Food and Agriculture Organization of the United Nations

Italian Ministry of Agriculture and Forestry Policies

GCP/RER/010/ITA/TD-13

Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea

AdriaMed Seminar on Fishing Capacity: Definition, Measurement and Assessment

ADRIAMED

AdriaMed Technical Documents No. 13

SCIENTIFIC COOPERATION TO SUPPORT RESPONSIBLE FISHERIES IN THE ADRIATIC SEA

MiPAF

Food and Agriculture Organization of the United Nations

Italian Ministry of Agriculture and Forestry Policies

AdriaMed

GCP/RER/010/ITA

AdriaMed Seminar on Fishing Capacity: Definition, Measurement and Assessment

AdriaMed Technical Documents No.13
GCP/RER/010/ITA/TD-13

Termoli (Italy), May 2004

Preface

The Regional Project “Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea” (AdriaMed) 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).

AdriaMed was conceived to contribute to the promotion of cooperative fishery management between the participating countries (Republics of Albania, Croatia, Italy and Slovenia), in line with the Code of Conduct for Responsible Fisheries adopted by the UN-FAO.

Particular attention is given to encouraging and sustaining a smooth process of international collaboration between the Adriatic Sea coastal countries in fishery management, planning and implementation. Consideration is also given to strengthening technical coordination between the national fishery research institutes and administrations, the fishery organizations and the other relevant stakeholders of the Adriatic countries.

FAO-AdriaMed Project HQ
Corso Umberto I, 30
86039 Termoli (CB), Italy

Tel: ++39 0875 708252-708240
Fax: ++39 0875 720065
e-mail: faoadriamed@faoadriamed.org
URL: http://www.faoadriamed.org

GCP/RER/010/ITA Publications

The AdriaMed Project publications are issued as a series of Technical Documents (GCP/RER/010/ITA/TD-00) and Occasional Papers (GCP/RER/010/ITA/OP-00) related to meetings and research organized by or conducted within the framework of the Project.

Occasionally, relevant documents may be translated into national languages as AdriaMed Translations (GCP/RER/010/ITA/AT-00).

Comments on this document would be welcomed and should be sent to the Project headquarters:

FAO AdriaMed
Corso Umberto I, 30
86039 Termoli (CB)
Italy
faoadriamed@faoadriamed.org

For bibliographic purposes this document
should be cited as follows:

AdriaMed. 2004. AdriaMed Seminar on Fishing Capacity: Definition, Measurement and Assessment. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-13. *AdriaMed Technical Documents*, 13: 119 pp.

Preparation of this document

This document is the final version of the report of the AdriaMed Seminar on Fishing Capacity, organised by the FAO AdriaMed Regional Project (*Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea*) on 24-25 October 2002 in Fano (Italy), hosted by the Laboratory of Marine Biology and Fisheries of the University of Bologna.

Over the last few years, the issue of excess fishing capacity has received much attention worldwide. It follows from decades of effort to deal with the degradation of fish stocks and the related issue of overexploitation without due consideration being paid to the direct or indirect effect of fleet capacity. The impact of fishing capacity on the biological and economic conditions of fishing communities is under consideration at various institutional levels. Its evaluation is considered fundamental for the fisheries management process.

In the Code of Conduct for Responsible Fisheries, particular recommendation is made to the States to prevent an excess of fishing capacity. The Code contains many suggestions that are related to the implementation of management measures aimed at ensuring that fishing effort is commensurate with the productive capacity of the fishery resources and their sustainable utilization. The International Plan of Action for the Management of Fishing Capacity (1999) was developed on this basis as highlighted in the Code.

In line with its mandate and coherently with the indications given by the Code of Conduct for Responsible Fisheries, the fishing capacity issue was raised by the AdriaMed Project. The AdriaMed Seminar was the first of such a topic specifically taking into account also Mediterranean Sea fisheries, in particular Adriatic fisheries. The Seminar aimed at providing the basic elements to define, measure and appraise the fishing capacity and at underlining how the management of fishing capacity could help in the fisheries management decision making process.

At the Twenty-fifth Session of the FAO Committee on Fisheries (2003), where reference was made to the progress towards the implementation of the Code of the Conduct for Responsible Fisheries and related International Plans of Action, the AdriaMed regional seminar on fishing capacity was acknowledged as one of the relevant initiatives contributing to strengthen their implementation.

The Seminar and this Technical Document fall within the fishery management component of the AdriaMed Project. This document is addressed primarily to fishery scientists, managers and professionals. It is an output of the FAO-AdriaMed Project and it is hoped that it will contribute to strengthen international cooperation and to promote responsible fisheries around the Adriatic Sea.

Acknowledgements

Thanks are due to Corrado Piccinetti and his staff at the Laboratory of Marine Biology and Fisheries of Fano for the kind and generous hospitality provided. Many thanks are also due to Dominique Gréboval and Massimo Spagnolo for their support to the organization of the Seminar. The assistance of Caroline Bennett and Nicoletta Milone is gratefully acknowledged.

AdriaMed.
AdriaMed Seminar on Fishing Capacity: Definition, Measurement and Assessment.
AdriaMed Technical Documents. No.13. GCP/RER/010/ITA/TD-13, Termoli, 2004: 119 pp.

ABSTRACT

The AdriaMed Seminar on Fishing Capacity was held at the Laboratory of Marine Biology and Fisheries, Fano, Italy on 24th and 25th October 2002. The Seminar aimed at familiarising experts from several fields related to fisheries in the Mediterranean to the issue of fishing capacity, its definition, measurement, assessment and related management options. The concepts of capacity utilization and target capacity, overcapacity and overcapitalization were introduced and clarified, together with the meaning of capacity under-utilization. In a context such as Adriatic fisheries, appropriate fleet segmentation is essential for capacity assessment. An important step is the establishment of a proper comparative monitoring system in the Adriatic Sea region, based on correct segmentation of the fleet and also accounting for the important issue of polyvalent vessels. Given the multi-species and multi-gear nature of the Adriatic Sea fisheries, one of the management options to resize the fishing capacity would be to redirect the effort, however the estimation of capacity is possible only as a total and not for a single species. Examples of fishing capacity appraisal were provided through case studies from the English Channel, the Mediterranean and Adriatic Sea's fisheries. To assess effective fishery management plans it is important to know the fleet size and structure, the potential output from the current fleet and the target management objectives, considering both biological and economic parameters. The Seminar reviewed possible ways to manage fishing capacity, all of which aim to contrast free and open access to fisheries. Healthy fisheries in an area such as the Mediterranean and Adriatic can only result from careful collaborative management with the sharing of national information at all levels.

Table of Contents

AdriaMed Seminar on Fishing Capacity: Definition, Measurement and Assessment

Fano, Italy, 24th and 25th October 2002

Introduction to the Seminar (Agenda item 1)

The AdriaMed Seminar on Fishing Capacity was held at the Laboratory of Marine Biology and Fisheries, Fano, Italy on 24th and 25th October 2002. The Seminar was attended by fishery biologists, economists, managers and representatives of the fishery associations from the countries participating in AdriaMed (Albania, Croatia, Italy and Slovenia), experts from some countries participating in the FAO MedSudMed Project (Malta and Tunisia) as well as experts from other Mediterranean countries also attended. The list of participants is given in Annex A.

The Seminar was organised in the framework of the AdriaMed Project component on management of Adriatic Sea fisheries, the Seminar is also considered part of AdriaMed's effort to strengthen national capacity in terms of expertise, thus standardising information and collaboration around the Adriatic region. This seminar served the further purpose of familiarising experts from several fields related to fisheries in the Mediterranean to the issue of fishing capacity, its definition, measurement and possible management strategies as indicated in the Seminar announcement (Annex B). The Agenda is attached as Annex C.

The Seminar was run by AdriaMed together with the staff from the Fishery Policy and Planning Division (FIPP) of FAO. Lectures were given by FAO experts from FIPP and AdriaMed, by experts from the Institute for Economic Research on Fisheries and Aquaculture (IREPA, Italy) and from the Centre for the Economics and Management of Aquatic Resources, University of Portsmouth (UK).

The Meeting was declared open by the Coordinator of the AdriaMed Project, who gave a brief introduction to the Project's activities and the aims of this Seminar, highlighting the relevance given to the issue of fishing capacity in the Code of Conduct for Responsible Fisheries adopted by the FAO Council in 1995. The Director of the Laboratory of Marine Biology and Fisheries of Fano then took the floor to welcome the participants. It was decided that the Director of IREPA and the expert from FAO FIPP should act as co-Chairs. AdriaMed constituted the Seminar secretariat.

Some aspects of Adriatic Sea fisheries (Agenda item 1.1)

An overview of Adriatic marine capture fisheries was given by AdriaMed (Mannini *et al.*, this report). The Adriatic Sea is probably the largest and the best defined area of occurrence of shared stocks in the Mediterranean. It was highlighted that the maximum total landing of both demersal and small pelagic resources was reached in the 1980s. The issue of the impact and sustainability of the expansion of demersal fisheries in recent times was raised, as well as the necessity for close monitoring of this sector as its growth may have led to excessively high exploitation rates, particularly affecting some key species. Factors behind small pelagic and demersal fisheries' production patterns were discussed.

Relevance was also given to the fact that in the specific case of the Adriatic Sea, fishery production dynamics are not only based on resource availability but are also strongly driven by market demand and prices. Socio-economic forces have been observed to be decisive in shaping fishery exploitation patterns. Basic reliable fisheries statistics are fundamental and, in the case of Adriatic shared fisheries, should necessarily be comparable and easily integrated. The understanding of any fishery system, and the Adriatic makes no exception, increasingly calls for a multidisciplinary analysis.

Fishery management policy framework (Agenda item 2)

A general overview of the issue of managing fishing capacity was made by Gréboval (this report), with some considerations concerning the Adriatic Sea. An outline was given of the International Plan of Action for the Management of Fishing Capacity endorsed in 1999 by the FAO Committee on Fisheries, together with the main reasons which led to its adoption to contrast excessive fishing capacity in world fisheries.

The issue of the management of fishing capacity within the overall fishery management policy framework was discussed. It was clarified that fishing capacity management should be considered both an objective and an integral part of fishery management, other key aspects of fisheries management being the enhancement of fishery stocks, effort allocation management and fleet management.

At a practical level, for a given fishery, fishing capacity can be defined as the level of fishing inputs that can be applied by the fleet if *fully utilized* or, alternatively, as the corresponding catch that can be produced for a given level of stock. It should be noted that full fleet utilization is intended as *normal but unrestricted* use (rather than maximum use).

The basic requirements for measuring and monitoring of excess fishing capacity and its inherent complexity were dealt with. As a result it was evident that a sound knowledge of fleet dynamics is an essential condition to address the management of fishing capacity as well as fisheries management in general. In simply terms, it must be recognised that fleet assessment is as important as stock assessment within the fisheries management process. Moreover, these two components should not only be developed at national level but, when necessary, at the appropriate regional (as in the case of Adriatic fisheries) or global level.

Specific references were made to the Mediterranean and in particular to the Adriatic fisheries. In this latter case it was remarked that, due to the substantial interaction of the various national fleets sharing the same resources, extensive and well-established international cooperation constitutes a basic requisite for the sustainable development and management of the fishery sector

Lastly, it was highlighted that fishing capacity management should be based on the joint control of both fishing inputs and outputs, irrespective of which one is chosen as the principal control variable.

Capacity appraisal framework (Agenda item 3)

A framework for assessing current and target capacity in fisheries was outlined and discussed (Pascoe, this report). Basic steps for such a framework were critically presented. These consist in capacity monitoring, assessment of existing and target capacity and assessment of overcapacity. The concepts of capacity utilization and target capacity, of overcapacity and overcapitalization were introduced and clarified, together with the meaning of capacity under-utilization. Relevance was given to the consequences of under-utilized capacity as economic waste and of overcapitalization in terms of loss of potential resource rent that could be obtained from the fishery.

Input and output based measures of capacity were reviewed stressing that both are needed in the fishery management system. The applicability and constraints of informal and formal methods were considered with reference to the estimation of capacity and capacity utilization. Implications of multi-species and multi-gear fisheries and stock size variability (e.g. small pelagic fish and cephalopod molluscs) were underlined.

In general fisheries management, therefore also fishing capacity assessment and management, relate to the management objectives which essentially focus on rent generation, where maximum economic yield may be an appropriate target, or food production in which case maximum sustainable yields can be considered as a target output level.

Appraisal of capacity to allow the detection of any existing overcapacity or capacity under-utilization requires the information from the above points as well as the availability of a sound knowledge of the fishery in terms of both fleet and resources. It should be noted that capacity appraisal does not provide information on how target capacity can be achieved. Management plans should be formulated and implemented to pursue target capacity levels.

The ensuing discussion focused on characteristics of Mediterranean and particularly Adriatic Sea fisheries. A main point made by the Seminar participants was that while the most bio-economically important stocks are shared by the fleets of the coastal countries, fleet characteristics may differ widely in terms of fishing power due to differences in average age of national fleets, available technology, crew skills and land-based infrastructures. It was also observed that a further aspect to consider, in addition to the vessel count, is the issue of the gear used as this is important in calculating capacity; moreover the existence in most Adriatic countries of multipurpose fishing vessels further complicates the situation.

It was therefore suggested that in an area of multi gear fisheries the Operational Units (vessel, gear, resource, fleet segmentation) should be taken into consideration, not just the fleet. In a context such as Adriatic fisheries, appropriate fleet segmentation is essential for capacity assessment although comparison of capacity assessments requires basic technology to be similar. It was observed that an important step would be the establishment of a proper comparative monitoring system in the Adriatic Sea region, based on correct segmentation of the fleet and also accounting for the important issue of polyvalent vessels. The Seminar participants acknowledged the efforts made by the AdriaMed Project through its networks, which aim to define appropriate standards in order to facilitate the establishment of an effective monitoring system.

It was suggested that the first step is to characterise the fishing fleet finding as much information on each type of vessel (especially if multipurpose fishing vessels are involved). This will allow an analysis of fleet evolution and an assessment of capacity utilization. When shared stocks are considered, the first step is to know exactly what fleet data are available to enable a better decision-making strategy for the assignment of capacity.

Given the multi-species/multi-gear nature of the Adriatic Sea fisheries, one of the management options to resize the fishing capacity is to redirect the effort, however the estimation of capacity is possible only as a total and not for a single species. As a result in the Adriatic Sea it is difficult to apply management options to one species if the biological parameters are considered.

The question of biological over-fishing was raised. From a biological point of view the assessment of overfishing could be very difficult and could affect different fractions of stock. The example was given of the European hake (*Merluccius merluccius*) in the Adriatic Sea and the problems related to the overfishing of juveniles component of the stock were reported. This gave the Seminar participants the opportunity to underline differences between biological and economic terminology. It was noted that common terminology for both economists and biologists is required in order to work usefully and profitably together.

Case studies (Agenda item 4)

Examples of fishing capacity appraisal were provided through case studies from the English Channel (Pascoe *et al*., this report) and the Adriatic Sea (Gambino, this report) fisheries.

English Channel fisheries to some extent may resemble Mediterranean fisheries as they are characterised by multi-species, multi-gear and multi-purpose vessels the majority of which consists of small vessels (less than 10 m length) with a large proportion operating on a part-time basis. In this case study capacity utilization was estimated by Data Envelopment Analysis (DEA). The analysis was further carried out through a multi-objective bio-economic model to determine the fleet configuration and size of main fleet segments that best met given fisheries management objectives in the long run. Assumption and concepts behind the application of the methods and the results obtained were critically presented. There was also discussion of the implications in terms of capacity under-utilization and latent effort of the fact that some components of the fleet work on a part-time basis.

DEA was applied to Mediterranean fisheries using data from some important segments of the Italian fleet operating in the Northern and Central Adriatic Sea. Results of the analysis and possible limiting factors were discussed. It was suggested that other variables such as the fishing area should be included in the model**.** Both case studies suggested taking into consideration stochastic analysis of the model results to improve the robustness of the results due to uncertainty in biological and economic parameters and to account for the random nature of fisheries.

Analysis of capacity and capacity utilization was integrated with analysis of bio-economic indicators such as commercial CPUE and relative index of biomass obtained from scientific groundfish appraisal surveys conducted in the area concerned (i.e. Adriatic GSA 17; Sabatella and Piccinetti, this report). Five commercially important fish and cephalopod species were considered. The relevance of some characteristics of the fishery taken into consideration, such as the activity pattern, effects of some externalities that occurred in the period considered and the presence of shared stocks were discussed. The work underlined the importance of a syncretic, multidisciplinary (i.e. biological and economical) approach for the assessment of the state of fisheries.

It was reiterated that since most Adriatic commercial stocks are shared by the fleets of the coastal states and given the distinctive geomorphological characteristics of the Adriatic Sea basin, careful monitoring is required; it is also essential to have knowledge of the variability of both resource abundance and fishing effort for the whole area. An internationally concerted regulatory framework for effort limitation and technical measures for fishery management are requisites to be pursued.

Further discussion ensued on the rise in capacity utilisation and three factors were identified: the decommissioning scheme which sees the withdrawal of vessels which are not fully used; the resulting reduction in crowding lead to a greater quantity of resources available for exploitation; the consequent price rises that provide an incentive for exploitation.

Fishery policy options: policy implications for Mediterranean/Adriatic Sea fisheries (Agenda item 5)

Fishing capacity and fishing effort management might, initially, be easily confused, to avoid this it was clarified to the Seminar participants that capacity management should be seen as an economic approach to fisheries management whereas effort management achieves biological objectives. For example halving the fishing days in a given fishery could help stocks recover and therefore give a positive biological result, however this does not manage capacity as the number of boats remains the same, they just become less efficient. Successful management should take all aspects into consideration and find the correct balance.

Using the example of the English Channel fishery, it was remarked that to assess effective management plans it is important for managers to know the fleet size and structure, the potential output from the current fleet and the target management objectives, considering both biological and economic parameters. Once the global picture is available, detailed analysis for each single subset of data (biological, economical) is possible. Essentially there are three ways to manage fishing capacity, all of which aim to contrast free and open access to fisheries: appropriate licensing schemes, individual transferable quotas (ITQs) and exclusive territorial rights. A fourth way to achieve management purposes is through taxation. It was observed that fishing will always be an attractive sector while there is a profit to be made, therefore a suitable system of taxes and licenses can be applied in order to manage fishing capacity.

The following issues, which are related to the first three approaches to the management of fishing capacity, were presented and considered: individual versus collective rights; monitoring, control and surveillance implications; rent creation and allocation; fleet reduction schemes (even though the problem of latent capacity could arise); regional cooperation as a way of reducing capacity in a given area; a regional plan of action based on basic measurement and assessment.

The management of fishing capacity in the Adriatic is theoretically the same as for any other area: in order to reduce the number of vessels it is possible to wait for existing ones to become non-viable and not replace them, to introduce a decommissioning scheme or to transfer vessels to other states (when appropriate). To implement any plan of action, however, greater effort is needed at national and regional level to assess capacity.

In summing up the Seminar at the end of the discussion some comparison was drawn with Northern European fisheries, which have seen dramatic decline in recent years. The Mediterranean can be considered somewhat “safer” for a range of biological, economic, sociological and geo-morphological reasons. The very complexity of the Mediterranean case, however, presses for a management plan that applies a careful, balanced mix of tools; it is particularly important to not oversimplify the management options for the area.

It was concluded that healthy fisheries in an area such as the Mediterranean and Adriatic result from careful collaborative management with the sharing of national information at all levels. Broadening the scope of the existing Regional Projects may be the way ahead and would certainly guarantee an appropriate exchange in information and the achievement of mutual understanding and cooperation.

Annex A

List of participants

Antonio Artegiani
Irpem CNR
Largo Fiera della Pesca
Ancona 60125, Italy
Tel: 0039 0712078836
Fax: 0039 07155313
Email: artegiani@ismar.cnr.it

Caroline Bennett
FAO AdriaMed Project
Corso Umberto I, 30
86039 Termoli (CB), Italy
Tel: 0039 0875 708252
Fax: 0039 0875 720065
Email: caroline.bennett@fao.org

Matthew Camilleri
Malta Centre for Fisheries Sciences
Marsaxlokk, Malta
Tel: 00356 21650933
Fax: 00356 21659380
Email: matthew.camilleri@gov.mt

Luca Ceriola
Laboratory of Marine Biology
Molo Pizzoli (porto)
Bari 70123, Italy
Tel: 0039 080 5211200
Fax: 0039 0805213486
Email: biologia.marina@teseo.it

Nando Cingolani
Irpem CNR
Largo Fiera della Pesca
Ancona 60125, Italy
Tel: 0039 0712078851
Fax: 0039 07155313
Email: cingolani@ismar.cnr.it

Giulio Cosimi
Irpem CNR
Largo Fiera della Pesca
Ancona 60125, Italy
Tel: 0039 071207881
Fax: 0039 07155313
Email: cosimi@ismar.cnr.it

Roberto D'Ambra
AGCI Pesca
Via Angelo Bargoni, 78
00153 Rome, Italy
Tel: 0039 06 58 328 1
Fax: 0039 06 58 328 350
Email: r.dambra@libero.it

Ervio Dobosz
Federpesca
Via Emilio de' Cavalieri, 7
Rome, Italy
Tel: 0039 06 8554198
Fax: 0039 06 85352992
Email: ervio.dobosz@federpesca.it

Gianna Fabi
Irpem CNR
Largo Fiera della Pesca
Ancona 60125, Italy
Tel: 0039 071207881
Fax: 0039 07155313
Email: fabi@ismar.cnr.it

Mario Ferretti
CIRSPE
Via dei Gigli D'Oro, 21
00186 Rome, Italy
Tel: 0039 06 6869400
Fax: 0039 06 6875184

Aleksander Flloko
Professional Fishery Association of Albania
Lagja Nr.4 Rr. Skederbej
c/o Fishery Research Institute
Dürres, Albania
Tel: 00355 4222264
Fax: 0355 4222264
Email: aflloko@abissnet.com.al

Maria Forleo
University of Molise, Campobasso
Faculty of Economics
Via F. De Sanctis
86100 Campobasso, Italy
Tel: 0874/404454
Fax: 0874 311124
Email: forleo125@inwind.it

Monica Gambino
IREPA - Institute for Economic Research on Fisheries and Aquaculture
Via S. Leonardo
Traversa Migliaro
84131 Salerno, Italy
Tel: 0039 089 338978
Fax: 0039 089 330835
Email: gambino@irepa.org

Otello Giovanardi
Istituto Centrale per la Ricerca Applicata al Mare (ICRAM)
Loc. Brondolo, 30015 Chioggia (VE)
Italy
Tel: 0039 041 5543933
Fax: 0039 041 5547897
Email: otgiovan@tin.it

Fabio Grati
Irpem CNR
Largo Fiera della Pesca
Ancona 60125, Italy
Tel: 0039 071207881
Fax: 0039 07155313
Email: grati@ismar.cnr.it

Dominique Gréboval
FAO FIPP
Room F418
FAO HQ
Viale delle Terme di Caracalla
00100 Rome, Italy
Tel: 0039 06 57052122
Email: dominique.greboval@fao.org

Ines Herrero
Dep. Economia y Empresa
Universidad Pablo de Olavide
Carretera de Utrera km 1
41013 Sevilla, Spain
Tel: 0034 625 738 488
Fax: 0034 954 349 339
Email: iherrero@cica.es

Othman Jarbuoi
National Institute of Science and Technology of the Sea
Centre de Sfax
BP 1035
3018 Sfax, Tunisia
Tel: 00216 74 497 117
Fax: 00216 74 497 989
Email: othman.jarboui@instm.rnrt.tn

Stjepan Jukić–Peladić
Institute of Oceanography and Fisheries
S. Ivana Meštrovica, 63
21000 Split, Croatia
Tel: 00385 21 358688
Fax: 00385 21 358 650
Email: jukic@izor.hr

Tjaša Kariš
Delamaris d.d Izola
6310 Izola, Slovenia
Tel: 00386 5 6605854
Email: tjasa.karis@delamaris.si

Gabriella Manfrin Piccinetti
Laboratorio di Biologia Marina e Viale Adriatico, 1/N
61032 Fano (PU) Italy
Tel.: 0039 0721 802689
Fax: 0039 0721 801654
Email: cpiccinetti@mobilia.it

Piero Mannini
FAO AdriaMed Project
Corso Umberto I, 30
86039 Termoli (CB), Italy
Tel: 0039 0875 708252
Fax: 0039 0875 720065
Email: piero.mannini@fao.org

Fabio Massa
FAO AdriaMed Project
Corso Umberto I, 30
86039 Termoli (CB), Italy
Tel: 0039 0875 708252
Fax: 0039 0875 720065
Email: fabio.massa@fao.org

Nicoletta Milone
FAO AdriaMed Project
Corso Umberto I, 30
86039 Termoli (CB), Italy
Tel: 0039 0875 708252
Fax: 0039 0875 720065
Email: nicoletta.milone@fao.org

Sean Pascoe
Centre for the Economics and Management of Aquatic Resources (CEMARE)
Department of Economics-University of Portsmouth
Locksway Road
Portsmouth P04 8JF
United Kingdom
Tel: 0044 23 92844242
Fax: 0044 23 92844037
Email: sean.pascoe@port.ac.uk

Anna Maria Pastorelli
Laboratory of Marine Biology
Molo Pizzoli (porto)
Bari 70123, Italy
Tel: 0039 080 5211200
Fax: 0039 0805213486
Email: biologia.marina@teseo.it

Paolo Pelusi
Consorzio Mediterraneo
Via Nazionale, 243
00184 Rome, Italy
Tel: 0039 06 47824705
Fax: 0039 06 47883077
Email: pelusi@mediterraneo.org

Corrado Piccinetti
Laboratorio di Biologia Marina e Viale Adriatico, 1/N
61032 Fano (PU), Italy
Tel.: 0039 0721 802689
Fax: 0039 0721 801654
Email: cpiccinetti@mobilia.it

Riccardo Rigillo
Fisheries Directorate
Ministry of Agriculture and Forestry Policies
Viale dell'Arte 16
00144 Roma, Italy
Tel: 0039 06 590 84746
Fax: 0039 06 590 84050
Email: r.rigillo@politicheagricole.it

Evelina Sabatella
IREPA - Institute for Economic Research on Fisheries and Aquaculture
Via S. Leonardo
Traversa Migliaro
84131 Salerno, Italy
Tel: 0039 089 338978
Fax: 0039 089 330835
Email: e.sabatella@irepa.org

Antonello Sala
Irpem CNR
Largo Fiera della Pesca
Ancona 60125, Italy
Tel: 0039 071207881
Fax: 0039 07155313
Email: sala@ismar.cnr.it

Alberto Santojanni
Irpem CNR
Largo Fiera della Pesca
Ancona 60125, Italy
Tel: 0039 071207881
Fax: 0039 07155313
Email: santojanni@ismar.cnr.it

Gorenka Sinovčić
Institute of Oceanography and Fisheries
S. Ivana Meštrovica, 63
21000 Split, Croatia
Tel: 00385 21 358688
Fax: 00385 21 358 650
Email: sinovcic@izor.hr

Massimo Spagnolo
IREPA - Institute for Economic Research
on Fisheries and Aquaculture
Via S. Leonardo
Traversa Migliaro
84131 Salerno, Italy
Tel: 0039 089 338978
Fax: 0039 089 330835
Email: spagnolo@irepa.org

Zeqir Taga
Professional Fishery Association of
Albania
Lagja Nr.4 Rr. Skederbej
c/o Fishery Research Institute
Dürres, Albania
Tel: 00355 4222264
Fax: 0355 4222264

Nicola Ungaro
Laboratory of Marine Biology
Molo Pizzoli (porto)
Bari 70123, Italy
Tel: 0039 080 5211200
Fax: 0039 0805213486
Email: biologia.marina@teseo.it

Nedo Vrgoć
Institute of Oceanography and Fisheries
S. Ivana Meštrovica, 63
21000 Split, Croatia
Tel: 00385 21 358688
Fax: 00385 21 358 650
Email: vrgoc@izor.hr

Valter Ziza
Aquarium in Piran
Kidricevo nabrezje 4
SI 6330 Piran, Slovenia
Tel: 00386 5 673 2572
E-mail: ziza.valter@guest.arnes.si

Annex B

FAO-AdriaMed Seminar on Fishing Capacity: Definition, Measurement and Assessment

Seminar announcement

Over the last few years, the issue of excess fishing capacity has received a lot of attention worldwide. It follows from decades of effort to deal with the degradation of fish stocks and the related issue of overexploitation without due consideration being paid to the direct or indirect effect of fleet capacity. Fishing capacity can be defined for a given fleet as the amount of fishing effort that it can be produced over a given period of time (e.g. a year) under full time utilization (i.e. assuming normal utilization, unrestricted by catch or effort constraints). Excessive fishing capacity, in the form of excess fleet size leads to economic waste. If catches are not regulated or poorly regulated, it may also lead to the degradation of fishery resources and the dissipation of food production potential. The impact of excessive fishing capacity on the biological and economic condition of many fisheries throughout the world has been a matter of growing concern.

