérieures à celles de la région Nord et celles de la région Sud sont les plus faibles (Tableau 3).

Tableau 3. Taille de première maturité sexuelle (longueur totale en centimètres) par espèce.

Espèce	Sardine	Allache	Anchois	Bogue
L50 (mm)	125	143	80	130

Le suivi mensuel de l'évolution du RGS moyen et des stades macroscopiques de maturité sexuelle (Tableau 4), permettent de conclure que :

- les périodes de reproduction moyenne de l'allache et de l'anchois sont estivales, elles correspondent respectivement à juin–septembre et mai–octobre ;
- la sardine se reproduit de décembre à mars et la bogue de février à mai ;
- indépendamment de la région et à n'importe quelle période de l'année on trouve des juvéniles de l'une ou de l'autre de ces espèces particulièrement dans les zones de faible profondeur, inférieure à 30 m.

Tableau 4. Période de reproduction moyenne par espèce.

Espèce	Janv.	Fév.	Mars	Avr.	Mai	Juin	Juill.	Août	Sept	Oct	Nov	Déc.
Sardine												
Allache												
Anchois												
Bogue												

Chez l’allache et l’anchois, la période de reproduction établie par le suivi du RGS et des stades macroscopiques est confirmée par l’étude histologique des ovaires (Figure. 4). Chez l’allache, la cinétique de l’ovogenèse chez une femelle type est illustrée par la Figure 5. Au cours de la période de ponte une femelle passe par une boucle qui se répète (n–1) fois le nombre (n) de séries de pontes. Ce système de boucle s’achève avec la diminution de la fréquence des ovocytes vitellogéniques et l’augmentation de la fréquence des ovocytes atrétiques. Les femelles types d’anchois ont la même cinétique de l’ovogenèse que celle de l’allache, quelques différences s’observent au niveau des fréquences des différents stades ovocytaires pour quelques types histologiques ovariens. La présence simultanée d’ovocytes à différents stades de développement et de follicules post-ovulatoires, témoins d’une ponte antérieure, permet de classer l’allache et l’anchois parmi les espèces à pontes sériées. Ceci est validé par l’absence d’hiatus dans les distributions de la fréquence des diamètres ovocytaires : le recrutement des ovocytes en vitellogenèse primaire est donc continu dès le début jusqu’à la fin de la période de reproduction (Figure. 6). Chez de telles espèces la fécondité annuelle n’est accessible qu’après la détermination du nombre *n* de séries de pontes. Pour l’allache, ce nombre a pu être estimé, il est égal à 4. La fécondité annuelle de l’allache est donc égale à quatre fois sa fécondité par lot.

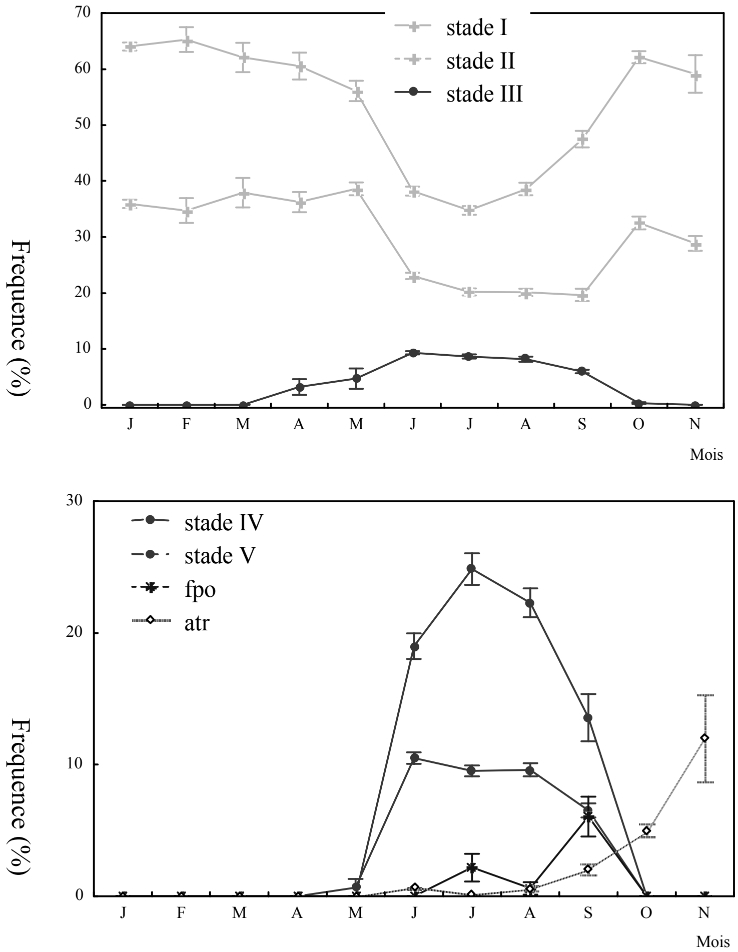


Figure 4. Evolution mensuelle de la fréquence des stades ovocytaires chez l'allache ; *fpo* follicules post-ovulatoires ; *atr* ovocytes atrétiques.

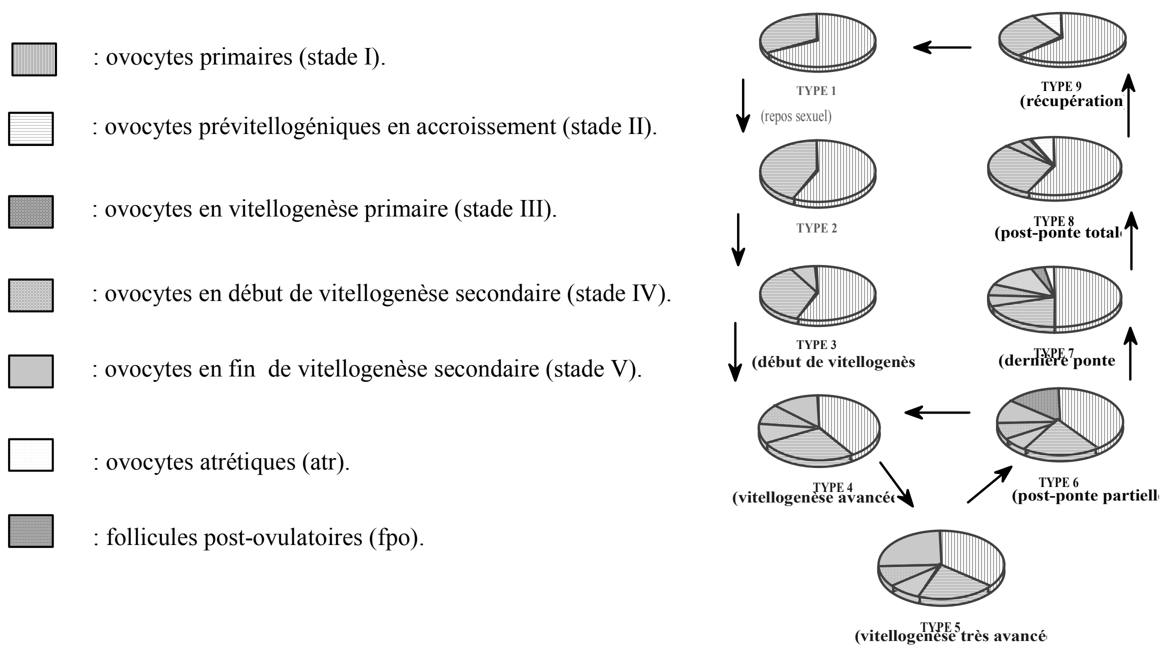
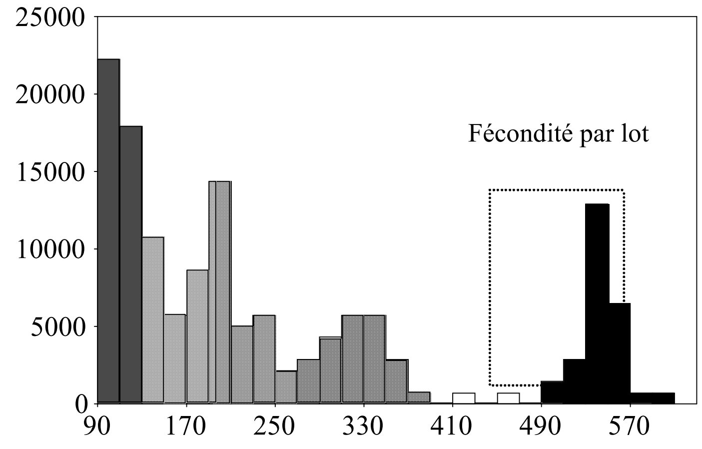
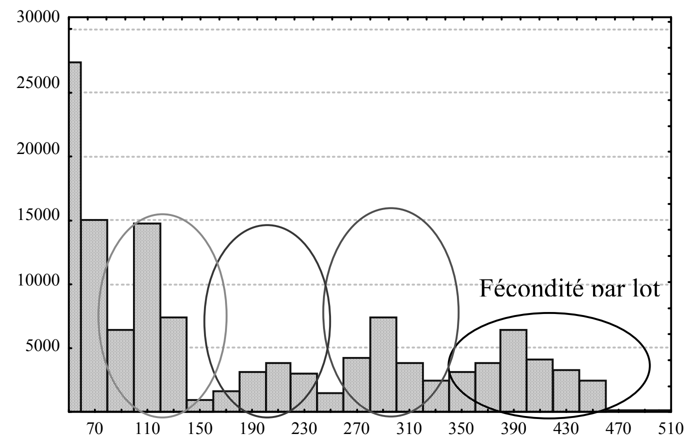


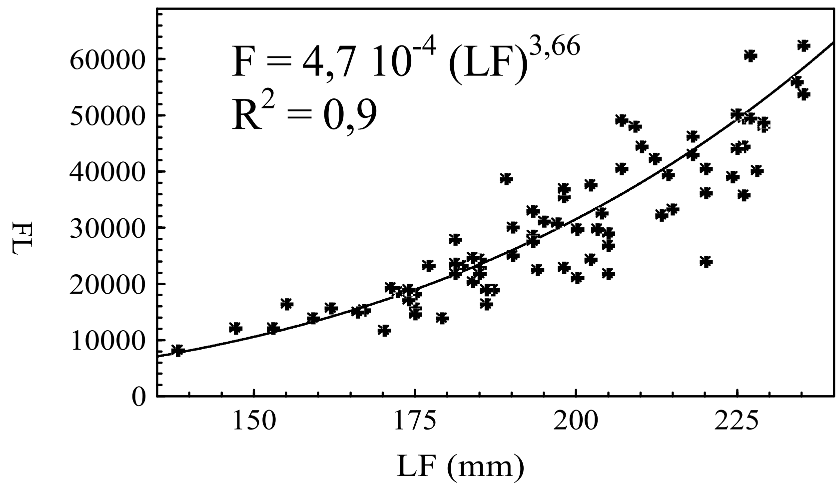
Figure 5. Cinétique de l'ovogenèse chez une femelle type d'allache.



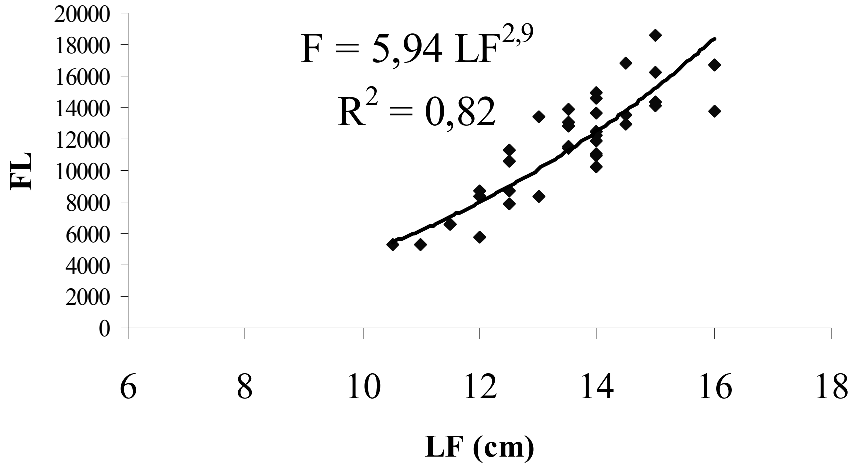
Distribution des diamètres ovocytaires chez une allache en préponte



Distribution des diamètres ovocytaires chez une anchois en préponte



Relation fécondité par lot-longueur à la fourche chez l'allache



Relation fécondité par lot–longueur à la fourche chez l'anchois

Figure 6. Distributions des diamètres ovocytaires et relation fécondité par lot (FL) longueur à la fourche (LF) chez l'allache et l'anchois.

Les débarquements des petits pélagiques dans les ports de pêche tunisiens sont assurés essentiellement par les techniques de la pêche au feu ou pêche au lamparo et la pêche à la petite senne ou pêche du jour. Le nombre moyen d'unités actives est de 318 unités, ce qui correspond à 7% du nombre total d'unités de pêche en Tunisie (Tableau 5). La région Est est la plus fréquentée par les pêcheurs professionnels des petits pélagiques, viennent ensuite les régions Nord et Sud.

Tableau 5. Nombre d'unités actives et nombre de sorties par région, année 2000.

	Nord	**Est**	**Sud**	**Total**
Nombre d'unités actives	87	129	102	318
% unités actives	27	41	32	100
Nombre de sorties par an	10.193	10.657	9.820	30.670

Dans les trois régions Nord, Est et Sud, l'activité des unités de pêche des petits pélagiques peut être établie entre avril et octobre. Cette saisonnalité de la pêche est liée aux conditions météorologiques, à l'état des unités de pêche et au changement d'activité de certaines unités particulièrement dans la région Sud (Figure. 7).

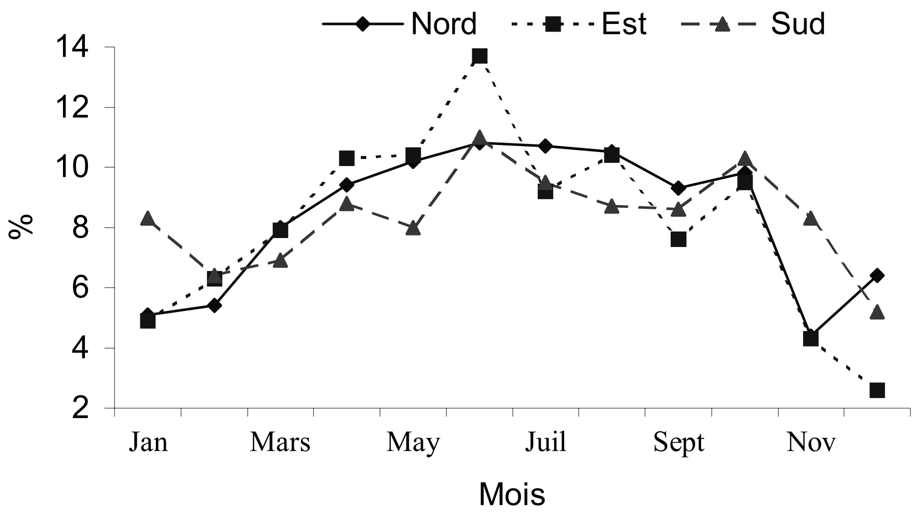


Figure 7. Evolution du pourcentage mensuel moyen du nombre de sorties par région.

Les débarquements des petits pélagiques sont en augmentation continue depuis 1995 (Figure. 8). Cette augmentation est le résultat des encouragements de l'Etat tunisien pour investir dans le secteur de la pêche aux poissons bleus et par l'augmentation de l'effort effectif de pêche suite à l'amélioration du savoir faire des pêcheurs et l'acquisition de nouvelles unités plus performantes.

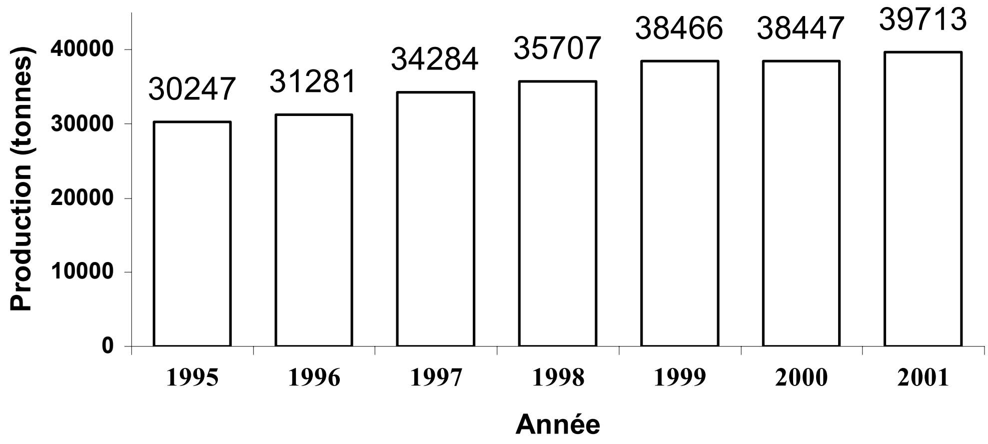


Figure 8. Evolution annuelle de la production des petits pélagiques en Tunisie.

Les captures des petits pélagiques sont composées essentiellement de sardine et d'allache (Tableau 6).

Tableau 6. Composition spécifique des débarquements des petits pélagiques en Tunisie.

Espèce	Sardine	Allache	Bogue	Anchois	Saurels	Maquereaux
Part (%)	39	31	9	1,5	12,8	5,7

Les captures de l'allache sont débarquées essentiellement dans la région Sud. Pour les autres espèces les débarquements sont réalisés en grande partie dans les régions Nord et Est (Tableau 7).

Tableau 7. Part relative (%) de chaque espèce dans les débarquements par région.

Espèce	Sardine	Allache	Anchois	Bogue
Nord	31,5	16,0	95,3	40,0
Est	40,0	26,0	4,7	51,8
Sud	28,5	58,0	0	8,2

En Tunisie, indépendamment de la région, la production des petits pélagiques est saisonnière (Figure. 9) :

- dans la région Sud la période de forte production s'étale de juillet à septembre avec un maximum en août. Le minimum de la production est atteint en avril.
- dans les régions Est et Nord, la période de forte production est estivale, elle s'étale de mai à août. La production minimale est enregistrée en hiver.

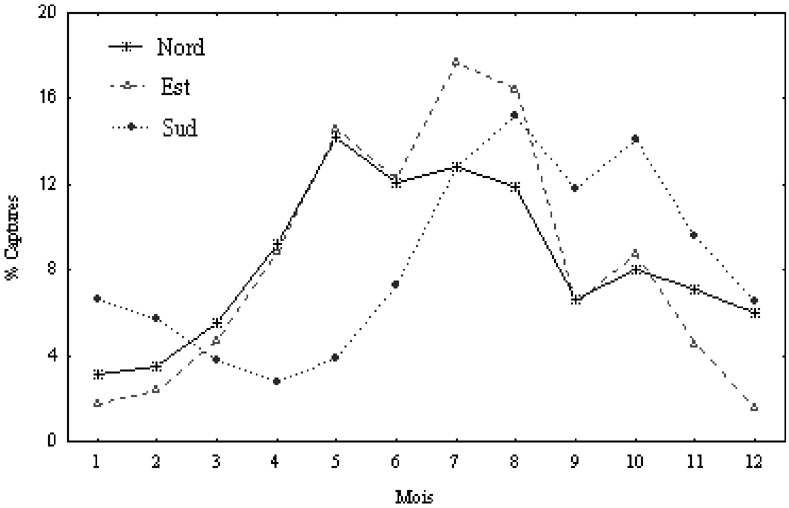


Figure. 9. Evolution du pourcentage mensuel moyen des captures des petits pélagiques par région.

Cette saisonnalité des débarquements des petits pélagiques est liée d'une part à la saisonnalité de l'activité de la flottille de pêche des petits pélagiques et d'autre part à la disponibilité de la ressource. En effet, les poissons bleus effectuent des déplacements à la recherche des frayères et des conditions optimales du milieu (Rijavec et Zarra, 1974 ; Rijavec et Gueblaoui, 1975 ; Boely, 1979 ; Belvèze, 1984 ; Cury et Fontana, 1988 ; Fréon, 1988 ; Marchal, 1991 ; Roy, 1992 ; Csirke, 1995 ; Binet, 1995 ; Pauly, 1997) ainsi une partie de la biomasse (généralement les individus de grande taille donc les adultes) en dehors de la période de reproduction devient inaccessible aux pêcheurs qui fréquentent les zones de pêche traditionnelles (franges côtières de faible profondeur).

Pour l'année 2000, la biomasse exploitable de la sardine, de l'allache, de la bogue et de l'anchois des eaux tunisiennes est évaluée, suivant la méthode directe d'hydroacoustique, à 67.000 tonnes, ce qui représente à peu prés 2,2 fois les débarquements de ces espèces. On peut donc multiplier par 2,2 l'effort effectif actuel de pêche sans risque de surexploitation (Figure. 10).

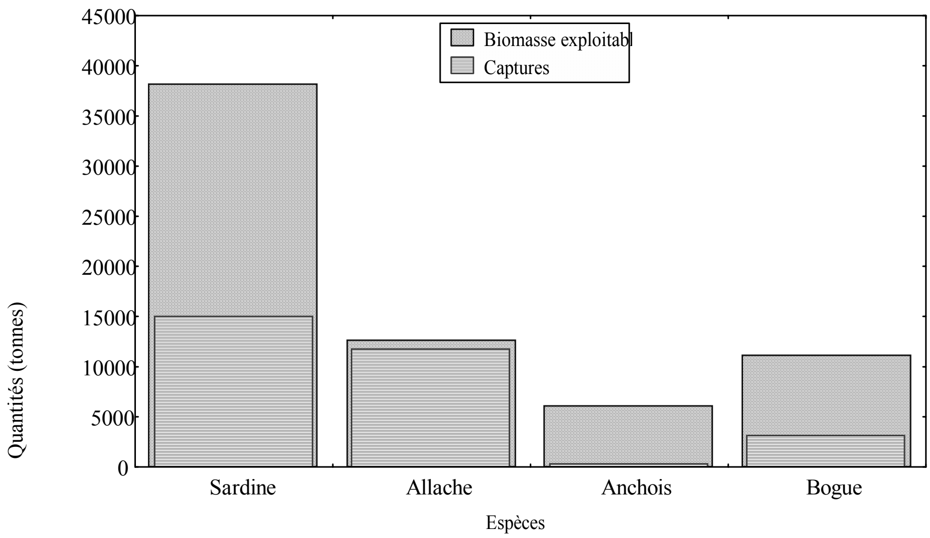


Figure. 10 : Biomasse exploitable et captures des petits pélagiques par espèce au cours de l'année 2000.

4. Conclusion et remerciements

Ce travail constitue un rapport de synthèse de la méthodologie employée et des principaux résultats obtenus, relatifs à la biologie et à l'exploitation des petits pélagiques des eaux tunisiennes, par le Groupe de Travail des Petits Pélagiques de l'INSTM dans le cadre des projets d'évaluation des ressources halieutiques tunisiennes. Le groupe de travail adresse ses remerciements aux Pr. A. El Abed et Dr O. Jarboui pour leur aide continue et leurs conseils fructueux au Groupe de Travail des Petits Pélagiques.

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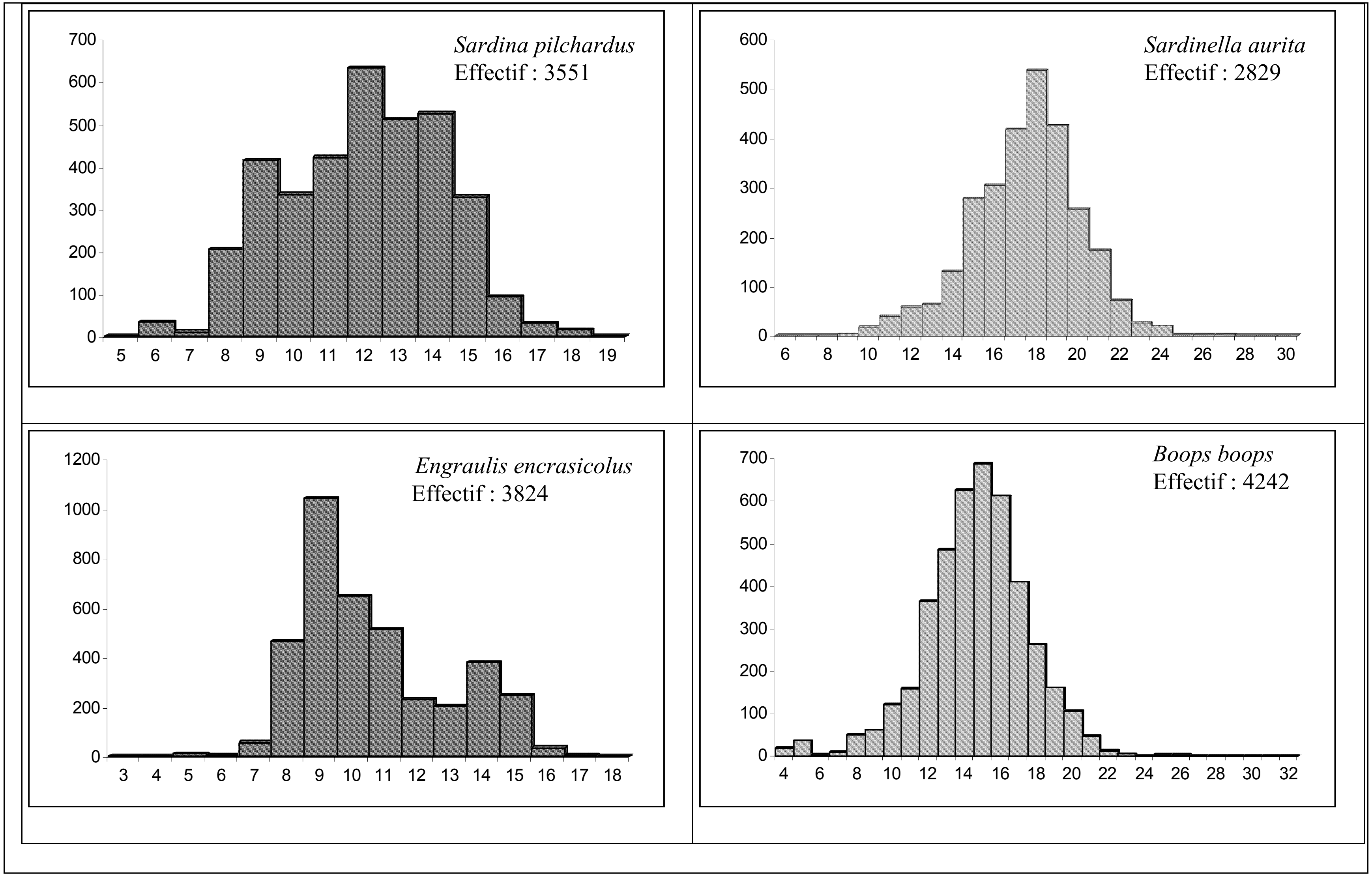
Annexe 1. Histogrammes des fréquences des tailles par espèces. Les abscisses correspondent à la longueur à la fourche en centimètres.



Annexe 2. Clé âge–longueur de l'allache. *LF* longueur à la fourche en millimètres ; *Age Gr* groupe d'âge ; *TF* taux de féminité

Month	J	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	1	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
LF \ Age	5	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
80-84	1																					
85-89	1																					
90-94	3																					
95-99	5		2																			
100-104	7		2	1																		
105-109	7	1	6																			
110-114	13		3																			
115-119	10	2	2	5																		
120-124	9	2	1	9	2																	
125-129	1	1	2	13	8	7																
130-134		2	1	22	2	7						2										
135-139		2		13	11	8		4			1	1										
140-144				7	9	4	4	20			4	12		7		10	2					
145-149					1	13	12	28	3	7	4	25		17	2	17	13	2	4	3		
150-154					3	9	15	34	11	9		20		6	8	24	21	23	18	9		
155-159							2	7	13	15	8	4	1	5	13	24	36	41	39	11	7	3
160-164									1	3	3	3	2	12	20	24	21	19	21	27	18	11
165-169														3		8	12	13	15	17	12	11
170-174																	3	1	18	8	27	25
175-179																	1	1		5	9	2
180-184																			1	2	5	1
185-189																					1	
190-194-																						
195-199																						
200-204																						
205-209																						
210-214																						
215-219																						
220-224																						
225-229																						
230-234																						
235-239																						
240-244																						
Total	57	10	19	70	36	48	33	93	28	34	20	67	3	50	43	107	109	100	116	82	79	53
Age Gr	1 : 428										2 : 829											
T F (%)	45										52											

Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
LF \ Age	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
80-84																								
85-89																								
90-94																								
95-99																								
100-104																								
105-109																								
110-114																								
115-119																								
120-124																								
125-129																								
130-134																								
135-139																								
140-144																								
145-149																								
150-154																								
155-159	1	3																						
160-164	2		6	2	8	1	1																	
165-169	3	3	12	11	11	11	2	2	2															
170-174	5	2	14	4	5	21	23	12	6	1	3			1										
175-179	2	3	15	9	5	26	20	10	19	2	5			1	4									
180-184	1	3	3	4	1	26	17	5	17	6	18				14	1	1	1						
185-189				2		13	11	5	11	1	11	3	1		11	2		4	3		1			
190-194-						3	3	8	6	3	10	3			4	1	1	8	8	6	6		1	
195-199							1	2	3		1		1		1	1		12	6	2	3			
200-204									1			1				2		6	7	10	4	1		
205-209																		2	2	9				
210-214																				2		2		1
215-219																								
220-224																								
225-229																								
230-234																								
235-239																								
240-244																								
Total	14	14	50	32	30	101	78	44	65	13	48	7	2	2	34	7	2	33	26	29	14	3	1	1
Age Gr	3 : 496												4 : 154											
T F (%)	58												62											

Month	F	M	A	J	J	A	S	J	A
	2	3	4	6	7	8	9	7	8
LF \ Age	54	55	56	58	59	60	61	71	72
80-84									
85-89									
90-94									
95-99									
100-104									
105-109									
110-114									
115-119									
120-124									
125-129									
130-134									
135-139									
140-144									
145-149									
150-154									
155-159									
160-164									
165-169									
170-174									
175-179									
180-184									
185-189									
190-194-	1								
195-199									
200-204	1			1		1			
205-209		1			1	4	1		
210-214				1	3	11	1		
215-219			1	1	2	8			
220-224						5			5
225-229								1	9
230-234									2
235-239									
240-244									
Total	2	1	1	3	6	29	2	1	16
Age Gr	5 : 44							6 : 17	
T F (%)	82							100	

Reproductive aspects of the European anchovy (*Engraulis encrasicolus*): six years of observations in the Strait of Sicily.

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Abstract

Several aspects of anchovy reproductive biology were assessed over a six-year period from commercial landing data from the main spawning ground of the anchovy population off the southern coast of Sicily. This work represents the first attempt to investigate the reproductive features of the anchovy population in this area. The intra-annual and interannual evolution of the gonosomatic index, condition factor, size at first maturity, sex ratio and length–weight relationships were assessed. Monthly gonosomatic index values and corresponding maturity stages show that the spawning season extends from late-March/early-April to August–September, though most of the spawning occurs in July–August. Size at first maturity is reached at 11.27±0.09 cm for males and 11.24±0.09 cm for females. Annual sex ratio differs statistically from the expected 1:1 ratio and shows the predominance of females. Monthly sex ratio values show the same trend, except that, in the spawning period, the females significantly outnumber the males. The sex ratio relative to body size underlines the decreasing number of males with increasing size above 12.0 cm length. Condition status reaches its highest value at the beginning and during the first part of the spawning period, in June, decreasing in August during the peak spawning.

Keywords: reproduction, anchovy, size at first maturity, condition factor, sex ratio, Strait of Sicily, central Mediterranean.

1. Introduction

The purse-seine fishery target species in the study area (hatched in Figure. 1) are small pelagic fishes, mainly anchovies and sardines. The value of the local production is relatively high, as a consequence of the high demand for these resources for direct consumption. The small-pelagic-species production is characterized by high interannual fluctuations that appear to be unrelated to the level of fishing effort. On the contrary, there is strong evidence that yearly production is connected to the success of reproduction, which in turn can be related to the direct or indirect effect of favourable environmental conditions (i.e. the availability of food, as determined by the timing of phytoplanktonic and zooplanktonic blooms). The anchovy resource in this area, according to previous acoustic and DEPM estimates (Azzali *et al.*, 1988; Mazzola *et al.*, 2000, 2002), may represent as much as 15% of the total Italian anchovy biomass estimates. From a socio-economic point of view, the anchovy stock of the Strait of Sicily is a relevant resource, historically exploited by fishermen from the north-western and southern coasts of Sicily. It supports several tens of thousands of families, which are exploiting these resources. In spite of the relevant economic and social impact of small-pelagic fishery resources in the study area, only two recent consecutive studies, funded by the European Commission, were carried out during 1997–2000 on biomass estimation and the

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ecology of the anchovy (Mazzola *et al*., 2000, 2002). A great deal of information on the anchovy population is lacking, in particular concerning its biological features. Therefore, the present paper is focused on anchovy reproduction, particularly the spawning season, condition factor, size at first maturity, sex ratio and their variability over the six-year study period.

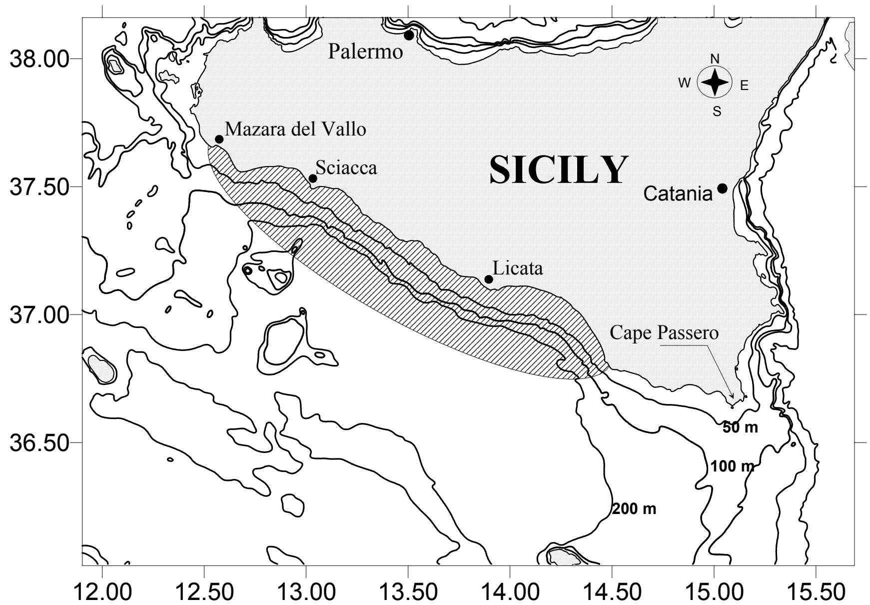


Figure 1. Map of Sicily with the study area (hatched); the 50-m, 100-m and 200-m isobaths are indicated.

2. Methods

The data were from the purse-seine and mid-water pelagic-trawl commercial catches, landed in Sciacca, the most representative port in the study area. For six years (1997–2002) at fortnightly intervals, 106 samples comprising 84,581 specimens were sexed and analysed. The total body length (TL) was recorded to the nearest millimetre and the total body weight, to the nearest gram. It was possible to determine the maturity stage of 64,019 specimens. Gonad weights (GW) were measured to an accuracy of 0.01 g. The sex was determined macroscopically and maturity stages were assigned according to the five-level maturity scale for partial spawners described by Holden and Raitt (1975). The spawning period was determined by evaluating the gonado-somatic index (GSI) and the monthly percentage of mature specimens. Length at first maturity (L_{50}) was computed from the percentage of mature individuals (stages III, IV and V) occurring over the reproductive period. The total length at which 50% of the specimens were mature was estimated by a method based on a logistic non-linear regression model (Hunter *et al*., 1992; Roa *et al*., 1999). Formally we have:

$$P(l_{\%}) = \frac{\alpha}{1 + e^{\beta_0 + \beta_1 l}} \qquad (1)$$

where P(l) is the proportion of mature at size l, α is the asymptote, β_0 the intercept and β_1 the slope of the logistic regression curve. In order to estimate the confidence limits (c.l.), the procedure recommended by Roa *et al*. (1999) was followed.

Length–weight relationships were computed for males and females and combined sexes on an annual basis by means of the equation:

$$TW = aTL^b \tag{2}$$

where *a* and *b* are the slope and intercept of the regression line fitted to the log-transformed data by the least-squares method (Sparre *et al.*, 1989). The combined sexes data included males, females and immature specimens, in order to cover the widest size range possible.

The GSI was calculated on a monthly and a seasonal basis. The corresponding equation was:

$$GSI = \frac{GW}{TW} \tag{3}$$

where GW is the gonad weight and TW is the total weight (Bougis, 1952).

The condition status was investigated on a monthly and a seasonal basis by the condition factor based on the following equation:

$$CF = \frac{TW}{aTL^b} \tag{4}$$

where *a* and *b* are the regression parameters of the length–weight relationship estimated for each year, and *TL* is the total length in centimetres (Le Cren, 1951). The choice of equation for the estimation of CF was based on literature data, which indicated the greater suitability of Le Cren's (1951) equation over Fulton's index (Fulton, 1911 in Tomasini *et al.*,1989) since the former relates more consistently with size, while that of Fulton increases considerably with larger size (see Giraldez and Abad, 1995; Millan, 1999).

To complete the picture of the reproductive aspects, the sex ratio, expressed as the ratio of the number of males to the number of females in a given sample, was investigated in terms of its intra-annual, interannualand length-class variability.

The significant differences from the expected ratio (1:1) were tested by means of a χ^2 test (Sokal and Rohlf, 1987).

3. Results

Length at first maturity. The estimates of this parameter over six years are shown in Table 1, on an annual basis for males, females and total. Mature specimens were detected starting at 9.4 cm (females and males), whereas complete maturity is reached at 13.5 cm. The analysis of data for the whole period gives values of L_{50} 11.27 cm±0.09 for males and 11.24 cm±0.09 for females (Figure. 2)

Length–weight relationship. The coefficients obtained from regression analysis for each sex and combined, yearly and over the whole period, are given in Table 2. The variations in the allometric parameter (*b*) between years, suggests differences in the weight of the population, with the highest weight values reached in 2000 and the lowest, in 1997. These differences were tested by analysis of covariance (ANCOVA) taking "length" (log-transformed) as the covariable and "year" as the factor. Results confirm the statistical significance of the differences ($F_{4,\ 84574}$=1512, p<0.000).

Table 1. Annual estimates of length at first (L_{50}) and full (L_{95}) maturity, and maturation range ($L_{25\text{-}75}$), total and as function of sex over the period 1997–2002. The 95% confidence limits for the L_{50} estimations (c.l.) are also listed; *n* number of specimens.

	Males				
Years	$L_{25–75}$	L_{95}	L_{50}	c.l.	n
1997	9.7–12.6	15.11	11.19	11.02–11.33	4,511
1998	10.3–12.1	13.65	11.18	11.10–11.25	4,485
1999	10.7–11.9	13	11.30	11.24–11.36	4,061
2000	10.5–12.2	13.7	11.34	11.24–11.41	4,157
2001	8.6–14.3	19	11.42	11.13–11.62	3,103
2002	11.0–12.2	13.3	11.64	11.55–11.71	2,139
1997–2002	10.1–12.4	14.4	11.27	11.22–11.31	22,456
	Females				
Years	$L_{25–75}$	L_{95}	L_{50}	c.l.	n
1997	9.3–12.2	14.7	10.75	10.53–10.93	5,705
1998	10.3–11.9	13.26	11.09	10.99–11.17	4,103
1999	10.8–11.9	12.8	11.33	11.27–11.38	3,850
2000	10.7–12.3	13.6	11.52	11.43–11.59	4,329
2001	9.5–12.9	15.7	11.04	10.70–11.28	2,533
2002	11.3–12.3	13.1	11.79	11.71–11.86	2,400
1997–2002	10.3–12.2	13.8	11.24	11.19–11.28	22,920
	Total				
Years	$L_{25–75}$	L_{95}	L_{50}	c.l.	n
1997	9.6–12.4	14.8	11.02	10.89–11.13	10,216
1998	10.3–12.0	13.5	11.14	11.08–11.20	8,588
1999	10.7–11.9	12.9	11.31	11.27–11.35	7,911
2000	10.6–12.2	13.6	11.41	11.35–11.47	8,486
2001	8.9–13.6	17.5	11.27	11.07–11.41	5,636
2002	11.1–12.3	13.2	11.71	11.65–11.76	4,539
1997–2002	10.2–12.3	14.1	11.26	11.23–11.29	45,376

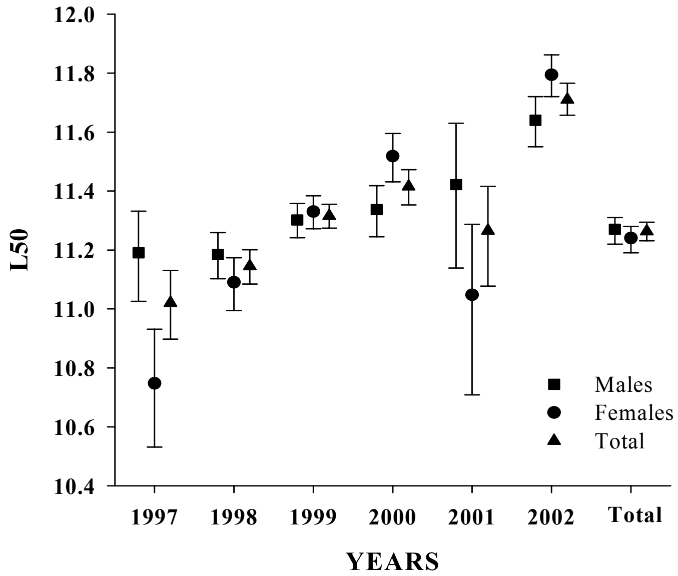


Figure 2. Length at first maturity estimates for each year and for the total, for males and females and combined sexes, with their 95% confidence limits.

Table 2. Values of the regression parameters (*a*, *b*, *r*) of the length–weight relationship, by sex and by year; *TL* total length; *TW* total weight; *n* number of specimens.

Years	*Males*				*Females*				*Total (M +F + Immature)*			
	a	b	r	n	a	b	r	n	a	b	r	n
TL(cm)/TW(g)												
1997	0.0053	3.3160	0.94	4,497	0.0047	3.2203	0.95	5,699	0.0047	3.2196	0.95	10,213
1998	0.0032	3.3497	0.94	6,755	0.0028	3.4082	0.96	7,096	0.0029	3.3838	0.95	13,859
1999	0.0027	3.4120	0.92	5,796	0.0020	3.5241	0.94	5,536	0.0023	3.4748	0.93	12,398
2000	0.0018	3.5540	0.95	5,798	0.0015	3.6224	0.97	7,850	0.0016	3.6005	0.96	15,327
2001	0.0029	3.3719	0.93	8,062	0.0028	3.3881	0.95	9,816	0.0027	3.4047	0.95	21,723
2002	0.0021	3.5179	0.95	4,518	0.0017	3.6001	0.95	5,965	0.0020	3.5298	0,96	11,058

Reproductive cycle. As already highlighted in other similar studies for others areas (Giraldez and Abad, 1995), spawning occurs during spring–summer with an interannual variability of one or two months. From monthly averages of the GSI, coupled with gonad maturity data (Figures. 3a, 4) it is possible to set a threshold value (in 0.01GSI units) indicating the start and the end of the spawning season. The reproductive period ranged from April–May to September–October. The peak of spawning usually occurred in August, except in 1998, when two peaks were recorded; the first in July and the second, lower, in September. Another interesting feature is highlighted in Figure. 3b: the interannual shift in the spawning period, from March–August in 1999 to June–October in 2001.

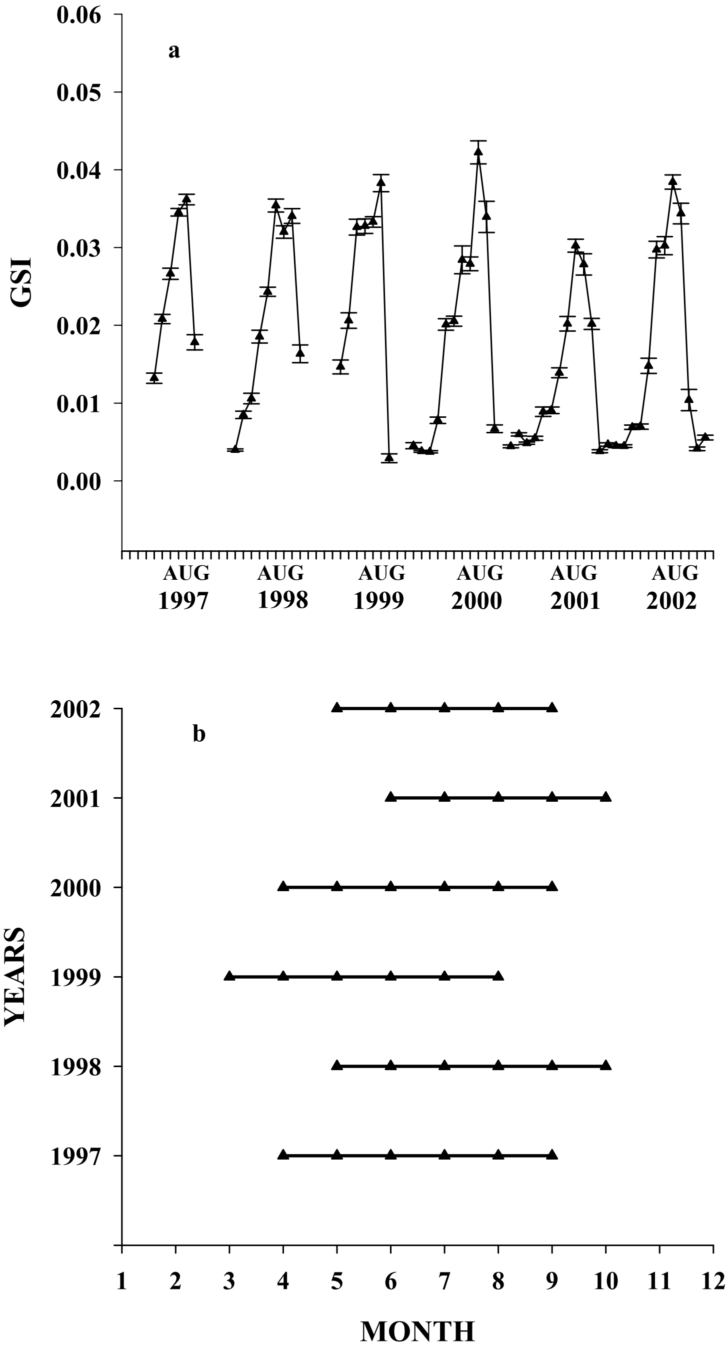


Figure 3. Mean monthly gonosomatic index for males and females (**a**) and interannual displacement of the spawning period, for females only, between 1997 and 2002 (**b**)

Maturity stages. A monthly bar graph (Figure. 4) shows the proportion of mature specimens over the whole study period. The maturity pattern confirms results from GSI data on the onset of the spawning period and the timing of the peak spawning.

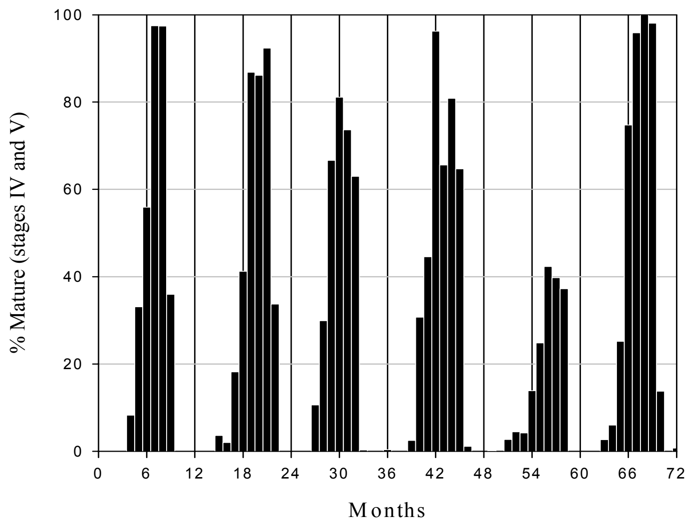


Figure 4. Proportion of mature females (stages IV and V), on a monthly basis, from 1997 to 2002.