Although the use of the term fishing capacity is increasingly widespread, its definition varies among countries and institutions and the related assessment and management aspects are not always familiar. In the Adriatic region, as well as in the whole Mediterranean, the issue of fishing capacity is relatively new.

The relevance of the fishing capacity issue is often referred to and highlighted in the FAO Code of Conduct for Responsible Fisheries. References to it may be found in several Articles of the Code such as Article 6 (at section 6.1, 6.3), Article 7, which deals specifically with Fisheries Management. (7.1.8, 7.2.1, 7.2.2, 7.4.3, 7.6.3, 7.6.5). The International Plan of Action for the Management of Fishing Capacity was developed on this basis and adopted by COFI in 1999.

Fishery management is one of the components of the AdriaMed Project and the fishing capacity issue is regarded a relevant aspect. This topic was discussed during the last meeting of the AdriaMed Coordination Committee (Tirana, Albania, 21-23 November 2001). It is specifically addressed in paragraphs 63, 64 and 65 of the adopted report (also available at: http://www.faoadriamed.org/html/av_documents.html).

Consequently, AdriaMed is in the process of organizing a Seminar on Fishing Capacity Definition, Measurement and Assessment. The Seminar will be run together with the staff from the Fishery Policy and Planning Division of FAO and it will also focus on the characteristics of the Mediterranean fisheries. The participants are expected to be fishery biologists, economists, managers and representatives of the fishery associations. The Seminar will take place on 24-25 October 2002 in Fano hosted by the Laboratory of Marine Biology and Fisheries of the University of Bologna.

Annex C

Agenda

1 **Introduction to the seminar**
- Some aspects of Adriatic fisheries

2 **Fishery management policy framework**
- Fishing capacity background and IPOA
- Definition
- Link between fishing capacity and fishery management

3 **Capacity appraisal framework**
- Monitoring
- Capacity utilization (level of fleet activity)
- Capacity assessment

Discussion

4 **Case studies**
- English Channel multigear/multispecies fisheries
- Applicability of English Channel methodology to Mediterranean fisheries

Discussion
- Example of capacity assessment of a Mediterranean fishery and relevant bio-economic indicators

Discussion

5. **Fishery policy options: policy implications for Mediterranean/Adriatic Sea fisheries**
- Brief overview of management
- Possibilities and constraints to their applicability.

Adriatic Sea Fisheries: outline of some main facts

Piero Mannini*, Fabio Massa, Nicoletta Milone

Abstract

Following a brief introduction to some principal characteristics of the Adriatic Sea, the paper focuses on two main aspects of Adriatic Sea fisheries: fishery production and the fishing fleet. The evolution of capture fisheries landings over thirty years (1970-2000) is outlined: demersal and pelagic fishery production is compared and the quantities landed of some key shared stocks are described. The evolution of the Adriatic fishing fleet is reported in terms of number of fishing units, length category and fishing technique. The importance of basic reliable, comparable and easily integrated statistics is underlined; in the case of Adriatic shared fisheries the need for international cooperation is fundamental together with increased multidisciplinary analysis for the management of shared fishery stocks for the achievement of effective sub-regional fishery management.

1. Brief introduction to the Adriatic Sea

The Adriatic Sea is a semi-enclosed[1] basin within the larger semi-enclosed sea constituted by the Mediterranean, it extends over 138000 km^2 (Buljan and Zore-Armanda, 1976) it may be seen as characterised by Northern, Central and Southern sub-basins with decreasing depth from the south toward the north. Along the longitudinal axis of the Adriatic geomorphological and ecological changes can be observed, resulting in the remarkable differences of the northern and southern ends. Six countries, whose coastline development differs greatly, border the Adriatic. Some key-features of Adriatic coastal states for which marine fisheries are relevant are given in Table 1.

The Adriatic is characterised by the largest shelf area of the Mediterranean, which extends over the Northern and Central parts where the bottom depth is no more than about 75 and 100 m respectively, with the exception of the Pomo/Jabuka Pit (200-260 m) in the Central Adriatic. The Southern Adriatic has a relatively narrow continental shelf and a marked, steep slope; it reaches the maximum depth of 1223 m (Figure 1).

In the Adriatic Sea all types of bottom sediments are found, muddy bottoms are mostly below a depth of 100 m, while in the Central and Northern Adriatic the shallower sea bed is characterised by relict sand (Alfirević, 1981). The Eastern and Western coasts are very different; the former is high, rocky and articulated with many islands, the Western coast is flat and alluvional with raised terraces in some areas (Bombace, 1990).

---

*FAO-AdriaMed. Corso Umberto I, 30 - 86039 Termoli (CB) Italy; Email: piero.mannini@fao.org

[1] Semi-enclosed and enclosed seas are here defined according to Art. 122 of the United Nations Convention on the Law of the Sea (1982) as follows: "… a gulf, maritime basin or sea surrounded by two or more States and linked to another sea or to the ocean via narrow straits of exit, or entirely or mostly made up of territorial seas and exclusive economic zones of two or more coastal States".

The hydrography of the region is characterised by water inflow from the Eastern Mediterranean (entering from the Otranto channel along the Eastern Adriatic coast) and fresh water runoff from Italian rivers. These features seasonally produce both latitudinal and longitudinal gradients in hydrographic characteristics along the basin (Buljan and Zore-Armanda, 1979; Artegiani *et al*., 1981).

Table 1. Some data on Adriatic coastal states participating in AdriaMed.

	Notes	Albania	Croatia	Italy	Serbia-Montenegro	Slovenia
Coastline*(km)	The total length of the boundary between the land area (including islands) and the sea.	362	5835 (mainland 1777 km, islands 4058 km)	7600 (inclusive of Ionian and Tyrrhenian coastline)	199	47
Population* (July 2002 est.)		3 544 841	4 390 751	57 715 625	10 656 929	1 930 132
Population growth rate*	Annual population growth rate.	1.06% (2002 est.)	1.12% (2002 est.)	0.05% (2002 est.)	-0.12% (2002 est.)	0.14% (2001 est.)
Gross Domestic Product (GDP - real growth rate)*	Measure of the economy of a country; the total market values of goods and services produced and capital within the country borders during a given period.	7.3% (2001 est.)	4% (2001 est.)	1.8% (2001 est.)	3.5% (2002 est.)	4.5% (2000 est.)
Education index, 1999 **	Based on the adult literacy rate and the combined primary, secondary and tertiary gross enrolment ratio.	0.80	0.88	0.94	n.a.	0.94
Human development index (HDI) value, 1999 **	A composite index measuring average achievement in three basic dimensions of human development—a long and healthy life, education and knowledge and an acceptable standard of living.	0.72	0.80	0.90	n.a.	0.87
Urban population (as % of total) 1999 **	The mid-year population of areas defined as urban in each country, as reported to the United Nations.	41	57.3	66.9	n.a.	50.3
Infant mortality rate (per 1,000 live births) 1999 **	The probability of dying between birth and exactly one year of age expressed per 1,000 live births.	29	8	6	17*	5
Diffusion of recent innovations: Internet hosts (per 1,000 people) **	A computer system connected to the Internet	0.1	6.7	30.4	n.a.	20.3
Personal computers (per 1,000 people) ***		8 (2001 est.)	86 (2001 est.)	195 (2001 est.)	23 (2000 est.)	276 (2001 est.)
Agriculture, value added (% of GDP) ***	Agriculture corresponds to International Standard Industrial Classification (ISIC) divisions 1-5 and includes forestry, hunting and fishing, as well as cultivation of crops and livestock production. The net output of the agriculture sector after adding up all outputs and subtracting intermediate inputs.	31 (2001 est.)	10 (2001 est.)	3 (2001 est.)	15 (2000 est.)	3 (2001 est.)
Industry, value added (% of GDP) ***	Industry corresponds to ISIC divisions 10-45. It comprises value added in mining, construction, electricity, water, and gas.	23 (2001 est.)	34 (2001 est.)	29 (2001 est.)	32 (2000 est.)	38 (2001 est.)
Services, etc., value added (% of GDP) ***	Services correspond to ISIC divisions 50-99 and they include value added in wholesale and retail trade (including hotels and restaurants), transport and government, financial, professional and personal services such as education, health care and real estate services.	42 (2001 est.)	56 (2001 est.)	68 (2001 est.)	52 (2002 est.)	59 (2001 est.)
Per caput fish supply (Kg/year, 1997-99) ****	Data should be regarded as giving only an order of magnitude indication of consumption levels.	2.0	4.3	21.9	2.7	6.7

***The CIA World Fact-book: Web 2002 Edition (public domain)** --- http://www.countryreports.org/ --- http://www.atlapedia.com/
****UNDP. Human Development Report ---** http://www.undp.org/hdr2001/indicator/
*****The World Bank ---** http://devdata.worldbank.org/data-query/
****** FAO Yearbook of Fishery Statistics - 2001 ---** ftp://ftp.fao.org/fi/stat/summ_01/appIybc2001.pdf

Geo-morphological characteristics of the Adriatic basin, geo-political changes along the Eastern coast, existing national statistical divisions and fishery resource distribution have led to the identification of the two Geographical Sub-Areas (GSA) as shown in Figure 2. Croatia, Bosnia-Herzegovina, Italy and Slovenia border the GSA 17 (North and Central Adriatic), Albania, Italy (South-Eastern coast) and Serbia and Montenegro are included in the GSA 18 (AdriaMed, 2001; GFCM, 2001).

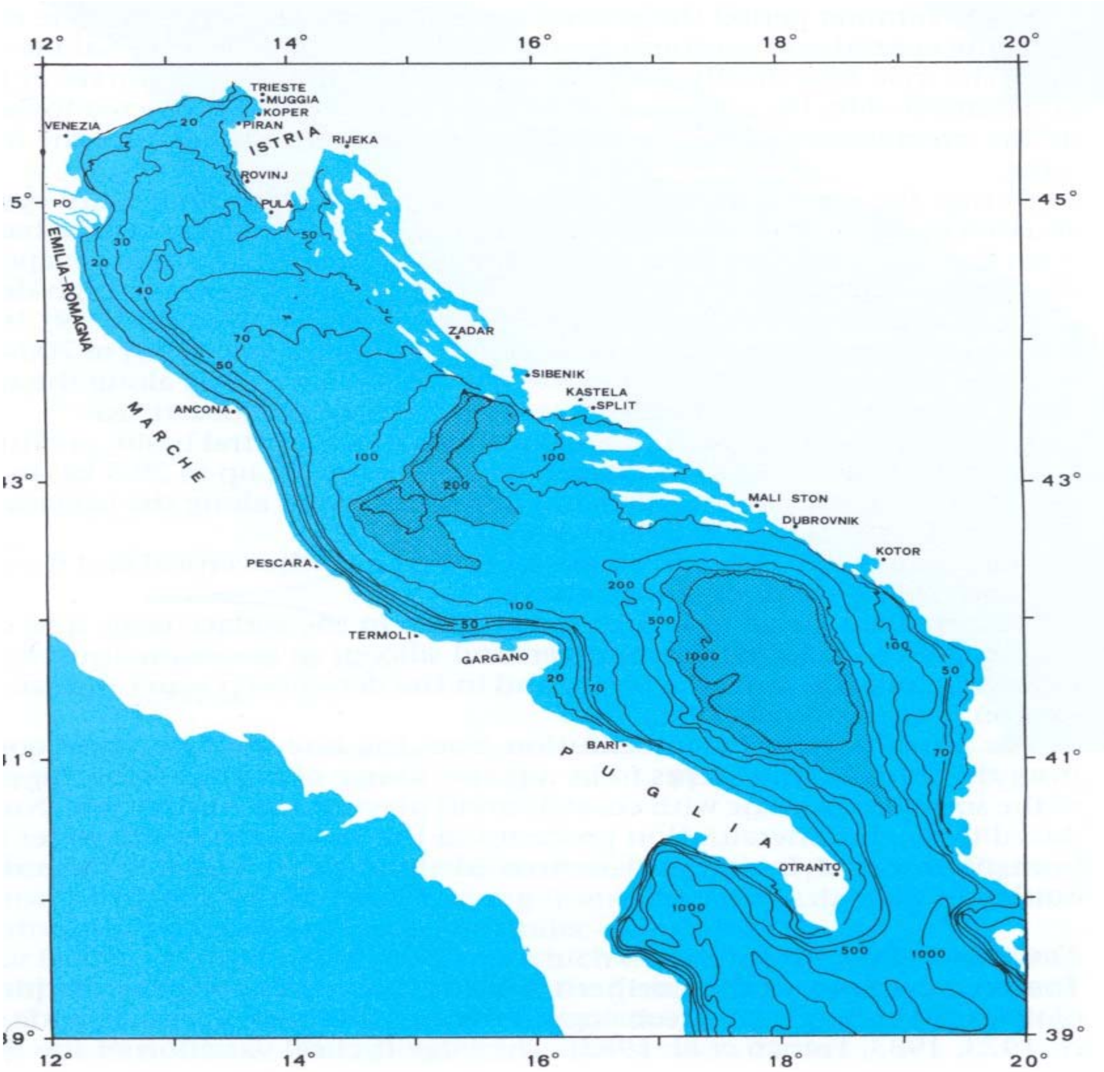


Figure 1. Adriatic Sea bathymetry (from Fonda Umani *et al.,* 1990).

The presence of the characteristics of a semi-enclosed sea as defined in Article 122 of the 1982 UNCLOS (United Nations Convention on the Law of the Sea) make the Adriatic a particularly suitable case to meet the provisions contained in Part IX (Article 23) of UNCLOS on cooperation of coastal states in enclosed or semi-enclosed seas (Sersic, 1992).

Finally, the Code of Conduct for Responsible Fisheries (as formulated by FAO in 1995) in coherence with UNCLOS and accounting for the Declaration of Cancun (1992), the Rio Declaration (1992), the provisions of the Agenda 21 of UNCED, the 1992 FAO Technical Consultation on High Sea Fishing, the 1984 FAO World Conference on Fisheries

Management and Development and other relevant international fisheries instruments (FAO and UN, 1998), further emphasizes the necessity, when in presence of shared stocks, for coastal states to cooperate for fisheries research and management.

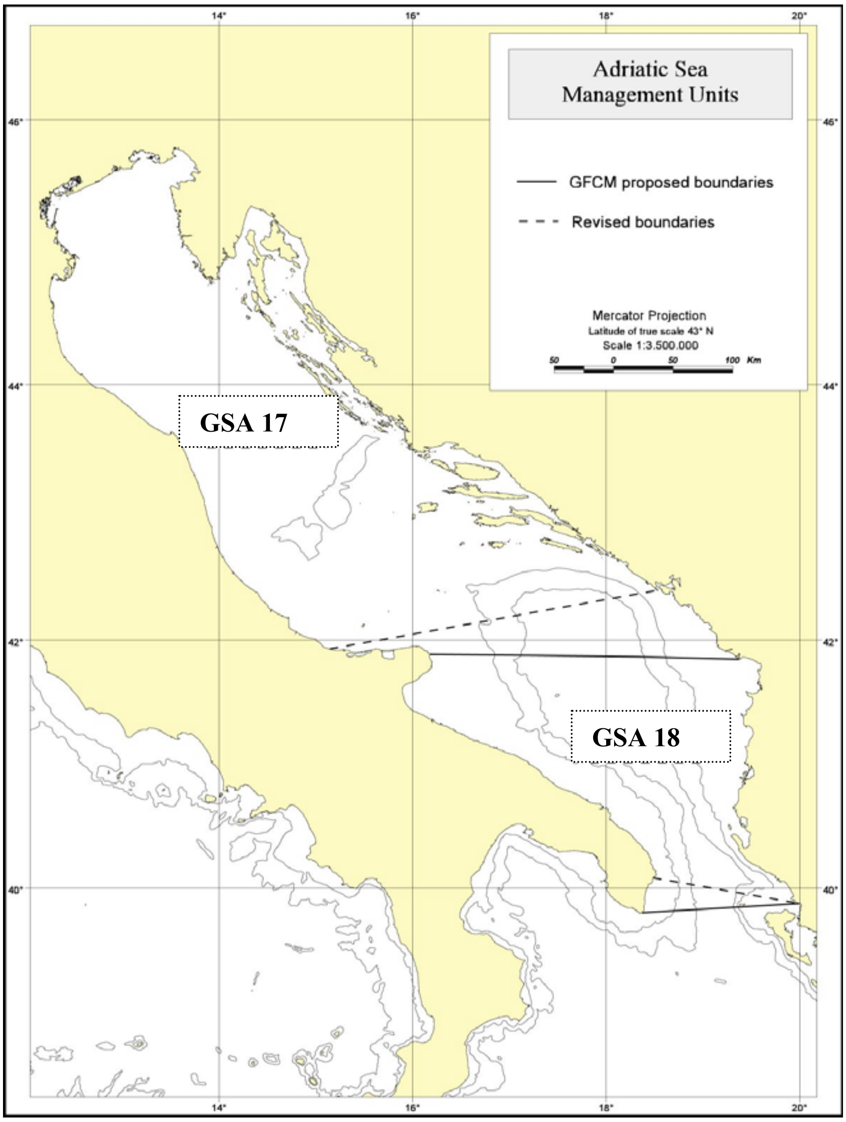


Figure 2. Map showing the boundaries of the Adriatic Sea Geographical Sub-areas 17 and 18 (formerly Geographical Management Units 37.2.1.a and 37.2.2.b) as originally indicated by the GFCM (solid line) and with the proposed (and currently adopted) revision (modified by AdriaMed, 2001).

2. Fishery production over time (1970-2000)

Recently the issue of shared fishery stocks in the Mediterranean has gained particular attention within international bodies such as the General Fisheries Commission for the Mediterranean (GFCM), its Scientific Advisory Committee (SAC) and the European Commission (EC). For instance, areas in the Mediterranean where shared stocks are reported or believed to occur are indicated in the EC Communication COM 535 (2002). It may be noted that with the exception of highly migratory stocks that are shared over the most of the

Mediterranean, the Adriatic Sea is one of the largest areas of occurrence of demersal and small pelagic shared stocks in the Mediterranean.

Evidence of the transboundary and straddling nature of some important stocks may be drawn from the geographical occurrence pattern in late spring and early summer of the European hake (*Merluccius merluccius*) and Norway lobster (*Nephrops norvegicus*) which are high-value stocks targeted by the Adriatic demersal fishery (Figure 3a, 3b).

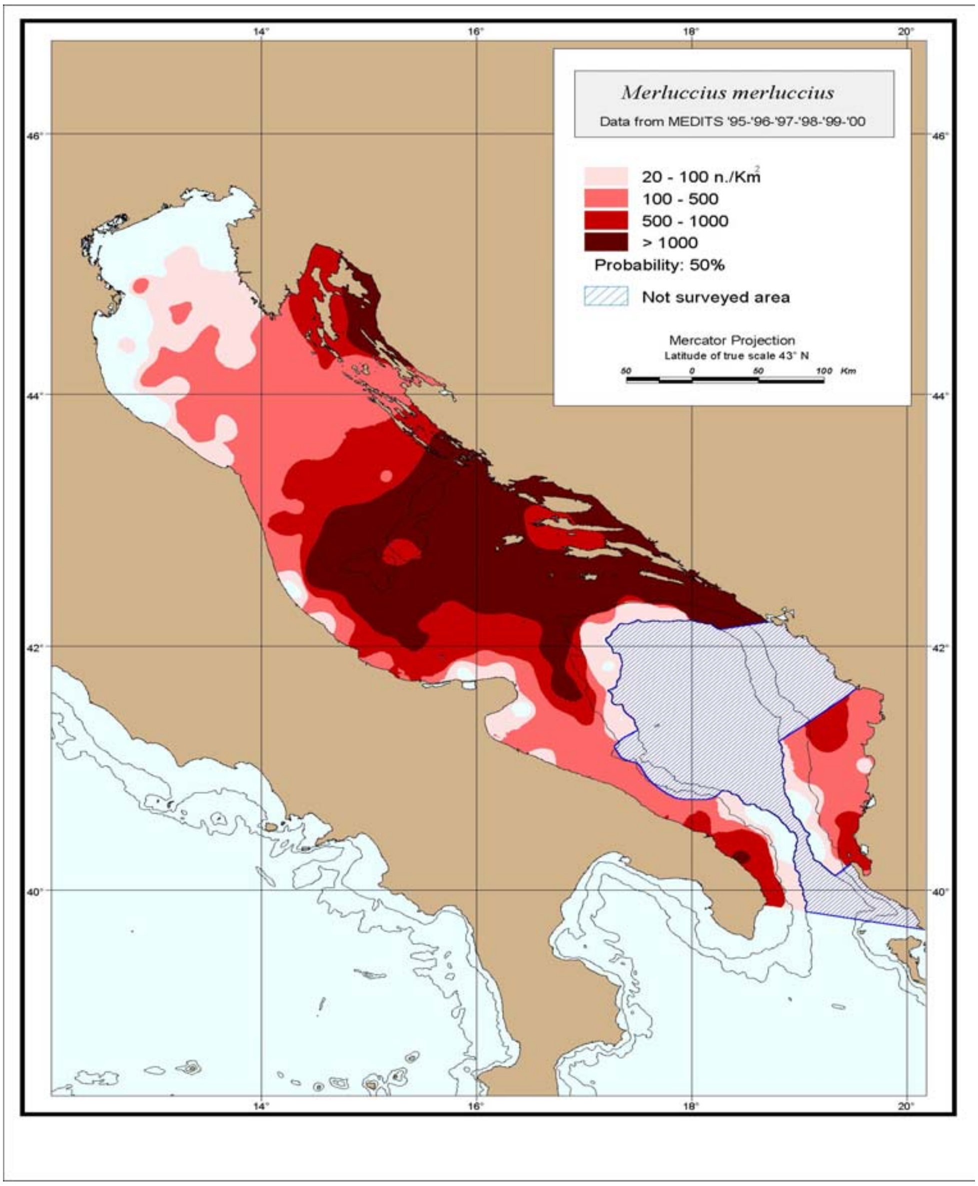
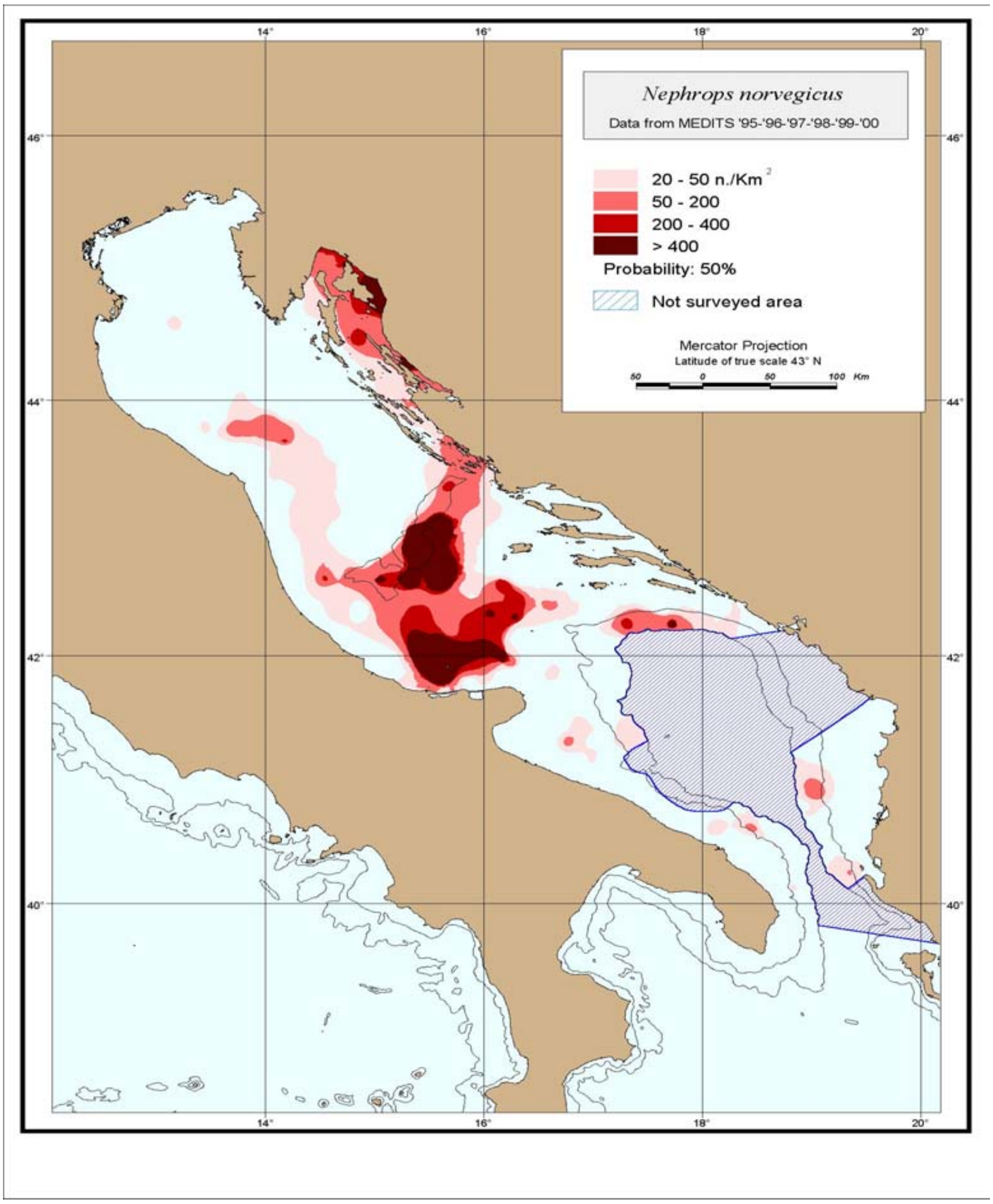


Figure 3a. Distribution of *M. merluccius* in the Adriatic Sea: indicator kriging representation (Gramolini *et al.,* in press). Data: Medits Programme.