Condition factor. There were no significant differences between males and females in respect of the mean monthly CF values; therefore, only the CF of unsexed specimens was analysed. The monthly mean CF values during the study period showed only one clear main peak, in June, but two other minor peaks occurred in spring and autumn (Figure. 5a). It appears that the peak nutritional conditions were met in spring and summer, but later, the energy reserve decreased during the onset of spawning. The breakdown of the thermocline in autumn facilitates the nutrient circulation in the photic zone of the water column, since another annual primary production peak occurs; it could correspond to the late increase in the value of the CF (Giraldez and Abad, 1995). The composite mean seasonal values show better the intra-annual pattern previously described (Figure. 5b) and some degree of interannual variability is more evident in the composite seasonal data.

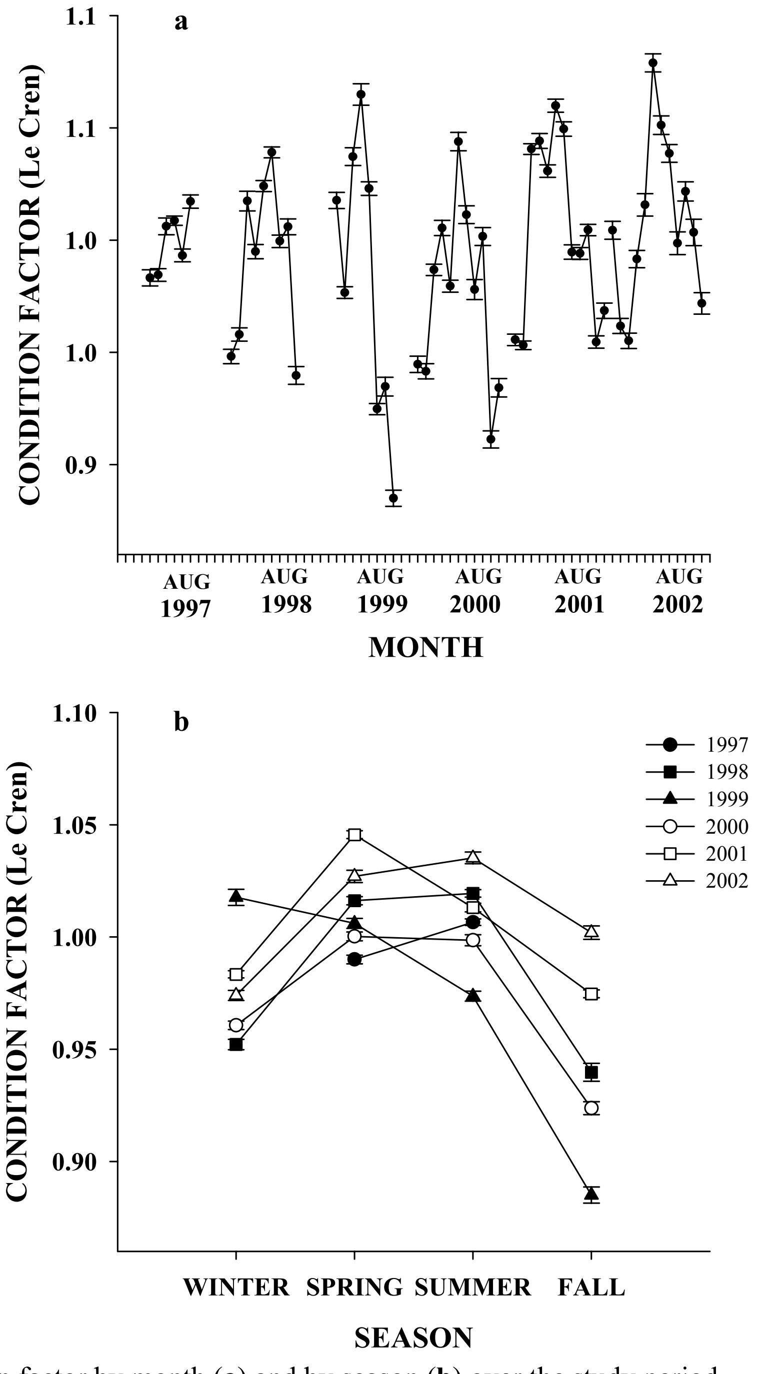
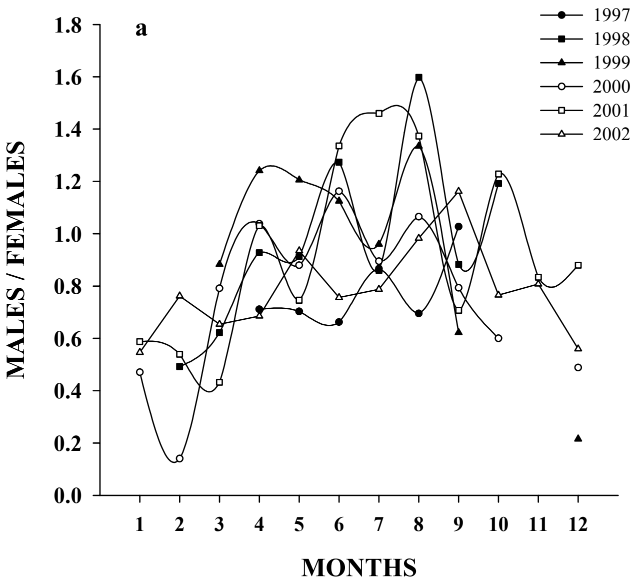


Figure 5. Condition factor by month (**a**) and by season (**b**) over the study period.

Sex ratio. The monthly mean values over the six years (Figure. 6a) show similar fluctuations, with male predominance between March–April and September–October; this feature is seen better in the seasonal values (Figure. 6b). The sex ratio by size-class for each year (Figure. 7) showed male predominance, in the size range 115–130 mm (whole period mean); above this size range, females constitute a majority in the catches.



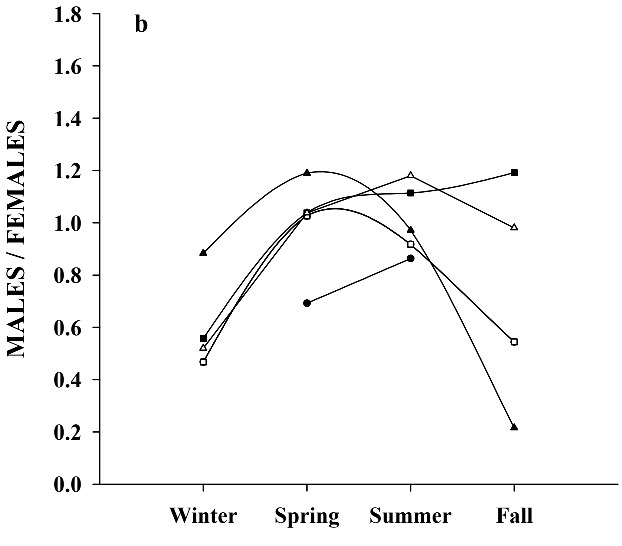


Figure 6. Monthly mean sex ratio by year (**a**) and seasonal sex ratio (**b**).

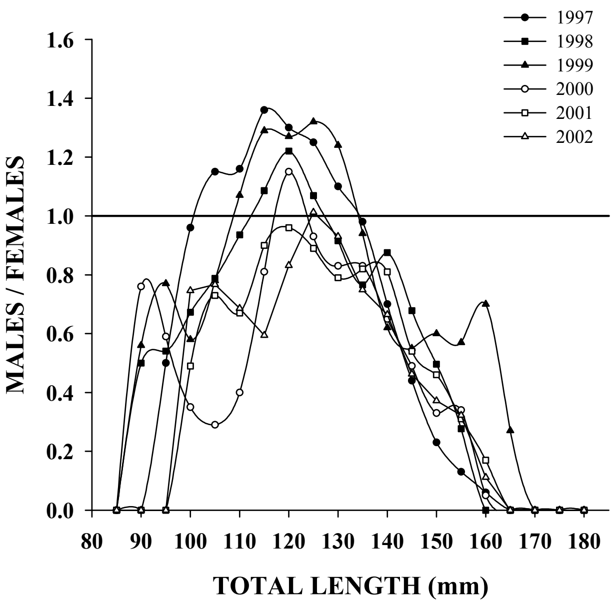


Figure 7. Sex ratio by size-class and by year.

A χ^2 test on monthly and seasonal sex ratios showed the significance of differences between the yearly and seasonally computed values (Table 3). Spring and summer values were more often not statistically different from the expected ratio (1:1), indicating that the catches are more homogeneous than in autumn or winter.

Table 3. Annual and seasonal sex ratios (M/F): χ^2 values with respective significance levels for the period 1997–2002. * $P<0.05$; ** $P<0.01$; *n.s.* not significant; *n* number of specimens.

Year		1997	1998	1999	2000	2001	2002
Annual	M/F	0.79	0.95	1.05	0.74	0.82	0.76
	n	10,200	13,855	11,336	13,652	17,882	10,487
	χ^2	141.6	8.4	5.9	308.4	172	199.6
	P	**	**	*	**	**	**
Winter	M/F	-	0.56	0.88	0.47	0.52	0.65
	n		2,674	1,034	3,850	6,306	3,116
	χ^2		235.7	3.9	572	669	141.4
	P		**	*	**	**	**
Spring	M/F	0.69	1.04	1.19	1.03	1.04	0.79
	n	3,828	4,982	4,661	5,189	4,322	3,396
	χ^2	125	13.1	43.6	0.3	0.01	49.4
	P	**	**	**	n.s.	n.s.	**
Summer	M/F	0.86	1.11	0.97	0.92	1.18	0.98
	n	6,372	5,366	5,257	3,297	4,033	2,343
	χ^2	40.8	2.8	2.7	5.2	24.9	2.4
	P	**	n.s.	n.s.	*	**	n.s.
Autumn	M/F	-	1.19	0.22	0.54	0.98	0.71
	n		833	384	1,316	3,221	1,632
	χ^2		6.3	160.1	119.1	0.1	54.4
	P		*	**	**	n.s.	**

4. Discussion and conclusions

The values for size at first maturity lie in the range of the literature data for the Mediterranean Sea. Interannual variability in the L_{50} estimates recorded by several authors (Hunter and Goldberg, 1980; Giraldez and Abad, 1995; Millan, 1999) was attributed to the spawning tactics to ensure survival of the early-life stages (Alheit, 1989). So the environmental conditions affect one or more of the spawning characteristics (batch fecundity, spawning frequency and age/length at maturity). In the Adriatic Sea, the fluctuation in the annual abundance of anchovy eggs coincided with fluctuations in primary production (Regner, 1974). More detailed study of the long-term fluctuations in the anchovy early-life stages showed that there is a positive relationship, with a one-year phase lag, between egg and post-larval abundance, on the one hand, and temperature and productivity, on the other (Regner, 1996).

The interannual variation in the allometric growth parameter *b*, in the length–weight relationship, follows the same trend as that of the size at first maturity, increasing from 1997 to 2000, regressing in 2001, and increasing again in 2002. This variation could also be related to the same habitat variability that affects size at maturity. Annual sex ratio does not differ from the expected 1:1 ratio, but varies seasonally and shows the predominance of females during the year, except in the spawning period, when it is evident that males significantly outnumber females. Otherwise, the change in the sex ratio with body size shows the decreasing number of males at sizes above 12.0 cm (almost the size at first maturity). As concerns the spawning season, GSI clearly shows a seasonal pattern. The mean spawning season extended from April to September, except during 1999, when it began one month before, and in 2001, when it ended two months later. The spring warming of the water body largely influences the onset of the anchovy spawning season (Furnestin, 1945; Cort *et al*., 1979) and Motos *et al*. (1996) suggested that the Bay of Biscay anchovy starts spawning (massive occurrence of eggs and larvae in the plankton) when the temperature rises above 14°C, and local spawning peaks were recorded at a sea-surface temperature between 16° and 18.5°C. Anchovy seems to diminish its spawning when the rate of surface-water warming decreases, and stops when this rate becomes zero or negative (Motos *et al*., 1996).

The interannual shift in the reproductive activity (Figure. 3b) could be related to the habitat variability, expressed as the warming and the food availability, and could explain this shift in spawning time; however, the chlorophyll concentration, even with two or three months lag, could not be strictly considered as food available for anchovy, because the transport by currents heavily affects the zooplankton distribution. Further data on zooplankton availability are needed to explain better the timing of anchovy spawning.

For the future, it will be interesting to investigate these interannual variations in timing (start and end) of the spawning season in relation to changes in environmental conditions (productivity, temperature, upwelling intensity, salinity) and/or to stock fluctuations.

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Growth of the European anchovy (*Engraulis encrasicolus*) in the Strait of Sicily

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Abstract

Age structure and growth parameters for the anchovy, *Engraulis encrasicolus,* were estimated for the first time in the Strait of Sicily. The sampling was carried out from May 2000 to October 2001 on board commercial fishing vessels. The age composition of the catches was dominated by the 2nd-year-class (55–63%) and the 1st-year-class (30–41%), whereas the 0-year-class (1–5%) and the 3rd-year-class (3–5%) represented a small proportion of the catches. The von Bertalanffy growth model and back-calculation were applied to estimate anchovy growth parameters using the FISAT programme. There were no significant differences between males and females; pooled mean parameters were L_∞=18.6 cm, k=0.29 year^{-1} and t_0=–1.81 years. The estimated parameter *k* of the Sicilian anchovy was at the lower end of the range observed for this fish species in different areas, ranging from 0.26 (Algeria) to 2.44 (northern Adriatic Sea).

Keywords: anchovy, growth, population structure, otolith, back-calculation, Strait of Sicily.

1. Introduction

The European anchovy (*Engraulis encrasicolus* L. 1758) is widely distributed along the coasts of Europe, north to about Bergen, Norway, but not in the Baltic and rarely in the North Sea; in the whole Mediterranean and Black and Azov Seas; along the coast of West Africa down to South Africa (see geographical distribution in the FAO–Fishbase web page). In the Strait of Sicily, there is one of the main pelagic resources for both the purse-seine and mid-water pair-trawl fleets. Anchovies are well represented in the catch throughout the year, except in winter, when landings decrease to low levels (Mazzola *et al*., 2002). Despite the importance of the anchovy fishery in the Strait of Sicily, there is no information available, either on the age structure or on the growth of the species in this area.

Short lived pelagic fish species, like anchovy, mainly consist of a few age-classes. When the stock is overexploited, the age-classes usually decrease in number and it is important to understand the extent to which the year-to-year fluctuation in the population depends on the recruitment (0-age-class).

The aims of this study were: (1) to determine the extent to which the anchovy fishery is supported by the smallest age-classes; and (2) to obtain the first estimates of growth parameters of the anchovy population in the Strait of Sicily

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2. Methods

Samples

The present study was of the exploited anchovy population of the southern shelf of the Sicilian coast (Figure. 1). The sampling was carried out from May 2000 to October 2001 in the Port of Sciacca, which is the most important landing port, for small pelagic fish species, along the southern coast of Sicily. The sampling was based on market landing and on deck-collected specimens.

To cover the widest possible size range, especially for the smallest sizes, two different fishing gears were used, two days per month: the purse-seine and the mid-water pair-trawl. Specimens were also examined in the laboratory.

A total of 11,769 specimens was measured to the nearest millimeter, and length data were grouped by 0.5-cm length intervals (Table 1), weighed to the nearest gram; sex and maturation stages were also determined. The minimum and maximum number of individuals per sample was 72 and 854, respectively. Otoliths were removed from a sub sample of 5 specimens for each 0.5-cm length interval, up to a total of 1,700 otolith pairs. The age reading and growth analysis were carried on 1,678 specimens: 730 males, 819 females and 129 specimens of undeterminable sex.

Analyses were carried on unsexed, males and females with a view to detecting any differences in growth patterns and to avoiding a bias in the estimation of growth parameters. The undetermined sex specimens were important to get a wider range of length for fitting the growth model, so the sex ratio was estimated for each 0.5-cm length interval from the individuals sexed, and the estimated values were applied to the immature specimens to obtain the relative number of females and males for each size-class.

The otoliths were cleaned and dried and stored in black plastic labelled moulds. For age reading, the otoliths were put in a solution of alcohol and glycerin to increase the visibility of the hyaline rings under reflected light over a dark background. The alternating white and dark rings are called hyaline and opaque, respectively.

The criterion followed to determine the age of a fish was as follows: as well documented in the literature, the wider opaque ring is laid down in the summer, and the narrow hyaline ring, in the winter; the birth date was established in summer time, the first day of July, based on the peak of spawning period in the Strait of Sicily (García Lafuente *et al*., 2002; Patti *et al*., 2002). Fishes sampled before this date were assigned an age equal to the observed number of hyaline rings bordered by opaque rings, whereas, if the fish came from sampling carried out during the second part of the year, the age was established only by the number of hyaline rings. Each otolith was read twice by two independent observers and when there was a discrepancy between readings, the otolith was excluded, but only 3% of analysed sagittae were discarded. The total radius and distance between the core and the rings were measured along the post-rostrum axis under a dissecting microscope at 25× magnification.

Table 1. Monthly anchovy length–frequencies obtained from landings and deck-collected data (n=11,769)

Size (cm)	05/00	06/00	07/00	08/00	09/00	10/00	11/00	12/00	01/01	02/01	03/01	04/01	05/01	06/01	07/01	08/01	09/01	10/01
6.0							1											
6.5							4											
7.0							2											
7.5							11											
8.0							10											
8.5					1		14											1
9.0					9		30			3	1							0
9.5					31		19			4	12							2
10.0			1		76		19	4		15	59							16
10.5			0		106		11	53		22	129	4		2	1		2	35
11.0		4	8		104	2	18	124	3	49	205	36		14	64	3	5	33
11.5	4	9	35	1	28	8	4	127	9	33	219	160		138	170	107	4	8
12.0	47	27	102	13	10	43	6	95	13	26	187	231		296	247	348	16	6
12.5	117	63	112	68	7	53	7	87	9	25	124	254	4	241	324	456	22	5
13.0	199	131	125	137	17	127	6	94	9	20	38	146	13	92	322	267	54	24
13.5	120	134	77	159	5	135	3	58	8	14	12	60	38	45	83	104	54	58
14.0	180	222	85	125	10	140	3	48	11	31	9	40	62	32	28	47	54	173
14.5	89	180	44	57	2	74	1	18	7	40	4	14	84	23	1	20	50	128
15.0	35	60	12	20	3	15	0	6	2	20	1	10	57	14		7	26	66
15.5	8	19	5	2	1	3	0	2	0	12		2	37	2		2	7	16
16.0	4	3	1				1		1	6		2	4				5	4
16.5	1	2											1				1	
Total	804	854	607	582	410	600	170	716	72	320	1000	959	300	899	1240	1361	300	575
Samples	2	1	1	1	1	1	1	1	1	2	2	2	1	2	2	2	1	2

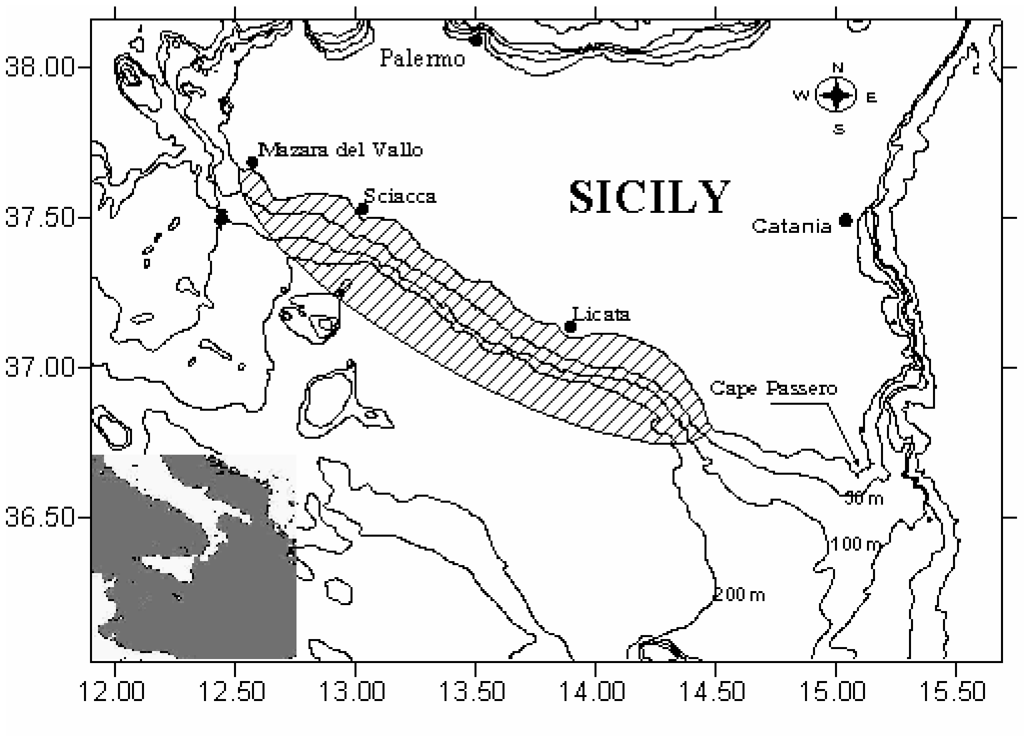

Figure 1. Sampling area (cross-hatched) and main spawning area (shadowed) on the south coast of Sicily; 50-m, 100-m and 200-m isobaths are shown.

Population age structure

The length–age key was obtained (Table 2) from fish length-at-age based on the interpretation of otolith data. By means of this key, when only length data were available, the age composition over the whole data set was computed. The total number of fish collected in each size-class was multiplied by the corresponding proportion of each length-at-age group, from the age–length key.

To avoid bias in the age composition due to the different sizes of the monthly samples, the analysis was performed on two different data sets. The first one was the whole data set and the second was composed of 200 specimens randomly selected every month. The monthly age distribution was also assessed.

Table 2. The age–length relationship obtained by otolith interpretation for *Engraulis encrasicolus*.

Total length (cm)	Age (in years) 0	1	2	3
7.0	2			
7.5	3			
8.0	6	1		
8.5	16	3		
9.0	14	8		
9.5	14	23		
10.0	6	38	1	
10.5	2	67	8	
11.0	2	104	27	
11.5	1	112	47	
12.0		112	94	
12.5		84	140	
13.0		70	140	5
13.5		36	140	6
14.0			137	15
14.5			91	16
15.0			55	11
15.5			12	9
16.0				3
Mean length (cm)	9.29	11.77	13.38	14.63
SD (cm)	0.84	0.1	0.1	0.78
No. of specimens	63	659	894	68

Growth estimation methods

The von Bertalanffy growth equation (VBGE) was used to estimate the growth parameters:

$$L_t = L_\infty \left(1 - \exp^{-k(t-t_0)}\right)$$

where L_t is the length (in centimetres) at the age t (in years), L_∞ the asymptotic length (the length at which growth rate is theoretically zero, in centimetres), k is the body growth-ratecoefficient (rate of asymptotic growth, in years^{-1}) and t_0 is the time when length would have been zero on the modelled growth trajectory.

An estimation of growth parameters was attempted using FiSAT software (Gayanilo and Pauly, 1997). The FiSAT package fits the VBGE function for the pooled-pair age-at-length data by means of non-linear regression analysis, based on iteration, that determines the growth parameters so as to minimize the sum of squares of deviation:

$$\sum_{i=1}^{n} \left(L_i - L_\infty \left(1 - \exp^{-k(t_i - t_0)}\right)\right)^2$$

where L_i is the length of the i^{th} fish and t_i is its observed age, and L_∞ and k are the growth parameters described above.

A complementary method was applied to compare results from the growth model estimation: the back-calculation method of Francis (1990) revisited. The back-calculation uses fish length and fish otolith radius measurements at the time of capture to infer the length at times in the past (Francis 1990). The dimensions of one or more marks in some hard part of the fish, together with its current body length, are used to estimate its length at the time of formation of each of the marks. This technique is based on the hypothesis of the linear relationship between the body size (length or weight) and the size of the hard part considered (e.g. radius of the otolith, scale, etc). The back-calculation equation is

$$L_i = \left(\frac{a + bR_i}{a + bR_c} \right) L_c$$

where L and R are the fish length and the otolith radius, respectively; c and i are the time of capture and the time of ring i formation, respectively. In the equation, the estimates of a and b were obtained from the linear regression of the otolith radius on the body length.