Figures 3b. Distribution of *N. norvegicus* in the Adriatic Sea: indicator kriging representation (Gramolini *et al.,* in press). Data: Medits Programme.

The most important demersal and small pelagic commercial species whose stocks are shared in the Adriatic were identified and agreed upon by regional experts convened by AdriaMed (AdriaMed, 2000; Mannini *et al*., 2001). The recognition of the shared-stock status of the priority species (Table 2) was subsequently proposed to the national management authorities of the AdriaMed member countries (Albania, Croatia, Italy and Slovenia), and then endorsed at the 28th Session of the GFCM (GFCM, 2003).

The overview of capture fisheries landing trends from the Adriatic over thirty years (1970-2000) roughly outlines the fisheries production performance of the region. Data are from the open-access FAO statistics as compiled in the Fishstat Plus version 2.3 (FAO 2001). Nominal

landing figures are provided to FAO by member states and their reliability, which can differ greatly between countries and regions, cannot be easily assessed.
Therefore, caution needs to be exercised when considering trends in fisheries landing. It is important to note that the following main factors may be behind apparent landing trends: changes in the level of accuracy of fishery statistics reporting, trends in fishing intensity on the species in question, environmental trends in the productivity of the system, socio-economic factors affecting relative demand or accessibility of the species concerned.

Table 2. Relevant common species whose stocks are shared by at least two Adriatic countries (from AdriaMed Technical Documents N. 2 and 3).

Species	**Area of Occurrence**		
Adriatic Sea basins	Northern Adriatic	Central Adriatic	Southern Adriatic
Geographical Sub-area	**17**		**18**
Eledone cirrhosa		●	●
Eledone moschata	●	●	○
Loligo vulgaris	●	●	●
Lophius budegassa	○	●	●
Lophius piscatorius		○	●
Merlangus merlangus	●	●	
Merluccius merluccius	●	●	●
Mullus barbatus	●	●	●
Nephrops norvegicus	●	●	●
Pagellus erythrinus	●	●	●
Parapeneus longirostris		○	●
Sepia officinalis	●	●	●
Solea vulgaris	●	●	○
Engraulis encrasicolus	●	●	●
Sardina pilchardus	●	●	●
Sprattus sprattus	●	○	
Scomber scomber	●	●	●

●: common occurrence; ○: scarce; blank: negligible.

Underestimation of quantities landed is a common problem affecting the available statistics to an often unknown extent. For instance, and as an extreme case, according to a field interview survey conducted in Montenegro, it would appear that this country's landing statistics in recent years were underestimated by a factor of six (Regner, 2002). Nevertheless, although landing figures are likely to be (sometimes largely) underestimated in many cases, it can be reasonably assumed that overall, major trend patterns in fisheries landings are reflected in the time series. During the thirty-year period under consideration (1970-2000) the total landings of the Adriatic commercial capture fisheries of Albania[2], Croatia, Italy, Slovenia, Federal

[2] According to GFCM definition of statistical sub-areas the Adriatic Sea falls within the area 2.1, thus including only the Northern and Central basins, while the Southern Adriatic basin and consequently the coast of South-eastern Italy and of Albania are included in the Ionian Sea (area 2.2). In order to have as comprehensive a picture as possible of all Adriatic Sea fishery production, Albanian data originally classified as from the Ionian Sea have been included in the Adriatic data set used. Unfortunately, this was not feasible for South-western Italy (Apulia Region).

Republic of Yugoslavia (FRY) and the ex-Yugoslavia Republic reached its maximum in 1981 with about 220000 t of declared landed catch, to subsequently decline to the minimum of 100000 t in 1999 (Figure 4). Nominal total landing of Adriatic fisheries amounted to about 110000 t in the last available year (2000).

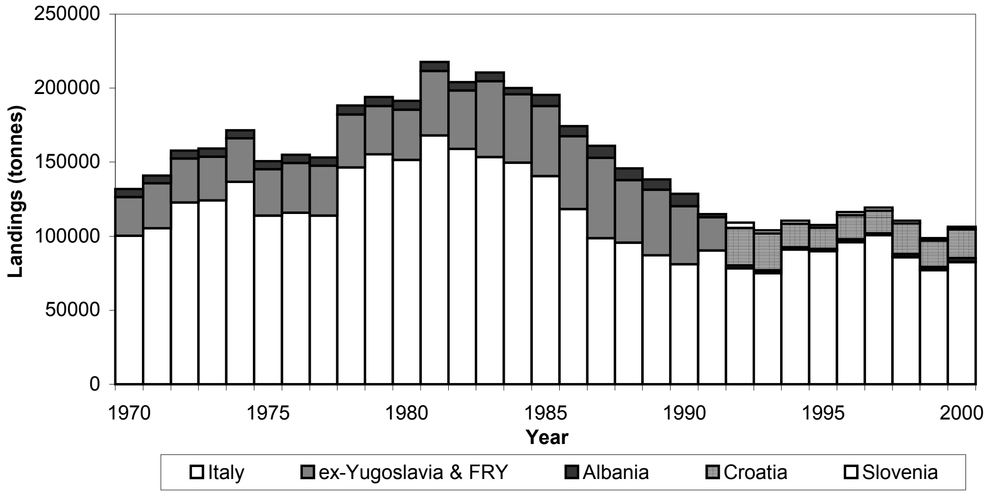


Figure 4. Adriatic Sea capture fishery production (excluding bivalve molluscs and aquaculture, see also text footnote 2). Data: FAO.

Recent demersal[3] and pelagic[4] fishery landings were compared to peak landings by area (Table 3). The comparison indicated that overall landing of the selected demersal species assemblage has currently declined to about 60-70% when compared to peak landing which in both western and eastern Adriatic demersal fisheries[5] was reached during the second half of the 1980s. In 1999 small pelagic fishery yields amounted to 53 % (western fishery) and 35% (eastern fishery) of the maximum pelagic landing achieved in the early and mid 1980s.

[3] Demersal species are here defined as those belonging to ISSCAAP (International Standard Statistical Classification of Aquatic Animals and Plants) groups 31, 32, 33, 34, 38, 43, 45, 47 and 57 which included, in this paper, mainly: soles, turbots, gurnards, hakes, sparids, surmullets, sharks and rays, cephalopods, spottail squillid mantis, deepwater rose shrimp and Norway lobster.

[4] Pelagic fish are here defined as those belonging to ISSCAAP groups 33, 35 and 37, which include, in this paper, clupeoids, mackerels, mullets and garfish.

[5] The terms Western fisheries and Eastern fisheries are used to mean the landings of the Italian fishery and those, pooled, of ex-Yugoslavia and Albania (1972-91) and of Croatia, Slovenia, Federal Republic of Yugoslavia (Republic of Serbia and Montenegro) and Albania (from 1992 onward) respectively.

Table 3. Comparison by area of recent landings to peak landings of selected species from Adriatic Sea demersal and pelagic fishery, based on three-year running means (see footnote 3 and 4). Year 1999 is the last data point available in the running mean series. Data source: FAO

Demersal fishery				
Area	**Recent landing (t)**	**Max landing (t)**	**Year of max landing**	**Recent/max landing**
West Adriatic	25951	42442	1986	0.61
*East Adriatic	5414	8124	1989	0.67
Pelagic fishery				
Area	**Recent landing (t)**	**Max landing (t)**	**Year of max landing**	**Recent/max landing**
West Adriatic	51825	97624	1980	0.53
*East Adriatic	16770	47772	1986	0.35

* Pooled data: 1972-1991 from Albania and ex-Yugoslavia, 1992-2000 from Albania, Croatia, Slovenia and FRY.

Pelagic catch dominated the marine fish landing, particularly in the East Coast fishery (Mannini and Massa, 2000), even though from the mid 1980s the contribution of pelagics to total fish landings decreased remarkably as a consequence of the successive downsizing of the anchovy and sardine stocks and, more recently, of the economic changes which took place in the eastern coastal countries.

Demersal and pelagic landing patterns, expressed as a percentage variation relative to the mean, highlights the regression of small pelagic fisheries production in both the anchovy-based western fishery and the sardine-based eastern fisheries (Figures 5a and 5b).

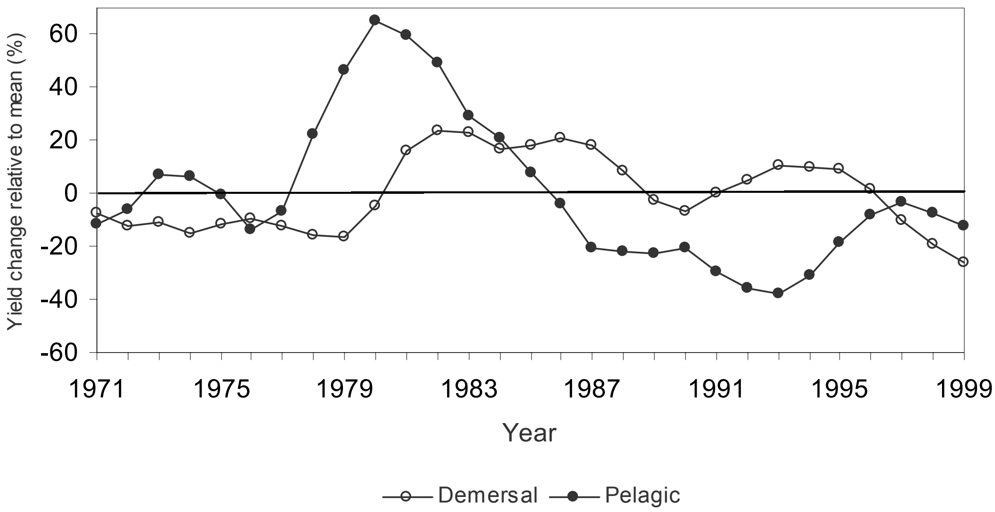


Figure 5a. Percentage landing change relative to mean value of Western Adriatic fisheries. Data source: FAO.

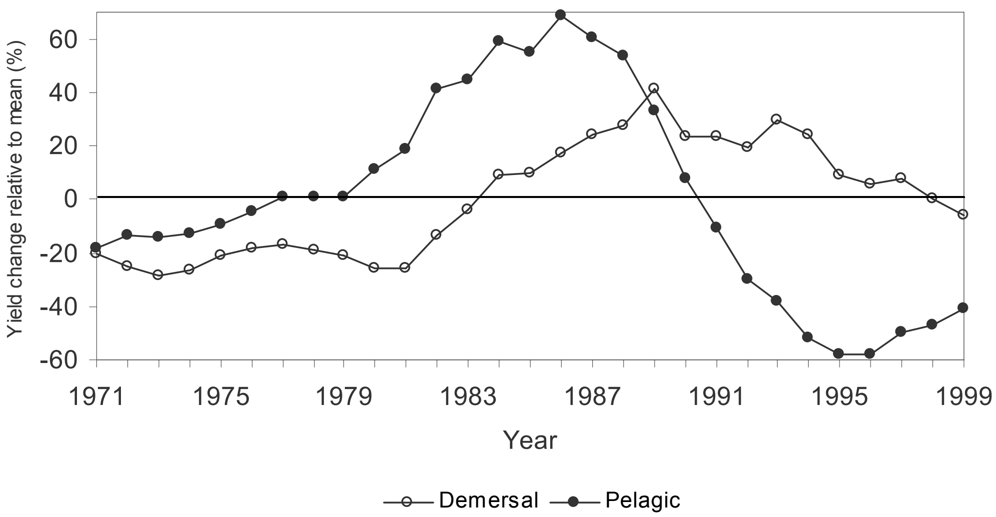
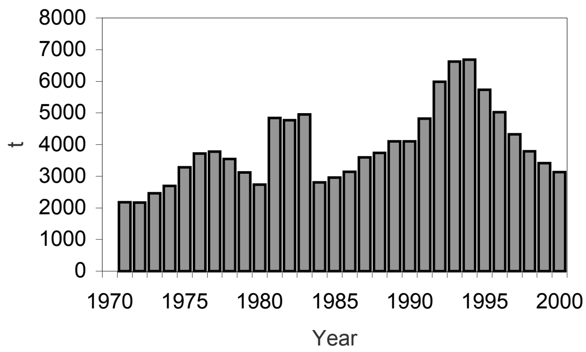


Figure 5b. Percentage landing change relative to mean value of Eastern Adriatic fisheries. Data source: FAO.

Both fisheries were strongly affected by factors of different origin producing a significant impact on the small pelagic fishery performance, such as subsidised production during part of the 1970s and 1980s (Bombace, 1993; Cingolani *et al*., 1998, 2000; Jukić-Peladić, 2001), anchovy recruitment failures (Bombace, 2001; Cingolani *et al*, 1996), and socio-economic changes affecting the sardine fishing industry in the Eastern Adriatic (Kapedani, 2001; Jukić-Peladić, 2001; Marčeta, 2001). Unlike the small pelagic fishery, demersal landing has developed and persisted above the average since the 1980s to begin declining in the second half of the 1990s. Out of the 15 species which currently contribute to total Adriatic landings with at least 1%, the quantities landed over time of some key-shared stocks are described hereunder.

Merluccius merluccius (2.6% average contribution to total landing; 10.7% average contribution to demersal landing as defined in footnote 3): The nominal landing of the European hake for the whole Adriatic Sea has been increasing since 1984 reaching the maximum of about 7000 t in 1994. Since then, this growing landing trend has reversed sharply declining to less than 4000 t according to the last available statistics (Figure 6). The average hake landing from 1970 to 2000 was about 4000 t.



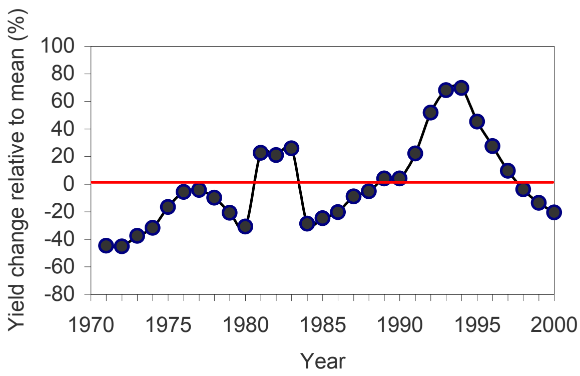


Figure 6. Landing (right) and percentage landing change relative to mean value (left) of *M. merluccius* from the Adriatic Sea (GFCM Geographical sub-area 17 and 18, three-year running average). Italian landings from area 18 are not included (see footnote 2).

Mullus spp. (1.3% average contribution to total landing; 5.5% average contribution to demersal landing as defined in footnote 3): The surmullets (*Mullus* spp.) landing has been increasing almost regularly with modest fluctuations since the second half of the 1980s, to reach multiple maxima each of about 3000 t throughout the second half of the 1990s somehow levelling the yield increase of the previous decade (Figure 7). Over the period from 1970 to 2000 the average landing of red mullet according to official statistics was about 2000 t.

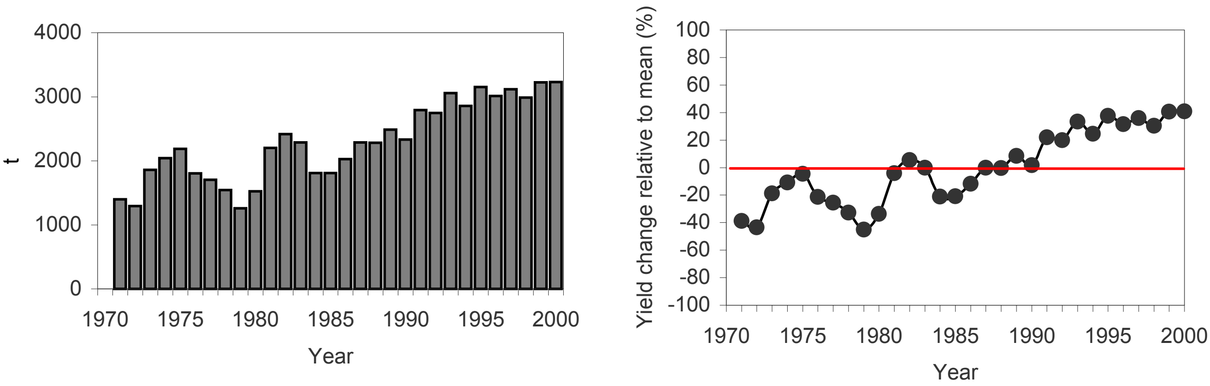


Figure 7. Landing (right) and percentage landing change relative to mean value (left) of *Mullus* spp. from the Adriatic Sea (GFCM Geographical sub-areas 17 and 18, three-year running average). Italian landings from area 18 are not included (see footnote 2).

Nephrops norvegicus (1 % average contribution to total landing; 4.3% average contribution to demersal landing as defined in footnote 3): The nominal landing of Norway lobster reached the highest level of about 2500 t in 1993, when the increasing pattern started during the early 1980s strongly reversed to less than 1000 t in the year 2000. The average landing over the 1970-2000 period could be estimated at about 1500 t (Figure 8).

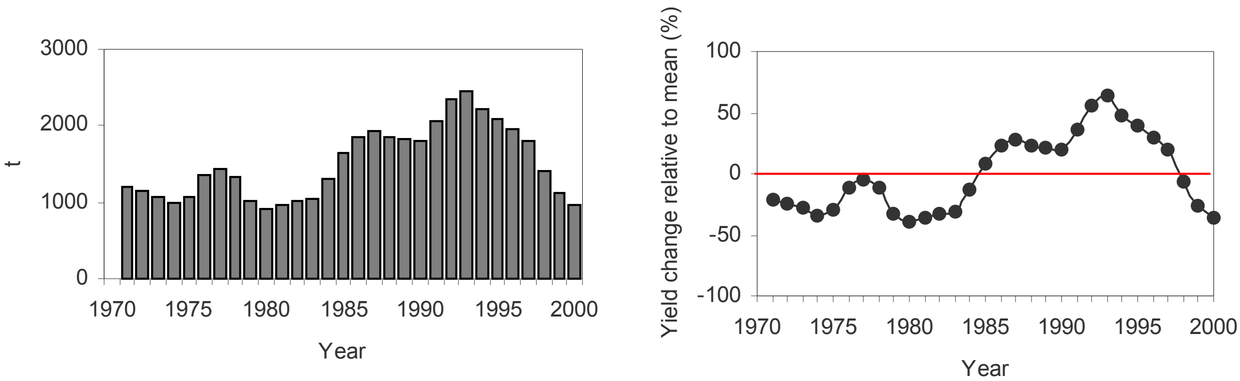


Figure 8. Landing (right) and percentage landing change relative to mean value (left) of *N. norvegicus* from the Adriatic Sea (GFCM Geographical sub-areas 17 and 18, three-year running average). Italian landings from area 18 are not included (see footnote 2).

Engraulis encrasicolus (19.1% average contribution to total landing; 32.3% average contribution to pelagic landing as defined in footnote 4): Anchovy landings during the last thirty years are characterised by two major factors: the landing peak of more than 50000 t in

1981 and the subsequent decline to the minimum of 10000 t in 1987, which lasted till the early 1990s.

Since then yield has been increasing to the current level of more than 30000 t (Figure 9). Average landings over this period can be estimated at about 27000 t.

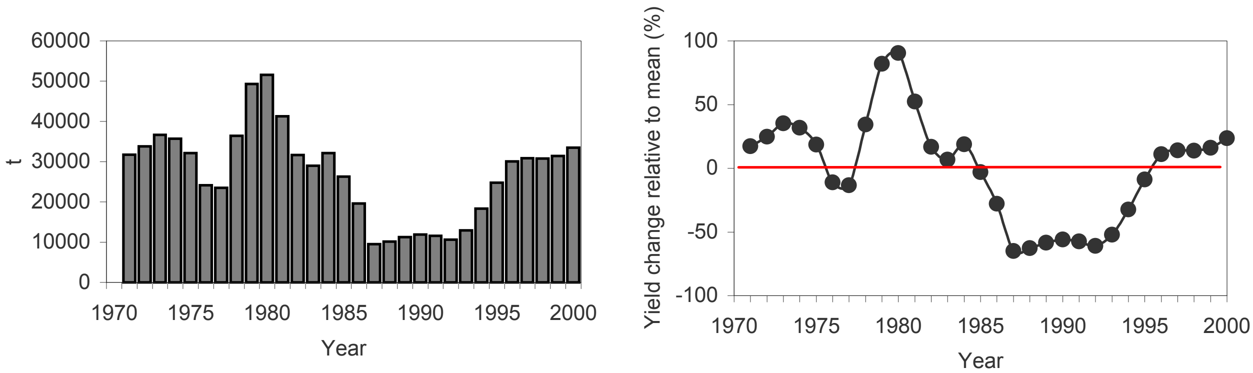


Figure 9. Landing (right) and percentage landing change relative to mean value (left) of *E. encrasicolus* from the Adriatic Sea (GFCM Geographical sub-areas 17 and 18, three-year running average). Italian landings from area 18 are not included (see footnote 2).

Sardina pilchardus (31.9% average contribution to total landing; 54% average contribution to pelagic landing as defined in footnote 4): the Sardine yield pattern shows a rising trend since the beginning of the available time series to peak at more than 80000 t in 1982 and to regress to the minimum of 28000 t from 1994 onwards. Over the whole period, Adriatic sardine landings averaged at about 48000 t (Figure 10).

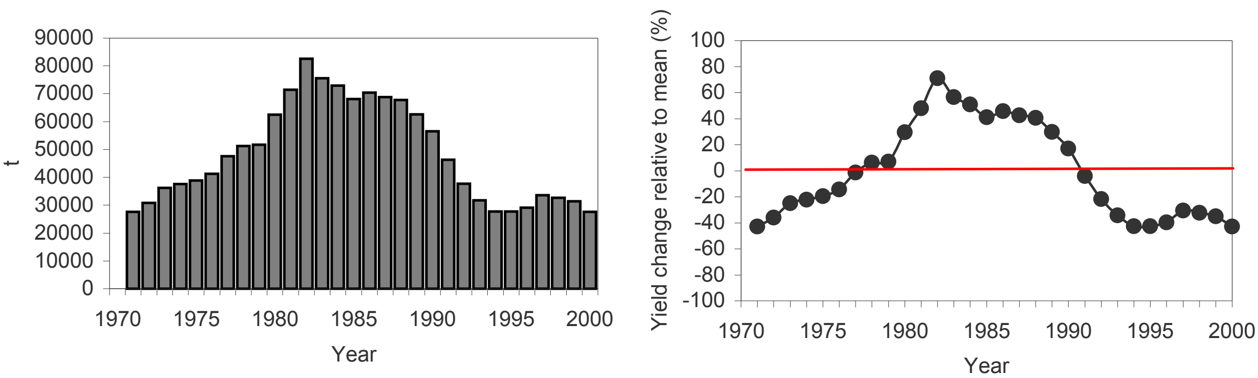


Figure 10. Landing (right) and percentage landing change relative to mean value (left) of *S. pilchardus* from the Adriatic Sea (GFCM Geographical sub-areas 17 and 18, three-year running average). Italian landings from area 18 are not included (see footnote 2).

The high number of species exploited by the demersal fishery characterizes the Adriatic fisheries (as well as Mediterranean fisheries in general) as remarkably multi-specific. The occurrence of many species in the demersal fishery landings would appear to confer a relatively moderate temporal variability to total landing. For instance, in Adriatic GSA 17 the temporal variability of the nominal total landed biomass (CV_t = 13.6) is lower that that of single species or species group landed biomass whose CV_i ranged from 17.7 to 78.9 (Table 4). Total demersal landed biomass variability between periods would be more conservative than single species or species group landings. This aspect of exploited demersal fishery communities has been recently investigated and discussed in detail by Blanchard and Boucher (2001) comparing different areas of the Eastern Atlantic and Mediterranean using both fishery dependent and independent data. Apart from the possible reasons behind this fact, its role with respect to Adriatic demersal fishery production should be taken into consideration. Within the overall exploitation of Adriatic demersal communities the relatively high variability of landed quantities of individual species (or groups of species) determines, within the observed trends, the relative stability of the temporal variation of total landing. This may cause the total landing of the valuable multispecies assemblages to rely on a relatively constant supply even if within decreasing total quantity. This fact, coupled with the rise in prices which maintains the profitability of fisheries, can contribute to promote fishing activity (i.e. effort) thus generating further exploitation (see Irepa, 2003, for detailed analysis of the performance of Italian fisheries).

Table 4. Individual and total coefficient of variation in the landed biomass of demersal resources of the Geographical Sub Area 17 in the Adriatic Sea.

Species	**Geographical Sub-Area 17**	**Species**	**Geographical Sub-Area 17**
Pagellus spp.	78.93	Rajiformes	38.76
Todarodes sagittatus	78.75	Pleuronectiformes	37.29
Parapenaeus longirostris	69.40	*Dicentrarchus labrax*	36.59
Conger conger	64.53	*Nephrops norvegicus*	35.03
Triglidae	60.56	*Micromesistius poutassou*	34.12
Dentex dentex	57.80	Scophthalmidae	34.01
Mustelus spp.	54.36	*Mullus* spp.	31.41
Gobiidae	52.70	*Loligo* spp.	31.22
Sparus aurata	51.04	*Sepia officinalis*	31.00
Boops boops	48.58	*Octopus vulgaris*	29.71
Eledone spp.	44.46	*Oblada melanura*	28.28
Merluccius merluccius	43.56	Scorpaenidae	27.18
Squalidae	40.60	*Solea solea*	26.70
Lophius piscatorius	40.00	Crustacea	22.19
Spicara spp.	39.41	*Squilla mantis*	17.68
		CV tot	**13.64**

3. Fishing fleet

Tentatively, the evolution of Adriatic fishing fleet size, in terms of total number of fishing units as available from various sources, is given in Figure 11. It is possible that in some cases the records concerning small-scale artisanal fishery vessels were inaccurate or incomplete.