To test the overall growth performance, the phi-prime index (ϕ') was calculated (Munro and Pauly, 1983; Pauly and Munro, 1984), of which, the main advantage that it overcomes the problem of the correlation between k and L_∞:

$$\phi' = log_{10}k + 2log_{10}L_\infty$$

3. Results

The age–length key applied to the whole length–frequency distribution provided the age composition shown in Table 3, in terms of proportions for each age-class in the years 2000 and 2001. There were no significant differences between the values obtained using the individuals randomly and those obtained using the whole data set (χ^2 test, $P<0.001$). The fishery is mainly supported by the 2nd-year-class (55–63%) and the 1st-year-class (30–41%), whereas the 0-year-class (1–5%) and the 3rd-year-class (3–5%) represent only a small proportion of the catch. Specimens older than 3+ years were not observed. The monthly age composition (Figure. 2) shows that the recruitment season started in September–October, whereas the highest proportion of the 0-year-class was observed in November 2000.

Table 3. The proportions of each age-class in the anchovy fishery in 2000 and 2001 obtained from two different data sets, one randomly selected (1) and the whole data set (2).

Age	Year 2000		Year 2001	
	Dataset 1	Dataset 2	Dataset 1	Dataset 2
0	5	2	1	1
1	33	30	36	41
2	58	63	58	55
3	4	5	5	3

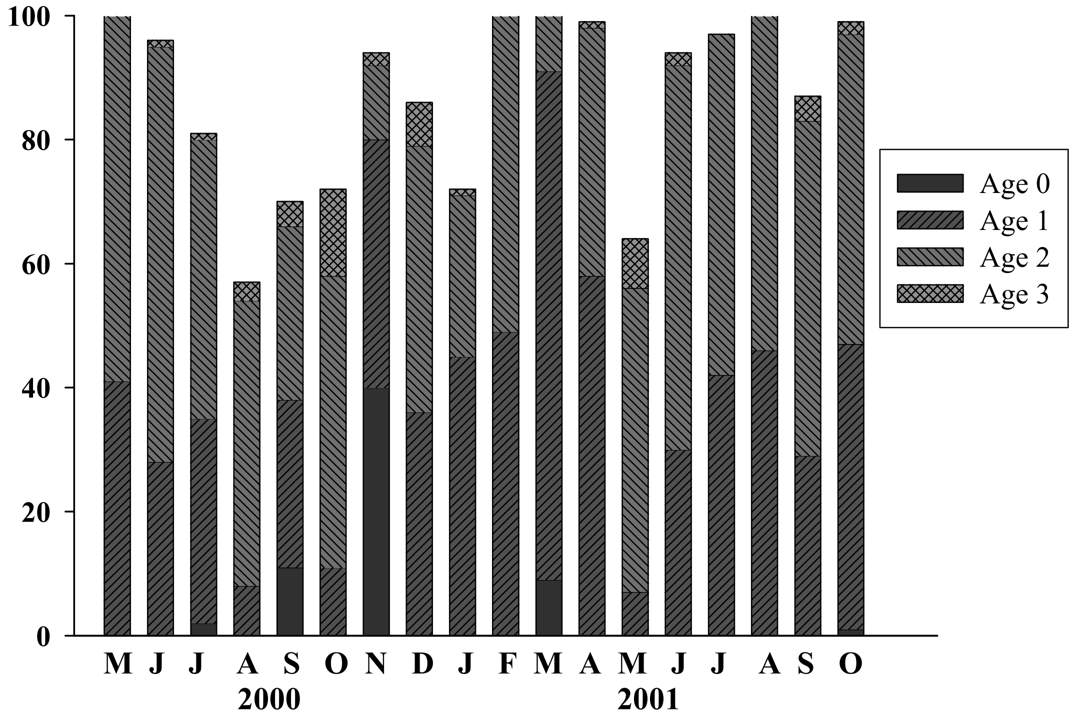

Figure 2. Monthly age composition of the catches over the study period.

The growth parameters are summarized in Table 4. An analysis of co-variance (ANCOVA), taking the length (log-transformed) as a variable, the age as a co-variable and the sex as a factor, showed that there were no significant differences in the growth parameters between males and females, if the individuals of undetermined sex are not considered ($F_{1,1301}$=1.4, P=0.24). The linear relationship between fish length and otolith radius for males and females are shown in Figure 3. An ANCOVA, taking the fish length as a co-variable and the sex as a factor, showed a significant difference between females and males ($F_{1,\ 1680}$=7.9, P=0.005).

Table 4. Von Bertalanffy growth parameters (L_∞, k and t_o) with the corresponding standard errors, estimated for anchovy; *M* males, *F* females, and *F+M* sexes combined.

Sex	**L_∞ (cm)**	**k (yr^{-1})**	**t_o (year)**
F	18.6±0.13	0.29±0.06	–1.94±0.3
M	17.5±0.11	0.33±0.06	–1.87±0.3
F+M	18.6±0.13	0.30±0.06	–1.81±0.2

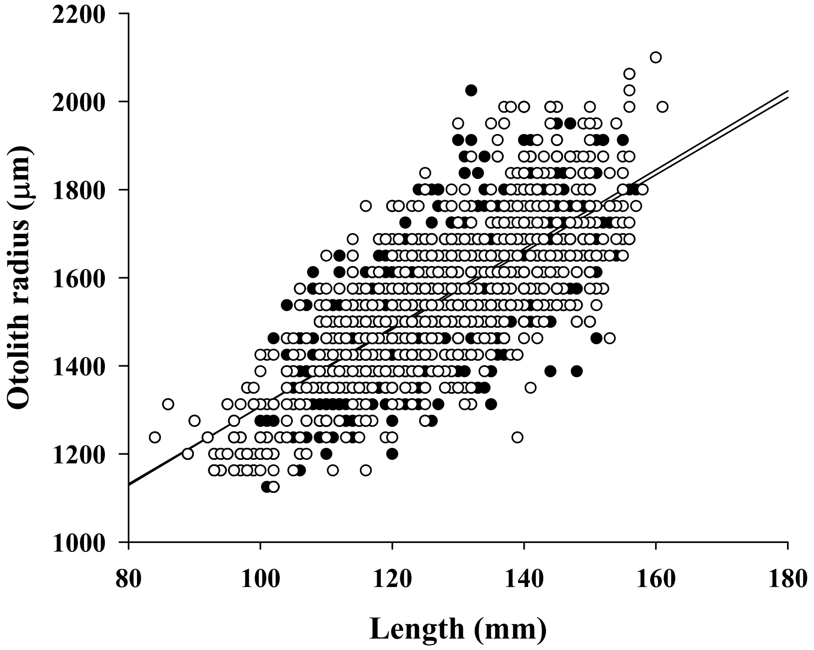

Figure 3. Otolith radius (TR in micrometres) versus total fish length (TL in millimetres); linear regression for males (● TR=413.3+8.9TL, n=803, r^2=0.52) and females (○ TR=430.5+8.77TL, n=887, r^2=0.55).

The mean size for the age-class, obtained by direct age readings, was compared with those obtained by the VBG model and by the back-calculation analysis: the results were similar (Table 5).

Table 5. The mean length, the standard deviation (s.d.), in centimetres, and the number of specimens (n) for each age-class, based on the lengths observed, estimated by back-calculation and by the von Bertalanffy equation (VBGE) for males (M) and females (F) of *Engraulis encrasicolus*.

	Observed						**Back-calculation**						**VBGE**								
Age	F	s.d.	n	M	s.d.	n	F	s.d.	n	M	s.d.	n	F	s.d	n	M	s.d	n	F+M	s.d	n
0	9.2	0.8	59	9.2	0.8	55							9.6	0.7	131	9.6	0.7	105	9.6	0.7	131
1	11.7	3.9	357	11.8	1.1	365	11.6	1.1	356	11.6	1.1	365	11.6	0.6	211	11.6	0.5	206	11.6	0.6	213
2	13.5	1.1	486	13.2	1.0	419	13.4	1.0	486	13.2	1.0	419	13.4	0.4	185	13.2	0.4	167	13.4	0.4	171
3	14.7	0.7	47	14.5	0.7	20	14.7	0.7	46	14.4	0.7	20	14.8	0.3	116	14.3	0.3	109	14.8	0.4	129
4													15.6	0.7	131	15.1	0.7	105	15.6	0.7	131

The growth parameters obtained from the literature for *Engraulis encrasicolus* in different regions are shown in Table 6. As it is now accepted that the anchovy species formerly named *Engraulis capensis* is in fact the same species as the European anchovy *Engraulis encrasicolus* (Whitehead, 1990; Hugget *et al*., 2003), the growth parameters for this species in South Africa (Waldron 1995) were also included. In most of the studies, the method used to estimate the growth parameters was based on otolith measurement, but also on length–

frequency analysis and scales. In those studies for which the method is unknown, the reason is that the information was obtained from the fish data base (http://www.fishbase.org). It has been demonstrated for the anchovy that similar growth parameters are obtained by using otolith data and length–frequency analysis (Morales-Nin and Pertierra, 1990). There are no studies comparing growth parameters obtained using otoliths and scales in anchovy, but in other pelagic fish species, such as sardine, a statistical difference between the otolith-based growth curve and the scale-based growth curve has been shown (Pertierra andMorales-Nin, 1989).

Table - 6. Growth parameters and the performance index (ϕ') in different regions for the anchovy *Engraulis encrasicolus*.

Area	L_∞ (cm)	k (yr^{-1})	ϕ'	Method	Source
Strait of Sicily	18.6	0.3	2.016	Otolith	This study
Catalonian littoral (NE Spain)	19.1	0.35	2.106	Otolith	Morales and Pertierra (1990)
Catalonian littoral (NE Spain)	19.4	0.41	2.199	Otolith	Pertierra (1987)
Gulf of Cádiz (SE Spain)	18.8	0.9	2.503	Frequency analysis	Bellido *et al*. (2000)
Northern Adriatic Sea (Po River, Italy)	15.3	2.44	2.757	Scale	Padoan (1963)
Central–northern Adriatic (Croatia)	19.4	0.57	2.331	Otolith	Sinovĉić (2000)
Algeria	18.6	0.26	1.954	Otolith	Hémida (1987)
Gulf of Lion (SE France)	19.1	0.35	2.106	Unknown	Campillo (1992)
Gulf of Lion (SE France)	20	0.42	2.225	Unknown	Lee and Juge (1965)
Gulf of Biscay	21.3	0.48	2.343	Otolith	Cendrero *et al*. (1981)
North Portugal	15.8	0.53	2.12	Otolith	Ramos and Santos (1999)
Algerian–Moroccan	20	0.39	2.2	Unknown	Arrignon (1966)
Central Ionian Sea (Greece)	17.5	0.51	2.194	Otolith	Machias *et al*. (2000)
West coast of South Africa	n.c.	1.32	n.c.	Otolith	Waldron (1995)

4. Discussion

In the study area, we found that the youngest age-class (0-year-class) represents a small proportion of the anchovy fishery. In contrast to our findings, Bellido *et al*. (2000) observed that the anchovy fishery was mainly supported by the young fish in the Gulf of Cádiz. There are two probable explanations for the low proportion of young age-classes in the Strait of Sicily fishery: sampling (by us and by the fishery) was not carried out in the nursery areas, and the fishing effort was not directed to juveniles. Garcia Lafuente *et al*. (2002) studied the link between the general circulation of the Atlantic Ionian Stream and the reproductive strategy of the anchovy in the Strait of Sicily. The main spawning ground is in the north-western part of the southern Sicilian coast. The main branch of the Atlantic Ionian Stream heads south-eastwards at the eastern end of the Sicilian coast, caryying the anchovy eggs and larvae; hence, the highest concentrations of larval anchovy were found off the south-eastern Sicilian coast, off Cape Passero. Therefore, larvae reach the juvenile stage off the south-eastern coast of Sicily, indicating that the 0-year-class anchovy was located in a region different from that in which the samples were collected for our study. Since the individuals collected during this study came from commercial fishing vessels, it means that fishing pressure is higher in the areas where adults are the predominant age-class, which is a positive factor for sustainable fishery. Therefore, although the proportion of the 0-year-class was low in the samples collected, we cannot decide whether the population is supported by the young age-classes, because the low proportion of the youngest class in the sampled population is probably due to the fact that the adults are located in a different area from the juveniles. The growth parameters obtained for our study area, compared with those from other areas, appear in the low end of the range for *k*, whereas the L_∞ value is in the higher part of the data range. Further studies on habitat conditions will be performed to try to explain the difference in growth parameters amongst areas for the same species.

The sampling programme was carried out under a European Commission-funded project: The purse-seine landing composition in the central an eastern Mediterranean Sea. Ref.: MED-99-035.

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Acoustic identification of small-pelagic fish species: target strength analysis and school descriptor classification

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Abstract

The acoustic identification of small-pelagic fish species is part of the INSTM ongoing project on the assessment of small-pelagic-fish species in Tunisian waters. The aim of this project is to develop a method for determining the species of fish detected by the EK–500 echosounder directly from their acoustic signature, instead of indirectly by experimental trawling.

Two principal subjects have been studied: target-strength analysis; and school descriptors as an indicator of fish species. Target-strength analysis empirically determines the constant *c* for each species in Foote's equation, which is then used for biomass estimation. Encouraging results have been obtained for the sardine (*Sardina pilchardus*), and work is continuing on other species. Fish-school descriptors (bathymetric, morphological etc.) are extracted from echograms and used for training artificial neural networks, which are then used as species classifiers. Two types of neural networks have been tested and three species have been successfully identified using probabilistic neural networks: the sardine (*Sardina pilchardus)*, the anchovy (*Engraulis encrasicolus)*, and the horse mackerel (*Trachurus trachurus)*. Results indicated that probabilistic neural networks are better for the acoustic identification of fish schools than feed-forward neural networks.

1. Introduction

Sonar techniques, especially echosounders, have been used since the beginning of the twentieth century for the detection of fish at sea by professional fishermen and by fishery oceanographers. It has been noted since the 1950s that the acoustic signature of fish can carry information on their species. In particular, the physical backscattering properties of small pelagic fish, such as their target strength or spectral response, are related to their species (Scalabrin, 1996; Simmonds *et al.*, 1996; Zakharia *et al.*, 1996). Moreover, small pelagic fish, known for their aggregation into schools, especially during the daytime, can be identified from the acoustic properties of these schools (Coetzee, 2000; Haralabous and Georgakarakos, 1996; Scalabrin, 1996). The technique of echo-integration, first developed by Dragesund and Ossien in 1965, makes possible an estimate of the biomass represented by schools of small pelagic fish (Masse, 1996). Since 1998, annual acoustic and experimental fishing surveys have been carried out during the summer for the study of the small-pelagic-fish stocks along the Tunisian coast. Small-pelagic fish-stock estimates can be improved by a better knowledge of the species composition of the biomass through acoustic identification of the detected schools. While many current acoustic identification studies are interested in wide-band and multi-beam echosounding technology, we chose to use a narrow-band echosounder. This is of special interest because most commercial trawlers in Tunisia use narrow-band echosounders operating at 38 kHz, and we hope that these results can eventually be used by professional fishermen for more selective fishing. Two main themes are explored by our research group:

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target strength (TS) analysis; and the use of school descriptors for species identification. Our objective with TS analysis is to determine the value of the specific constant *c* in Foote's equation (Maclennan and Simmonds, 1995) for the species of interest: $TS = 20\log(L_t) + c$

The parameter *c* is then used in echointegration formulae for biomass assessment. Data from three surveys were used. Currently, we have obtained results for sardine (*Sardina pilchardus*), since this species was the predominant species in most trawls, but work is progressing on other species. School descriptors as a function of species has been discussed by several authors (Cotzee, 2000; Haralabous and Georgakarakos, 1996; Scalabrin, 1996). Neural networks have been proposed as an alternative tool to parametric statistical methods for the identification of small pelagic species (Haralabous and Georgakarakos, 1996; Simmonds *et al.*, 1996; Zakharia *et al.*, 1996). Data from three acoustic surveys were used for the extraction of school decriptors. The data from 120 schools of sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and horse mackerel (*Trachurus trachurus*) were used to train two types of neural networks, and data from 137 schools were used to test these networks.

2. Methods and data collection

2.1 General methodology

A detailed methodology for acoustic identification based on *in situ* data can be found in Scalabrin (1996). This is the approach that we used and it can be summarized in the following four steps:

- Acoustic survey at sea and digital recording of data from the echosounder
- Establishing experimental information by fish trawls
- Selection of the fish schools for which the species is known
- Choice and application of pattern recognition and classification methods

2.2 Data collection at sea

The data used in this study were collected by the R.V. "Hannibal" during the hydroacoustic surveys of the INSTM along the Tunisian coast, between July 2000 and August 2002. During each survey, the prospected areas were covered by a network of parallel transects adapted to the topography (MacLennan and Simmonds, 1995). Prospecting and trawling were both carried out during the daytime, while schools were closer to the seafloor. A SIMRAD EK–500 echosounder with a split-beam transducer operating at 38 kHz with a 7º×6.9º beam width and 100-ms pulse duration was used during these surveys. Calibration of the echosounder was done *in situ* at a depth of 25 m, using a copper sphere with a known TS value (-33.6 dB) and specialized software. Both the copper sphere and the software were provided by SIMRAD. Movies+ software, developed by the Institut français de recherche et d'exploitation de la mer (IFREMER) was used with the built-in EK–500 echointegrator for the analysis of the acquired data. Experimental fishing was carried out using a mid-water trawl, with a vertical opening of about 6 to 7 m. Trawls were made whenever a significant amount of small-pelagic-fish schools were observed with the echosounder. The speed of the vessel was about 3 to 4 knots during trawling. A netsonde sonar, attached to the mouth of the trawl, was used to monitor the catch in real time. The catch was then sorted by species and the length–frequency composition was determined for each species.

2.3 TS analysis

Of the 128 hauls made during our surveys, sardine was present in 55 of them. We limited ourselves only to hauls in which sardine represented more than 70% of the catch. Therefore, only 18 hauls were retained for TS analysis.

For each haul we established the size–frequency distribution (Table 1) and we sought the tables of the corresponding TS, as illustrated in the example below for haul no. 21 of the OASIS 6 survey (2002) (Fig. 1 and Table 2). The water column was divided into ten layers. Depending on the duration of the haul and the position of the schools in the water column, one or several TS values were attributed to the same size–frequency distribution.

Table 1. Distribution of sardine size frequencies for haul no.21, OASIS 6, 2002. The length mode (15.5 cm) is in bold.

Lt (cm)	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	**15.5**	16.0	16.5	17.0	17.5	18.0
%	0.4				0.4				1.8	0.7		1.1	11.9	**33.9**	26.4	14.1	4.3	1.1	0.4

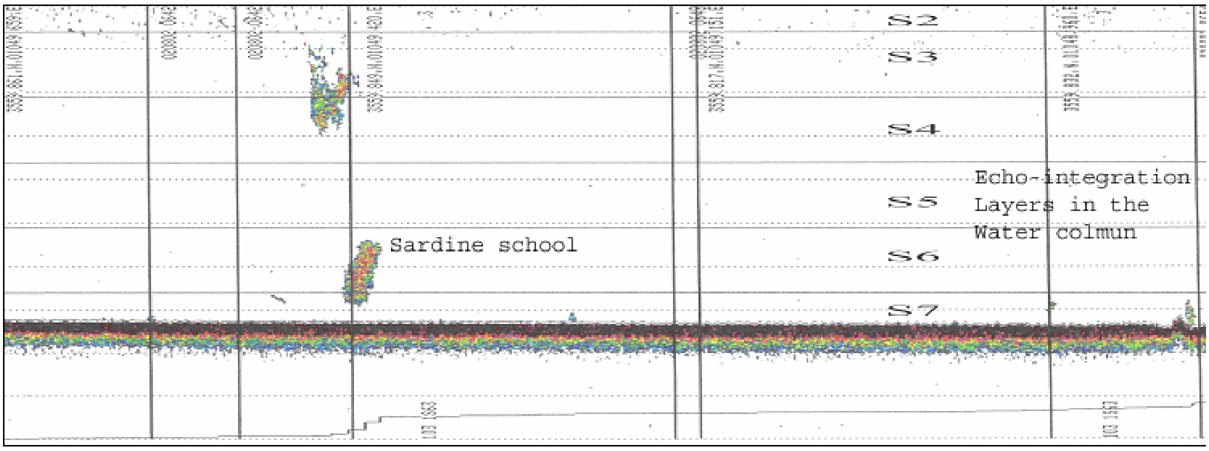

Figure 1: Sample of the echogram during haul no21 of OASIS 6, 2002.

Table 2. Count of the TS for each layer in haul no.21 of OASIS 6, 2002. The circle indicates the TS mode for layer S6 where the sardine school is present.

TS-max = -24.0 dB		TS-step = 1.5 dB				-60		-57		-54		-51		-48		-45		-42		-39		-36		-33		-30		-27		-24
1290.0	1	1 Sur.	2.0	702.0	658	8	7	14	22	26	12	6	2	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	
02/08/02	38	3 Sur.	9.0	24.0	23	17	22	22	4	4	4	0	0	9	0	0	0	0	4	4	0	9	0	0	0	0	0	0	0	
06.55.09	kHz	4 Sur.	24.0	39.0	152	16	12	22	31	14	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		5 Sur.	39.0	54.0	259	5	6	13	19	38	13	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		6 Sur.	54.0	69.0	172	4	4	8	20	24	22	11	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		7 Sur.	69.0	84.0	52	2	4	6	17	15	4	12	0	4	0	6	2	4	4	6	4	4	0	4	2	0	0	2	0	

From the two distributions presented in Table 2 and in Figure 2, we took only the modes and thus obtained the modal lengths according to the TS (Table 3). The catch in some hauls was bimodal. Data from those hauls were not used in the final result.

Table 3. Length and corresponding TS modes.

Mode (cm)	10.0	11.0	11.0	11.0	11.0	11.0	12.0	13.0
Ts (dB)	-53.50	-53.40	-53.25	-51.90	-54.75	-53.57	-52.50	-52.50
Mode (cm)	14.0	14.0	15.0	15.5	16.0	16.0	17.5	
Ts (dB)	-49.50	-50.25	-51.75	-49.50	-51.75	-50.00	-48	

2.4 School descriptor extraction and classification

2.4.1 Descriptor extraction

Movies+ uses the digital output of the EK–500 to display echograms on a PC and record them for later use. Algorithms included in the software make it possible to recognize individual schools of fish on the echograms and to extract a set of school descriptors (Diner *et al.*, 2001). These descriptors can be used to identify the species of each school (Haralabous and Georgakarakos, 1996; Scalabrin, 1996) (Fig. 2, Table 4).

About 50,000 schools have been detected during these surveys. For the training of the chosen classifier, only those schools whose species identity has been established by experimental trawling can be used. If the catch was monospecific (i.e. 95% of the fish in the net belonged to one species), then all the schools detected during the trawling are considered to belong to that species (Scalabrin, 1996). This reduced the number of usable schools to less than 2,000, most of which were schools of sardines, anchovies and horse mackerel. It was considered preferable to use the same number of training examples for each species, so that the classifier would not be biased and would learn to recognize one species better than the others. The amount of usable data was thus reduced even more, since the number of horse mackerel schools detected was considerably less than the number of sardine and anchovy schools. Finally, only 120 schools were used for the training, 40 from each species; and 137 schools were used for testing the classifiers, comprising 59 sardine schools, 51 anchovy schools and 29 horse mackerel schools.

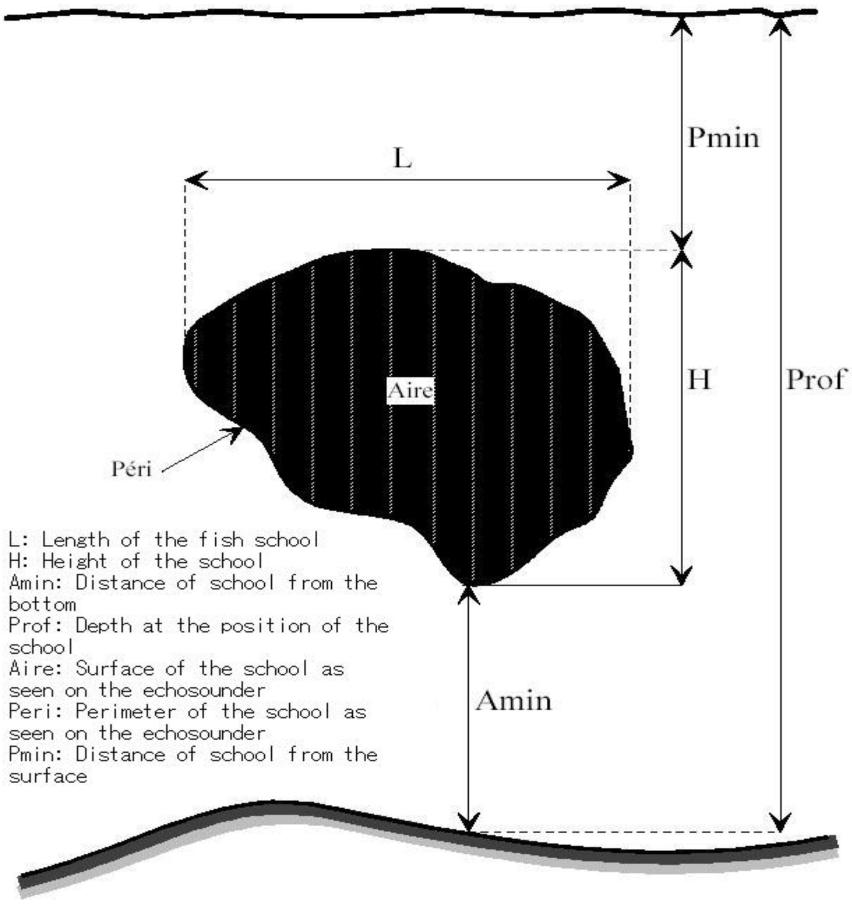

Figure 2. Some of the school descriptors used in this study (Diner *et al.*, 2001)

Table 4: School descriptors used in this study

Descriptors	***Units***
E: mean energy backscattered by the school per unit of surface	mV^2/m^2
S_v: total reverberation index of the school	dB
Vmoy: Mean amplitude of samples (pings) backscattered by the school	mV
Coefficient of variation of the amplitude of the samples	%
Prof: Bottom depth	m
Amin: minimum altitude	m
Pmin: minimum depth	m
Lmax: maximum length	m
Hmax: maximum height	m
Elon: Elongation = Hmax/Lmax	%
Peri: Perimeter	m
A: Area	m^2
Dfrt: Fractal dimension = 2ln(P/4)/lnA	
Arel: Relative altitude = [Amin + (Hmax/2)]/ Prof	%

2.4.2 Classification using neural networks

Artificial neural networks are a programming method based on a mathematical approximation of the functioning of human brain cells. A neural network (ANN) can be seen as a set of interconnected nodes implementing a mapping function from an input space (in this case the school descriptors) to one of several output categories or classes (in our case, a species of fish) (Fig. 3). The network is initialized with random values (or almost), then it is trained by successive examples of the problem to be solved, until it converges to the desired mapping. ANN have started to replace traditional statistical techniques in many modeling and classification problems, although some studies have criticized them for being a black-box method that does not provide any information on the models they approximate. A good overview of ANN, as well as their use in ecology and marine sciences, can be found in Recknagel (2003).

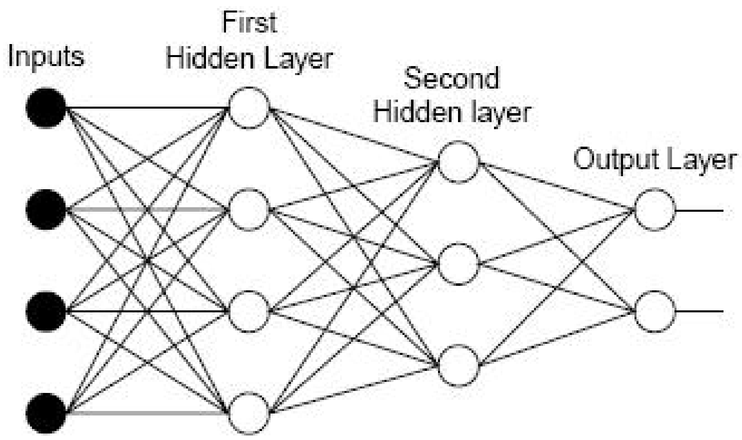

Figure 3. A standard feed-forward ANN

Two types of neural networks were used in this study: multi-layer perceptrons (MLP) and probabilistic neural networks (PNN). MLPs are trained by incrementally reducing the error between the real and the desired output for successive training examples. Several algorithms can be used for this purpose, the most common method being the gradient descent algorithm, in which the network weights are adjusted according to the following rule:

$$w_{i+1} = w_i - \eta \frac{\partial MSE}{\partial w_i}$$

where w_i is the network at the *i*th increment, η is the learning rate, and *MSE* is the mean-square error between the desired output and the real output.

For this study we chose a variant of this rule, in which the weight adjustment is in accordance with:

$$w_{i+1} = w_i - \eta(i) \frac{\partial MSE}{\partial w_i} - mc|w_i - w_{i-1}|$$

Using a variable learning rate $\eta(i)$ increases the learning speed, and adding a momentum term $mc|w_i - w_{i-1}|$ improves the chances of avoiding local minima.

PNNs (Specht, 1990; Ganchev *et al.*, 2002; Grman *et al.*, 2001) are a type of ANN in which the training examples are used to estimate each class's probability distribution, and then the Bayes decision rule is used to determine the most likely class given the input vector. The Bayes decision rule can be formulated as:

$$x \subset Class_i \text{ if } P(Class_i/x) > P(Class_j/x) \text{ for all } j \neq i.$$

The posterior probability $P(Class_i/x)$ is given by:

$$P(Class_i/x) = P(x/Class_i)P(Class_i)$$

The prior probability $P(x/Class_i)$ is estimated using the Parzen window technique (Specht, 1990). Matlab software was used for the design and simulation of the ANN.

3 Results

3.1 Results of TS analysis

The values that we used in the study are represented in Table 5.

Table 5. Modal length and mean TS.

Modal length (cm)	10.0	11.0	12.0	13.0	14.0	15.0	15.5	16.0	17.5
TS mean	-53.5	-53.4	-52.5	-52.5	-49.9	-51.8	-49.5	-50.9	-48.0

A linear correlation is established between TS and log(L) (Fig. 4) and we obtained:
$TS=20.568\log(L_t)–74.617$ with $R^2=0.77$

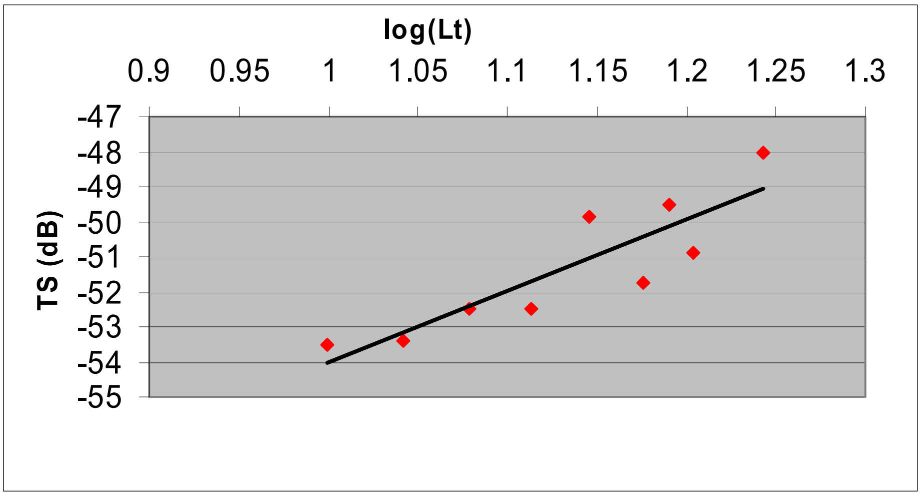

Figure 4. Graph of $TS=f(\log L_t)$.

If we consider that

$TS=20\log(L_t)+c$

then $20\log(L_t)+c=20.568\log(L_t)–74.617$.

Therefore,

$c=0.568\log(L_t)–74.617$

Thus for each length L_t, we have a value of c (Table 6).

Table 6. Values of L_t and c; c=f(L_t)

L_t(cm)	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50
c	-74.05	-74.04	-74.03	-74.01	-74.00	-73.99	-73.98	-73.97
L_t(cm)	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50
c	-73.97	-73.96	-73.95	-73.94	-73.93	-73.93	-73.92	-73.91

For sardines with a total length (L_t) between 10 and 17.5 cm, C_{mean} = –73.97 and the Foote equation becomes:

$TS=20\log(L_t)–73.97$

3.2 Discussion of TS analysis

Several relations for sardine TS are in use in other countries, as indicated below (Table 7)

Table 7. Various TS in use for the sardine.

Author	**TS for 38 kHz**
Spain (Ben Abdallah *et al.*, 2000)	$20\log(L_t)–72.6$
ICES (3) (Diner and Marchand, 1995)	$20\log(L_t)–71.2$
Italy (10) (Patti *et al.*, 2000)	$20\log(L_t)–70.44$

The obtained value of *c*, compared with those in use elsewhere, is relatively low. Indeed, the TS factor depends on several aspects, such as the physiological state of the fish, its behaviour and the time of day (Ona, 1999). In our case, all the measurements were carried out during the day and in the summer, which reduced the variations due to diel and seasonal factors. Moreover, during the day, the sardines gather in schools close to the bottom, consequently their swim bladders will have a lower volume, which may partly explain the difference between the obtained value and that recommended by ICES.

3.3 Results of classification using ANN

Several different configurations of MLP were designed and trained, and we finally settled on a three-layer network with 21 input neurons, 17 hidden neurons and 3 output neurons. For the PNN, the design was pretty straightforward; the only factor that we had to choose was the spread factor, which could be chosen manually. The rest of the network parameters (number of neurons, layers, etc.) are a function only of the training set and the training algorithm. The results are in Tables 8 and 9.

Table 8. Confusion matrix: classification rates using MLPs.

Real species	*Predicted species*			
	Anchovy	*Horse mackerel*	*Sardine*	*Unassigned*
Anchovy	100%	0%	0%	0%
Horse mackerel	0%	93%	3.5%	3.5%
Sardine	1.8%	0%	58%	40.2%

Table 9. Confusion matrix: classification rates using PNNs.

Real species	*Predicted species*		
	Anchovy	*Horse mackerel*	*Sardine*
Anchovy	100%	0%	0%
Horse mackerel	0%	96.5%	3.5%
Sardine	7%	2%	91%

3.4 Discussion of ANN classification

Tables 8 and 9 show that PNNs perform better than MLPs in fish-school classification. It has already been shown by Ganchev *et al.* (2002) and Grman *et al.* (2001) that PNNs are better than MLPs in other typical classification problems, such as voice recognition or fault recognition, especially when the training set is relatively small (as in our case). Moreover, it may be that PNNs are more robust than MLPs and are thus more suitable for dealing with the noise inherent in the training examples of fish schools.

4. Conclusion

A new relationship between TS and total length has been found for the sardine (*Sardina pilchardus*) off the Tunisian coast for the size range 9–18 cm and for the acoustic frequency of 38 kHz:

$$TS=20\log(Lt)–73.97$$

The obtained result must be regarded as provisional, because it does not cover all the sardine size-classes. Moreover, this relation can vary with the physiological state of the animal (stage of sexual maturity and fat content). However, this relation can be used under the same conditions in which it was established, but it is necessary to update it continuously, because any change not taken into account can affect the biomass estimation. For the school classification using ANN, the training data have also to be constantly updated. This will lead to better classification results for the three studied species, and the addition of other species to the training set. The results of future surveys are necessary before any definitive classification method can be achieved.

5. Acknowledgements

The authors would like to thank Guilherme N. Ramos and the reviewers for insights, comments on, and help in editing, the manuscript.

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Distribution, abundance and biological features of picarel (*Spicara flexuosa*), Mediterranean (*Trachurus mediterraneus*) and Atlantic (*T. trachurus*) horse mackerel based on experimental bottom-trawl data (MEDITS, 1994–2002) in the Strait of Sicily

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Abstract

Information was gathered during the international experimental bottom-trawl survey programme MEDITS. Nine years of data (1994–2002), collected during the spring–summer seasons, were analysed in order to determine the horizontal distribution, depth preference, index of abundance and the basic biological features (length composition, sex ratio and size at maturity for females). All the three investigated species showed a marked preference for the continental shelf; they had a wide though not time-oriented, variability in abundance and in the biological features considered. The bulk of the samples were represented by immature or maturing specimens. Given its wider distribution and higher abundance, *Trachurus trachurus* was the most relevant species in respect of its possible interaction with the small pelagic species (*Engraulis encrasicolus* and *Sardina pilchardus*) targeted by the purse-seiners in the Strait of Sicily.

1. Introduction

The small epipelagic neritic species, *Spicara flexuosa*, *Trachurus mediterraneus* and *T. trachurus*, represent a common by-catch of coastal fisheries in the Mediterranean, especially those operating bottom trawlers. These species, although of low commercial value, play an important role at the ecosystem level being either a food source or important predators of other important commercially (Froese and Pauly, 2003).

In particular, the blotched picarel (*Spicara flexuosa* Rafinesque, 1810) is a protogynous hermaphrodite necto-bentonic fish occurring down to 130 m depth (but specimens move regularly in the water column). It is distributed in the eastern Atlantic, the Mediterranean and the Black Sea. In the Mediterranean, individuals of this species reach a maximum size (total length, TL) of 180 mm, for females, and 210 mm, for males; they have a longevity of 4–5 years. Individuals up to 160 mm are generally females, although even primary (small) males and large females can be found in the populations (Relini *et al*., 1999). Spawning occurs mainly in March–April, whereas recruitment is mainly in September. The growth is very fast and the picarel completes half of its potential growth span within the first five months. It feeds on small benthic invertebrates (preferably crustaceans).

The Mediterranean horse mackerel (*Trachurus mediterraneus* Steindachner, 1868) is a pelagic migratory (in large schools) oceanodromous fish occurring between 40 and 500 m depth, though usually near the bottom, but at times also in surface waters. It is distributed in the eastern Atlantic and the Mediterranean Sea, and in the southern and western parts of the Azov

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Sea. In the Mediterranean, this species reaches a maximum size of 400–600 mm and and age of 10–12 years (Stergiou *et al*., 1997; Relini *et al*., 1999). The main spawning and recruitment periods are summer and autumn, respectively. It feeds on other fishes, either larval or adult (especially sardines and anchovies), and small crustaceans.

The Atlantic horse mackerel (*Trachurus trachurus* L., 1758) is a pelagic oceanodromous fish occurring down to 600 m depth (especially in winter), although it prefers coastal areas with sandy substrate, where large schools can be found. It has a wide geographical distribution: eastern and western Atlantic Ocean, Indian Ocean, western Pacific Ocean and the Mediterranean Sea (including the Sea of Marmara and the Black Sea). In the Mediterranean, this species attains a maximum size of 300–600 mm and an age of 11 years. Females are batch spawners, with an extended spawning period, though with a peak in spring (Tsangridis and Filippousis, 1991; Campillo, 1992; Stergiou *et al*., 1997). Recruits concentrate mainly in spring and summer. The growth is very fast and the Atlantic horse mackerel completes half of it potential growth span within the first year of life (Campillo, 1992). The feeding habit of this species is similar to that of its congener *T. mediterraneus*.

In this paper, information on the distribution, abundance and basic biological features of the populations off the southern coast of Sicily are reported, with a view to obtaining, for the first time, an overall picture of the general characteristics of these stocks. Comparison is made with the homologous data for the northern Mediterranean populations within the framework of the SAMED programme (SAMED, 2002).

2. Materials and methods

Data were gathered during nine (from 1994 to 2002) spring–summer experimental trawl surveys carried out under the international programme MEDITS; in particular, a common protocol was adopted and the demersal resources of a large part of the Mediterranean (from the Alboran Sea to the water around Crete) was monitored (Abello *et al*., 2002). An *ad hoc* (GOC 73) trawl was utilized; it was only slightly modified after the 1994 and 1995 surveys, by reducing its vertical opening from 3 to 2.5 m; Fiorentini *et al.*, 1999). In the Strait of Sicily, the same trawler (F.V. "S. Anna") was employed to perform half-hour (shelf) and one-hour (slope) hauls; methodological details and further information on the MEDITS programme can be found at http://www.sibm.unige.it/.

Data were elaborated following the methodological framework developed within the international programme SAMED (SAMED, 2002). First, the frequency of occurrence (% of positive hauls), mean abundance indexes by number (DI, N/km^2) and by weight (BI, kg/km^2), and the corresponding coefficient of variation (CV%) were estimated for the shelf (10–200 m depth) and slope (201–800 m depth) strata. The average individual weight (g, grams) was obtained as the BI/DI ratio. For successive analyses, the whole sample was considered instead. Overall and by sex (males, females and unsexed) median length, sex ratio (Sr=F/sexed animals), and mean size of females by maturity stages (1, immature; 2, maturing; 3, mature; 4, spent) were hence computed. Thereafter, the length–frequency distribution (LFD) for females and for males was obtained, after having distributed the unsexed specimens according the average Sr value of the first three classes with representative (>30) sexed specimens. To allow a proper comparison, the LFD were standardized to an arbitrary surface of 10 km^2.

All computations were implemented with a specific software (SEA-TrIM) developed by MaLiRA Group.

3. Results

Spicara flexuosa

Apart from a handful of specimens found in deep water, this species was caught almost exclusively on the shelf (Figure. 1) indicating a more restricted preferential depth range of 50–100 m (Figure. 2). Considering only the shelf data, the positive hauls ranged between 62 and 82%, without any temporal trend.

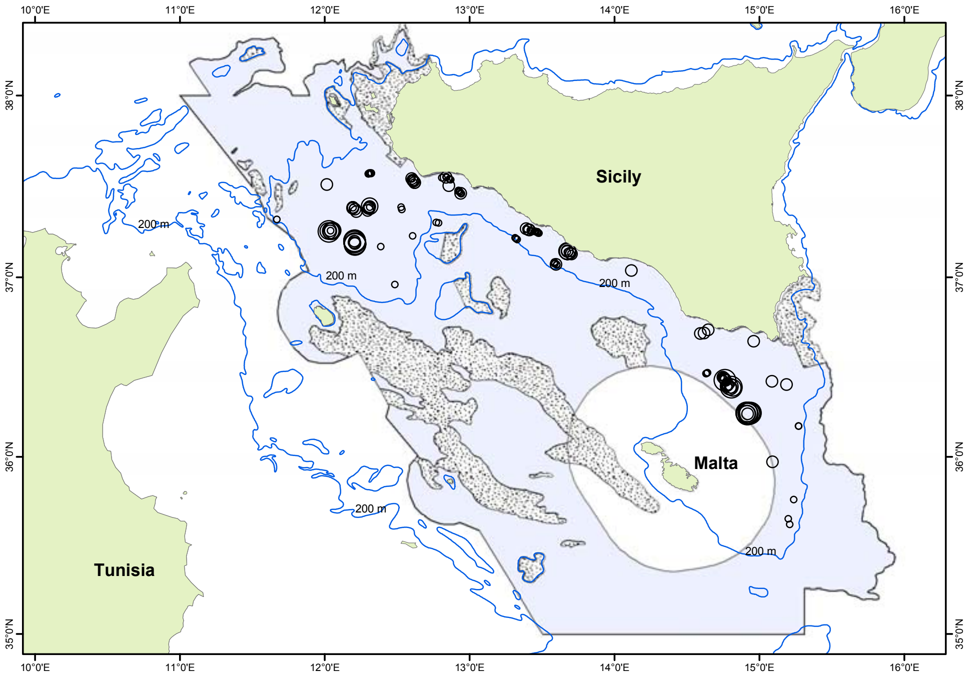

Figure 1. Density (DI=N/km^2) distribution for *Spicara flexuosa* (1994–2002, average) in the Strait of Sicily.

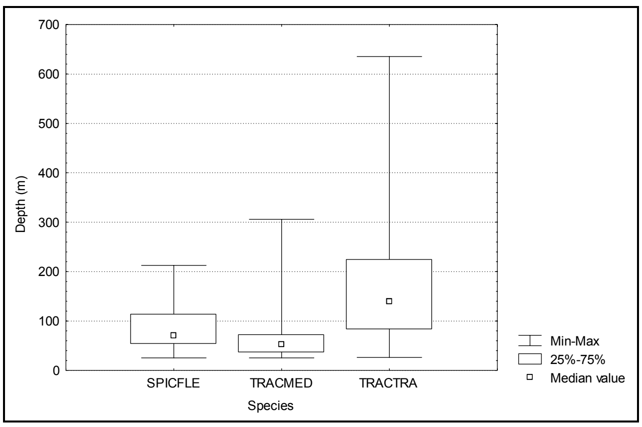

Figure 2. Depth occurrence of *Spicara flexuosa*, *Trachurus mediterraneus* and *T. trachurus* in the Strait of Sicily.

The DI (Figure. 3a) ranged from 830 to 5,907; the highest values were observed in 1994 (DI=5,907) and 2000 (DI=4,795); the CV range was 24–71%. The mean BI ranged between 21.2 and 87.0 (Figure. 3b), whereas the corresponding CV range was 21.2–54.3. A decreasing, though not significant, temporal trend was observed for both DI and BI. The range of mean weight was 12–27 g, with no trend (Figure. 3c).

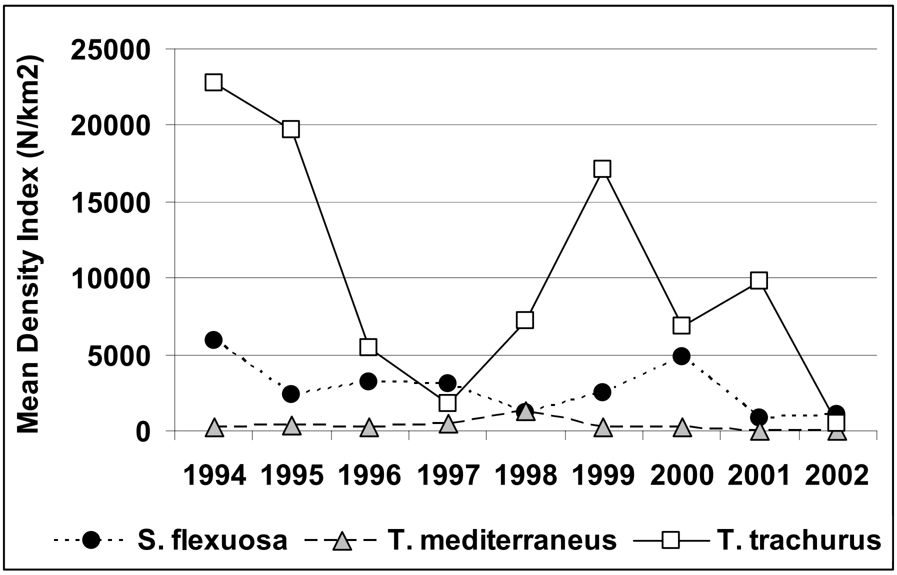

Figure 3a. Mean density index (DI=N/km^2) of *Spicara flexuosa*, *Trachurus mediterraneus* and *T. trachurus* in the Strait of Sicily (shelf).

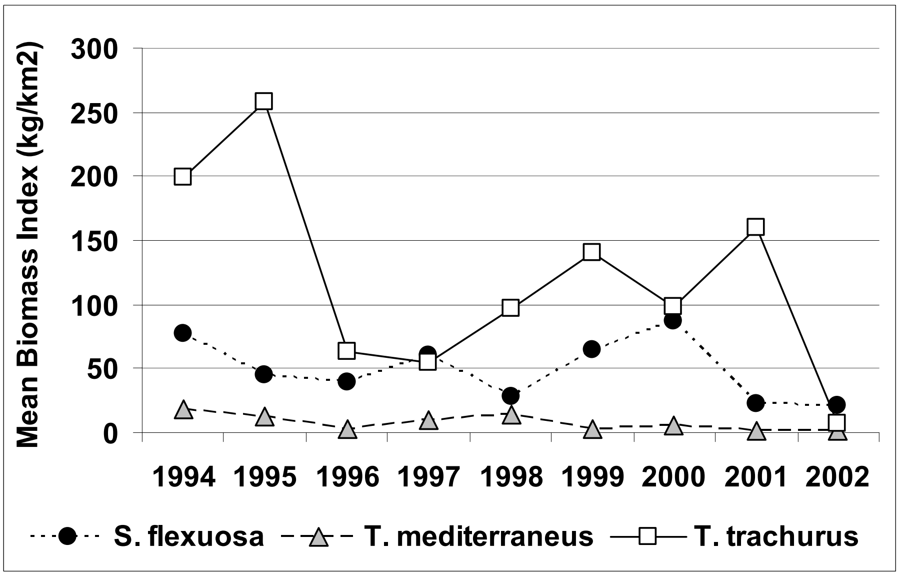

Figure 3b. Mean biomass index (kg/km^2) of *Spicara flexuosa*, *Trachurus mediterraneus* and *T. trachurus* in the Strait of Sicily (shelf).