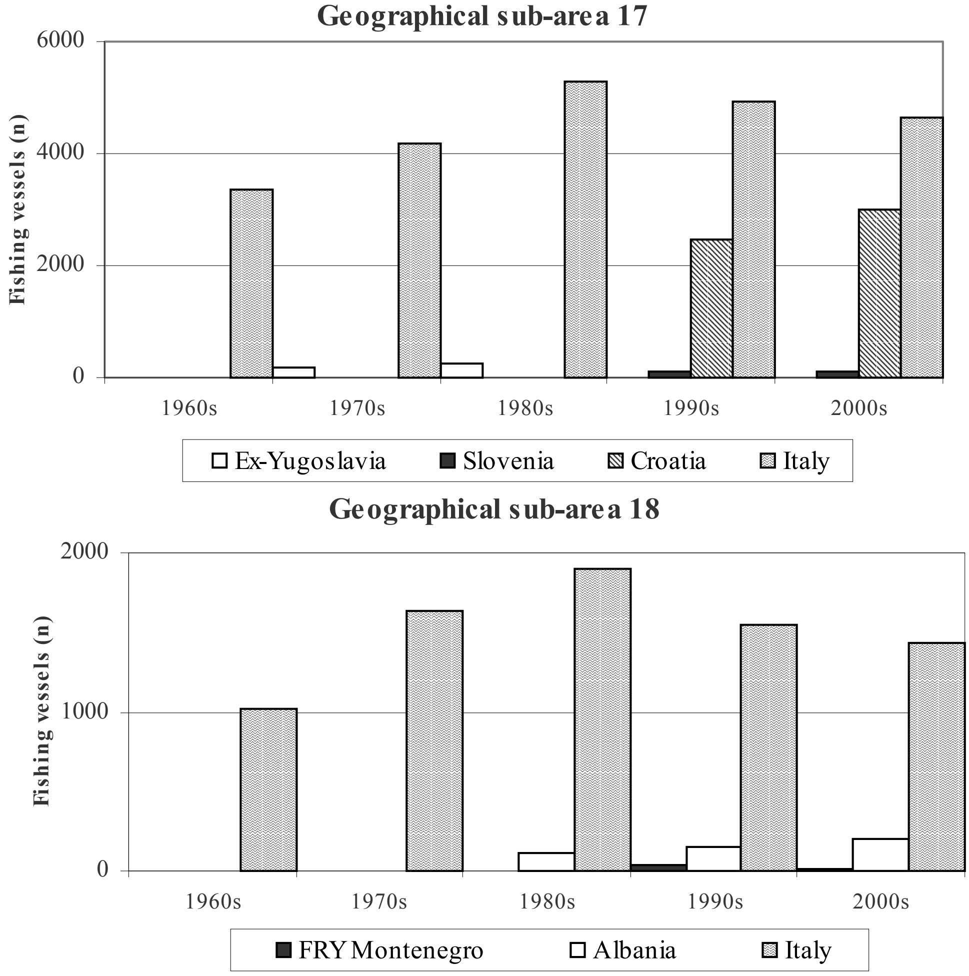


Figure 11. Tentative estimate of the Adriatic fishing fleet evolution in terms of number of units from the 1960s taken from available literature and the AdriaMed database (year 2001). In some cases, data on small-scale fishing fleets are approximate or incomplete. Source: AdriaMed (unpubl.), Breuil (1997), Caddy and Oliver (1996), Dujmušić (2000), Ferretti and Arata (1987), Katavić (2002), Regner (2002), Irepa.

The regional fleet including all fleet segments, i.e. from small-scale fishery vessels to large trawlers reached its maximum numerical size between the 1990s and the year 2000. However, since the 1980s two trends appear to have taken place: the number of fishing vessels has been decreasing along the Italian coast and in Montenegro (in this latter case small-scale fishing vessels were not included) while the opposite can be observed in the cases of Croatia and Albania.

The size of the Adriatic fishing fleet (Albania, Croatia, Italy and Slovenia) in 2001, on the basis of official and semi-official sources, was about 10000 registered/licensed fishing vessels, although the actual number of small artisanal units was certainly under-reported[6]. This is due to the fact that in some countries artisanal fishery is partially recorded or an official census is not taken. Average vessel age of national fleets ranged from about 25 (Italy) to 38 years (Croatia).

At present (as of 2001), the numerical composition of the Adriatic Sea fishing fleet by vessel/gear consists of three main categories made up of fishing units equipped, or permitted to operate, with multiple gears (i.e. polyvalents), passive fixed gears (mostly belonging to small scale fishery) and bottom trawl gear (Figure 12). To some extent the unspecified polyvalent category might be overestimated and consequently others underestimated, as vessels within this group could carry out a specific fishery (e.g. passive gear fishing or small coastal trawling) for a consistent part of the year.

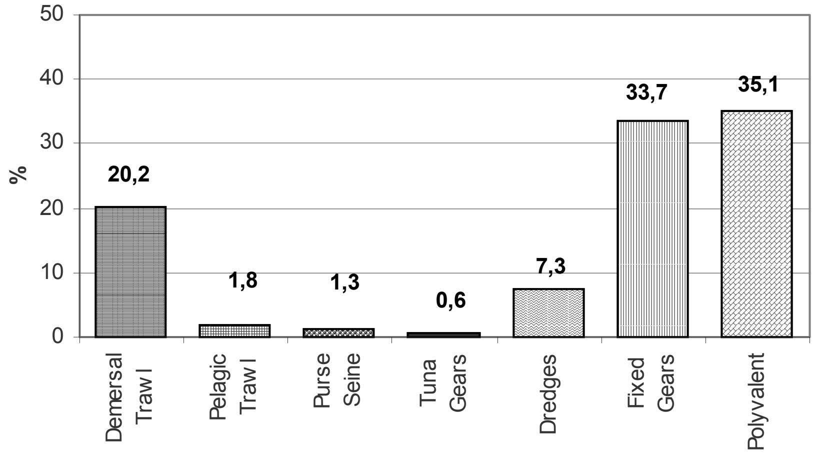


Figure 12. Adriatic Sea fishing fleet composition in 2001 (Albania, Croatia, Italy and Slovenia) expressed as the numerical percentage of vessels by fishing technique category. Source: AdriaMed database compiled in cooperation with the Fisheries Directorates of Albania, Croatia, Italy (through Irepa assistance), and Slovenia.

In terms of fishing capacity, a more indicative insight into the Adriatic fleet is obtained using vessel tonnage (Figure 13). Overall fleet tonnage for the most part resulted as allocated within the demersal trawl category followed by the polyvalent category. Fishing units performing pelagic fishery (mostly small pelagic fishery) ranked third (including both pelagic trawlers and purse seiners).

[6] At the time of the preparation of this paper, national fleet size estimates were being reviewed and updated by the Countries concerned.

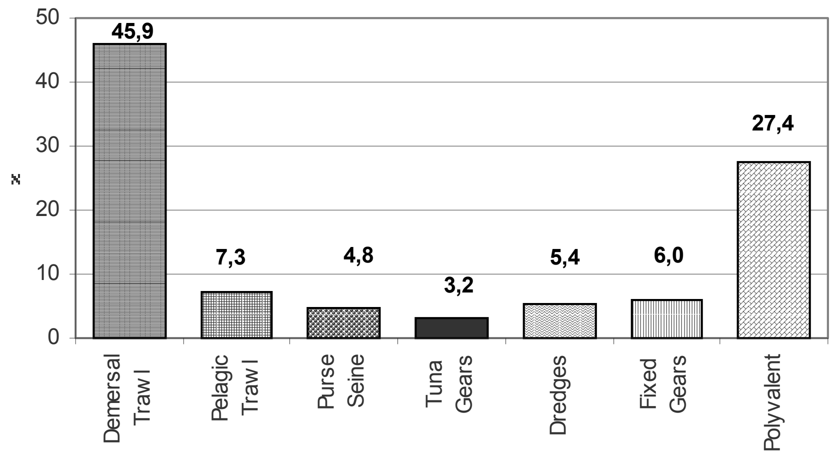


Figure 13. Adriatic Sea fishing fleet composition in 2001 (Albania, Croatia, and Italy) as percentage tonnage (GT) allocation by fishing technique category. Source: AdriaMed database compiled in cooperation with the Fisheries Directorates of Albania, Croatia, and Italy (through assistance from Irepa).

Fishing fleet composition in number by vessel size (length overall, LOA) and fishing gear showed (Figure 14) that most of the small scale fixed gear fishery is performed by small units of less than 12 m (LOA), most polyvalent vessels fall within the small vessel class with only about 20% being within the medium-size vessel category.
Most demersal and pelagic trawlers, purse seiners and tuna vessels belong to the medium-size category (12-24 m LOA) even though they are also present with various percentages in the small vessels segment. Lastly, consistent percentages of pelagic trawlers, tuna vessels, purse seiners and demersal trawlers in decreasing order of occurrence within each vessel/gear group, belong to the large vessels category (length above 24 m).

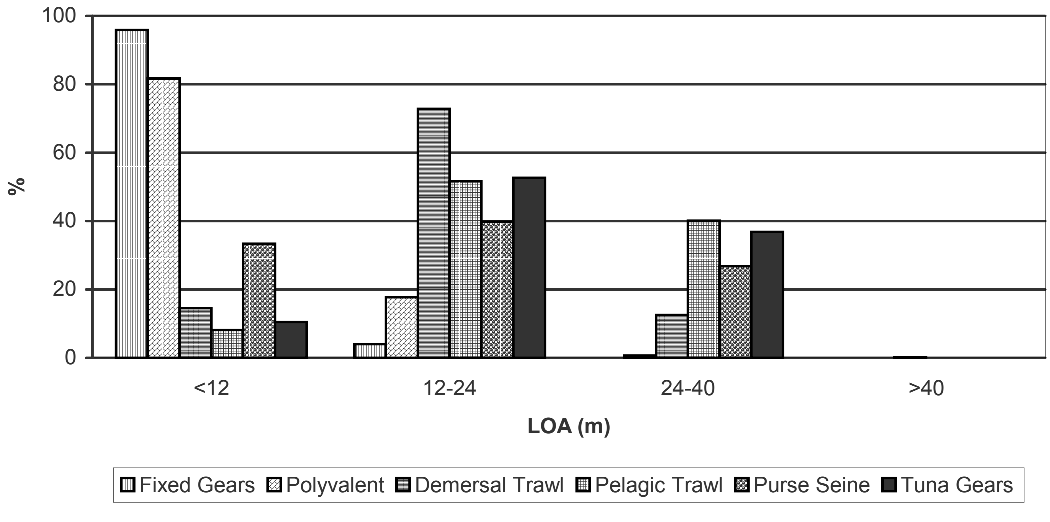


Figure 14. Adriatic fishing vessels numeric distribution in 2001 (Albania, Croatia, Italy and Slovenia) by length class (LOA) and fishing technique category. Source: AdriaMed database compiled in cooperation with the Fisheries Directorates of Albania, Croatia, Italy (through assistance from Irepa), and Slovenia.

4. Some remarks

The Adriatic Sea is probably the largest and the best-defined area of occurrence of shared stocks in the Mediterranean. The main issues related to shared stocks and to the management of their fisheries have been known for a long time. In 1980 Gulland observed with reference to scientific cooperation in research on shared stocks that “The main benefit from international cooperation in research is that it becomes possible to consider all the information concerning a stock of fish wherever it occurs. In the absence of such information it is very easy for a country to misinterpret what is happening to the stock in its EEZ, even when it has good information on everything that is happening in that zone” (Gulland, 1980, p. 8). With reference to the Adriatic Sea fisheries some facts can be pointed out and taken into account for the needs of fishery management planning.

Maximum total landing of both demersal and small pelagic resources was reached in the 1980s. Small pelagic fishery production has been affected by both environmentally induced stock size fluctuations (emphasised to some extent by fishery exploitation) as in the case of the western anchovy fishery and socio-economic factors (most likely combined with low stock size) as in the case of the eastern sardine fishery. Western demersal fishery in terms of landed production fully developed during the 1980s while the eastern demersal fishery has been developing since the 1980s. The western fishing fleet size reached a maximum in terms of number of vessels during the 1980s to start decreasing from the 1990s. The eastern fishing fleets started to increase considerably in the 1980s. Owing to several reasons (e.g. vessel age, available technology, crew skills, land-based services and infrastructures) vessel fishing power and fleet capacity can be assumed to vary widely between national fleets.

The development of Adriatic fisheries, as may be observed from the available landing data time series, seems to some extent to resemble the generalized fishery development model (Grainger and Garcia, 1996) which is composed of four phases: underdeveloped, developing, mature and senescent. This could be particularly the case for demersal fisheries, which are in general less prone to environmentally induced stock size fluctuations. Following Grainger and Garcia’s definition of “meta-fishery” to mean a fishery targeting a species assemblage through an interacting multi-gear fleet in a given area (Grainger and Garcia, 1996), Adriatic demersal meta-fishery would appear to have developed through the 1980s reaching the mature phase in the late 1980s and 1990s to subsequently go through a senescent phase. The impact and sustainability of the overall growth of the demersal trawl fleet (as number of fishing units) in recent times should be closely monitored as it may have led to excessively high exploitation rates particularly affecting some key-species (Ungaro *et al*., 2003).

The state of heavy exploitation of Adriatic fishery resources is evident and for some stocks is critical. It can be noted that several different factors, often interacting simultaneously, have affected Adriatic fisheries. Fishery production dynamics are based not only on resource availability but are also strongly driven by market demand and prices. Socio-economic forces have been observed to be determinant in shaping fishery exploitation patterns. The understanding of any fishery system, and the Adriatic makes no exception, increasingly calls for multidisciplinary analysis; basic reliable fisheries statistics are fundamental and, in the case of Adriatic shared fisheries, should necessarily be comparable and easily integrated.

Recently, management of shared stocks has been the topic of the Government of Norway-FAO Expert Consultation on the Management of Shared Fish Stocks where beyond the biological aspects, the economics of the management of shared stocks was also given relevance (Munro, 2003). The Consultation, while noting that the management of shared fishery resources is one of the great challenges in the pursuit of sustainable fisheries, highlighted the fact that non-cooperative management easily leads to overexploitation. It has to be recognised that management and enforcement of rules are rather obviously more complex for shared fisheries than for non-shared fisheries.

The Code of Conduct for Responsible Fisheries (FAO, 1995; *Article 7.1.3; 7.3.1; 7.3.2; 7.4.6; 12.7*) clearly and unequivocally addresses issues concerning shared stocks, emphasis is given to cooperation among States as an essential and unavoidable requirement for the responsible exploitation of such resources. Nevertheless, cooperative fishery research and, above all, management can be really effective when each part foresees benefits equal or superior to those it would expect in a scenario with no cooperation (FAO, 2002).

5. References

AdriaMed. (2000) Priority Topics Related to Shared Demersal Fishery Resources of the Adriatic Sea. Report of the First Meeting of the AdriaMed Working Group on Shared Demersal Resources. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-02: 21 pp.

AdriaMed. (2001) The Geographical Management Units of the Adriatic Sea. Paper presented at the GFCM-SAC Working Group on Management Units (Alicante, 23rd-25th January 2001). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-02: 12 pp.

Alfirević S. (1981) Contribution a la connaissance des caractéristiques bathymétriques et sédimentologiques de l'Adriatique. *FAO Rapp. Peches/FAO Fish*. Rep., (253): 43-52.

Artegiani, A., Azzolini, R., and Paschini, E. (1981) Seasonal thermocline evolution in the northern and middle Adriatic Sea. *FAO Fish. Rep*., 253: 55-64.

Blanchard, F., and Boucher, J. (2001) Temporal variability of total biomass in harvested communities of demersal fishes. *Fisheries Research*, 49: 283-293.

Bombace, G. (1990) Fisheries of the Adriatic Sea. The Adriatic Sea, Papers presented at the 25th European Marine Biology Symposium, University of Ferrara, pp. 57-67.

Bombace, G. (1993) Ecological and fishing features of the Adriatic Sea. In: K. Sherman, M. A. Lewis, B. D. Gold (eds), Large marine ecosystems: stress, mitigation, sustainability. American Association for the Advancement of Science. Washington DC. pp: 119-136.

Bombace, G., (2001) Influence of climatic changes on stocks, fish species and marine ecosystems in the Mediterranean Sea, *Archo. Oceanogr. Limnol*., 22, pp. 67-72.

Breuil, C. (1997) Les pêches en Méditerranée: elements d'information sur le contexte halieutique et les enjeux économiques de leur aménagement. FAO Circulaire sur les pêches. No. 927. Rome, FAO, 39p.

Buljan M. and Zore-Armanda M. (1976) Oceanographic properties of the Adriatic Sea. *Oceanogr. Mar. Biol*., 14: 11-98.

Buljan, M., and Zore-Armanda, M. (1979) Hydrographic properties of the Adriatic Sea in the period from 1965 through 1970. *Acta Adriatica*, 20(1-2): 1-368.

Caddy, J.F. and Oliver, P. (1996) Some future perspectives for assessment and management of Mediterranean fisheries for demersal and shellfish resources, and small pelagic fish. In: J.F. Caddy (ed.), Resources and environmental issue relevant to Mediterranean fisheries management. *Studies and Reviews. General Fisheries Council for the Mediterranean*. No. 66. Rome, FAO, 19-60.

Cingolani, N., Giannetti, G., and Arneri, E. (1996) Anchovy fisheries in the Adriatic Sea. *Sci. Mar*., 60(Supl. 2), 269-277.

Cingolani, N., Kirkwood, G., Arneri, E., Rousseau, J., Belardinelli, A., Giannetti, G., Santojanni, A., and Barry, C. (1998) Optimal allocation of effort in sampling for age and length from commercial fisheries. Final Project Report to the Commission of the European Communities, EC XIV/95/33, 185 pp.

Cingolani, N., Kirkwood, G., Arneri, E., Santojanni, A., Belardinelli, A., Giannetti, G., Colella S., Donato, F., and Barry, C. (2000) Discards from the Adriatic small pelagic fishery. Final Project Report to the Commission of the European Communities, EU 97/065, IX+439 pp.

Commission of the European Communities. (2002) Communication from the Commission to the Council and the European Parliament -- laying down a Community Action Plan for the conservation and sustainable exploitation of fisheries resources in the Mediterranean Sea under the Common Fisheries Policy. Brussels, 09.10.2002, COM(2002) 535 final, 37p.

Dujmušić, A. (2000) Hrvatsko ribarstvo ispod površine. Zagreb, Rabus media, 215p.

Food and Agriculture Organization of the United Nations (FAO). (1995) Code of Conduct for Responsible Fisheries. Rome, FAO, 41p.

FAO - Fishery Information, Data and Statistics Unit (2001) FISHSTAT Plus, Universal software for fishery statistical time series. FAO Fisheries, Software version 2.3 (available on line at http://www.fao.org/fi/statist/fisoft/fishplus.asp

FAO. (2002) Report of the Norway-FAO Expert Consultation on The Management of Shared Fish Stocks. Bergen, Norway, 7-10 October 2002. *FAO Fisheries Report*. No. 695. Rome, FAO. 2002. 34p.

FAO and UN. (1998) *International Fisheries Instruments with Index*. Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessel on the High Seas. Code of Conduct for Responsible Fisheries. UN. New York. 110p

Ferretti, M., Arata, P. (1988) Evolution technologique de l'effort italien de pêche au chalut dans l'Adriatique au courses des quarante dernières annés. In: Caddy J.F. et M. Savini (eds) Rapport de la cinquième Consultation Technique du Conseil Général des pêches pour la Méditerranée sur l'évaluation des stocks dans l'Adriatique et la mer Ionienne. Bari, Italie, 1-5 Juin 1987. *FAO Rapp. Pêches* 394: 275-278.

Fonda Umani, S., Franco, P., Ghirardelli, E., Malej, A. (1990) Outline of oceanography and the plankton of the Adriatic Sea. The Adriatic Sea, Papers presented at the 25th European Marine Biology Symposium, University of Ferrara, pp. 25-43.

General Fisheries Commission for the Mediterranean (GFCM). (2001) Report of the twenty-six session. Lacco Ameno, Ischia, Italy, 10-13 September 2001. *GFCM Report*. No 26. Rome, FAO, 27p.

GFCM. (2003) Report of the twenty-eight session. Tangiers, Morocco, 14-17 October 2003. *GFCM Report*. No 28. Rome, FAO, 21p.

Grainger, R.J.R, Garcia, S.M. (1996) Chronicles of marine fishery landings (1950-1994): trend analysis and fisheries potential. *FAO Fish. Tech. Pap.,* 359. Rome, FAO. 51 pp.

Gramolini, R., Jukić, S., Mannini, P., Marčeta, B., Osmani, K., Piccinetti, C., Ungaro, N., Vrgoč, N. Distribution of some demersal stocks shared in the Adriatic: GIS representation from MEDITS Programme data. (in press).

Gulland, J.A. (1980) Some problems of the management of shared stocks. *FAO Fish. Tech. Pap.* 206: 22p.

Irepa. (2003) Osservatorio economico sulle strutture produttive della pesca marittima in Italia 2001-2002. Franco Angeli, Milano. 342 pp.

Jukić-Peladić, S. (2001) Development of Responsible Fisheries in Zadar and Sibenik-Knin Counties. World Bank: framework for a Regional Development Vision, October 2001.

Kapedani, E. (2001) Small pelagic fishery and research in Albania. In: Priority topics related to small pelagic fishery resources of the Adriatic Sea. P. Mannini, F. Massa, N. Milone (eds). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents*, 3: 30-38.

Katavić, I. (2002) Status and future of Croatian marine fisheries. Proceedings of the International Conference on Mediterranean Fisheries (Naples, 21-22 June 2002). Naples, 421-428.

Mannini P., Massa F. (2000) Brief overview of Adriatic fisheries landing trends (1972-97). In: F. Massa and P. Mannini (eds), Report of the First Meeting of the AdriaMed Coordination Committee. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-01: 31-49.

Mannini, P., Massa, F., Milone, N. (eds). (2001) Priority Topics Related to Small Pelagic Fishery Resources of the Adriatic Sea. Report of the First Meeting of the AdriaMed Working Group on Small Pelagic Resources. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents,* 3: 92 pp.

Marčeta, B., (2001) Status of Slovene research and fishery on small pelagics. In: Priority topics related to small pelagic fishery resources of the Adriatic Sea. P. Mannini, F. Massa, N. Milone (eds). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents*, 3: 24-29.

Munro, G. (2003) On the management of shared fish stocks. Papers presented at the Norway-FAO Expert Consultation on the Management of Shared Fish Stocks. Bergen, Norway, 7-10 October 2002. *FAO Fisheries Report.* No. 695, Suppl. Rome, FAO.

Regner, S. (2002) Present state and problems in Yugoslav sea fisheries. Proceedings of the International Conference on Mediterranean Fisheries (Naples, 21-22 June 2002). Naples, pp. 451-455.

Sersic, M. (1992) The crisis in the Eastern Adriatic and the Law of the Sea. Ocean Development and International Law, 24: 291-299.

Ungaro, N. Mannini, P., Vrgoč, N. (2003) The biology and stock assessment of *Merluccius merluccius* (L.) in the Adriatic Sea: an historical review by geographical sub-areas. *Acta Adriatica*, 44 (1): 9-20.

The Management of Fishing Capacity: general overview and preliminary considerations in reference to the case of the Adriatic Sea

Dominique F. Gréboval*

Abstract

In 1999, the FAO Committee on Fisheries adopted an International Plan of Action for the Management of Fishing Capacity. The paper briefly presents this new international fisheries instrument and discusses the main issues which would need to be addressed to ensure its implementation. Specific attention is given to measurement aspects, management methods, fleet reduction programmes, high seas fisheries and the need for a comprehensive approach to factors which contribute to overcapacity and unsustainability. The paper concludes that implementation raises important issues that need to be further addressed at national, international and global levels. It also suggests that comprehensive research work on the management of fishing capacity is much needed, especially in relation to the use of alternative policies instruments and management methods.

1. Introduction

The issue of managing fishing capacity was raised formally in 1997 by the FAO Committee on Fisheries (COFI) in reference to growing concern about the spreading phenomenon of excessive fishing inputs and overcapitalization in world fisheries. Work undertaken by FAO on this basis led to the preparation of the International Plan of Action for the Management of Fishing Capacity (FAO, 1998a and 1998b). This International Plan of Action was adopted by COFI in February 1999 (FAO, 1999).
In simple terms, the issue is essentially one of having too many vessels or excessive capacity in a growing number of fisheries. The existence of excessive fishing capacity is largely responsible for the degradation of fishery resources, for the dissipation of food production potential and for significant economic waste. This manifests itself especially in the form of redundant fishing inputs and the overfishing of most valued fish stocks.

Excess fishing capacity affects many domestic fisheries throughout the world and, in an even more pervasive form, many high seas fisheries. The globalization of the phenomenon is illustrated by the relative stagnation of world marine catches of major species since the late 1980s. FAO data indicate that nominal fleet size seems to have peaked during the mid-1990s. However, actual fishing capacity may still be increasing if one takes into account the improvement in efficiency and refitting of older vessels.

*FAO-FIPP. Via delle Terme di Caracalla, 00100 Rome, Italy. Email: dominique.greboval@fao.org

Excessive fishing capacity in world fisheries came about progressively as a result of various factors, such as:

- the effect of the extension of maritime areas under national jurisdiction on private and public investment strategies and of related policies of national exploitation of newly created exclusive economic zones (EEZ), generally accompanied by sizable subsidization programmes;
- the failure of fisheries management in general, and of commonly used management methods in particular, such as total allowable catch (TAC) and other methods which aim essentially at regulating the catch rather than the harvesting capacity itself;
- the relative mobility of harvesting capacity, which allowed for a pervasive spill-over of excess capital among fisheries, both within areas under national jurisdiction and on the high seas;
- the resilient profitability of fishing activities whereby technical progress and relative price inelasticity have largely compensated for diminishing yields in overfished fisheries; and
- the changing nature of the industry, which is increasingly competitive and capital-intensive, with markets that are now largely based on internationally traded commodities.

At the individual fishery level, the origin of excess fishing capacity stems essentially from the widespread tendency of overinvestment and overfishing under open-access conditions. This textbook case of market failure implies a divergence between rational individual investment behavior and societal optimality. It can be noted that imposing various constraints on harvesting patterns (*regulated open-access*) does not significantly change the incentive for overinvestment.
It is also necessary to clearly differentiate 'localized overfishing' from overcapacity. The first is clearly the case of excessive effort being applied to an isolated stock (with fleet size being otherwise judged appropriate); the second, after allowing for possible reallocation, is clearly one of having, throughout the fishing sector or for a large group of fisheries, excessive and redundant harvesting capacity which cannot easily be re-allocated. It is therefore a global problem which takes all its significance at national and international levels rather than at the level of individual, narrowly-defined fisheries. As such, the management of fishing capacity is a broader concern which needs to be addressed within and across various fisheries and jurisdictions.

2. The International Plan of Action

The Code of Conduct for Responsible Fisheries recognized that excessive fishing capacity threatens the world's fishery resources and their ability to provide sustainable catches and benefits to fishers and consumers. In Article 6.3, it is recommended that *"States should prevent overfishing and excess fishing capacity and should implement management measures to ensure that fishing effort*[†] *is commensurate with the productive capacity of the fishery resources and their sustainable utilization"*.

[†] The quote could have referred to fishing effort *and fishing capacity*. This could be misleading as the two concepts are related but different (see Section 4, *infra*).

The International plan of Action for the Management of Fishing Capacity (IPOA) is a voluntary instrument elaborated within the framework of the Code of Conduct for Responsible Fisheries, as an element of fisheries conservation and management. The objective of the IPOA is "*for States and regional fisheries organizations, to achieve worldwide preferably by 2003, but not later than 2005, an efficient, equitable and transparent management of fishing capacity*". The IPOA further specifies that when confronted with an overcapacity problem ("*where capacity is undermining achievement of long-term sustainability outcomes*"), States and regional fisheries organizations (RFOs) should endeavor to limit to the present level and progressively reduce the fishing capacity applied to the fisheries affected. Otherwise, the IPOA calls for States and RFOs to exercise caution to avoid growth in capacity undermining long-term sustainability.
The IPOA implicitly defines fishing capacity in terms of fishing inputs (fleets) and establishes a definite linkage between excessive fleet size and wide-spread overfishing. As such, the IPOA clearly aims at achieving a balance between fleet size (inputs) and sustainable production (output), even if it does not explicitly mention the economic waste implied by an overexpansion of fleet size that may not lead to overfishing.
Management objectives are not stipulated in the IPOA, as the definition of such objectives is clearly a prerogative of States and RFOs. Management objectives can be set with explicit reference to resource sustainability, economic efficiency and precautionary principles. A minimum standard would be to achieve a long term balance between fishing inputs and MSY (or a related target catch level aimed at ensuring sustainable resource use). Even in this context, the IPOA would allow for increased economic efficiency in the form of avoiding redundant fleet expansion beyond the level of fleet capacity required to harvest MSY. While management measures required to manage fishing capacity are not really specified in the IPOA, balancing inputs and outputs clearly requires a direct or indirect control on both fleet size and harvesting capacity.