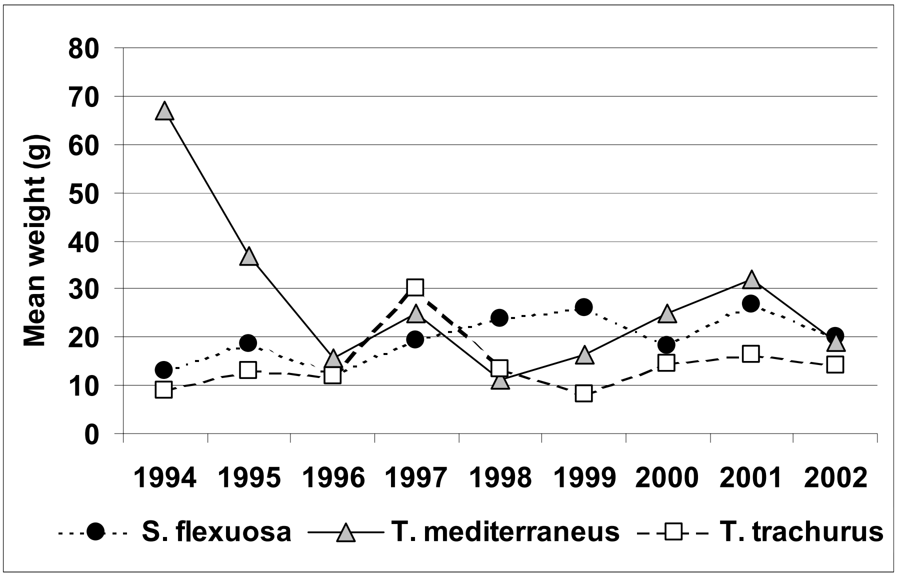

Figure 3c. Mean weight (in grams) of *Spicara flexuosa*, *Trachurus mediterraneus* and *T. trachurus* in the Strait of Sicily (shelf).

Overall, 19,955 specimens were examined, resulting in a yearly median length between 90 and 130 mm. The sex of 41.5% (8,282) of the specimens could not be determined (i.e. unsexed). Males showed a higher median length than females (140 versus 110 mm), although the maximum sizes were very similar (210 versus 200 mm).

The overall Sr was 0.80, without any trend. The Sr by size-class showed a significant (r^2=0.94) increase in the proportion of males above a length of 80 mm; these results are consistent with the sexual characteristics of this species (proterogynous hermaphrodite), since females are generally found up to 160 mm length (Relini *et al.*, 1999).
All the four maturity stages were always irregularly represented, although the stages 3 and 4 comprised only a few females (171 and 8 specimens, respectively). The bulk of the sample was represented by immature (14,462 in stage 1) and maturing (1,263 in stage 2) individuals. The maturity stages were poorly discriminated by the corresponding size structures; the mean size of the females at stage 3 (140 mm) was slightly above the corresponding value in the literature (~120 mm; in Relini *et al.*, 1999).

The length–frequency distributions (LFD) were very variable in the period studied (Figure. 4), without any particular temporal pattern. Male and female LFDs showed the same basic typology: skewed (right-tailed) with a platycurtic (flattened) peak, with variable modal length between years. In 1994 and 1995, the LFDs of the two sexes overlapped (peak at about 100 mm), whereas, in the other years, male LFDs were biassed towards the large size-class (modal length around 110–120 mm and 130–170 mm in females and males, respectively). The maximum displacement was detected in 2002, when the modal length was 120 and 170 mm for females and males, respectively.

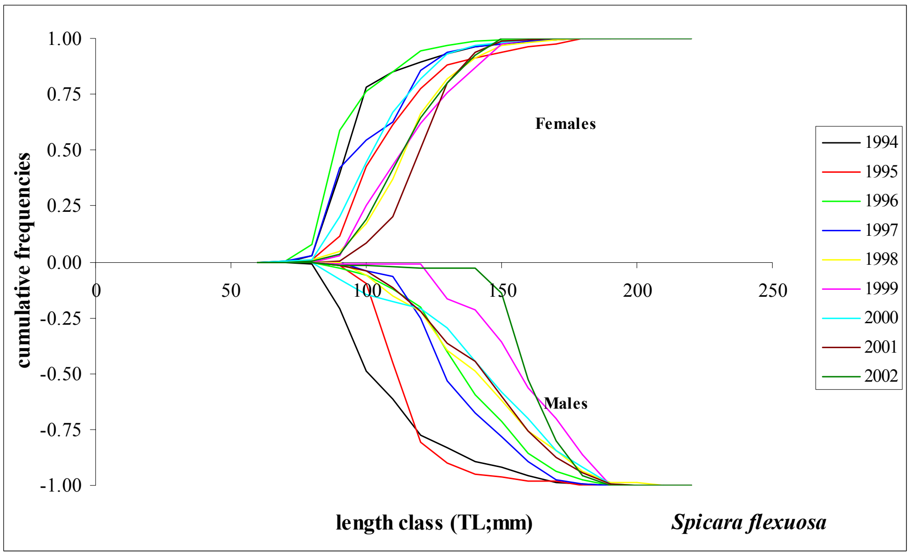

Figure 4. Relative length–frequency distribution by year for females and males of *Spicara flexuosa*

Trachurus mediterraneus

Although captures were scanty in the upper part of the slope (down to 300 m depth), it was caught on the shelf over practically all the investigated area (Figure. 5), though with a narrower preferential depth range (20–80 m) (see Figure. 2), which is close to the preferential depth reported by Relini *et al*. (1999). Frequency of occurrence oscillated around 30% of the hauls (range: 22–35%).

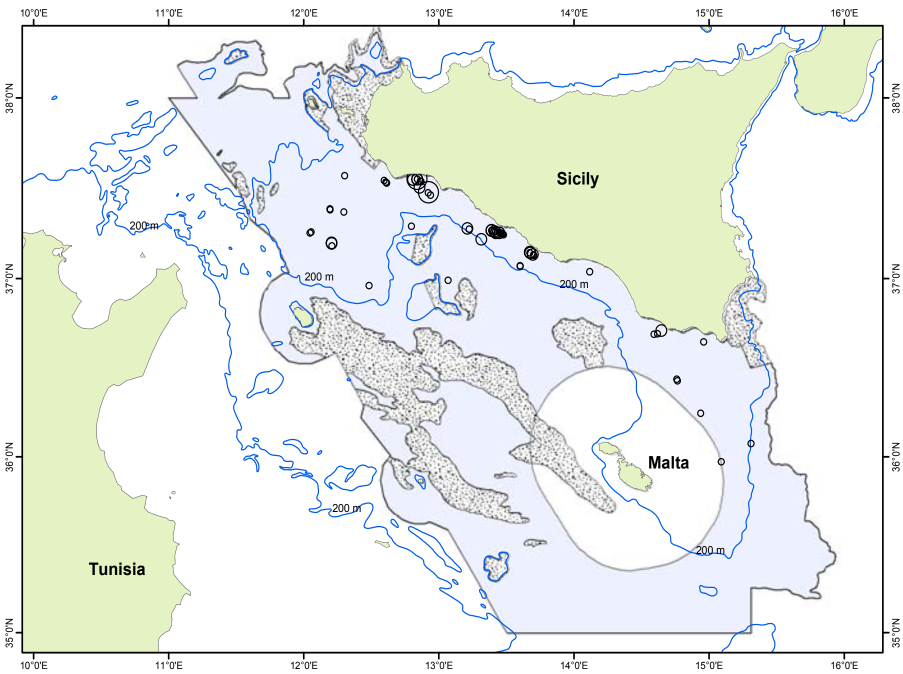

Figure 5. Density (DI=N/km^2) distribution for *Trachurus mediterraneus* (1994–2002, average) in the Strait of Sicily.

The mean DI (see Figure. 3a) ranged irregularly between 203 and 415, with the exception of 1998 (DI=1,282) and 2001–2002 (DI=47–50); the CV varied from 44 to 62%. The mean BI (see Figure. 3b) went from 1.0 (CV=38%), in 2002, to 18.2 (CV=68.0%), in 1994. An irregular decreasing, though not significant, trend characterized the BI. Excluding the 1994 value (65 g), the range of mean weight was 11–35 g, with no trend (Figure. 3c).

Overall, 3,417 specimens were examined, giving a median length by year between 80 and 160 mm; the sex of 57.8% (1,976) of the specimens could not be determined (i.e. unsexed). Although the maximum size was higher in females (430) than in males (390 mm), the latter were almost as large as females (130 versus 140 mm, median length); the largest specimens (>350 mm) were observed only in the first survey (1994).

The mean overall Sr was 0.39, with a very irregular evolution over the years (0.20–0.72). Considering the sex ratio by size-class (up to 140 mm), males were more abundant than females (about 65%); thereafter, the latter become more abundant (Sr 67% at 220 mm).

As regards maturity, the first three stages occurred in each year, with some variability, but only the first two were consistently represented. Maturity stages were characterized by different length structures (136, 211 and 207 mm for stages 1, 2 and 3, respectively). The mean size of mature females (207 mm) fell at the lower limit of the range reported in the literature (200–230 mm; Campillo, 1992; Stergiou *et al*., 1997; Relini *et al*., 1999).

Length–frequency distribution (LFD) showed high variability (Figure. 6), but without any temporal pattern. Male and female LFDs showed the same basic typology: two main components with a modal length between 120–130 and 170–220 mm, depending on the year. A scanty component of large female specimens (380 mm) was observed in 1994, whereas a "juvenile" (80 mm) peak was clearly detected in 1997. Hence, three components characterized the LFD of males and females, the latter showing the possible presence of a fourth component.

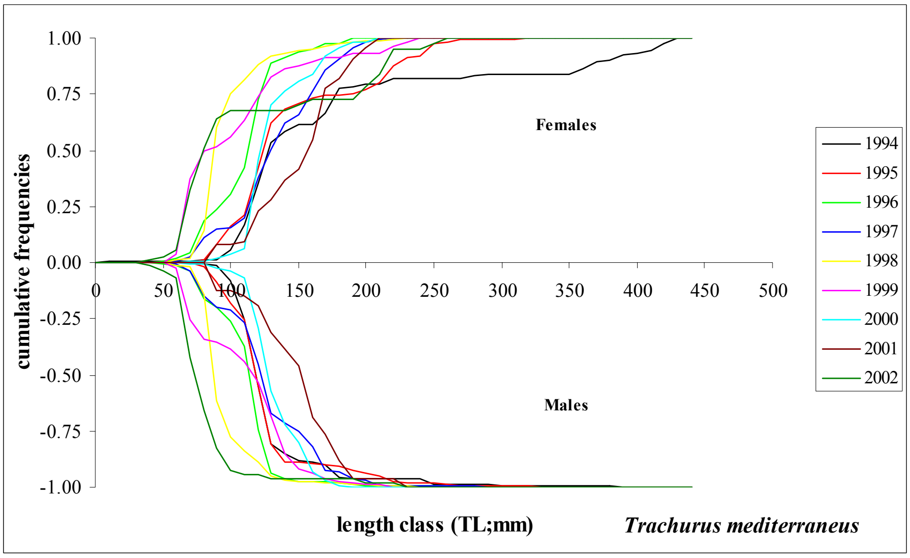

Figure 6. Relative length–frequency distributions by year for females and males of *Trachurus mediterraneus.*

Trachurus trachurus

Some catch of this species was recorded also in deep water (down to 600 m depth or more), especially in the first two years. Overall, it occurred exclusively on the shelf (see Figure. 2), showing a preference for the external edge (100–200 m) off the southern coast of Sicily (Figure. 7).

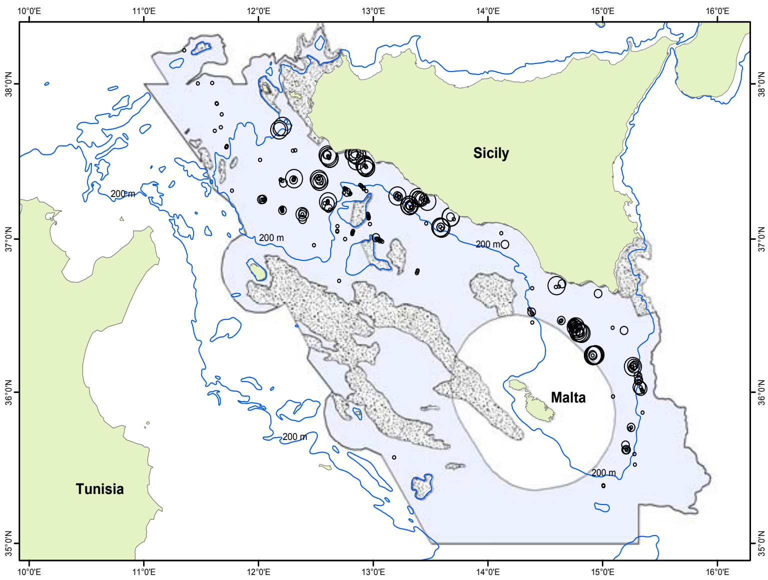

Figure 7. Density (DI=N/km^2) distribution for *Trachurus trachurus* (1994–2002, average) in the Strait of Sicily.

A temporal discontinuity was evident in the frequency of occurrence; on the shelf, it went from 96–100% in 1994–95 to 74-87% thereafter. A similar pattern was observed also on the slope: from 40–36% in 1994–95 to 21–32% between 1995 and 2001, and a minimum of 10% in 2002.

A sharp negative trend characterized the slope abundance; the mean DI went from 2,045–2,989 in 1994–95, to a few hundred (in 1996–97) and to few (in 1998–2002) specimens. The CV was very high (43–93%), especially in the years of high abundance (93–79%).

Considering the shelf (see Figure. 3a), the mean DI peaked in 1994 (DI=22,702; CV=28%), 1995 (19,657; CV=25%) and 1999 (17,049; CV=63%), whereas the values ranged between 1,813 and 9,768 (CV=42–55%) in the other years, except 2002, when the minimum DI (502; CV=22%) was observed.

A similar pattern also resulted for the abundance in weight. On the slope, the mean BI went from 94.4–129.3 in 1994–95 to 16.1–15.5 (in 1996–97) and about 2 (in 1998–2002). As expected, the minimum BI (0.5) was observed in 2002. The CV was very high (35–92%).

Considering the shelf, the highest mean BI (199.0–257.6 kg/km^2) was detected in 1994–95 (see Figure 3b). Intermediate values (140.0–159.7) occurred in 1999–2001, whereas low values characterized the other years (with a minimum of 7.1 in 2002). The CV was very high

(43–93%). The range of mean weight (considering only the shelf) was 8–30 g, with no trend (see Figure 3c).

Overall, 118,447 specimens were examined, producing median lengths from 90 to 150 mm, depending on the year; the sex of 74.1% (87,783) of the specimens could not be determined (unsexed). Although the maximum size was higher in females (430 mm) than in males (410 mm), the latter were as large as the former (160 mm) in terms of median length. The mean overall Sr was 0.60, with a very irregular evolution over the years (0.38–0.78). No size effect was detected.

As regards maturity, all the four stages occurred irregularly in each year, but only the first two were consistently represented. Maturity stages 1, 2 and 3 overlapped, showing a similar mean (155, 166 and 185 mm) length. The mean size of the females at stage 3 (185 mm) was lower than the available literature data on this species (210–230 mm; Campillo, 1992; Stergiou *et al*., 1997).

The length–frequency distributions (Figure. 8) were very variable over the study period, without any particular temporal pattern; the LFD of 1997, however, showed some particular feature as a consequence of the reduced presence of small-sized specimens. Also for this species, males and females showed the same basic LFD typology: two main components with modal length between 80–100 and 160–180 mm in different years. In some years, a secondary pulse, with a peak at about 70 mm, was detectable in the first component.

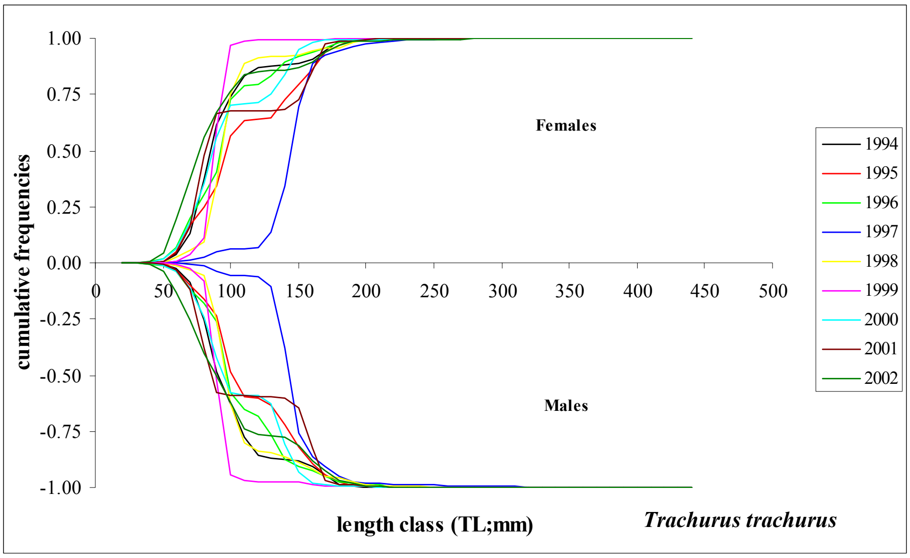

Figure 8. Relative length–frequency distribution by year for females and males of *Trachurus trachurus*.

4. Discussion

In spite of a common preference for the shelf, present results highlight a patchy distribution of the investigated species in the Strait of Sicily. *T. trachurus* was the most frequent and abundant species, which likely reflects both a higher efficiency of the MEDITS gear for *T. trachurus* (Fiorentini *et al*., 1999) and true biological effects, such as a habitat preference in *S. flexuosa* and different behaviour in *T. mediterraneus* (Relini *et al*., 1999).

Another evident common feature observed was the highly irregular temporal development of almost all the parameters considered, as expected for short-lived (*S. flexuosa*) and highly oceanodromous (*Trachurus* spp.) fishes; the abrupt decline in both the abundance and the mean weight of *T. trachurus* does not, in fact, reflect a true negative trend, but the reduction of the vertical opening of the MEDITS gear after 1995 (Fiorentini *et al*., 1999). Considering that large fish were caught only before this reduction, it is highly probable that these specimens are able to avoid capture, representing a safety valve for stock maintainance.

As concerns a comparison over a wider area of the Mediterranean than the Strait of Sicily, no comparable data were available, since these species are seldom or never the object of systematic and regular monitoring. Moreover, data are often reported as “mixed” (for example, *Trachurus* spp.; Campillo, 1992). Practically, the only comparable data are those in the SAMED report (SAMED, 2002), which are summarized in Tables 1, 2 and 3 for areas in which the species were more abundant.

Spicara flexuosa (Table 1) - the relevant SAMED data confirm this species' almost exclusive preference for the shelf; small captures on the upper slope were, in fact, recorded only in the Ionian Sea. Only this macrostratum will be considered hereafter. The percentage of positive hauls in the Strait of Sicily (62–82%) was among the highest in the Mediterranean Sea. Comparable frequency of occurrence was observed in Corsican (60–80%) and Sardinian (48–84%) waters, northern Sicily (71–93%) and Cretan waters (67–100%).

Table 1. Main biological information, by area, of *Spicara flexuosa* (%=percentage of positive hauls; *DI* density index in N/km^2; *BI* biomass index in kg/km^2; median length in mm: upper range is combined sexes, lower values are for females and males, respectively; *SR* sex ratio expressed as F/(F+M); size at maturity = mean length of mature females in mm ±1 standard deviation)

Areas	*Spicara flexuosa*					
	%	**DI**	**BI**	**Median length**	**SR**	**Size at maturity**
Spanish coast	27–60	89–368	2.1–10.9	110–140 120; 180	0.80–0.94	146.2±26.1
Corsica	60–80	751–2727	22.8–73.1	130–140 130; 140	0.57–0.96	135.5±10.7
Sardinia	48–84	575–1102	16.8–33.3	120–150 140; 150	0.58–0.68	134.0±10.8
Ligurian and Tyrrhenian	54–69	406–1095	5.3–12.7	90–120 110; 140	0.66–0.89	114.4±14.1
Northern Sicily	71–93	524–2192	13.7–65.6	120–140 130; 170	0.75–0.86	153.0±20.5
Western Ionian	57–63	475–1855	11.4–44.5	-	0.79–0.88	120.0±14.5
Eastern Ionian	32–55	263–1048	8.6–38.1	120–130 120; 140	0.47–0.74	n.a.
Aegean	38–49	541–855	12.9–23.4	130 130; 140	0.60–0.72	112±14.9
Crete	67–100	201–1935	4.5–37.2	100–120 110	0.63–0.90	n.a.

Present data are also in agreement with the irregular temporal pattern in the indexes of abundance: a decreasing, but not significant trend, was evidenced only in a few of the SAMED areas. Considering only the mean BI, and excluding the Adriatic and Alboran Seas, the maximum values were lower than those observed in the Strait of Sicily. As concerns length−frequency distribution, a high similarity was evident in all the SAMED areas. The overall (all specimens pooled) median length varied between 90 mm and 150 mm. Regarding sex, unsexed specimens were, overall, poorly represented in all areas, whereas females regularly outnumbered males.

Generally, females were slightly smaller than males. The maximum size (in millimetres) were in the range 170−230 mm for females (Aegean Sea, Spanish coast), and 190−240 mm for males (Crete, Greek continental coast).

As a rule, all the four maturity stages were irregularly present and not characterized by different length−frequency distributions; however, the bulk of examined specimens falls within the first two stages (one exception was found in Sardinia). The size at maturity (stage 3) ranged from 112 mm (Aegean) to 153 mm (northern Sicily), values which embraced the value (140 mm) obtained in the Strait of Sicily.

Trachurus mediterraneus (Table 2): Although some captures were recorded on the upper slope of many SAMED areas (off the Italian Tyrrhenian continental coast, Adriatic, Greek continental coast, Crete and Aegean), the bulk of this species was sampled on the shelf; consequently, only this macrostratum will be considered hereafter. The percentage of positive hauls of the Strait of Sicily (22−35%) was lower than that computed for most of the SAMED areas. Comparable frequency of occurrence were observed only in the Alboran (10−30%) and Ligurian and Tyrrhenian (32−48%) Seas.

Table 2. Main biological information, by area, for *Trachurus mediterraneus* (% = percentage of positive hauls; *DI* density index in N/km^2; *BI* biomass index in kg/km^2; median length in mm: upper ranges are for combined sexes, lower values, females and males; *SR* sex ratio expressed as F/(F+M); size at maturity = mean length of mature females in mm ±1 standard deviation).

Areas	*Trachurus mediterraneus*					
	%	**DI**	**BI**	**Median length**	**SR**	**Size at maturity**
Spanish coast	47–67	214–853	28.1–8.1	70–160 150	0.48–0.58	205.6±36.7
Gulf of Lions	30–64	57–268	1.5–10.3	130–190 190	0.46–0.62	224.5±30.7
Corsica	30–100	248–4181	24.2–73.9	110–220 150;140	0.35–0.47	188.7±43.0
Sardinia	22–50	32–264	0.8–7.5	110–140 170;140	0.25–0.52	180.1±28.2
Ligurian and Tyrrhenian	32–48	230–977	8.7–25.3	120–170 150	0.43–0.63	198.2±31.8
Western Ionian	26–65	46–1,264	2.1–31.9	120–160 130	0.41–0.61	175.0±30.7
Eastern Ionian	38–73	89–1,260	1.2–21.5	70–170 170;150	0.32–0.53	184.0±24.0
Aegean	34–55	48–2,305	1.4–40.8	90–170 160;150	0.33–0.66	171.0±24.7

As concerns the BI, the maximum values fall within the range 4.0 (Alboran Sea) and 73.9 (Corsican water); consequently, the estimate in the Strait of Sicily (18.2) is close to the lower limit. An increasing trend has been detected in three areas, the Tyrrhenian and Ionian Seas, and the Greek continental coast, but only the latter was significant ($r2=0.72$).

As concerns the length–frequency distribution and other biological features, no analysis was performed within the SAMED project for the Alboran, southern Tyrrhenian (northern Sicily), Adriatic Seas and Cretan water, given the weak and irregular presence of the species.

For the other areas, the overall (all specimens pooled) length–frequency distributions were not stable from year to year, showing a wide range of median length (70–170 mm), similar to that reported in the present paper (80–160 mm). Females and males showed the same or almost coincident median length, although with different values according to area.

Considering sex, with the exception of Sardinian water and the Ionian Sea, unsexed specimens were generally well represented. Females and males were in fairly equal number. The lowest values were observed in Sardinia.

Considering the sex ratio by size-class, no evident effect was generally found and only a slight increase in the number of females in the larger size-classes was found in few areas (for example, the Gulf of Lions).

The maximum size (in millimetres) were in the range 230–440 for females (Spanish coast, Crete), and 230–430 for males (Spanish coast, Tyrrhenian).

As regards maturity, all the four stages were present, but in most areas only the first three stages occurred consistently in each year. The maturity stages were characterized by slightly different length–frequency distributions. Attempts to fit a logistic curve gave heterogeneous results (from 144 mm, for Sardinian water, to 198 mm, in the Gulf of Lions. The size at stage 3 was lower than that reported in the present paper (207 mm) for the Strait of Sicily, in contrast to the value for the Gulf of Lions (224.5 mm).

Trachurus trachurus (Table 3): Although some captures were recorded on the upper slope of almost all the SAMED areas, both the highest frequency of occurrence and the abundance indexes were recorded for the shelf; consequently, only this macrostratum will be considered hereafter.

Table 3. Main biological information, by area, of *Trachurus trachurus* (% = percentage of positive hauls; *DI* density index in N/km^2; *BI* biomass index in kg/km^2; median length in mm: upper ranges are for combined sexes, lower values, females and males; *SR* sex ratio expressed as F/(F+M); size at maturity = mean length of mature females in mm ±1 standard deviation).

Areas	*Trachurus trachurus*					
	%	**DI**	**BI**	**Median length**	**SR**	**Size at maturity**
Alboran	50–90	195–4,390	6.2–118.1	75–150 160	0.24–0.65	262.1±60.8
Spanish coast	76–92	633–3,415	7.4–39.8	80–90 160;170	0.47–0.60	199.6±17.1
Gulf of Lions	71–98	983–10,646	10.1–98.7	70–100 190;180	0.25–0.52	332.2±74.2
Corsica	38–70	943–7,778	16.7–254.0	80–200 200	0.43–61	254.7±20.1
Sardinia	83–95	1804–5,728	11.6–40.3	60–90 150;160	0.47–0.89	236.7±72.0
Ligurian and Tyrrhenian	25–51	102–1,414	1.6–19.5	80–100 220	0.20–0.46	236.7±82.4
Northern Sicily	36–86	836–12,319	15.1–175.8	90–160 170;160	0.40–0.72	195.7±29.9
Western Ionian	58–96	800–7,981	18.3–55.0	n.a.	0.47–0.78	281.0±69.6
Southern Adriatic	87–100	1621–6,599	12.6–38.7	60–90 250;170	0.23–0.71	324.0±45.8
North-central Adriatic	65–90	189–2,153	3.3–13.3	80–120 180;170	0.26–0.62	277.0±76.0
Eastern Ionian	23–73	707–2,889	9.9–28.4	70–100 200	0.31–61	n.a.
Aegean	53–73	395–4,636	2.9–77.0	70–100 190;180	0.39–0.61	201.0±83.2

T. trachurus was widespread over almost all the shelf area covered by SAMED, with a range in the percentage of positive hauls similar to that observed in the Strait of Sicily (74–100%).

As concerns the BI, SAMED data confirm the general lack of any specific pattern; a negative, though not significant, trend was detected only in two areas (Alboran Sea and Corsican water). The maximum values fall within the range 13.3 (northern Adriatic) and 254 (Corsican); consequently, the highest estimates in the Strait of Sicily are higher than the upper limit of the SAMED values.

The overall (i.e. all specimens pooled) length–frequency distribution was generally not stable in the different areas, showing a wide fluctuation in median length (60–200 mm). Females and males showed the same or almost coincident median length, although with different values according to area.

Considering the sex, unsexed specimens were generally well represented. Females and males were in fairly equal number: the Sr went from 0.48 (Alboran) to 0.57 (Spanish coast). The lowest values were observed in Gulf of Lions and the Ligurian and Tyrrhenian Seas.

Considering the sex ratio by size-class (millimetres), there was a slight predominance of females, but in variable length ranges: in the Gulf of Lions (120–280 mm), Tyrrhenian (120–160 mm), Ionian (100–220 mm), southern Adriatic (240 mm) and Aegean Sea (200 mm).

Maximum size (millimetres) was in the range 310–460 mm for females and 220–480 mm for males; the minimum and maximum values were observed in Cretan water and the Aegean Sea, respectively.

All four stages of maturity were identified, with high irregularity within years, owing to the low number of females examined. The size at stage 3 ranged from 200 mm (Spanish coast) to 324 mm (southern Adriatic), values larger than those reported in the present paper (185 mm) for the Strait of Sicily.

5. Conclusions

Present results are the first systematic source of information for these three species, which share an ecological and overall potential commercial interest. Although some variability hampered a detailed interpretation of the collected information, it is evident that at least part of this variation does reflect the true adaptability to the variable (environmental and man-made) conditions in the different areas. If this hypothesis is confirmed, a meta-analysis, including also the growth and mortality assessment, might help in improving knowledge of these species. For the epipelagic resources of the Strait of Sicily, meanwhile, the likely influence of *Trachurus trachurus* may be noted; this species showed the capability to produce a standing stock accessible to the MEDITS gear at a level of thousands of tons, considering only the shelf (about 19,500 km^2). In fact, although not fully quantifiable, an impressive fraction of the catch (Andaloro, 1996; Tsimenides *et al*., 2000) is discarded at sea, enhancing the scavenger food chain at the bottom; on the other hand, this stock represents a food source for mankind and a predator for other commercially important species, such as the pilchard and the anchovy. There are, consequently, many reasons to consider *Trachurus trachurus* in the ecosystemic analysis of the epipelagic domain, with a view to attain a basic understanding of the dynamics of such a complex system.

6. Acknowledgements

The MEDITS programme has been funded jointly by the Italian Ministry of Agriculture, Fisheries and Forestry (Mipaf) and European Union (EU); in particular, the authors wish to tank Dr. Riccardo Rigillo for having authorized the use of 2001 and 2002 data. The authors also thank Gaia Morizzo for her assistance in preparing the present contribution.

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Methodology adopted for the study of eggs and larvae of small-pelagic fishes in Tunisian waters

R. Zarrad* and R. Bedoui

Abstract

For the sustainable exploitation of small-pelagic fish resources in Tunisia, the study of the entire life-cycle (egg, larva, juvenile and adult) is necessary. It is assumed that the level of annual recruitment is determined in the early-life stages. However, in Tunisia, such studies are rare. The INSTM had started a research programme in 2002 to study fish eggs and larvae of small-pelagics in their ecosystem.

Four seasonal and twelve monthly surveys were carried out in the Gulf of Tunis in order to determine the spawning and nursery areas and to study mortality, growth and trophic relationships through the relevant biotic and abiotic environmental parameters.

Keywords : egg, larva, small-pelagics, biotic, abiotic, environmental, Gulf of Tunis.

1. Introduction

Small-pelagic fish species represent an important marine resource in Tunisia. In recent years, the average production has been about 30,000 metric tons. In 2002, the production was estimated at 31,521 tons (DGPA, 2002). However, the exploitable biomass was estimated at about 80,000 metric tons. Therefore, there is a high possibility of increasing the production. For sustainable exploitation, it is necessary to study the entire life-cycle: egg, larva, juvenile and adult. Early-life stages of fish in Tunisian waters have not been thoroughly studied, though it is assumed that the level of annual recruitment is determined during the early-life stages. It seems that the environmental conditions (biotic and abiotic) influence highly the recruitment variability and, in the future, the exploitable biomass.

However, few studies have been carried out in Tunisia. Ktari-Chakroun (1979) had studied the anchovy spawning areas along the Tunisian coast, in the sea passage between Tunisia and Sardinia and the Strait of Sicily. Two studies concerned the Gulf of Tunis, and were aimed at determining the spawning period of teleostean fishes (Turki and Ktari-Chakroun, 1985) and at inventorying their larvae (Turki, 1989). Daly-Yahia (1998), in the study of seasonal zooplankton dynamics had determined the spatio-temporal distribution of anchovy eggs and larvae sampled accidentally with zooplankton in the Bay of Tunis (off Tunis in the small Gulf of Tunis).

The INSTM started a research programme in 2002 to study fish eggs and larvae in the ecosystem.

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2. Materials and methods

Studied area, sampling stations and investigation frequency

The research programme on fish eggs and larvae concerns all Tunisian waters. Currently, we are working in the Gulf of Tunis which is considered the best area to start such study. The Gulf is connected to many lagoons (notably the Tunis and the Ghar El Melh lagoons), and it receives the discharge of the only permanent river in Tunisia (the Majreda River). It seems to attract many fish species to spawn. It is commonly assumed that this Gulf is the nursery of the northern coast of Tunisia.

Sampling was conducted according to two strategies. During the seasonal survey, we used the R V. “Hannibal”. Samples were taken in the grid of 29 stations (Fig. 1) separated from each other by 4.8 nautical miles East-West and 6 nautical miles North-South. The monthly sampling was carried out at six stations between the seasonal stations (stations: 2; 3; 6; 11; 12 and 20).

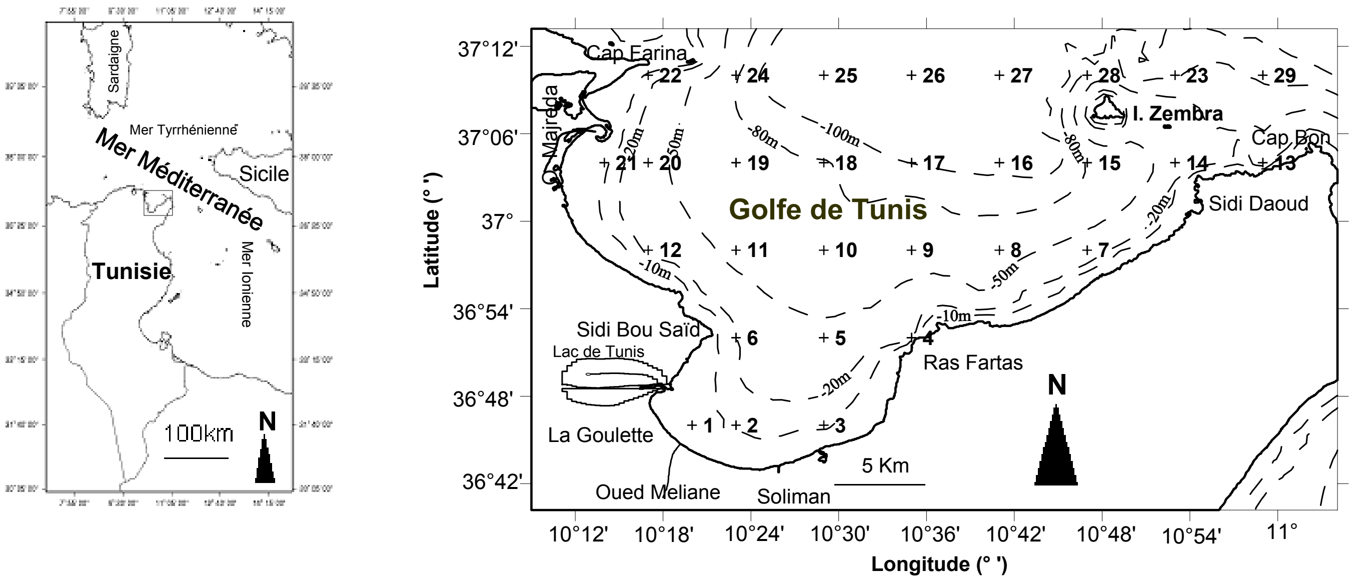

Figure 1 : Sampling stations in the Gulf of Tunis.

Measurement and sampling

At each station, sea-surface temperature, salinity, dissolved oxygen, pH and turbidity were measured monthly and seasonally. The marine currents – speed and direction – were measured only seasonally.

Some climatic data, such as temperature, direction and speed of wind, were collected in situ. Water samples were collected to study phytoplankton and to analyse nutrient salts and chlorophyll-*a*.

Zooplankton was sampled by trawling at sea surface with a net of 17 cm diameter and a 100-µm mesh size during 10 minutes. In addition, zooplankton was collected with fish eggs and larvae. All zooplankton was collected with the aim of studying the prey larvae and the predators of the eggs and the larvae.

Seasonal ichthyoplankton sampling was carried out by oblique Bongo-net tows at a ship speed of 3 knots and with a wire speed of 1 m/s. The same gear was used for each seasonal survey: a 60-cm-diameter Bongo-net (mesh size 335 µm). A *Hydrobios* flowmeter was placed in the mouth of the net to estimate volume filtered. Monthly sampling was carried out with a simple net of 47 cm diameter and a 300-µm mesh size. The tows were made at the sea surface and at night during 15 minutes.

Zooplankton with ichthyoplankton samples were preserved in 4% buffered formaldehyde.

Surveys

Four seasonal surveys were carried out in: summer, from 26 to 30 August 2002; autumn, from 21 to 25 October 2002; winter, from 13 to 17 February 2003; and spring, from 11 to 15 April 2003. The monthly surveys were started in February 2003 and until October we carried out nine surveys.

3. Results

We shall have data on environmental parameters. Meteorological data will be collected: temperature, wind speed and direction, atmospheric pressure, precipitation and evaporation.

Following plankton analysis, sorting, identification and counting, we shall have data on distribution and abundance of phytoplankton, zooplankton and ichthyoplankton. A data base will be established, perhaps using Access software. It will be interrogated for use in GIS applications (for example ArcView software).

4. Conclusion

Initially, the research programme on fish eggs and larvae has allowed the training of Tunisian researchers in sampling techniques which allowed seasonal and monthly surveys to be carried out in the Gulf of Tunis.

Currently, we need to identify species of eggs and larvae, particularly of small-pelagic species. Subsequently, we shall be able to localize specific spawning areas and nursery. In the future, we shall study daily growth and mortality. Then, we could study eggs and larvae in interaction with their environment.

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Overview of the available information on the fisheries for small-pelagic fish in Maltese waters

E. Muscat*

Abstract

The Malta Centre for Fisheries Sciences in collaboration with the FAO Fishery Department and the FAO-COPEMED Regional Project has developed a National Statistical System, the Catch and Effort Assessment Survey for Small-Scale Fisheries.

The Catch and Effort Assessment Survey is restricted to vessels under 10 metres in length, representing more than 92 per cent of the Maltese fishing fleet. The objectives of this Survey are to provide monthly catch and effort estimates for Malta and Gozo by fleet typology, gear used and species caught. The data are also used in scientific analyses and fish-stock assessments.

The major small-pelagic species caught in Maltese waters by vessels under 10 metres in length are: *Aphia minuta, Atherina presbyter, Boops boops, Sardina pilchardus*, *Spicara flexuosa*, *Scomber japonicus* and *Trachurus* spp.

Data collected between January and September 2003 on small-pelagic fishes landed in the major Maltese fishing ports, by various fishing gears, are presented in tabular and graphical formats.

1. Introduction

The fishing industry in Malta is mainly artisanal, with the majority of fishing vessels (more than 92 percent) being less than 10 metres in length. Only the larger vessels operate on the high seas.

At the end of October 2003, the total number of registered fishing vessels was 2,252. Small-scale vessels (under 10 metres in length) totalled 2,074, with the majority (1,498) registered as part-time. There were 297 registered full-time vessels, with the remaining 279 being registered as market fishermen.

The fishing gears used in Malta are: demersal trawls, lampara nets, purse-seines, pelagic and demersal longlines on the high seas, inshore longlines, trammel nets, traps, gill nets, trolling lines, surrounding nets and “kannizzati” (fish-attracting devices).

Small-pelagic species are mainly caught by lampara nets and traps (bogue traps). A small number is also caught by trammel nets.

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2. Materials and methods

Catch and effort estimates for the small-scale fishing fleet were obtained using a sampling scheme (Coppola et al., 2003) carried out in six representative sampling ports, three in Malta and three in Gozo. Surveys were carried out in these six ports every other month between January and September 2003.

The sampling days were limited to six consecutive fishing days per month per port. In the Malta stratum, monitoring and sampling were undertaken for 8 hours per day for the first three fishing days and over 24 hours per day for the remaining three fishing days.

In the Gozo stratum, monitoring and sampling were undertaken over 8 hours per day during all the six consecutive days. Each month, the sampling frame per port was adjusted according to the number of operational vessels.

Catch and effort estimates were produced on a monthly basis, by stratum, by vessel and gear used and by species. The fishing area/zone for each sample taken was also recorded. At the end of each month the stratum estimates of production and effort were summed up by a time- and area-raising factor to obtain an estimate for the Maltese islands.

3. Results

a) Gear used by small vessels

As shown in Figure 1, the majority of small-scale registered vessels, almost 45 per cent, use set bottom longlines as their main fishing gear. Another 17 per cent use trammel nets. Trolling lines are used by about 15 per cent of the vessels and more than 8 per cent use traps.

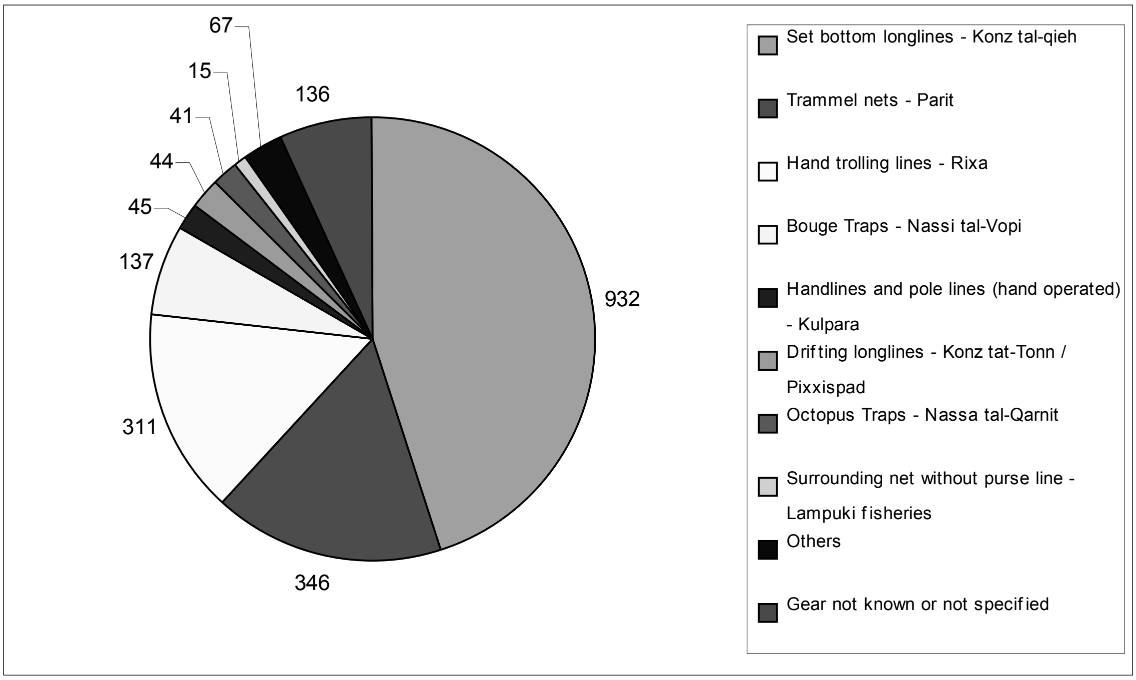

Figure 1. Main fishing gear used by small-scale fishing vessels

b) Operational registered fishing vessels

Of the 2,074 registered small-scale vessels, the actual number of operational vessels each month was about 1,400. The number of vessels that go out fishing every day is much less and during the sampling period only about 20 per cent of the activity for each given day was observed.

c) Catches recorded during sampling months (January–September 2003)

The small-pelagic fish species caught in the Maltese waters are: *Boops boops*, *Spicara* spp., *Scomber japonicus* and *Trachurus* spp.

During the sampling months, it was noted that small-pelagic species were mainly caught by traps and trammel nets, with the exception of May, for which, 9.5 per cent of the catches by trolling lines consisted of *Trachurus* spp. The rest of the troll catches were composed of other migratory species.

Boops boops, recorded as being caught by traps, from January to September 2003, amounted to or 88 per cent of total catch, as shown in Table 1. Figure 2 summarizes the estimated average daily catches for the five sampling months.

Table 1. Data collected during the sampling period for catches by traps

Month	Total Catch by Octopus/Bogue Traps kg	*Boops boops* kg
January	59,826	58,451
March	1,371	40
May	3,518	2,789
July	4,336	1,910
September	2,871	144
Totals	**71,922**	**63,334**
Total percentage catch	100%	88%

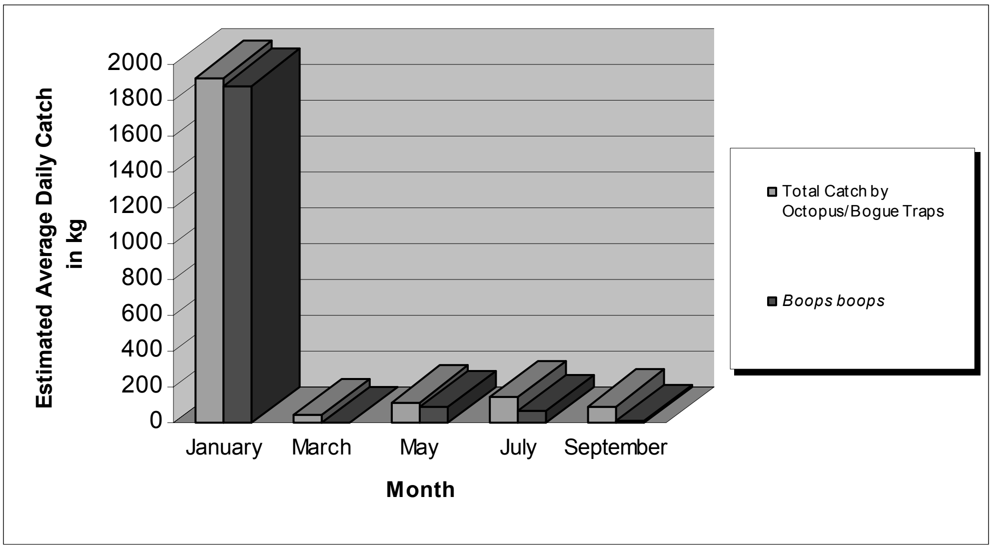

Figure 2. Estimated average daily catches by traps.

Data collected during the sampling period show that only 6.12 per cent of catches by trammel nets consisted of various small-pelagic species, as shown in Table 2. Figure 3 summarizes the estimated average daily catches during the five sampling months.