3. The management of fisheries and of fishing capacity

A fishery can be defined as set of interacting fish stocks and fishing units which can be managed to a large extent as a separate entity - with additional considerations to be given to relevant post harvest aspects. Obviously, the more interactions between stocks on the one hand and the more interactions (actual or potential) between stocks and fishing units on the other hand, the more difficult it will be to isolate and therefore define fisheries as management units. Once fisheries are defined, it is also rather obvious that fisheries management would generally prove much more difficult for multi-species multi-fleet fisheries, such as those of the Adriatic Sea. The definition of management units has been the object of much deliberation in the General Fisheries Commission for the Mediterranean (GFCM). Geographic management units have been adopted (GFCM, 2001) and there is on-going work on the determination of operational units as defined in GFCM (2000), essentially in reference to fleets or fleet segments operating within a geographical management unit). As shown in a study undertaken for the Adriatic (AdriaMed, 2001) much work remains to be done for the effective application of these concepts for fisheries management. Capacity management considerations should add perspective to this question.

Fisheries management involves, *inter alia*, four main types of measures:

- Measures aimed at **enhancing fish stocks**. Among these are measures such as the establishment of protected area (areas permanently or seasonally closed to fishing, e.g. nurseries), mesh size and other gear restrictions, the prohibition of detrimental fishing practices, closed seasons used to protect the stock at critical periods. These measures should essentially aim at preserving and enhancing the stock quite independently of its level of exploitation.

- Measures aimed at **managing effort allocation**, e.g. by limiting the fishing effort applied to a particular stock, when effort can be applied to various stocks. Among these are total catch quotas (TACs) and individual effort quotas. These measures should essentially aim at exerting control on the allocation of effort amongst alternative stocks (forcing effort to reallocate to less exploited stocks) or at restricting fishing on fluctuating stocks that are quite temporarily threatened.

- Measures aimed at **managing fleet configuration** in terms of vessel and gear size. Among these are zones that are reserved for certain fishing units (e.g. small scale fishing), limits imposed on vessel size (such as the limit imposed by some countries in the Mediterranean regarding the length and power of trawlers) and limits imposed on the number or size of gear. These measures are socio-economic in nature and should reflect policy choices, e.g. in terms of preserving small businesses, life style or employment in coastal communities. They imply broader benefits that are not always appreciated and may involve costs (in the form of foregone profits) for the fishing units for which access and/or inputs are restricted.

- Measures aimed at **managing fishing capacity**. These involve the direct or indirect management of fleet size. It could also involve measures aimed at further delimitating fisheries by limiting stock-fleet interactions (e.g. through restrictions imposed on vessels with respect to geographic mobility and the use of multiple gear). Fleet size can be managed in various ways: (a) directly through limited entry schemes applying to the sector and to specific fisheries, (b) indirectly through the economic incentive built into individual transferable quotas (ITQs) or exclusive territorial rights (e.g. concessions for the exploitation of sedentary species), and (c) similarly at collective level, through a duly organized and empowered community of fishers (individuals/enterprises/cooperatives). The buyback of vessels (to reduce excess fleet capacity) and taxation (to reduce the incentive for excessive buildup) may be considered as complementary instruments. Overall these measures should aim at balancing inputs and output at or around some agreed upon target level of exploitation.

All four types of measure will generally be required for proper management and they are actually applied to some extent for fisheries management in the Adriatic (AdriaMed, in prep.). As mentioned above, each category of measures has a clear objective and the four objectives are generally compatible. The management of fishing capacity should therefore be seen as an integral part of fisheries management. This means, *inter alia*, that all other management measures will have to be assessed, or reassessed when introducing measures aimed at managing fishing capacity.

In practice things are not that simple. The management of fishing capacity is essentially about ensuring effective control of access to fisheries. As such, it is politically quite sensitive and in most countries decisions have been delayed long enough for the issue to become even more difficult to address.

Typically, in the early stage of fisheries development, overcapacity is not yet an issue. If overexploitation occurs as a result of excessive effort being applied to a fishery, the excessive effort can be pushed to other fisheries through reallocation measure, such as TACs. Introducing effective measures to manage access is easier at this stage, given the fact that fleet redeployment and some controlled access are still possible.

As fisheries mature, effort starts proving difficult to reallocate; fishing capacity (in the form of fishing effort that could be applied to one or alternative fisheries) become progressively too large for the range of opportunities that exits and start threatening many fisheries. This often occurs in a cascading manner (when a stock is overexploited and brought under effective management, significant fishing effort is transferred to the next most favorable stock, which itself faces progressive overexploitation, etc.). In other words excess capacity starts creeping into the sector. If steps have not been taken earlier, one is now confronted with the problem of introducing measures aimed at controlling capacity in the presence of overcapacity – with a harvesting industry that is often in financial trouble as a result.

A key issue in fisheries management is that, short of being able to introduce an effective control on fishing capacity, fisheries management authorities have started to blur the aim of the four types of measures presented earlier. In other words, measures that are not the most appropriate for that purpose have been used increasingly to constraint fishing capacity or to counteract its impacts irrespective of basic economic considerations. Not only did these fail for the most part, but these measures also contributed to make fisheries management an even greater challenge.

A basic example is the extensive use of TACs in the northern hemisphere, with TACs being used *de facto* not only to control the allocation of available fishing effort among stocks but also to restrict its overall level of use to counter the presence of overcapacity. When TAC limits are effective, this approach results in many fleets being under utilized (meaning added cost). It may also result in excess capacity in land based-facilities, e.g. when processing plants cater for specific fisheries that are closed for a significant part of the year.

Many other measures may be used this way: from limits on vessels and gear or fishing trips that are introduced essentially for the purpose of decreasing capacity; spawning-related seasonal closure that are progressively extended to a large part of the year; and spawning-related area closures that are also progressively extended, sometimes to become actual marine reserves[‡]. The consequences of this approach are many. *Inter alia*, it implies additional economic waste (promotion of economic inefficiency); further delays addressing the management of fishing capacity; fisheries regulations that become difficult to comprehend; and poor compliance.

The above considerations on the use of some management measures should actually be accounted for when defining and measuring fishing capacity. For a given fishery, fishing capacity can be defined as the level of fishing inputs that can be applied by the fleet, **if fully utilized**, or the corresponding catch that can be produce for a given level of stock. An indicator of fishing inputs is required that may be quite simple (e.g. GRT or HP) or more complex (standard fishing days).

Full utilization is understood here as **normal but unrestricted** use, rather than maximum use. For example, if vessel capacity is expressed in terms of fishing effort, fishing capacity can be defined, for a given resource condition, as the amount of fishing effort (e.g. standard fishing days) that a fleet could produce over a period of time (e.g. a year) if the fleet is fully utilized, that is if effort and catch are not constrained by restrictive management measures.

A fishery has been defined earlier as set of interacting fish stocks and fishing units which can be managed to a large extent as a separate entity. Another important consideration for fisheries management is that the four types of management measures which were discussed earlier do not imply a common delimitation of fisheries. This is most relevant to the difficulty of assessing and managing fishing capacity. For example, measures aimed at preserving/enhancing stocks may involve a delimitation of fisheries that is largely based on stocks showing common characteristics and related ecosystem considerations. Measures aimed at controlling effort allocation may involve a definition limited to specific stocks and related fleets. Measures related to protecting a certain mode of production will essentially be based on fleet characteristics.

Measures aimed at managing fishing capacity imply a definition of fisheries that fully accounts for main stocks-fleets interactions. At this level, a major difficulty is that these interactions are themselves the result of policy decisions. In an unregulated fisheries sector, stocks/fleets interactions will be determined by biological, technical and financial characteristics. Regulations introduced to manage fisheries may increase such interactions, e.g. when fishing effort is pushed around through TACs and other seasonal restrictions on access to specific stocks, leading for example to the proliferation of multi-purpose fishing boats. Other regulations may limit interactions, e.g. restrictions imposed on geographic mobility and access to specific stocks through gear or landing restrictions.
These considerations imply that the management of fishing capacity would not only account for existing interactions (looking at ways to balance inputs and output in each so-delimitated fishery) but that it is also quite likely to aim, at least initially, at controlling some of theses interactions and therefore at redefining fisheries as management units.

[‡] In the sense of marine reserve for fisheries management, as opposed to marine reserves aimed at protecting coastal environment and biodiversity.

4. The assessment of fishing capacity

The IPOA calls for States and RFOs to monitor and assess fishing capacity. It also calls for States to establish compatible national records of fishing vessels and to support the establishment by FAO of an international record of vessels operating on the high seas - awaiting the entry into force of the FAO Compliance Agreement (FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas).

The measurement and monitoring of excess fishing capacity is a complex endeavor. For a well-delimitated **simple** fishery, assessing fishing capacity requires estimating:

- the level of physical fishing inputs, e.g. effort (E), that is actually applied in the fishery by the existing fleet (V); and the corresponding production (C) given present stock size (S) ;

- the level of physical fishing inputs (e.g. potential effort PE) that could be applied in the fishery if the existing fleet was fully utilized; and the corresponding production (PC) given present stock size;

- the short-term target level of physical fishing inputs (E*) that should be applied in the fishery to achieve a short term production objective C* (e.g. a TAC aimed to stock recovery towards a long term stock target S**); short term target fleet size V* can also be estimated on this basis assuming full utilization;

- the long-term target level of physical fishing inputs (PE**) and the corresponding fleet size (V**) that could be applied sustainably in the fishery to achieve a given long term production objective C**

Overall the assessment may show several situations:

- an undesirably low level of **capacity utilization** (sometimes referred to as **excess capacity**): if PE is significantly greater than E, reflecting the impact of direct or indirect limitations on fishing activity;

- signs of **overexploitation**: if E is significantly greater than E* and even more so if PE is also significantly greater than E;

- signs of **overcapacity**: if the existing fleet (V) is greater than what it should be in the long term (V**), or if the existing fleet V is significantly greater than what it should be in the short term (V*) with a low probability of fast stock recovery.

Assessing excess capacity thus requires: a relevant delimitation of the fisheries, the selection of fleet/input indicators, some information on the status of the stocks under consideration and the definition of target exploitation levels. A range of target levels (or reference points) have been discussed in the literature, in reference to biological, economic and social concerns, as well as in reference to precautionary principle and specific fisheries (Caddy and Mahon, 1995). Present methods of capacity assessment have been relatively empirical (FAO, 2000). These are usually sufficient to estimate grossly the magnitude of excess fishing capacity, even if applied research is still required for the development of more appropriate monitoring and assessment tools.

In simple fisheries a quantitative assessment can explicitly account for the existing and potential interaction between inputs (fleet and effort) and a stock. In multi-fleet multi-species fisheries such an assessment may prove difficult to conduct (especially because the relationship between potential effort and potential catch become quite intractable). In this case, and for the case of Adriatic fisheries in general, it may be preferable to look somewhat separately at fleet and stocks.
A simple step-by-step approach combining specific investigations and expert opinion can indeed be used as follows:

1. Select two reference years (RYs) for which vessel, catch, and catch rate data are available: one being representative of the present situation (e.g. underutilization in many fleet segments and/or many stocks show signs of overexploitation) and one that is representative of a situation judged in line with more sustainable outcome (fair level of utilization, most stocks in relatively healthy condition).
2. Assess present level of utilization in selected segment of the fleet (e.g. through case studies) and its likely evolution between RYs (e.g. through interviews);
3. Estimate fleet size (e.g. in GRT or HP) for RYs, if possible by main fleet segments and its likely evolution between RYs;
4. Assess the impact of technological change over time, so as to be able to compare the relative efficiency of the indicator of fleet size in both RYs;
5. Assess the status of exploitation of main stocks for both RYs (using results of stock assessment work) as well as complementary indicators such as revenue per vessel (e.g. value of catch in RYs using a constant base-price for all species);
6. Use all available information to estimate the required decrease in fishing effort by stock or groups of stocks (in reference to agreed upon reference points);
7. Use all available information to estimate the required decrease in fishing capacity, in general and when possible in reference to major fleet segments.

An important challenge to the monitoring and assessment of fishing capacity is the lack of fleet data. But even if fleet data are available, a significant departure from present monitoring procedures is required for the purpose of assessing and managing fishing capacity.
Typically, most countries still monitor inputs and outputs in a rather disjointed manner. For example, inputs and outputs may be monitored as follows:

- A record of vessels (register) is established at national level with vessel data that may include the physical characteristics of the vessel (length, tonnage, HP, etc.) as well as information such as year built, year of first operation in the area/fishery, port of operation;

- Key economic indicators, including vessel cost, crew size, annual catch and revenue could also be gathered for each vessel;

- Complementary landing and marketing data are obtained, generally at port level;

- Catch-effort data are gathered selectively for the purpose of stock assessment, to complement the direct monitoring of stock conditions.

This approach does not easily allow for the assessment of fleets-stocks interactions and for the management of fleet capacity in general. A more precise knowledge of fleet dynamics would be required for the management of fishing capacity and for fisheries management in general.

In addition to monitoring the physical characteristics of vessels through an appropriate register, **fleet assessment** would involve looking in particular at the dynamics of fleets in terms of: (i) inter-year fleet adjustments: investment-disinvestment by fleet segment; improvement of technology and harvesting efficiency; capacity utilization; pattern of gear use; pattern in targeting specific stocks or groups of stocks; and (ii) within year fleet deployment: allocation of fishing inputs (vessels, gear and effort) in time and space, and especially among fisheries[§].

As such, fleet assessment should be considered to be as important as stock assessment. We are very far from this situation, even though both types of assessment are essential. Enhanced fleet monitoring and assessment capabilities should be developed not only at national level, but at regional and global levels, with due emphasis being given to creating appropriate fleet records and to addressing the issue of fleet mobility.

5. Capacity management methods

The management of fleet capacity involves the control of fleet size, with due consideration being given to the level of capacity utilization (Cunningham and Gréboval, 2001). Basically this can be done only in two ways: through central command mechanisms and through a mixed system of central command and economic incentives. Capacity management methods may indeed be classified in two groups: (i) those which attempt to block the incentive of open-access which leads fishers to race for fish and to overextend their investment -*incentive blocking methods*; and (ii) those aiming at changing the incentive system itself -*incentive adjusting methods* (Gréboval and Munro, 1999).

A central command approach will rely essentially on **limited entry schemes**. In this context the central authority decides on the number of vessels that will be authorized to fish. Licenses will usually be given to a specific vessel for use in relation to one or several specific gears. Attached to the license may be restrictions on the area in which the fishing unit can operate as well as restrictions on the transfer of the license to another vessel. Limited entry schemes are generally implemented in connection with other management measures such as those aimed at effort allocation.

The efficiency of this method has often been limited in the past by the conditions under which it has been implemented, such as: introduction of such schemes in already mature or

[§] When catch-effort data are gathered systematically for all vessels (or a representative sample), data can actually be used both for stock assessment (data processing based on the catch of selected species) and for fleet assessment (data processing based on vessel operation of selected fleet segments).

overexploited fisheries with rather unrestrictive conditions for initial license allocation; insufficient attention paid to input substitution possibilities; insufficient account taken of gains in productivity resulting from technological improvements; and, too often, implementation against a sectoral policy background of laissez-faire, subsidization and of prompt compromise on socially or politically sensitive aspects.
It is felt that when these issues are carefully addressed, license limitation schemes can prove relatively effective in managing fishing capacity. In this context, one may stress nevertheless the need to address carefully input substitution and the impact of technological development on fishing capacity. Interestingly enough, license limitation may take many of the attributes of incentive adjusting schemes. This is the case, for example, whenever the implementation of license schemes purposely leads fishermen to coalesce, rather than compete. Examples exist of fishers' organizations buying back vessels or temporary limiting the utilization of the fleet (to help a stock recover or to manage the capacity applied to highly fluctuating stocks).

The indirect control of fleet size at individual (firm/enterprise) level can be achieved through the economic incentive built into **individual transferable quotas** (ITQs), with each individual deciding how to optimally harvest his quota. In principle it can be expected that the level of capacity used will be optimal, at least in the long term. A similar case can be made for **exclusive territorial rights** (e.g. concessions for the exploitation of sedentary species), under the assumption that the sole owner will face similar incentives. Both measures are of course applicable only under certain conditions.

The direct or indirect control of fleet size can be exercised similarly at collective level, through some form of **co-management** involving small-scale fishing communities or specific segments of the fishing industry. At collective level, the control of fleet size can be exercised (a) on a territorial basis, e.g. through a port-based fishermen organization managing the fleet within a given capacity quota and related limitations; (b) on a fleet basis, e.g. through an organization of trawl fishermen managing the fleet within similar constraints; or (c) on a stock basis, e.g. through a fishermen organization representing the fleet which exploits a particular stock within a given catch quota. The three approaches are not necessarily exclusive, e.g. approach (a) and (c) can be used simultaneously. It should also be noted that if applied by itself, approach (c) will only have an indirect impact on capacity if used in a rather specialized fishery or if all major fisheries can be managed through quotas. In all cases, co-management can only be exercised by a duly organized community of fishers (individuals/enterprises/cooperatives), duly empowered and receiving support and overall guidance (e.g. setting quotas) from the central fisheries management authority.

For co-management to be effective in this context, schemes must therefore imply a certain degree of empowerment, exclusivity and collective cohesion. Schemes must also specify clearly the respective role and responsibilities (i) of the central fisheries management agency, in particular regarding the way overall limits are set and adhered to; and (ii) of the fishermen organizations and (iii) of the fishers involved in collective action.

The management of capacity does require the adoption of policies which clearly specify access conditions. Rent extraction through the imposition of royalties has also been proposed as a means of controlling capacity. It remains difficult to apply, especially when entry

conditions are such that profitability is very much reduced. Nevertheless it can still prove an interesting tool for capacity management, e.g. in the case of a co-managed fishery as a way to finance effective management. While much experience has been gained over the years in the application of limited entry and ITQ schemes, other schemes based on territorial rights and co-management are less commonly used and still insufficiently researched.
Overall, the elaboration and implementation of more appropriate management schemes require that extensive consultation with stakeholders be promoted so as to ensure maximum consensus on capacity management among various user groups. Indeed, the available methods for controlling fishing capacity imply strictly controlled and rather exclusive access and a direct or indirect control of both inputs and output. Getting around such controls might involve, *inter alia*, under-reporting of catch and/or fishing inputs, illegal fishing practices, and the partial reallocation of fleet capacity to other fisheries. There are a number of steps that can be taken to avoid undesirable reactions to management, such as:

- adopting improved monitoring, control and surveillance (MCS) methods, such as vessel monitoring systems (VMS;
- opting for capacity management methods that do provide a real incentive for long term sustainability;
- promoting enhanced industry participation in each management scheme, eventually aiming at the co-management of specific fisheries;
- establishing clearer responsibilities and answerability in the management of any fishery; and
- ensuring a greater compatibility between the management of fishing capacity, the management of fisheries and the management of the industry as a whole.

6. Fleet reduction programmes

The reduction of excess capacity implies disposal of vessels and the layoff of fishers. Within areas under national jurisdiction, capacity which cannot be re-allocated to underused resources would have to be left to depreciate, to be scrapped or exported. Obviously, in countries where re-allocation possibilities have been exhausted, capacity adjustment is a rather difficult and sensitive task. Capital depreciation would generally involve too slow a joint process of capital reduction and fish stock rebuilding. Thus some induced capital reduction would generally be called for, with specific accompanying measures for labor reduction, when required.

Incentive adjusting schemes involving property rights, such as ITQs, do provide strong incentive for capacity adjustment but not necessarily for the permanent disposal of redundant vessels. In this context some form of buybacks may speed up or facilitate the adjustment process. Incentive blocking schemes, such as license limitation, do not provide such incentive and buyback schemes may be used to reduce fleet size. However buyback programmes may not be very efficient when implemented within such management frameworks. For example, the buyback of older boats can be more than compensated in terms of fishing capacity by the 'creeping' net increase in capacity which may occur in the process of subsequent fleet modernization. In other words, license limitation has to be very tight for buybacks to be

efficient. As noted by Holland et al. (1999), there are also other reasons why caution should be exercised when designing and implementing any buyback programmes.
Under rights-based management schemes, the internalization of the potential rent[**] should make it possible for the industry and the management authority to find arrangements to finance buyback schemes. Cost sharing mechanisms to undertake vessel reallocation or scrapping should preferably be negotiated when introducing schemes aiming at effectively controlling capacity. In any case both sides would need to be convinced that capacity will be controlled effectively, meaning that potential rent really will be transformed into actual rent.

If the industry may be expected to participate in the cost of downward capacity adjustments, it is also likely that capacity reduction schemes would involve significant subsidies. A trend in this direction is already observed. These subsidies could be considered as subsidies to the 'resource' and its sustainability. But if these subsidies failed to have a lasting impact on fishing capacity, these would amount to subsidies to the harvesting industry.

A related problem is that of vessel disposal. Short of scrapping vessels that are considered redundant from a national perspective, capacity reduction schemes may induce transfer to the high seas (e.g. outside the Adriatic Sea) or to the EEZs of other nations. The transfer of excess capacity to the EEZs of other nations may be undertaken through private sales of used vessels or in the context of international access agreements. Regarding such transfers, the IPOA only calls for States to ensure that no transfer of capacity to the jurisdiction of another State should be carried out without the express consent and authorization of that State.

This may seem insufficient in view of the impact that capacity reallocation could have on the management of capacity in developing countries. Developing countries have benefited from the possibility of acquiring cheap second-hand vessels originating from efforts aimed at reducing harvesting capacity or from fleet modernization schemes undertaken in developed countries. But the massive disposal of generally subsidized used vessels also had negative impacts in these countries: distorting input prices; exacerbating conflicts with the small-scale sector; and precipitating the rapid build-up of excessive capacity in many fisheries. The transfer of excess capacity may also take place in the context of international access agreements. While access agreements are negotiated among sovereign States, one notes, however, that such transfers are often subsidized and may involve developing countries that could be induced to compromise easily between immediate returns and long-term resource sustainability. A code of good practice may be required to ensure more cautious transfers and to facilitate the negotiation of more appropriate access agreements (WWF, 1999).

[**] In fisheries, the resource rent can be defined as the net benefits that can be derived from limiting exploitation at a certain level. In financial terms (the view point of the fishing firm), it takes the form of above normal profits (over the 'normal' profits that could have been expected from similar, relatively risky, investment). Under open access, the rent is typically dissipated (any above normal profits being an incitation for more investment and therefore a greater level of exploitation. Under rights-based management (including limited entry if transferable licenses have been effectively introduced) the rent that could be produced in the future is internalized, as expressed by the value of the ITQ or of the licence. The rent can be left entirely to the industry or shared with the rest of society in the form of royalties or of participation to management cost.

The transfer of excess capacity to the high seas will be easier as it does not involve negotiating international agreements. The IPOA recalled the duties of flag States to avoid approving such a transfer to areas where it would be inconsistent with responsible fishing under the Code of Conduct. Furthermore, in recognition of any eventual change of flag, the IPOA also stressed in Article 20 the need to deal with the problem of States which do not fulfill their responsibilities as flag States.

Appropriate capacity reduction is central to the successful implementation of the IPOA. Poor implementation in terms of non-lasting reduction and undesirable transfer may actually aggravate the overcapacity problem and contribute to illegal, unregulated and unreported (IUU) fishing. A major challenge is for States to ensure that reduction schemes be promoted only when effective control of capacity has been duly achieved. Another is for States to control the export or transfer of capacity outside their jurisdiction and to adopt mechanisms that would selectively prevent any transfers to fisheries and areas recognized as significantly overfished.

7. High seas fisheries

Given that GFCM members have not declared an EEZ for the Mediterranean, a significant portion of the fishing activity takes place in high seas. However, with the noticeable exception of the tuna fleet, most fishing fleets show limited geographic mobility. This allows for the fisheries of many of geographic management units adopted by the GFCM (GFCM, 2001) to be managed to a large extent on a national basis (e.g. in geographic units such as the Golf of Lions or the South and Central Tyrrhenian Sea). The case of the two geographic management units of the Adriatic is different in the sense that it involves a significantly greater interaction between national fleets. The need for extensive international cooperation is therefore more important in terms of dealing with fisheries based on shared and straddling stocks. The following remarks are rather general and some pertain in particular to tuna fisheries.

The management of fishing capacity in the high seas does remain a challenge under existing international law. The IPOA urges States to participate in international agreements which relate to the management of fishing capacity and in particular the FAO Compliance Agreement and the 1995 UN Fish Stocks Agreement. It also calls for various measures which would strengthen international collaboration and the role of regional fisheries organizations vis à vis the management of shared stocks and high seas fisheries.

High seas fisheries may be confronted with an even greater overcapitalization problem than EEZ fisheries. This stems from the prevalence of rather open-access conditions, with coastal countries fishing increasingly in adjacent high seas areas, and from the fact that there are at present no internationally agreed measures to oblige States to control fishing capacity. Within the present legal framework of the high seas, contained in the 1982 UN Convention on the Law of the Sea, the management of capacity is very much subsumed within a catch quota system, with the regional fishery organizations administering quotas being largely unable to limit access by vessels of participating States and to deny access to vessels from non-participating States.

The 1995 UN Fish Stocks Agreement does not specifically include provisions for reducing fleet capacity. However, it tightens the obligations of flag States to adhere to conservation and management measures imposed by regional fishery organizations and allows these organizations to monitor fleet capacity and deployment better, and to adjust limit reference points in order to account for fishing capacity considerations. Furthermore The FAO Compliance Agreement provides a mechanism for collating fleet information at global level and a basic tool for compliance and enforcement of authorizations. The IPOA recalled that improved management of the high seas requires first and foremost the urgent ratification of these agreements.
The IPOA also recommends, *inter alia*, that States:

- take steps to manage the fishing capacity of their vessels involved in high seas fisheries and cooperate as appropriate with other States in reducing the fishing capacity applied to overfished fisheries;
- recognize the need to deal with the problem of those States which do not fulfill their responsibilities under international law as flag States with respect to their fishing vessels, and in particular those which do not effectively exercise their jurisdiction and control over vessels which operate in a manner that contravenes or undermines international law and international conservation and management measures;
- support multilateral cooperation to ensure that these flag States contribute to regional efforts to manage fishing capacity;
- ensure that no transfer of capacity to the jurisdiction of another State be carried out without the express consent and formal authorization of that State; and
- avoid approving the transfer of vessels carrying their flag to high seas areas where such transfers are inconsistent with responsible fishing under the Code of Conduct.

More specific measures need to be adopted at national, international and global levels to ensure active implementation of these rather general principles. In relation to the management of fleet capacity, this may involve, *inter alia*, defining more specific conditions for: entry and participation in the fishery sector and specific fisheries; the implementation of fleet reduction programmes; access to high seas fisheries by flag vessels. Further steps may be required in the strengthening and empowerment of regional fishery organizations, the creation of new organizations to ensure full coverage of the resources concerned, and in encouraging non-members to become member of such organizations.

8. Factors of unsustainability

The IPOA recognizes that several factors do contribute to overcapacity and unsustainable exploitation of fisheries resources. In the elaboration of national plans, the IPOA urges States to assess, reduce and progressively eliminate all factors, including subsidies and economic incentives, contributing directly or indirectly to the build-up of excessive capacity. A complementary recommendation called for FAO to assist with: *a further analysis aimed at*

identifying factors contributing to overcapacity such as, inter alia, lack of input and output control, unsustainable fishery management methods and subsidies which contribute to overcapacity.
Some of these factors relate to the resilient prevalence of open access conditions, in spite of management efforts deployed to limit harvesting behavior. The lack of appropriate conditions for entry and participation, linked to the direct or indirect control of both inputs and output would thus appear to be the principal factor of unsustainability and overcapacity. Other factors appear to be secondary.

Among these factors is the difficulty of implementing fishery-specific management schemes, even if theoretically appropriate. This is especially the case when the incentive to circumvent regulations remains strong and if industry involvement remains ineffective. The present inefficiency of many MCS systems is another factor which may be addressed, directly or by adopting fishery management schemes that are more efficient in terms of incentive and industry participation. The growing imbalance between the demand and the necessarily limited supply of fish, as well as other factors affecting inputs and outputs prices may also play an important role in promoting undesired capacity expansion and unsustainability.

One such factor is the use of subsidies and other economic and fiscal incentives which have a direct bearing on fishing capacity. There is no doubt that heavy subsidization contributed substantially to the rapid and often excessive growth of the fishing fleets in the 1970s and 1980s. Although this remains insufficiently documented, subsidization programmes appear to have been significantly reduced in many countries since the late 1980s. The IPOA recommended that States endeavor to reduce and progressively eliminate subsidies that directly or indirectly promote overcapacity. Work is presently underway in FAO, in collaboration with WTO, to address this issue further by identifying the types of subsidies that contribute either to overcapacity and unsustainability or to trade distortion. This suggests that subsidies, when required in a fishery or sectoral development context, could be shifted from conventional capital to the promotion of resource conservation, human skills and institutional development. As pointed out before, it is likely that subsidies will be used increasingly to reallocate or reduce fishing capacity. Experiences in this area tend to indicate that insufficient caution is usually exercised regarding the conditions under which such schemes are implemented.

9. Conclusions

The adoption of the IPOA on the Management of Fishing Capacity is symptomatic of a radical evolution by which key elements of fisheries governance are being addressed at international and global levels, in reference to the guiding principles of the FAO Code of Conduct for Responsible Fisheries. The strengthening of fisheries governance is indeed increasingly recognized by Nations as a basic requirement for the sustainable and responsible use of fishery resources. The adoption of the IPOA is also a strong sign that increasing attention is paid to the economics of fisheries and that related policies issues are being consequently reassessed.

The management of fishing capacity raises a key issue: that of the joint control of fishing inputs and outputs - independently of which component is selected will be the prominent control variable. Excess capacity is indeed the symptom of an underlying limitation of 'conventional' fisheries management. The management of fishing capacity can only point to new avenues which directly address the conditions of entry and participation in fisheries. These are likely to be based on two emerging and related notions, that of right-based management schemes and that of active industry participation. Meanwhile related issues pertaining in particular to the reduction of fishing capacity (transition strategies) and fleet mobility will remain areas of specific concern. Applied research is much needed in these areas.

The management of fishing capacity may also benefit from: the adoption of more specific conditions for access to high seas fisheries by flag vessels; the strengthening and empowerment of regional fishery organizations; the creation of new organizations to ensure full coverage of the resources concerned; strengthened mechanisms to encourage non-members to become member of such organizations; and more effective donor support to the implementation of the IPOA and similar international agreements by developing countries.

10. References

AdriaMed. (2001) A preliminary contribution to the Mediterranean Operational Units. Paper presented at the GFCM-SAC Working Group on Operational Units (Ancona, 18th -19th March 2001). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-04: 9 pp. (also available at www.faoadriamed.org/html/av_documents.asp).

AdriaMed. Review of Fisheries Legislations and Regulations in the AdriaMed Countries. AdriaMed Project. Rome, FAO. (in preparation)

Alverton, D.L., and Dunlop. (1998) Status of world fish stocks. Fisheries Research Institute, University of Washington. FRI-UW-9814.

Caddy, J. and Mahon. (1995) Reference points for fisheries management. *FAO Fisheries Report*. No 347. Rome, FAO. 83 pp.

Cunningham, S. and Gréboval, D. (2001) Managing Fishing Capacity: A Review of Policy and Technical Issues. *FAO Fisheries Technical Paper*. No 409. Rome, FAO. 60 pp.

Food and Agriculture Organization (FAO). (1998a) Report of the technical Working Group on the management of fishing capacity, La Jolla, USA, 15-18 April 1998. *FAO Fisheries Report.* No. 586. Rome, FAO.

FAO. (1998b) Report of the consultation on the management of fishing capacity, shark fisheries and incidental catch of seabirds in longline fisheries, Rome 26-30 October 1998. *FAO Fisheries Report*. No. 593. Rome, FAO.

FAO. (1999) International Plan of Action for reducing incidental catch of seabirds in longline fisheries. International Plan of Action for the conservation and management of sharks. International Plan of Action for the management of fishing capacity. Rome, FAO. 26 pp.

FAO. (2000) Report of the Technical Consultation on the Measurement of Fishing Capacity. Mexico City, Mexico, 29 November to 3 December 1999. *FAO Fisheries Report*. No. 615. Rome, FAO.

General Fisheries Commission for the Mediterranean (GFCM). (2000) Report of the twenty-fifth session. *GFCM Report* No 25. Rome, FAO. 27 pp.

GFCM. (2001). Report of the twenty-sixth session. *GFCM Report* No 26. Rome, FAO. 27 pp.

Gréboval, D., and Munro, G. (1999) Overcapitalization and excess capacity in world fisheries: underlying economics and methods of control. In: Managing Fishing Capacity: Selected papers on underlying concepts and issues. *FAO Fisheries Technical Paper.* No. 386. Rome, FAO.

Holland, D., Gudmundsson, E., and Gates, J. (1999) Do fishing vessel buyback programs work: a survey of the evidence. *Marine Policy* 23 (1): 47-69.

World Wildlife Fund (WWF). (1999) Report of WWF expert workshop on developing a model fishery resources access agreement, Rome, Italy, November 8-10, 1999.

A framework for capacity appraisal in fisheries

Sean Pascoe[1]

Abstract

The need for effective management of fishing capacity has been highlighted in recent years following the realization that many of the world's major fishing resources are overexploited. In order to manage fishing capacity, managers need to first establish the level of any overcapacity that may exist in individual fisheries. This requires an estimate of the current level of fishing capacity as well as the target, or desired, level of fishing capacity. The latter will largely depend on the objectives of management, which may vary from fishery to fishery. In this paper, a framework for assessing the extent of overcapacity in fisheries is presented. The framework consists of several steps – monitoring; assessment of existing capacity; assessment of target capacity; and, finally, assessment of overcapacity.

1. Background

Many of the major fishery resources of the world are currently being exploited by an excess number of vessels, and are in a state of decline due to over-fishing. About 50 per cent of stocks are fully exploited and are, therefore, producing catches that have either reached or are very close to their maximum limits, with no room expected for further expansion. Another 15 to 18 per cent are overexploited and are in a state of decline. A further 10 per cent of stocks have been depleted or are recovering from depletion (FAO 2000).

Within Europe, most fisheries are currently both biologically and economically overexploited. Reductions in TACs in excess of 50 per cent have been imposed for many stocks in 2002, with most other stocks subject to TAC reductions of between 10 and 30 per cent (DG Fish 2001). Removal of excess capacity is necessary to ensure the longer-term sustainability of the stocks, and to improve the economic performance of the fleet. DG Fish (2000) estimate that, in 2000, there was more than 40 per cent overcapacity in the EU fleet as a whole.

As a result of the relatively poor state of many world fisheries, the effective management of fishing capacity has become a major issue internationally. The management of capacity requires several key elements – a means to assess the current level of capacity, a means to identify the desired level of capacity (i.e. target capacity), and a mechanism to move from the current situation to the desired situation.

The objective of this paper is to outline a framework for assessing current and target capacity in fisheries. The first section will review the basic definitions underlying capacity estimation.

[1] Centre for the Economics and Management of Aquatic Resources (CEMARE), University of Portsmouth, Locksway Road, Southsea PO4 8JF, UK. Email: sean.pascoe@port.ac.uk

A framework for assessing capacity is presented, involving monitoring and the estimation of current and target levels of capacity. A number of methods for estimating output-based measures of capacity are outlined, and the use of bioeconomic modeling is proposed as a means to identify target levels of capacity.

2. Definitions and problems of over capacity and capacity under-utilization

In December 1999, a Technical Consultation on the Measurement of Fishing Capacity was held in Mexico City to define capacity and develop methods for measuring and assessing fishing capacity (FAO 2000). During the meeting, definitions of capacity were developed along with a range of methods for estimating capacity. Fishing capacity was subsequently defined as: *the amount of fish (or fishing effort) that can be produced over a period of time (e.g. a year or a fishing season) by a vessel or a fleet if fully utilized and for a given resource condition.* Full utilization in this context means normal, but unrestricted use, rather than some physical or engineering maximum.

From the above definition, capacity can be expressed in terms of inputs (e.g. potential fishing effort) or outputs (e.g. potential catch). These measures are not equivalent except under certain conditions that rarely hold in fisheries.[2]

A measure that has recently gained increase use in fisheries is *capacity utilization*. This is primarily and output based measure, determined as the ratio of the current output or level of fishing effort to the potential output or level of effort under normal working conditions. A similar input based measure could be defined as the ratio of current fishing effort to potential fishing effort, again assuming normal working practices and given the state of the resource.

Capacity under-utilization is an indicator of potential future problems in the fishery, as will be outlined in more detail below. The existence of capacity under-utilization may imply the existence of excess capacity.[3] That is, the existing level of capacity is greater than that required to harvest the resource at the current level. Both capacity utilization and excess capacity are short run concepts only, as under different circumstances (e.g. a recovered stock), the existing fleet size may be fully required to harvest the resource at the optimal level.

Changes in capacity utilization over time can provide information on the effectiveness of management in controlling fishing capacity. Declining capacity utilization may indicate that

[2] Equivalence between input and output based measures of capacity requires the existence of a perfectly linear relationship between the level of inputs and the level of outputs (e.g. $C=qEB$). That is, doubling the level of all inputs would double the level of outputs. In most fisheries, this relationship is non-linear. In some cases, output may increase by a greater degree with an increase in inputs (increasing returns to scale), while in other cases output may increase by a smaller proportion than inputs (decreasing returns to scale).

[3] Capacity under-utilization is not a reliable indicator of excess capacity, particularly if the under-utilization is due to market forces as detailed below. Further, the existing level of inputs may be appropriate given higher stock levels. Removal of this ‘excess capacity’ might adversely affect the future productivity of the fishery if it is recovering. As a consequence, capacity utilization should only be used as a ‘rough’ indicator of problems of excess capacity in fisheries.

management is not constraining capacity growth, just its utilization. In contrast, increasing capacity utilization may indicate that capacity management is working

The concepts of capacity and capacity utilization relate to the existing condition of the resource. In the longer term, some other level of the resource may be desirable, particularly if the stock is currently overexploited. Associated with this desired stock level would be a desired level of output that would represent the sustainable yield that could be attained, and a desired fleet size/configuration that would take this sustainable yield at lowest cost. These desired long run levels of output and fleet size can be considered as measures of *target capacity*.
A long-term output based measure of overcapacity would relate the potential output from the current fleet given the desired stock level to the target level,[4] while an input based measure would relate the level of investment in the fishery now (in terms of boat numbers, GRT or some other unit) with the desired level of investment.

This latter measure is generally termed *overcapitalization*, and can be illustrated in Figure 1. From this figure, the current fleet size, *F*, is producing a current level of output, *O*. In contrast, a greater yield O_{msy} can be achieved with a smaller fleet size F_{msy}. The difference between the current fleet and target fleet is the level of excess capital, and is a measure of the level of overcapitalization of the fishery. The actual target level of output will depend on the management objectives for the fishery. In some cases, maximum sustainable yield may be the target level of output while in others maximum economic yield may be more appropriate.

In summary, capacity and capacity utilization are short-term concepts that relate to the ability of the existing fleet to increase their output given current conditions. In contrast, overcapacity and overcapitalization are longer-term concepts that indicate the extent to which the current fleet may need to be reduced in order to achieve a long run target level of output.

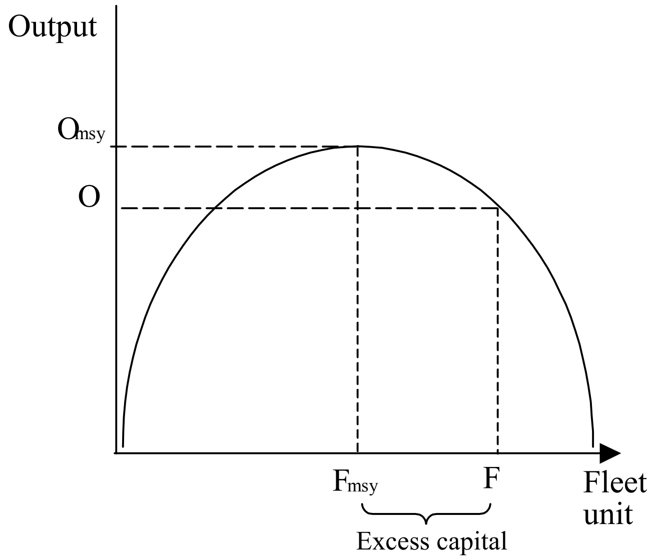


Figure 1. Overcapitalization in fisheries.

[4] A short run equivalent measure of overcapacity could also be the ratio of the current potential catch to some target catch in the current period (e.g. a TAC). This may be an unreliable indicator of overcapacity if a TAC has been set at a low level to allow the stock to recover.

2.1 Causes and problems of capacity under-utilization

Capacity under-utilization may occur for several reasons. Management induced capacity under-utilization can occur if the fishery output is constrained, such as by a total allowable catch (TAC) limit or as a result of a restriction in the number of days that can be fished (e.g. seasonal closures, days-at-sea limits). Conversely, capacity under-utilization may occur as a result of adverse market conditions. For example, if the price of fuel increased or the price of fish decreased, the profitability from fishing would decrease and this may cause some (less efficient) operators to fish less than they might otherwise fish.

Market induced capacity under-utilization is not of concern to fisheries management as the individual fisher is operating in a rational manner. In many cases, market induced capacity utilization is self adjusting, as either prices (costs) will rise (fall) to their original levels, or less efficient vessels who cannot operate under these new market conditions will seek to exit the fishery. Management induced capacity under-utilization, however, can have implications for the effective management of the fishery.

From a pure stock conservation perspective, the existence of management induced capacity under-utilization does not pose any threat provided that the total output of the fishery is constrained to a sustainable level (e.g. through an enforced total allowable catch (TAC) quota). However, the existence of underutilized capacity creates a number of economic problems, some of which may also have implications for the success of the stock conservation measures. These include economic incentives to exceed any quota imposed, as well as incentives to race to fish, and to increase capitalization in a bid to increase individual returns.

At the aggregate fishery level, the existence of underutilized capacity indicates a waste of resources, as, by definition, the same catch could have been taken with fewer boats operating at full capacity. The additional vessels are therefore not adding any additional value to the industry, and the costs incurred by these vessels directly reflects the potential economic cost to the industry (and society as a whole) of the excess capacity.

As well as imposing a direct economic cost on the industry, the existence of underutilized capacity can produce other incentives that are detrimental to both the stock and the longer-term profitability of the industry. When the harvesting capability of the fishing fleet exceeds the available catch, incentives are generated to increase investment in the industry in a bid to get a larger share of the catch. This may take the form of a larger boat and/or a larger engine, and the use of more fishing gear in order to maximize the individual catch. In the short term, undertaking such investment is likely to increase the profitability of the investor. However, in the longer term other fishers will be forced to either increase their investment to increase their (now reduced) share of the catch or exit the fishery. As a consequence, the ‘race to fish’ arising from the existence of excess capacity may result in further increases in excess capacity, with detrimental effects on both the stock and profitability of the fishery.

The alternative to increasing investment to maintain catch shares under such a scenario is to exit the fishery. However, the lack of alternative uses of fishing vessels makes exiting the fishery difficult. If the revenue from the restricted level of catch is not sufficient to cover existing fixed costs, incentives can be created to exceed any quota imposed. The actual extent of illegal landings will depend on the level of surveillance and expected fines, but it is likely that levels of illegal landings will be correlated with the level of excess capacity.

A related problem that can result in apparent capacity under-utilization is the existence of part time fishers. These vessels will be identified as underutilized when compared with full time vessels, but their potential to increase their level of fishing activity may be limited while they remain in the control of the current owners. However, as it is possible for these owners to change their operation to full time, or to sell the vessel to a new fisher who would use it on a full time basis, it is appropriate to treat these as vessels as having underutilized capacity for the purposes of capacity management.

In summary, the existence of underutilized capacity imposes direct costs on the industry through forgone economic profits, and indirect costs through the incentives created to increase investment (and thereby further increase excess capacity) and increase illegal landings.

2.2 Causes and problems of overcapitalization

The existence of overcapitalization is often attributed to the lack of property rights in fisheries. Without well defined property rights, individuals will increase their effort, and in fisheries without license limitations, new fishers will enter, provided that greater profits can be earned in the fishery than in other industries or activities. As a consequence, the resource rent (the implicit value of the resource used in the production process) is dissipated. Further, depending on the actual harvest costs, the level of investment in the fishery can exceed that required to harvest the resource at its greatest productivity level (e.g. maximum sustainable yield), and also the level required to harvest the resource to achieve its greatest economic value to society (maximum economic yield).

A major problem with overcapitalization is the loss of potential resource rent that could be obtained from the fishery. This rent could be returned to the local community to improve local facilities, or retained by the fishers in the form of increased profitability. The loss of this rent therefore leads to lower incomes of the fishers and their crew, which can lead to lower incomes in the regional as a whole through reduced use of local services.

Overcapitalization is also generally associated with lower levels of output, which may have effects on processing and retail sector performance. Excessive levels of overcapitalization can result in stock collapse.

2.3 Input versus output based measures of capacity

Management of fishing capacity requires some estimate of the existing level of fishing capacity in a fleet and the corresponding level of excess capacity in the fishery. To this end, many countries have developed a range of capacity indicators, mostly based on physical attributes of the fleet (FAO 2000). Key indicators of capacity applied in many countries are measures such as gross tonnage (a measure of the volume of the vessel), engine power, and the number of boats. In some countries, engineering measures such as vessel capacity units,[5] generally based on a combination of characteristics, have also been developed. More recently, output based measures of capacity have been developed that relate to the potential level of output of a fleet.

Input based measures of capacity involve an implicit assumption that the level of output is related to the level of physical inputs employed in the fishery. If these inputs were fully utilized, then the capacity of the fleet would be a function of these inputs. The level of utilization in this case would relate to the level of activity (e.g. days fished). Hence, the capacity of the fleet is related to the fixed inputs employed, e.g. capacity = *f*(boat size, engine power etc) on the assumption that they are fully utilized. As a consequence, changes in effort levels do not change the *potential* output of the fleet, so do not directly affect the capacity (just capacity utilization).

The link between the level of inputs and the level of outputs is generally the basis for management of fisheries using input controls. Changing the level of inputs (e.g. though decommissioning) or their utilization (e.g. through days at sea restrictions, seasonal closures), is assumed to have a proportional effect on the level of output. However, as noted previously, this assumes that the fisheries are subject to constant returns to scale. Several studies (e.g. Pascoe and Coglan 2000, Pascoe, Coglan and Mardle 2001) have demonstrated that input measures are often not equivalent to output measures of capacity, and changes in the distribution of the inputs can have a substantial effect on the output in a fishery even if the total input-based 'capacity' is unchanged.

Output based measures of capacity attempt to measure the potential output and/or the level of capacity utilization directly, usually at the individual vessel level. Implicit in the estimation of the output based capacity measure is also a relationship between the level of fixed inputs, their level of utilization and the level of output. However, the methods for estimation do not generally impose the same assumptions that are implicit in the input based measures. As a result, the measures are not affected by the distribution of inputs.

While providing a better estimate of capacity and capacity utilization in fisheries (FAO 2000), the output-based measures are not as useful for the purposes of management. As noted above, most fisheries are managed using some form of input control. In order to reduce capacity under such a management system, inputs need to be withdrawn so some input based measure is necessary. Consequently, there is a need for both types of measures in fisheries management, with identification of the relationship between the different measures an important component of the management information system.

3. Capacity assessment framework

The capacity assessment framework is illustrated in Figure 2. An over-riding activity that is required for any capacity assessment is a monitoring program to collect appropriate data for

[5] For example, the UK define vessel capacity units (VCUs) as: $VCU = length*breadth + 0.45*kw$. VCUs are used as the basis for capacity management in the UK, including decommissioning.

any subsequent analysis. Given the existence of appropriate data, capacity appraisal involves the estimation of the current level of capacity and capacity utilization, the assessment of target capacity levels, and the potential fleet reduction, if any, that is required to achieve the target capacity levels.

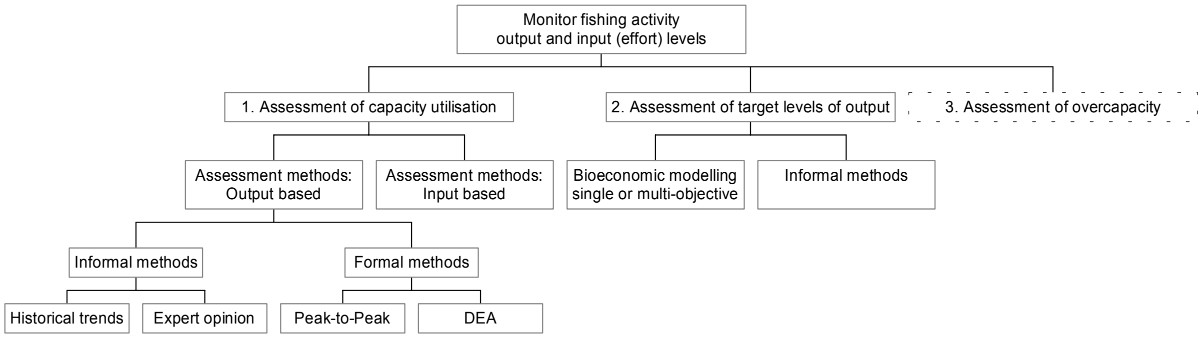


Figure 2. The capacity assessment framework.

The process of assessing current and target capacity can be either formal (i.e. using a quantitative modeling approach) or informal. Examples of these approaches are outlined in the following sections.

3.1 Monitoring and data needs

The data requirements for capacity assessment are no different to those that are required for the effective management of a fishery, and are routinely collected in many countries already.

3.1.1 Input data

Input data are required for the estimation of both input and output measures of fishing capacity. Input data can be divided into two main types: measures of physical capacity and levels of activity. Measures of physical capacity provide, as the name suggests, an immediate input-based measure of capacity. Measures include, for example, total boat numbers, engine power (e.g. kW or Horsepower), length, and Gross Registered Tonnage (GRT). In most fisheries, it is possible to identify several different fleet segments (e.g. defined by different gear types, target species or fishing location), and vessels can be allocated to these fleet segments where possible.[6] In order to estimate appropriate output-based measures of capacity, the vessel information ideally should be collected at the individual boat level. Input based measures, however, can be derived from totals for the fleet segments (e.g. total GRT, engine power etc).

Fishing activity information includes days/hours fished as well as the quantity of gear used (e.g. km nets, number of. traps, etc.). Again, this is required at the individual vessel level for output-based measures. It is also useful to have this information at the boat level in order to estimate potential fishing effort (an input based measure).

[6] This becomes complicated in fisheries where the vessels are multi-purpose, and may operate using several gear types over the year.

3.1.2 Output data

Output data are ideally required at the level of the vessel, and also disaggregated into species. This information is collected in many countries already through vessel logbooks, and is used for monitoring landings.

3.1.3 Economic data

Economic data are required for the assessment of target capacity,[7] but provide useful information on the status of the fishery in their own right. Key economic information that is required includes the price of each species, and the costs and earnings of the individual fishing boats. The key cost information required includes a measure of the running costs (e.g. fuel, ice, bait etc), crew costs, annual fixed costs (e.g. harbor dues, administration costs, license fees, maintenance etc) and capital costs (e.g. value of the boat and gear).

3.2 Estimation of capacity and capacity utilization

The estimation of input-based measures capacity and capacity utilization is relatively straight forward as the information collected on the physical attributes of the fleet forms the measures directly. This section will therefore focus on estimation of output-based measures. Depending on the degree of data availability, either informal or formal methods of assessment may be appropriate.

Informal methods of estimation of capacity utilization and capacity output can include an examination of historical trends or the use of expert advice. Examination of catch per vessel over time can provide a crude measure of how much an individual vessel could catch. The highest observed catch rate can form a measure of capacity output, and hence capacity utilization is the ratio of the current output to that capacity output. However, this ignores changes in stock conditions and also possible changes in technology that could have affected the catch rate over time. Discussion with fisheries experts could also provide estimates of capacity output. These experts may include scientists and/or industry members. Based on their experience, they could provide estimates of what different types of vessel should catch if fully utilized given the current stock conditions. This information may be collected either on an *ad hoc* basis (e.g. through discussion with key players in the fishery), or systematically through some form of survey of industry members. Other formal mechanisms for extracting information from experts include the Delphi Technique, which is an iterative process involving collecting opinions from a group of experts, feeding back the compiled information to the group and then eliciting modified opinions. The process is repeated until the group reaches a final consensus.

[7] Economic information can also be used for the estimation of capacity utilization directly. Incorporation of cost and price information into the capacity utilization provides an economically efficient measure of capacity rather than just a technically efficiency measure of capacity.

More formal methods for estimation capacity and capacity utilization include peak-to-peak analysis and data envelopment analysis (DEA).[8]

3.2.1 Peak-to-peak analysis

A key advantage of peak-to-peak analysis relative to other methods for estimating capacity utilization is that it requires minimal data. Peak-to-peak estimates of capacity and capacity utilization are estimated at the fishery level, so require information on only total fishery output and the level of physical inputs.[9] Catch per unit of physical inputs are estimated, and it is assumed that peak output levels indicate full capacity utilisation, and lower levels indicate capacity under-utilization.

Changes in peak catch rates are assumed to be due to technological change. The average rate of technical change is applied to derive a full capacity rate. Capacity output is estimated by multiplying the capacity rate by the number of fishing units. Given capacity output, capacity utilization can be derived.

This can be illustrated with a simple example using data from the Dungeness crab fishery in the US (Table 1 and Figure 3).[10] The peak catch rates were observed in 1959 and 1968. Average technical change between these periods was subsequent estimated 10.79 (i.e. (520.4-423.3)/9, the trend indicated in Figure 3). This technical change rate was used to derive the capacity catch rate – the catch rate if boats were operating at full capacity. For example, the capacity rate in 1960 was estimated as the catch rate in 1959 (assumed to be equivalent to the capacity rate) plus 10.79. The potential catch was estimated by multiplying the capacity catch rate by the number of boats. Capacity utilization can then be estimated by dividing the current catch by the capacity catch. From Table 1 and Figure 3, the fishery was subject to long periods of low capacity utilization.