Table 2. Data collected during the sampling period for catches by trammel nets

Month	Total Catch by Trammel Nets (kg)	*Boops boops* (kg)	*Trachurus* spp (kg)	*Spicara* spp (kg)	*Scomber japonicus* (kg)	Total Catches of Small-Pelagics (kg)
January	6,586	550				550
March	10,514	374	193	203		770
May	8,973	278	272			550
July	9,785	431	226			657
September	7,571	11			119	130
Totals	**43,429**	**1,644**	**691**	**203**	**119**	**2,657**
Total percentage catch	100%	3.79%	1.59%	0.47%	0.27%	6.12%

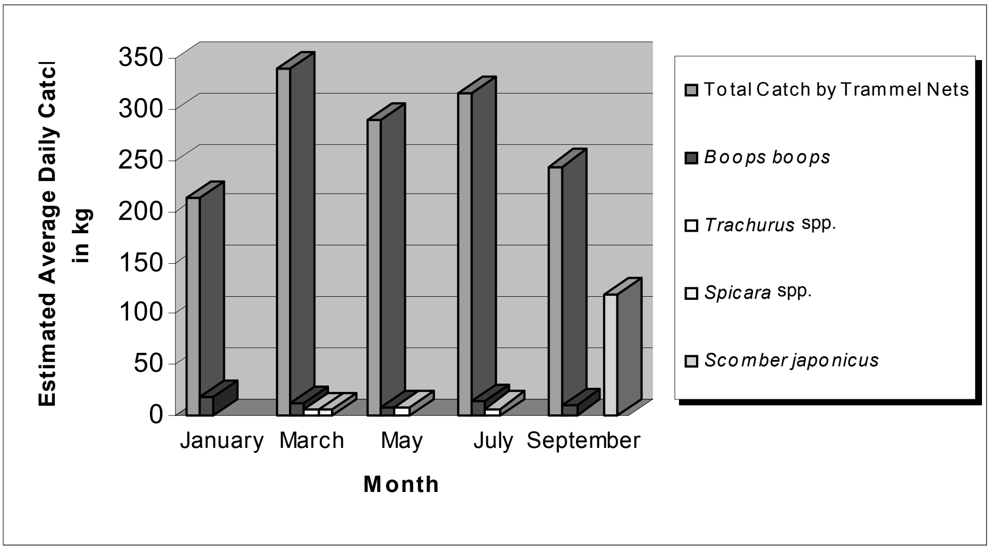

Figure 3. Estimated average daily catches by trammel nets

d) Operational statistics on fishing gears

Statistics related to gear used in catching small-pelagic species during the sampling period are listed in Table 3.

Table 3. Gear dimensions and fishing time

	Gear		
	Trammel Nets	**Bogue Traps**	**Trolling Lines**
Average fishing time	14 h 29 min	10 h 16 min	5 h
Average length of net	130 m		
Average height of net	1.3 m		
Average number of pots		5.8	
Average number of hooks			2.5

e) Spatial distribution of fishing effort using bogue traps and trammel nets

Figures 4 and 5 give rough estimates of the spatial distribution of the fishing effort by bogue traps and trammel nets, respectively, for small-pelagic species, by vessels operating from the six sampling ports.

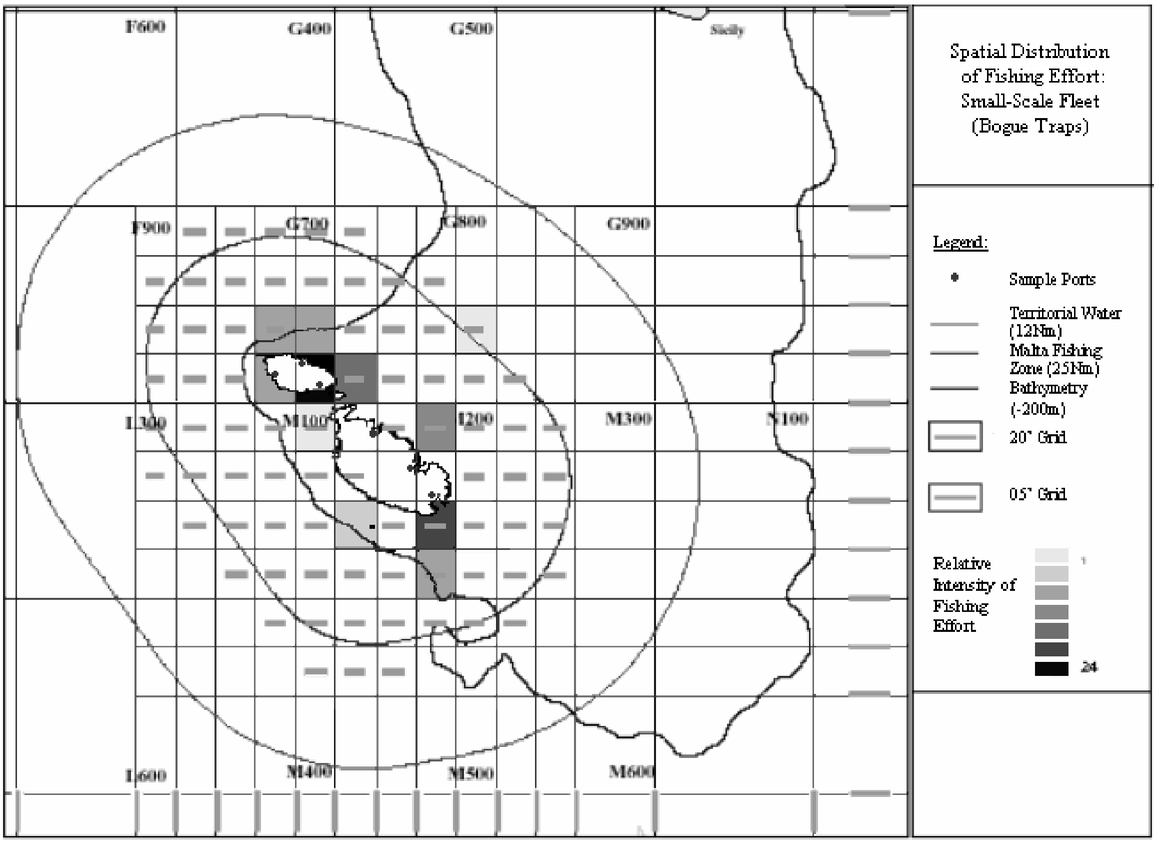

Figure 4: Spatial distribution of fishing effort by vessels operating with bogue traps.

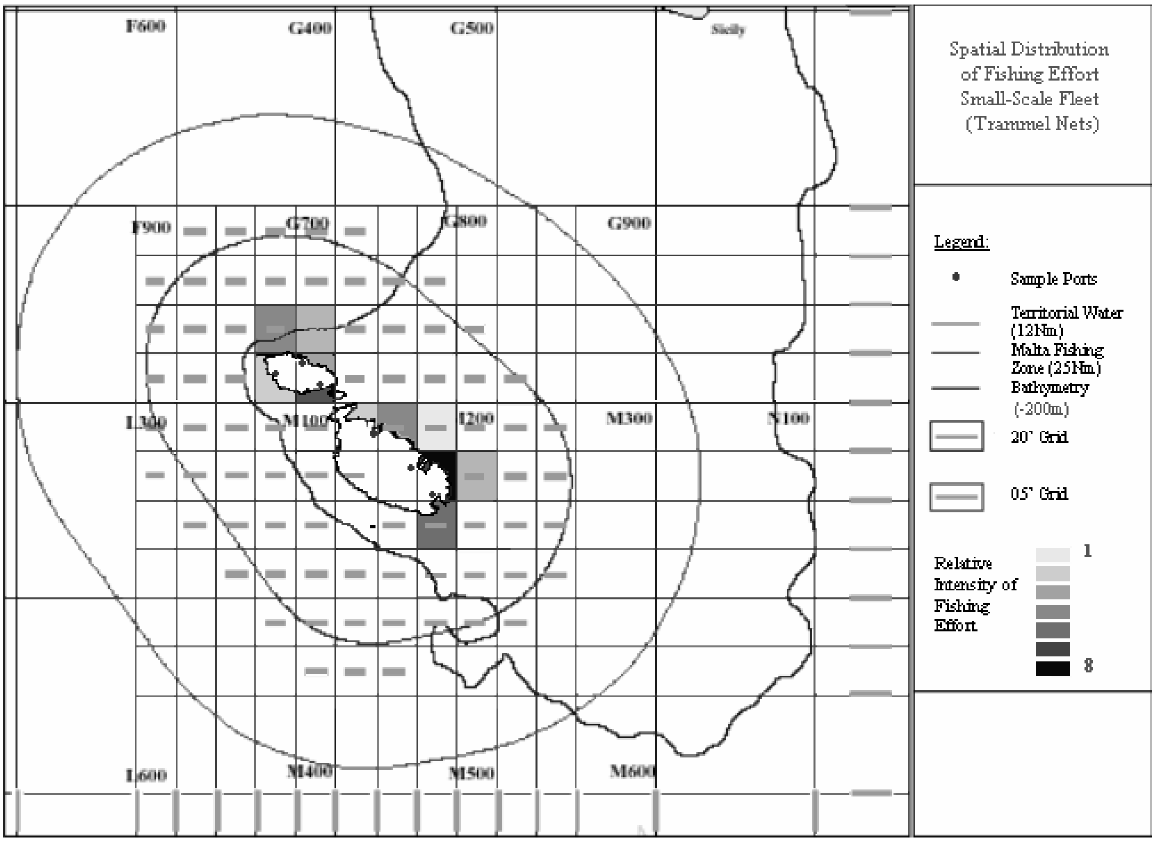

Figure 5. Spatial distribution of fishing effort by vessels operating with trammel nets.

4. Conclusion

Data presented in this report were collected during the catch and effort assessment survey applied to the registered small-scale fishing fleet. In the sampled ports, no registered vessel less than 10 metres in length uses a lampara net.

Up to a few years ago, fishing with a lampara net was a very important part of the total national fishing effort. Landings of *Scomber japonicus, S. scombrus, Trachurus trachurus, T. mediterraneus, Boops boops, Alosa alosa, Sardina pilchardus* and *Engraulis encrasicolus* were quite abundant. However, nowadays, lampara fishing effort has become insignificant.

At present, only two larger vessels (over 10 metres in length) and another two small-scale fishing vessels, operating from other ports than those sampled, are registered to operate using lampara gear. Small-pelagic fish landings by vessels using lampara nets were not covered by this report.

The data collected show that the most abundant small-pelagic fish species caught in the Maltese waters is *Boops boops*.

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Design of a geographical information system prototype for the management of fishing with light in the Gulf of Tunis(Methodology)

F. Ben Rais Lasram*, S. Gana,L. Ben Abdallah, A. Bel Hadj Ali

The design of the information system

The first step in the design of the information system is the data-gathering, the second is the establishment of the physical background and the third is the implementation of "geo-entities". Then, we need to define a unit of fishing effort and to formulate a distribution function of the fishing effort.

1. The data-gathering

To gather the necessary data we have carried out surveys based on questionnaires among the fishermen at the ports of Ghar El Melh, La Goulette and Sidi Daoud.

The surveys covered the following parameters:

- the general and structural characteristics of the fishing vessels
- the engine
- the electronic equipment
- the deck machinery
- the fishing gear
- the auxiliary boats
- the light production
- the fishing operations and fishing areas
- the crew
- the ownership
- the conservation mode
- the sale of the landings

We have also carried out surveys among the fishery entities on the catch statistics, the legislation and the port infrastructure.

2. The determination of the physical background

To determine the physical background, the coastline has been digitized from topographic maps on a scale of 1:25,000 and the bathymetry has been digitized from topographic maps and marine charts.

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A numerical depth model has been generated from the isobaths and the bathymetric probe points, digitized from the marine chart. This model has been used for the extraction of any isobath needed but not figuring on the charts.

3. The geo-entities

A geo-entity is a set of rules, activities, practice and physical characteristics defining the spatial extent of a fishery. Five geo-entities are defined, as follows:

3.1 "Legislation"

This geo-entity represents the zones closed to light-fishing and is composed of polygons.

3.2 "Accessible zone"

This geo-entity represents the zone accessible to each fishing vessel, depending on the height of the gear used.

3.3 "Radius of action"

This geo-entity represents the minimal and the maximal radius of action of each fishing vessel from its port. The data were collected from the fishermen.

3.4 "Abundance zone"

This geo-entity was generated from the acoustic survey OASIS 5 and shows the resource abundance in the Gulf of Tunis.

3.5 "Activity zone"

This geo-entity represents the potential activity zone for each fishing vessel. It results from the intersection of the geo-entities "legislation", "accessible zone" and "radius of action". It is represented by a grid with a cell size of 0.025° latitude × 0.025° longitude. Each cell of the grid in which a fishing vessel is active is assigned the score 1 and those in which it is not are assigned the score 0.

4. Modelling

All the geo-entities and the other parameters of the fleet typology were introduced into a conceptual data model, transformed into a logical data model and into a physical model. A data dictionary describing all the components of the information system was conceived.

5. The distribution function of the fishing effort

After choosing a unit of fishing effort, we formulated a distribution function of the fishing effort, following the “friction of distance” approach by Caddy and Carocci, 1998.

This function is:

$$\mathbf{Fij=(fj.Cij)/\Sigma Ckj} \qquad \mathbf{(1)}$$

k from 1 to N(j) and where:

- N(j) is the total number of grid cells in which vessel *j* is active;
- fj is the fishing effort of vessel *j* over the whole area;
- Cij=[(dij–xjmin)/xjmin] . [(xjmax–dij)/xjmax].exp[–(xjmax–dij)/xjmax];
- dij is the distance from the centre of the grid cell *i* to the port of vessel *j*; and
- xjmin and xjmax are, respectively, the minimum and the maximum radius of action.

The output is a file including the cells' coordinates and the fishing-effort value by vessel and by cell, calculated according to equation (1).

The cells assigned the score 0 will have a zero fishing effort, and those assigned the score 1 will have the corresponding fishing effort.

The influence of meteorological parameters on fisheries, especially those on small-pelagic-fish species.

F. Gauci*

Abstract

The central Mediterranean is our Project Area. In this area, the main catch of small-pelagic-fish species would consist of *sardines, sardinellas, anchovies, mackerels and horse mackerels.*

Since the studies that have been done so far in the Area have proved to be rather limited in number, it has been necessary to look farther afield. The Aquatic Sciences and Fisheries Abstracts (ASFA) has quite an extensive data base on studies that are relevant to the Project. In fact, no less than 300 records have been extracted from ASFA.

Numerous studies that have been carried out in various climatic regions all over the world, together with the results obtained from such studies, are catalogued in ASFA.

Top of the list, due to its particular importance and to the large areas under its influence, are studies of El Niño, the climatic phenomenon originating in the tropical Pacific, but which seems to affect the climate all over the globe. El Niños that were particularly strong had severely affected catches of pelagic species off South America. In fact El Niño was found to affect the productivity, faunal distribution and fish survival, besides having been the cause of intense rainfall and subsequent landslides in certain areas, and drought in others.

The paper also discusses some of the results of the studies done on small-pelagic species (such as sardine, mackerel, shrimp, squid and crabs) and the environmental factors, with special reference to the meteorological parameters that affect their behaviour. Most of such studies considered have so far taken place outside the Mediterranean region.

It would also be of great interest to find out the possible effects of global warming on fisheries. Thus a list of studies conducted world-wide has been presented, together with an indication of trends for the next two or three decades that would result from the global warming.

The presentation ends by describing the long time period of meteorological data available in Malta, an island at the centre of the Project Area.

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Outline of the results of the COPEMED International Workshop on Environmental Variability and Small-Pelagic Fisheries in the Mediterranean Sea

P. Hernández*

1. Background

During the First Session of the Scientific Advisory Committee (SAC) of the GFCM (Rome, 23–26 March 1999), the need for studies dealing with the coupling between the distribution of small-pelagic-fish species and oceanographic features was stressed (document GFCM/SAC/99/inf 5).

The COPEMED Project, one of whose major aims is to support the work of GFCM, has contributed during the last six years by organizing a series of workshops with the purpose of assisting the SAC in the fields of research of major concern.

In June 2001, a workshop focused on the study of relationships between fluctuations in the abundance of small-pelagic-fish species and oceanographic features was organized in Palma de Mallorca with the support of the Instituto Español de Oceanografía's Balearic Centre which hosted the event.

2. Goals of the Workshop

- To encourage the exchange of knowledge/dialogue between experts in the field.
- To agree on an approach to the study of coupling mechanisms between fish population dynamics and environmental factors which could be applied in a possible future project.
- To begin to identify the useful data sources and owners.
- To begin to assess the availability of these data.
- To assess the feasibility of a future cooperative project.

3. Report[1]

Participants from eight Mediterranean countries (Morocco, Algeria, Tunisia, Malta, Libya, Italy, France and Spain) and three experts from outside the region (A. Bakun and P. Cury, of IRD, France, and W. Wooster, of the University of Washington, Seattle) attended the workshop. Scientists with different areas of expertise (fishery biology, oceanography, GIS) presented their work in the region.

The workshop was organized in four sessions: one for presentation of the theme, and three other sessions for discussions, in which a conceptual model and a set of indicators were

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[1] Full text report of the workshop is available at http://www.faocopemed.org/vldocs/0000744/index.htm

agreed upon. The research of several participants was presented and, finally, recommendations were made for future possible scenarios.

In Session I, a *conceptual diagram* was introduced, discussed and agreed upon. This diagram is intended to be a framework for discussion of the proper approach and to provide a list of items that needs to be addressed in the study of fishery and environmental variability. The final design is given in Figure 1.

A diagram, as any model that is intended to produce an abstract representation of reality, has always some limitations. In this particular case, the limitations of the model were identified:

- Loss of information due to simplification
- False view of the ecosystem due to compression into one or two boxes
- Loss of generality (applicability to different geographic areas) due to excessive elaboration.

Likewise, some misrepresented components were identified:

- The biomass box should be detailed.
- Factors driving horizontal flow in the Mediterranean.
- Horizontal flow in the Mediterranean is driven by buoyancy loss (heat flux) in well identified areas; the resulting density-driven surface circulation is only slightly modified by wind stress.
- Mixing of processes and variables in the conceptual diagram.
- Ecosystem.

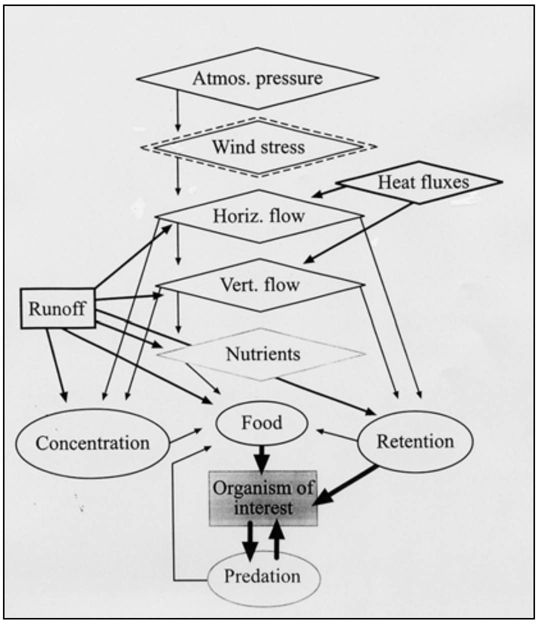

Figure 1. Conceptual diagram for the study of the relationships between the distribution of small-pelagic-fish species and environmental conditions.

Going one step forward, A. Bakun introduced a *potential method to be employed in the analysis of marine ecosystems.*

STEP 1. Perform climatological analysis of the ecological system to identify potential controls on environmental processes.

STEP 2. Construct time-series indicators of variabilty in environmental control processes.

STEP 3. Assume responses to values of anomalies (negative–positive or absolute).

STEP 4. Construct multiple seasonal-anomaly time-series of independent variables (different response time-scales).

STEP 5. Perform multiple empirical tests to identify: (1) a favoured form of response; (2) best-fit adaptive time-scale; (3) etc.

STEP 6. Repeat steps 1 to 5 for different regional fish-environment systems.

STEP 7. Identify informative patterns in 1, 2, 3 of step 6 that may yield generalized insights.

In Session II, the participants identified a series of *indicators* to represent diagram components outlined during Session I. Indicators were identified for each component. A preliminary list is presented in Table 1. This list needs to be expanded and further refined taking into account the needs of particular geographic areas, and the experience of other groups of experts, etc.

The main difficulties encountered in this process of identification were: lack of definition of space- and time-scales and the variety of methods for data collection.

4. Monitoring and data analysis

The proper design of a monitoring programme and the possibilities for the establishment of a monitoring network in the Mediterranean were discussed during Session III.

A number of key steps were outlined as follows:

- The identification of existing programmes and the availability of data.
- The establishment of a system for quality-control of data.
- The identification of a system for sharing/pooling data.

Workshop participants emphasized the need for objective assembly and analysis of data on ecosystem forcing and response. Holistic analysis of changes in ecosystems will be useful for informing governments about changes that might affect resource use.

A formal scientific organization, such as PICES in the North Pacific and ICES in the Atlantic, was suggested as a body that could coordinate: (1) operational monitoring; (2) data exchange; (3) analysis; (4) promotion, development and execution of required research.

Table 1. Indicators

Component	Indicator
Atmospheric pressure	Sea-level pressure
Atlantic inflow	Sea-level height on both sides of the Strait of Gibraltar
Wind speed	Wind stress
Heat fluxes and evaporation	Air and sea-surface temperature; wind intensity
Horizontal flow	Front position and meso-scale activity (satellite SST); satellite altimetry (only valid at least 10 km offshore in the open sea and for relatively intense horizontal flows)
Vertical flow	Wind-stress curl (open sea), SST images (wind-driven upwelling near the shore)
Nutrients	P, Si, nitrates
Food	Primary production (chlorophyll-*a*, phytoplankton abundance) Zooplankton (abundance, species composition)
Biomass	Recruitment, spawning, egg and larval abundance, daily egg production, spawning area, catches
Retention	Indices provided by numerical simulation. Analysis of time-series of SST images
Parameters for biomass indicator	
DEPM parameters: Daily egg production, batch fecundity, mean female weight, spawning fraction	
Condition parameters: Gonado-somatic index, condition factor, lipid content, hepato-somatic index, macroscopic fat content, larval daily growth and annual growth, larval condition (RNA/DNA), genetic quality (maternal effects)	
Other parameters: Egg and larval abundance, length–weight relationship, size at first maturity, zooplankton biomass, phytoplankton biomass, food availability) microzooplankton biomass	

The present nature and the future of existing Mediterranean data bases and monitoring programmes (MEDITS, MEDATLAS, MedGOOS) were discussed. The short-term nature of these programmes may result in the termination of valid data collection. At present the main effort is on physical-data collection. The situation for biological data and for resource information (i.e. fisheries) is not as clear. The existence of a large number of data in the form of unpublished reports was also discussed. The importance of trying to retrieve this information was emphasized. The role of a central body to pool, quality-control and organize all these data was again discussed. Such a body was considered essential for the success of such an effort.

The danger of duplicating effort in the Mediterranean was stressed. The existence of Mediterranean organizations, such as MedGOOS and ICSEM (CIESM), which could provide an umbrella for this type of activity, was discussed. The need for a biological focus in the MedGOOS programme was discussed, since the initial emphasis of this observing system is on the physical components of the system. A biological focus might be ensured by adopting the living marine resources component of MedGOOS's parent programme, the IOC–WMO Global Ocean Observing System (GOOS).

Available data sets

A preliminary list of data sets available for each sub-area was generated, though it was not comprehensive; however, it may serve as a first approach. It can be found at http://www.faocopemed.org/vldocs/0000744/index.htm. The participants agreed on continuing its further elaboration.

6. Final discussion and recommendations

Long-term actions were viewed as necessary, although outside *the scope of COPEMED,* through:

- the establishment of a monitoring programme
- the establishment of a Mediterranean body analogous to ICES or PICES, which would coordinate: (a) operational monitoring; (b) data exchange, quality-control and analysis; (c) promotion, development and execution of required research
- the establishment of a cooperative regional project to try to elucidate mechanisms linking changes in population of small-pelagic fishes with environmental processes.

Two types of short term action, feasible *within the COPEMED context,* in order to have a more realistic prospect, were suggested:

- Organization of workshops:

  (a) to assess data availability in specific areas: Alboran Sea and the Strait of Sicily to be given priority

  (b) to provide training in data analysis, for standardization throughout the region

  (c) to begin conducting data analysis in areas of interest using the approaches/tools agreed at workshop (a).

- Preparation of a catalogue of existing Mediterranean data sets/data bases specifying:

  (a) type of data

  (b) data owner

  (c) contact information.

COPEMED expressed its interest in supporting the execution of some of the short-term actions proposed, provided they correspond to the priorities of COPEMED, which are to support GFCM/SAC and bridge the gap between the northern and southern sides of the Mediterranean.

The development of such activities in the COPEMED context was subject to the request of the interested countries and to the availability of the necessary held data by the national institutions involved. Unfortunately, COPEMED has not received any formal request in this sense, meaning that no action has been taken so far.