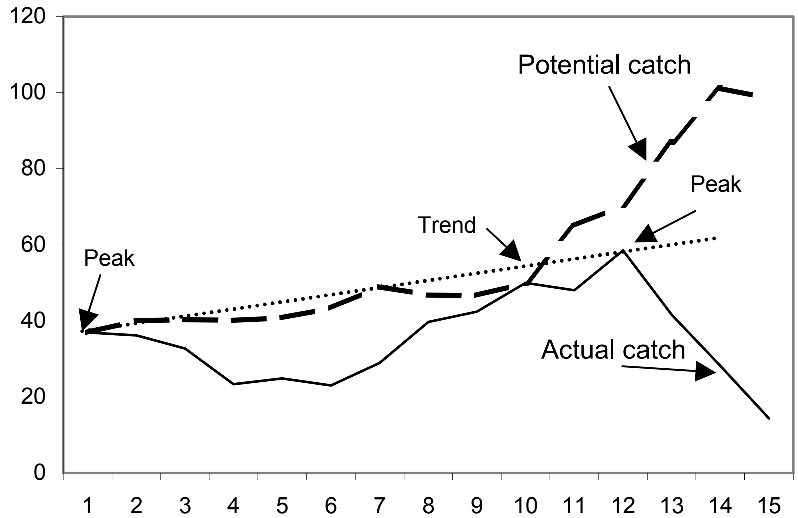


Figure 3. Peak-to-peak analysis of the Dungeness crab fishery.

---

8 Other methods are also available, including the use of stochastic production frontiers. A detailed overview of methods available for estimating capacity and capacity utilization is given by Kirkley and Squires (1999).

9 Peak-to-peak estimates can also be made at the species level.

10 Data for this example were taken from Kirkley and Squires (1999). Other examples of the technique are presented by Hsu (1999)

Table 1. Example: Peak to Peak analysis of the Dungeness crab fishery.

Year	Catch	Boats	Catch rate	Capacity rate	Potential catch	Capacity utilization
1959	36.95	87.3	**423.3**	423.3	37.0	100.0%
1960	36.16	92.3	391.8	434.0	40.1	90.3%
1961	32.7	90.55	361.1	444.8	40.3	81.2%
1962	23.36	88.01	265.4	455.6	40.1	58.3%
1963	24.86	87.49	284.1	466.4	40.8	60.9%
1964	23.04	90.82	253.7	477.2	43.3	53.2%
1965	28.91	100.36	288.1	488.0	49.0	59.0%
1966	39.72	93.91	423.0	498.8	46.8	84.8%
1967	42.44	91.7	462.8	509.6	46.7	90.8%
1968	49.97	96.03	**520.4**	520.4	50.0	100.0%
1969	48.06	122.44	392.5	531.1	65.0	73.9%
1970	58.51	130.08	449.8	541.9	70.5	83.0%
1971	41.61	157.43	264.3	552.7	87.0	47.8%
1972	28.25	179.52	157.4	563.5	101.2	27.9%
1973	14.37	171.45	83.8	574.3	98.5	14.6%

Source: Kirkley and Squires (1999).

The key advantages of the method are its simplicity and relatively low data requirements. However, the method has a number of problems that need to be considered. Firstly, in multi-species fisheries, analysis of capacity utilization at the species level may become problematic if fishers are able to target individual species and effort is switched between species. In such cases, there is the potential for 'under-utilization' to appear as a result of switching between species. In some cases, it may appear that all species are under-utilized when considered separately, even though the fleet may be fully utilized.

The method also ignores changes in stock conditions. Lower catch rates in some years could indicate smaller stocks rather than under-utilization of boats. Conversely, peak catch rates may coincide with above average stock levels. Actual capacity utilization may be high in the intermediate (normal stock condition) periods, although will appear low if the peak periods are affected by above average stock levels. This is particularly a problem if stocks are highly variable, such as often occurs with small pelagics (e.g. sardines, anchovies). In the case of the Dungeness crab example above, the low capacity utilization in the last 4 or 5 years most likely represented a decline in the stock rather than capacity under-utilization per se. As a consequence, the interpretation of the results needs to consider these factors.

3.2.2 Data Envelopment Analysis (DEA)

DEA is an output-based measure that can provide information on both a species by species basis as well as a fleet segment basis. Estimates of capacity and capacity utilization can be made at the fleet level directly, or, preferably, at the individual vessel level and aggregated up to the fleet level.

DEA is a 'frontier' based method: the outputs of individual boats in the fleet are compared, with the 'best' set of vessels used as a benchmark. The 'best' boats are those that have the greatest level of output per unit of input. These boats determine the 'frontier'. For example, in Figure 4, the two axes represent the average catch per unit input (e.g. kg/GRT) of two species. The points *A, B, C* and *D* represent the catch composition of four boats. These boats define the frontier as no other boats have greater catches per unit input. Point *E* represents a boat with a lower catch per unit input of both species. If the boat was operating at the same level as the other vessels, it could potentially catch more of each species. Based on the catches of the other vessels, the boat at point *E* could potentially operate at point *E**. This latter point defines the capacity output of the boat at point *E**, and the ratio of the distances *OE/OE** is a measure of its capacity utilization.[11]

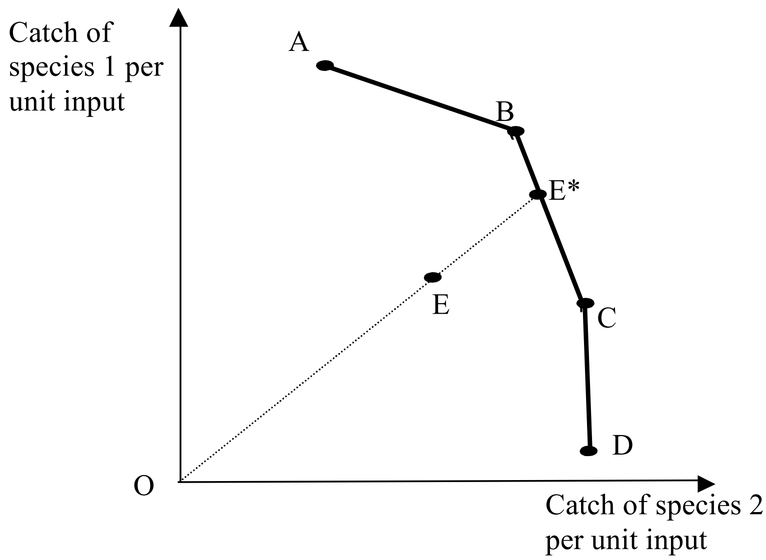


Figure 4. Two-output production possibility frontier.

DEA is a non-parametric technique, solved using a linear programming model, so cannot directly deal with random error (e.g. "luck" in terms of catch). However, the method that has been developed and applied in fisheries is not affected by random error,[12] making it suitable for use in even highly variable fisheries.

The Technical Consultation on the Measurement of Fishing Capacity (FAO 2000) suggested that DEA is the preferred method for estimating capacity and capacity utilization in fisheries as it can directly accommodate multiple inputs (e.g. boat size, engine power, gear and area fished etc) and multiple outputs (i.e. catches of different species). Hence, it can be used for multi-species fisheries without the problems experienced using peak-to-peak. Further, capacity utilization is assessed in each time period separately, so is not affected by stock fluctuations. Industry capacity can be estimated as the sum of the individual capacity output

[11] Technical efficiency is also estimated in a similar way, with variable inputs also considered in the analysis. The estimation of capacity utilization used information only on fixed inputs.
[12] Details on the equations underlying the DEA methodology are given in Kirkley and Squires (1999). See Holland and Lee (2002) for details on the sensitivity of the results to random variation.

levels, although this is an underestimate of the actual industry capacity output level as it may be possible for higher catches to be realized through a different allocation of inputs.

3.3 Assessment of target capacity

The management of fishing capacity requires not only some measure of the existing level of fishing capacity, but also some measure of the desired level of capacity. A wide range of sustainable yields can be achieved in a fishery. Indeed, even an overcapitalized fishery, as illustrated in Figure 1, can produce a sustainable yield that may be considered 'optimal' under some circumstances. The target capacity therefore relates to the objectives of management, and the 'optimal' yield is that which best achieves these objectives. In fisheries where employment is considered a key consideration, lower yields and income levels may be considered an acceptable trade-off. Conversely, in industrial fisheries, resource rent generation may be considered of greater importance, accompanied by higher yields but lower employment levels. Hence the maximum economic yield may be an appropriate target output capacity. Where the fishery is a main provider of food, the maximum sustainable yield (MSY) may be considered the target output level.

In fisheries managed through input controls, the assessment of target levels of capacity requires estimates both in terms of outputs and inputs.[13] For example, if the objective of fisheries management was to maximize the sustainable yield, then both the output at MSY and the fleet size/configuration required to achieve it need to be estimated.

The estimation of the 'optimal' yield can be undertaken either through a formal assessment using some form of model when sufficient data are available, or informally through the use of reference points/periods when data are limited.

3.3.1 Informal approaches

As with the estimation of current capacity, expert opinion can be used to derive a 'rough' estimate of the target level of capacity. This may involve consideration of the output and input levels in the fishery when it was believed to be operating at a sustainable and optimal level. Similarly, the average output over an extended period of time may be considered as an initial indicator of the target yield in the absence of more appropriate information.

3.3.2 Formal approaches

Stock assessment techniques are well established that allow for the estimation of sustainable yields in fisheries, provided sufficient data are available to estimate the required model parameters. These models are sufficient to estimate both target output capacity and input levels provided biological sustainability is the only objective of management.

---

[13] This is also true for fisheries managed using a combination of input controls and aggregate output controls (e.g. TACs) as the main mechanism for capacity management will still involve the use if input controls (e.g. decommissioning schemes). The only management system in which just an output-based measure of target capacity may be appropriate is a system of individual transferable quotas.

Where other factors are considered important, such as incomes and employment for example, some form of bioeconomic model is required. Optimization model can be used to estimate the optimum yield and fleet size that are both sustainable and also improve fisher incomes. Multi-objective models can be developed that allow the 'optimal' to be defined in terms of several criteria (e.g. employment, profitability, etc).[14]

Bioeconomic models are particularly useful for the analysis of optimal fishing capacity in multi-species, multi-gear and multi-purpose fisheries. To determine the optimal target capacity, consideration needs to be given to all activities undertaken by the vessels. The overall optimal level of output of any species may not be optimal for each species individually. That is, the optimal fleet size for the fishery as a whole may result in some species being harvested at beyond their individual optimal level, while others harvested below their individual optimal level. These synergistic effects cannot be adequately addressed solely in biological models. Costs and revenues, and the technical interactions that may exist between the species given the gears employed, affect the behavior of fishers, and subsequently the distribution of fishing activity in response to any management change.

The use of any model – biological or bioeconomic – for the purposes of estimated target capacity, however, requires some caution. There is generally considerable uncertainty about many of the biological and economic parameters that are used in these models. As a consequence, the results need to be considered as indicative rather than prescriptive. That is, they can act as a guide, but should not be used as a recipe for capacity management.

3.4 Capacity appraisal

The process of capacity appraisal involves both qualitative and quantitative approaches based on the analyses undertaken and knowledge of the fishery. The principle objective of capacity appraisal is to identify how much overcapacity exists, if any, and also where the overcapacity may exist. For example, are all fleet segments in a fishery overcapacity or just some? Can fleet reduction reduce overcapacity on all species or does an 'optimal' fleet involve some overcapacity still for some species?.

The estimates of capacity utilization provide a short-term indicator to the existence of overcapacity in a fishery. However, the appraisal needs to take into consideration a range of other factors. For example, in highly fluctuating stocks, some degree of capacity under-utilization may be required in an average (or poor) year in order to allow sufficient capacity in the fishery to take advantage of a good year. Similarly, if capacity under-utilization is a result of temporary adverse market conditions, then under more normal conditions the fleet may be operating at full capacity. Finally, if capacity under-utilization is the result of management interventions (e.g. a restriction on the number of days that can be fished) with the aim of allowing the stock to recover, then the existing fleet may operate at full capacity once the stock has recovered and the restrictions removed. Consequently, the interpretation of capacity under-utilization needs to be made in the broader context of information on what is happening in the fishery.

---

[14] A detailed review of the use of multi-objective models in fisheries is given by Mardle and Pascoe (1999).

Deriving output-based measures of overcapacity is considerably more complex than input based measures. It is not appropriate to compare the existing capacity to the optimal capacity estimated using bioeconomic models in order to derive a longer-term measure of overcapacity. For example, a fleet may be operating at full capacity in a depleted fishery and producing an output less than the long-term target output, but that same fleet, if operating under conditions of stock recovery could produce an output well in excess of the target output. As a result, in order to estimate the extent of any overcapacity, the models developed above need also to be used to estimate the capacity output of the existing fleet under the long-term stock conditions (i.e. when the stock has recovered). This is illustrated in Figure 5, where the current fleet has a capacity output O under current stock conditions, but could catch O* if the stocks were at the level that could produce maximum sustainable yield.

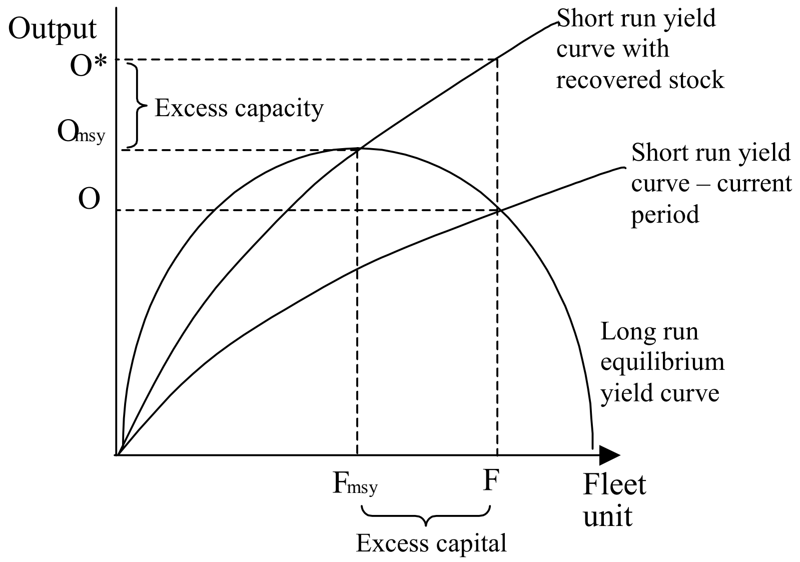


Figure 5. Estimation of overcapacity in the longer term.

In contrast, the level of excess capital can be more easily estimated using bioeconomic (or biological) models, as the difference between the current fleet size and the 'optimal' fleet size.

4. Summary and conclusions

The capacity appraisal framework can be summarized as consisting of four main steps. Essential to any capacity management program, and indeed any fisheries management, is the monitoring of the current level of exploitation. This involves collecting information on the vessels that are operating in the fishery, their level of activity and their level of output. These data can then be used to estimate the level of capacity utilization to provide a short-run indicator of where problems may exist in different fisheries and fleet segments.

The data can also be used to develop models of the fisheries in order to estimate target levels of capacity. The 'optimal' level of capacity will depend on the objectives of management.

In some cases, data will not be available in order to either assess capacity utilization or develop models for assessing target levels of capacity. In such cases, expert opinion can be used to derive estimates as an interim measure while data are being developed for more formal assessments. Lack of data should not be considered a valid reason to ignore potential problems in fisheries, particularly as they can result in greater problems in the longer term if not addressed.

The final capacity appraisal process involves using the information developed in the previous steps to determine the extent of any overcapacity in a fishery. As the methods outlined previously provide indicators only, any appraisal of overcapacity needs to take into consideration the assumptions underlying the formal analysis.

The capacity appraisal framework does not provide information on how target capacity levels can be achieved. Management plans need to be developed and implemented that will move the fishery from the current situation to that identified as the target. This in itself will present difficulties, as capacity reduction plans may be unpopular with the industry, which may create challenges in its implementation. FAO have recently held an Expert Consultation on Catalyzing the Transition away from Overcapacity in Marine Fisheries (Metzner and Ward 2002) to address these issues.

The purpose in this paper was to present an overview of the capacity appraisal framework. The methods for capacity assessment have only been briefly summarized in this paper. The estimation of output based measures of capacity and capacity utilization in fisheries is still relatively new, and now doubt will continue to evolve in the future. In contrast, the development and application of bioeconomic models has been well established, although the use of these models for the capacity appraisal has also been limited. The need to effectively assess and manage capacity, however, is going to stimulate increased research efforts in these areas in most countries over the coming years.

5. References

Directorate-General for Fisheries (DG Fish). (2000) MAGPIV not effective enough in dealing with overcapacity. EU press release 1.10.2000. [available online from: europa.eu.int/comm/fisheries/pcp/faq2_en.htm]

DG Fish. (2001) Fisheries: "alarming state of fish stocks" requires further substantial cuts for 2002 fishing catches. EU press release 4.12.2001. [europa.eu.int/comm/fisheries/news-corner/press/info01_70_en.htm]

Food and Agriculture Organization (FAO). (2000) The State of World Fisheries and Aquaculture, 2000. FAO, Rome.

FAO. (2000) Report of the technical consultation on the measurement of fishing capacity. *FAO Fisheries Report* No. 615 (FIPP/R615(En)). FAO, Rome. http://www.fao.org/DOCREP/005/Y8169E/Y8169E00.HTM

Holland, D.S., and Lee, S.T. (2002) Impacts of random noise and specification on estimates of capacity derived from data envelopment analysis, *European Journal of Operational Research* 137(1): 10-21.

Hsu, T. (1999) Simple capacity indicators for peak to peak and data envelopment analyses of fishing capacity, FAO Technical Consultation on the Management of Fishing Capacity, Mexico City, Mexico 29 November – 3rd December, 1999.

Kirkley, J. and Squire, D. (1999) Measuring Capacity and Capacity Utilization in Fisheries. In: Gréboval, D. (ed). Managing Fishing Capacity: Selected Papers on Underlying Concepts and Issues. *FAO Fisheries Technical Paper* No 386. Rome, FAO. 75-200.

Mardle, S., and Pascoe, S. (1999) A review of applications of multiple-criteria decision-making techniques to fisheries. *Marine Resource Economics* 14(1), 41-64.

Metzner, R., Ward, J.M. (comps.) (2002) Report of the Expert Consultation on Catalysing the Transition away from Overcapacity in Marine Capture Fisheries. Rome, 15-18 October 2002. *FAO Fisheries Report*. No. 691. Rome, FAO. 2002. 89p.

Pascoe, S., and Coglan, L. (2000) Implications of differences in technical efficiency of fishing boats for capacity measurement and reduction. *Marine Policy* 24(4): 301-307.

Pascoe, S., Coglan, L, and Mardle, S. (2001) Physical versus harvest based measures of capacity: the case of the UK vessel capacity unit system, *ICES Journal of Marine Science*, 58(6) 1243-1252.

Capacity appraisal in the English Channel fisheries

Sean Pascoe[1], Simon Mardle and Diana Tingley

Abstract

The English Channel fisheries are characterised by multi-species, multi-gear, multi-métier vessels. Most of the vessels operating in the Channel are based in either France or the UK, although vessels from Belgium and other European countries are also active in the Channel. Many of the vessels are small scale, and are effectively artisanal. Six main gear types are used in Channel – trawl (both demersal and mid-water), beam trawl, dredging, lines, nets and pots. Many boats operate using several gear types over the year. Around 90 species are caught commercially, with most caught in different combinations depending on gear type used. As a result, the fishery is about as complex as any fishery in the world. The level of capacity utilization in the different UK fleet segments is examined using Data Envelopment Analysis. Target capacity is estimated for the fishery as a whole using a bioeconomic model.

1. Introduction

The measurement and management of fishing capacity has become a major international theme in fisheries management over the last few years. This is reflected in the number of international conferences and workshops dedicated to capacity measurement and management (e.g. FAO 1998, 2000) and the development of an "International Plan of Action on the Measurement of Fishing Capacity" (FAO 1999).

Capacity management requires some form of assessment of the current state of the fishery and the longer term desired state of the fishery. This essentially requires both a short term and long term assessment, the former providing information on current activity in the fishery and the latter on where the fishery should be in order to achieve the objectives of the fisheries management plan. For the purposes of deriving effective management plans, managers need to know the potential output from the current fleet, the target output in order to achieve the management objectives, and the fleet size and structure that is consistent with the 'optimal' levels of output.

The key short-term measure of capacity in the fishery is derived through estimating capacity utilization. From this, estimates of the harvesting capacity of the current fleet can be obtained. Capacity utilization (CU) refers to the ratio of actual to potential output. A measure of capacity utilization less than one implies that the same fleet, if fully utilized, could produce more than it is currently doing. Conversely, a smaller fleet if fully utilized could have taken the same level of catch. As a result, capacity under-utilization could represent the existence of

[1] Centre for the Economics and Management of Aquatic Resources (CEMARE), University of Portsmouth, Southsea, UK PO4 8JF. Email:sean.pascoe@port.ac.uk.

over-capacity in the fishery, at least in the short term. However, as it is possible for capacity under-utilization to exist as a result of short term management imposed constraints, as well as short term market fluctuations (e.g. prices and costs), the existence of capacity under-utilization does not necessarily mean that over-capacity exists. Further, with highly variable stocks, some degree of capacity under-utilization may be desirable in 'average' or 'poor' seasons if it means that sufficient capacity exists to fully exploit the stock in 'good' seasons. The 'problem' of capacity under-utilization needs to be assessed taking these factors into account.

Nevertheless, the measurement of capacity utilization can provide valuable information relevant to capacity management. In particular, differences in capacity utilization across a fleet can have significant implications for management through effort controls, as in many cases these may form non-binding constraints (i.e. days at sea limits may not reduce effort if capacity is already under-utilized; fleet reduction policies may be ineffective if only those boats that are under-utilized are removed).

Several methods have been developed to estimate capacity utilization, with the most commonly employed being Data Envelopment Analysis (DEA). The DEA technique has been suggested as the preferred approach to capacity measurement in fisheries largely as a consequence of being able to measure capacity at the individual species level in a multispecies fishery (FAO, 2000). In fisheries, the technique has been applied to the Malaysian purse seine fishery (Kirkley, Squires *et al.,* 1999), US Northwest Atlantic sea scallop fishery (Kirkley, Färe *et al.,* 1999), Atlantic inshore groundfish fishery (Hsu, 1999), pacific salmon fishery (Hsu, 1999), the Danish gillnet fleet (Vestergaard *et al.,* 1999), and the total world capture fisheries (Hsu, 1999).

The estimation of target levels of capacity requires some form of bioeconomic model. Bioeconomic models are mathematical representations of the fishery that include the key biological relationships as well as economic factors that influence fisher behaviour and affect fishery profitability. Multi-objective bioeconomic models can be developed that enable 'optimal' output and fleet configurations to be estimated based on several conflicting objectives of management.

In this study, capacity utilization is estimated using DEA for a number of different UK fleet segments operating in the English Channel. Trends in capacity utilization over the period for different size classes of boats are examined. A multi-objective bioeconomic model of the fishery is also used to estimate the fleet configuration that best meets the fisheries management objectives in the long run. The level of overcapacity in the key fleet segments is assessed based on the long run results, while implications for capacity management are considered based on the short-term capacity utilization analysis.

2. The fisheries of the English Channel

The English Channel contains of a wide variety of fishing activities that are aimed at targeting a variety of species. Approximately 4000 boats operate within the English Channel, over half of which are UK boats (Tétard *et al.*, 1995). These broadly fall into 7 gear types: beam trawl, otter trawl, pelagic/mid-water trawl, dredge, line, nets and pots. In total, 92 species are landed by boats operating in the English Channel. However, the majority of the landed weight and value are made up of around 30 species.

The fleet is made up primarily of small vessels, with over two thirds of the fleet being less than 10 metres in length, and around half of these under 7m in length (Figure 1). A large proportion of the under 7m vessels operate essentially on a part time basis, fishing for generally less than half the number of expected full time days.

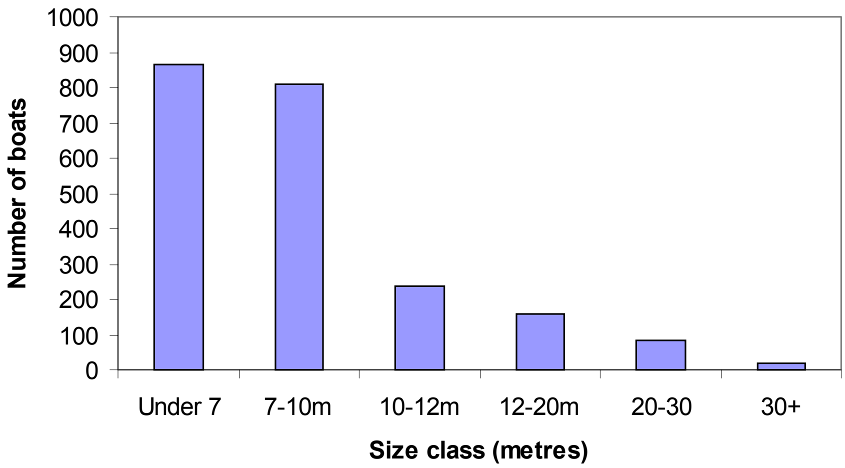


Figure 1. Size distribution of the UK Channel fishing fleet.

The boats are generally multi-purpose, operating with different gears over the year, and in some cases, using different gears in the same month. Fishing activity has been classified into a number of métiers based on gear used and area fished[2] (Tétard *et al.,* 1995). Boats may operate in different areas in the same month as well as with different gears, resulting in their activity being recorded in a range of métiers.

3. Assessment of capacity utilization

Capacity utilization in the main fleet segments was estimated using data envelopment analysis. The method involves comparing the level of output and inputs of different boats operating in the fishery. Details on the DEA methodology are given in Appendix A.

3.1 Data

An extensive database of fishing trip level log-book data from the fishery covering the period 1993-1998 was disaggregated into eight different fleet segments based on recorded fishing activity (beam trawl, otter trawl, scallop dredging, lining, netting, crab potting, whelk potting

[2] This classification was undertaken using cluster analysis to identify different activities within a given gear type.

and ‘other’ activities). The data had also been pre-classified into the different métiers by the UK Centre for Environment, Fisheries, and Aquaculture Science (CEFAS). Trip-level data were aggregated to provide monthly levels of output and effort by vessel over the period examined. In total, the combined data sets contain over 150,000 observations.

Many boats in the data set were multi-purpose, particularly the smaller ones, so the number of boats using a particular gear type varied from year to year and over the year. As many of the smaller boats (as well as larger boats that do not target quota species) are not required to complete logbooks, it was expected that much of the data may be unreliable. An assumption was made that boats that had consistently supplied data would be more reliable. To this end, only boats that used the gear for at least four months in a year and in at least three of the six years were allowed to remain in the data set, resulting in 20,250 observations (Table 1).

Table 1. Summary of consolidated data sets used in the analyses

	Total in data set		Average per boat per month				
Gear	**Boats**	**Number of Obs.**	**Catch[a] (Kg)**	**Value[b] (£)**	**Days fished**	**Deck area**	**Engine power (Kw)**
Beam trawl	101	6840	4801	10,352	6	160	422
Otter trawl	171	8215	1141	6454	12	56	155
Scallop Dredge	37	1553	14,806	21,860	11	143	375
Pots	28	916	6030	8121	9	43	95
Gillnets	51	2276	2618	3444	5	50	127
Longline	15	452	6270	2910	8	40	186

a) The catch has been weighted by revenue shares. b) Values have been inflated to 1998 values using a Fisher price index.

The key inputs used in the DEA analyses were days fished, 'deck' size (estimated as overall vessel length*breadth) and engine power (kW). Unbiased CU[3] was estimated using multiple outputs. For the multiple output measures, a composite revenue-based output measure, derived using revenue shares, was used for each main gear type. The 'other' catch (in weight terms) category was also derived using revenue shares, and all revenues were inflated to 1998 values.[4]

To address the problem of working with multi-purpose multi-métier fleet data, an additional input of days fished in other métiers in the same month was also included in the modified analysis.[5] Additional composite outputs were also created, both weight and revenue-based, to incorporate a measure of the catch generated in a particular month by a vessel’s activity outside the particular métier being analysed.

[3] This is a more robust measure of capacity utilization as it takes into account differences in efficiency of the different fishermen, and also implicitly removes the effects of random variation in output. See Appendix A.
[4] Multi-output analysis was also carried out using individual outputs representing the catch of the top five species in terms of value. Catches of the remaining species were represented by a sixth composite category derived using revenue shares. However these results are not presented in this paper.
[5] This approach is further described in Tingley, Pascoe and Mardle (forthcoming).

3.2 Results

The results were produced using a linear programming model developed in GAMS (Brooke, Kendrick and Meerhaus, 1992). The model was run separately for each métier. Data on stock abundance was not available, however for the purposes of the secondary stage-analysis, with all vessels fishing in the same area, in the same month, being compared to each other to determine which vessels lie on the full efficiency or full capacity utilization frontier and for those that lie within it, how far inside it they are found. It was assumed that stock levels did not vary considerably during a given month, hence lack of stock abundance data was not perceived to be a significant problem.

The unbiased CU scores for each gear type in turn are shown in Figure 2. These have been disaggregated by vessel length categories to focus on small inshore vessels (less than 10m in overall length), medium-sized vessels (10 to 15.9m) and large vessels (greater than 16m).

Also presented in Figure 2 are the sample sizes used to provide average results for each vessel length category. For example, the average unbiased CU results for medium-sized otter trawlers was calculated from the results of between 102 to 151 vessels on average for each year, whilst results for the larger vessels were produced using data from between 13 to 21 vessels each year over the period 1993-98[6].

The results for the mobile gear types (otter trawl, beam trawl and scallop dredge) suggest that the medium sized vessels were operating more closely to maximum unbiased CU levels (i.e. 1) than the larger vessels. The difference was very significant for the beam trawl and otter trawl vessels across the whole period. The difference was less clear for scallop dredges.

The results are similar for the static gear potting vessels. Unbiased CU was highest for medium-sized potting vessels and generally lowest for smaller potters. As many of the smallest potters operate on a part-time basis, this result was not unexpected. However the smaller gillnetting vessels tended to have higher unbiased CU scores as compared to the largest gillnetters, which have the lowest scores. Attention should be paid to the numbers of vessels proving data for analysis in each length category.

While capacity utilization fluctuated from year to year, there appeared to be a general, gentle upwards trend in average annual unbiased CU for all major gear types between 1993 and 1998 (Figure 3). The rise between the years of 1993 and 1998 was 1% for beam trawlers, 2% for scallop dredgers, 4% for potters, 5% for otter trawlers and 9% for netters.

Overall, potters achieved the highest unbiased CU scores in four out of the six years studied (Figure 3). However, these annual scores are derived from the average of the 12 separate monthly analyses carried out for each gear type. They are not, therefore, directly comparable across gear types. During the four years when potters achieved the highest scores, they should be interpreted that, on average, more vessels achieved greater levels of unbiased CU as

[6] All vessels were included in the same analysis, so the sample size of the group analyses is the sum of the sub-groups.

compared to those operating on the frontier (in each time period for that métier) than appears to have been the case in any other gear type.

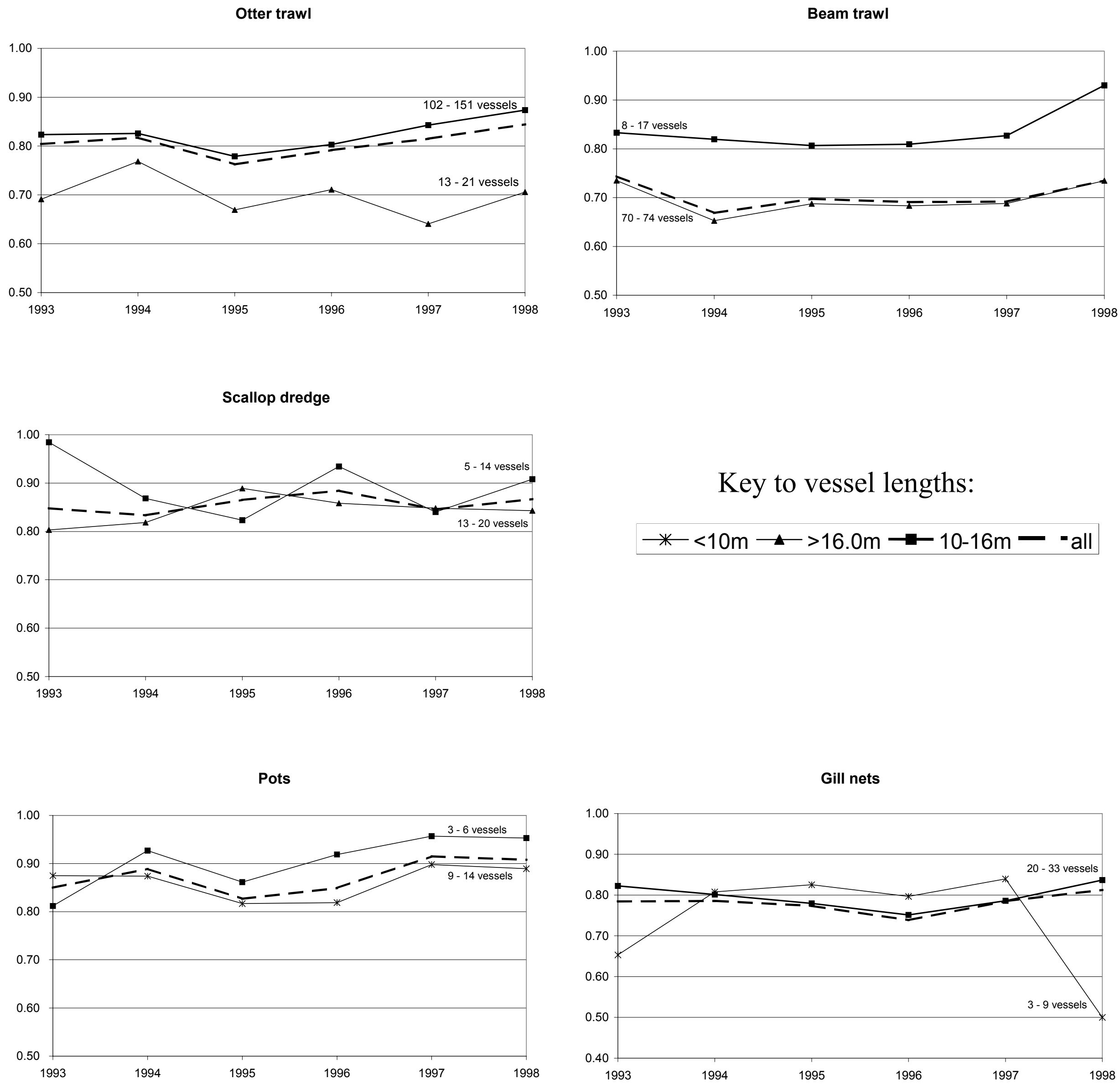


Figure 2. Unbiased CU results, single output revenue index, by gear type and vessel length category (1993-98).

Scallop dredgers appear to achieve the next highest consistent score, averaging between 85 and 90% of unbiased CU as compared to those dredgers operating on the frontier in each time period. Gill netters achieved consistently lower results of between 80 and 85% whilst beam trawlers appear to have the lowest average unbiased CU averaging a score of 78% over the period and 81% in 1998.

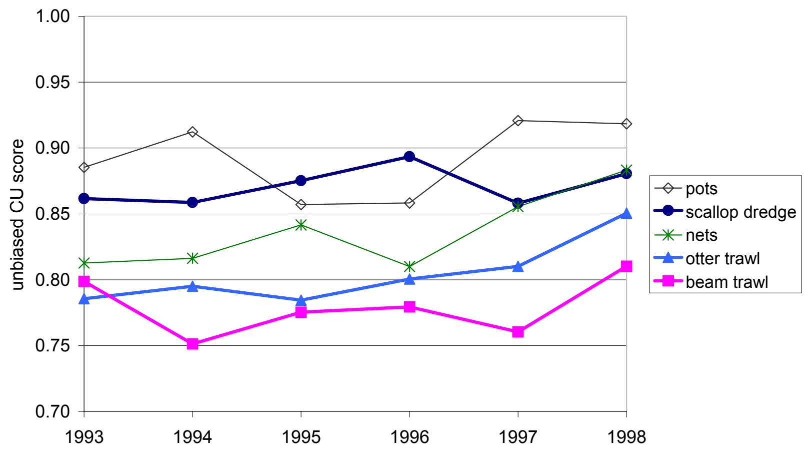


Figure 3. Average annual unbiased CU by major gear type (1993-98).

The numbers of vessels included in the analysis generally decreased between 1993 and 1998. As only records of vessels fishing a particular gear type for four or more months per year and for at least three years in the 1993-98 period were included in the analysis, their numbers used in the analysis provide a very crude measure of fishing effort. With the exception of scallop dredging and beam trawling, vessel numbers used in the analysis decreased between 1993 and 1998; by 28% of otter trawlers, 22% of potters and 32% for netters. Numbers of beam trawlers in the sample increased by only 3% over the period whilst numbers of scallop dredgers increased by 44%.

3.3.1 Distribution of capacity utilization

While on average the fleet is operating at below full capacity utilization, the distribution of CU in the fishery can also provide useful information for management. From Figure 4, it can be seen that for most fleet segments, most of the vessels are operating at or near full capacity, although a significant number are operating at low levels of capacity, reducing the overall average. Those boats operating at or near full capacity are therefore not able to increase their output above current levels. However, there also exists substantial latent effort in the fishery that could become active if economic conditions improved (i.e. prices increased) or new entrants to the fishery bought out the licenses of the relatively inactive vessels.

The distribution of CU in Figure 3 is only based on the boats that provided sufficient logbook data for the analysis. The fishery is characterised by a large number of part time vessels. As mentioned previously, survey estimates of fishing activity suggest that around 90 per cent of the under 7 metre vessels operate at less than 50 per cent of their potential days fished. As a result, the level of latent effort in the fishery is substantially greater than that indicated by the above analysis.

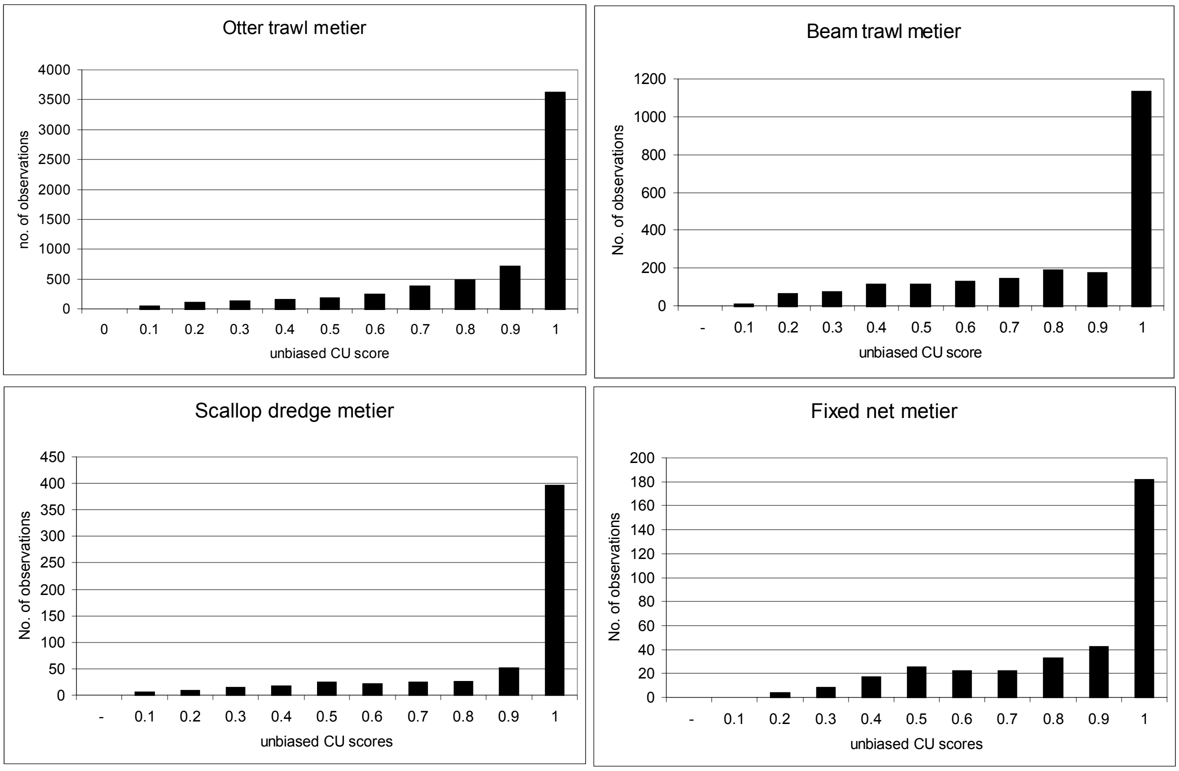


Figure 4. Distribution of unbiased CU in the UK Channel fleet.

3.3 Implications of the results

The results from the CU analysis indicate that the fleet as a whole was not fully utilized. In some fleet segments, there was the potential to increase output in the fishery through increased utilization (i.e. fishing more). Many boats were under-utilized to a high degree in all fleet segments, and there was considerable latent effort in the fishery due to part time fleet. As many of the part-time vessels are not included in the analysis due to lack of data, the level of latent effort in the fishery was even greater than suggested by the above results. There exists the potential, then for a considerable increase in fishing activity (effort) in the fishery, and corresponding increases in catch.

The other key result was that utilization appears to have increased as the number of vessels in the fishery has decreased. This could be due to a reduction in crowding pressure resulting in improved economic performance and an increase in fishing activity. Prices have also increased over the period so this would also be expected to have had an impact. Conversely, decommissioning programmes may have removed the boats with low CU, which consequently raised the average value. If this were the case, then the impact of the decommissioning programme in the fishery would have been less effective in reducing fishing effort than might be expected.

4. Multi-objective bioeconomic analysis

A multi-objective bioeconomic model was also used to determine the 'optimal' fleet configuration and size for the key fleet segments operating in the fishery assuming a long-run equilibrium position can be achieved. The model, described in Pascoe and Mardle (2001), include both the French and UK fleets operating in the Channel, as well as taking into account fishing activity of other EU Member States (which combined contribute around 5 per cent of the fishing activity). All commercial species caught in the Channel are included in the model, and for some species (e.g. crustaceans) several stocks have been included where these have been identified. The model includes a combination of age-structured biological models as well as surplus production models for some species. That is, all outcomes are sustainable in the long run (both biologically and economically). The model was also specified as an 'optimization' model, in that it produces the best outcomes given the objectives provided. The output of the model was the sustainable catch of each species, the fleet size and structure that produces that catch, and the relevant socio-economic measures of performance given the fleet structure and catch (e.g. profits, employment).

The model solution was based on the key management objectives in place in the fishery. Conservation objectives are over-riding, as all solutions are sustainable in the long run. The economic objectives were specified as maximising profits in the fishery, with each country having a separate profit target based on its own potential maximum profit (see Pascoe and Mardle 2001). Employment objectives were also included through setting target employment levels based on the current level of employment in the fishery. Finally, the EU principle of relative stability was imposed such that each country could not incur a greater proportion of benefit (or incur losses) than the other. The multiple objectives were incorporated into the model though the specification of an 'achievement function'. The deviations away from the targets for each objective can then be minimized using a technique known as goal programming.

4.1 Multi-objective optimization

The model was run with the dual objectives of both increasing economic profits and maintaining employment. The economic profit objectives were taken as the maximum economic profits that could be achieved in each country (see Pascoe and Mardle 2001). The employment objectives were taken as the current level of employment in each country. The additional objective that each country can only incur the same proportion of the potential social cost was also imposed to ensure relative stability was maintained.

Essential to the achievement function was the definition of the weights associated with each goal. Different weights are likely to result in different optimal solutions. As deviations from all goals are unwanted, one method is to set all weights to unity since there is no need to differentiate their importance (Ignizio and Cavalier 1994).

A number of different weights were applied in the model. The model was run with equal weights being applied to both the profit and employment goals. The model was also run with a lower weight on economic profits and with a lower weight on employment. A common weight was used for both countries with each objective. This ensured that neither country was given preference relative to the other country.

As would be expected, the optimal fleet configuration depends on the relative weights given to the profit and employment objectives (Table 2). An optimal fleet with a higher weight on employment was characterized by a large number of smaller boats, particularly in the UK. Conversely, increased weight on economic profits results in the total capital (and employment) in the fishery decreasing. Comparing the current situation with the case in which employment was given greater weight than profits (i.e. $w_p=0.5,\ w_e=1$), economic profits could be increased from the current situation by 65 per cent with only an 8 per cent reduction in employment.

Table 2. Multi-objective optimization results.

	Current situation		Different weights on objectives					
			$w_p = 0.5; w_e = 1; w^s_e = 1$		$w_p = 1; w_e = 1; w^s_e = 1$		$w_p = 1; w_e = 0.5; w^s_e = 1$	
	UK	France	UK	France	UK	France	UK	France
Boat numbers								
• otter trawl	129	207	64	173	40	134		98
• beam trawl	92	86	74	65	65	63	92	56
• dredge	18	253	18	253	18	253	18	253
• trawl/ dredge		300		295		255		127
• pots	65	159	65	157	65	141	65	132
• nets		172		168		108		62
• lines		51		43		43		39
• net/line	137		122		122		122	
• whelk pots		44		42		38		25
• seaweed		59		59		59		56
• fixed gear		216		194		194		172
• misc.		127		126		119		79
• inshore mixed	1613		1613		1250		832	
Revenue (€m)								
• Channel fleet[a]	155.8	257.6	132.2	246.9	122.8	219.0	139.0	172.2
• External fleet	11.0	17.3	11.2	21.0	11.3	25.2	11.5	29.1
Profits[b] (€m)	-6.1	31.7	0.0	42.3	8.8	51.1	17.6	51.8
Capital[b] (€m)	195.5	319.2	149.1	260.4	113.9	182.1	114.3	102.1
Employment[b]	4343	4840	3978	4433	3216	3584	2198	2450

a) includes revenue from Channel fleet generated outside the Channel. b) Channel fleet only.

4.2 Trade-offs between employment and fishery profit

Comparing the results with the different weight combinations in Table 2, it is clear that there is a trade-off (as would be expected) between the level of employment and the level of fishery profits. A trade-off curve between the two objectives was estimated using the model. The level of employment in the fishery was set as a constraint and varied incrementally from 0 (zero) to 9200 (the current level of employment). The maximum sustainable profit that could be achieved given each level of employment was then estimated using the model (Figure 5)[7]. The additional constraint of relative stability was not imposed in estimating the frontier.

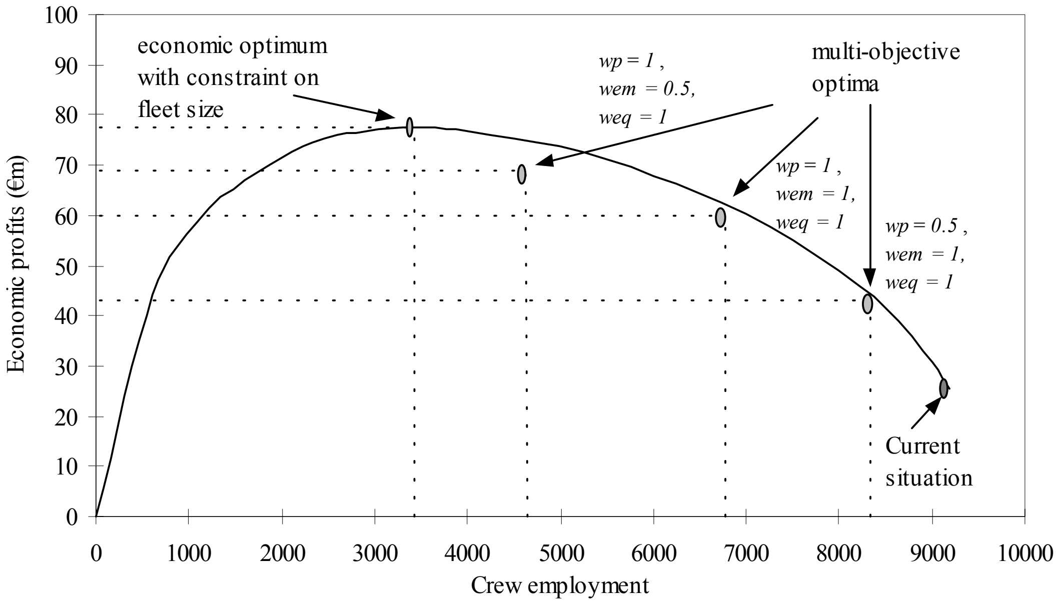


Figure 5. Economic profit and employment frontier.

From Figure 5, it can be seen that employment can be increased from the profit maximising level with a less than proportion decrease in profits. However, profits were estimated to decline sharply beyond the level of employment associated with the multi-objective optimum with equal weights (i.e. the slope of the tangent - equivalent to the marginal rate of transformation (MRT) - is equal to -1). At employment levels below this point, the slope of the tangent is greater than minus 1 (i.e. 0 > MRT > -1), such that a one per cent increase in employment can be achieved with a less than one percent decrease in profits. Above this point, the MRT is less than -1 so that increased employment is achieved through a greater than proportional decrease in economic profits.

The level of profits and employment associated with all three multi-objective optima examined are interior to the profit-employment frontier. The relative stability constraint was estimated to prevent the fishery from achieving the greatest level of employment for a given level of economic profits (and vice versa). For example, for the optima with greater weight associated with profits, almost 10 per cent more economic profits could have been generated for the same level of employment. Conversely, an extra 1000 crew could have been employed for the same level of economic profits, an increase of more than 20 per cent. Hence, the

[7] The model was run as a single objective (profit maximisation) model only to derive this function. The level of employment was given as an equality constraint. That is, the model was used to estimated the maximum economic profits that could be achieved given a fixed total level of employment in the fishery.

equity considerations embodied in the stability constraint impose a cost in terms of forgone profits and/or employment in the fishery as a whole.

4.3 Extent of overcapacity

As noted previously, the extent of any overcapacity in the fishery will depend on the actual objective of fisheries management. From the above analysis, several different fleet configurations were identified based on different levels of importance given to each objective. Potentially, an infinite number of 'optimal' fleets can be identified, but only one will be truly optimal.

The percentage of overcapacity can be estimated by dividing the current fleet number by the 'optimal' fleet (Table 2). From this, it can be seen that the estimate of overcapacity varies substantially based on the objectives of management. For example, if maximising employment was the main objective, then there is no overcapacity in the inshore fleet, but if maximising profit was a main objective, then there was considerable overcapacity in the inshore sector.

Table 3. Extent of overcapacity in the UK fleet segments of the Channel fishery (%).

Fleet segment	Weights given to each objective		
	$w_p = 0.5$; $w_e = 1$; $w^s_e = 1$	$w_p = 1$; $w_e = 1$; $w^s_e = 1$	$w_p = 1$; $w_e = 0.5$; $w^s_e = 1$
otter trawl	102%	223%	inf
beam trawl	24%	42%	0%
dredge	0%	0%	0%
pots	0%	0%	0%
net/line	12%	12%	12%
inshore mixed	0%	29%	94%

5. Discussion and conclusions

The use of bioeconomic models for assessing the extent of overcapacity needs to be undertaken with some caution. Most optimisation models are sensitive to the data provided, and a small change in the main parameters may result in a different optimal solution. For example, if the price of the fish species targeted by the otter trawlers increased, then the optimal number of vessels in this segment may also increase. Similarly, if fuel prices decreased, the optimal number of all mobile gear boats (otter and beam trawlers and dredges) could increase. As prices and costs are likely to change in the future, the results of the models should not be seen as prescriptive, but indicative of the problem areas in the fishery.

Many biological parameters in the model are also subject to uncertainty. This again would affect the optimal fleet size and structure if errors are introduced into the model through inaccurate biological parameters.

The robustness of the results to uncertainty in biological and economic parameters can be examined through either sensitivity analysis or stochastic simulation. This was not presented in this paper in order to keep the analysis fairly simple, but a stochastic analysis of the model results was presented in Pascoe and Mardle (2001).

The results from the bioeconomic analysis largely confirm the results of the capacity utilization analysis. That is, that there exists overcapacity in the otter and beam trawl fleet segments. These groups were identified as having under-utilized their capacity in the short term CU analysis. Further, this suggests that fewer vessels can take the same or greater catches in the short term. The long run indicates that a more profitable fleet would develop as a result of reduction in these segments. The large reduction in the inshore fleet (in terms of total boat numbers) indicated by the bioeconomic analysis also raises the problem of part time fishing. As many of the smaller boats did not return logbooks, there was not sufficient data to estimate their capacity utilization. However, the model (using activity data collected through a survey of fishermen) estimated that there was considerable over-capacity in this fleet segment, largely as a result of the high proportion of part time fishers.

The above analysis demonstrates that CU can provide useful indicators as to the areas likely to be problematic for capacity management. However, CU does not tell you how much you may need to reduce capacity. Bioeconomic models can provide targets for capacity management, but the analyst needs identify the trade-offs that exist between objectives. The analyst must also be aware of the sensitivity of the models to prices, costs etc as well as potential errors in the underlying relationships before making firm recommendations to managers.

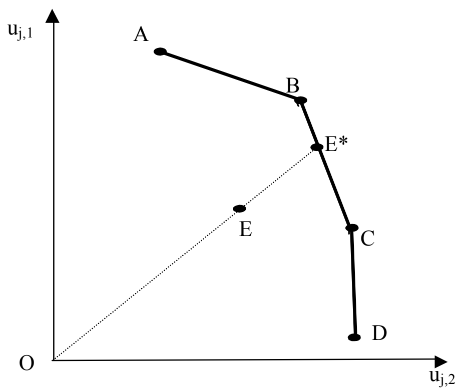
Appendix A. Capacity and capacity utilization measurement using DEA

The measurement of capacity of a firm (e.g. boat) can be described as its potential output given its fixed factors of production. Therefore, to measure this level of overall capacity, in practice the potential output of a firm is determined by a comparative analysis of the output levels achieved by other firms of similar size with similar activities. Differences in output between similar firms can be due to either differences in capacity utilization or differences in technical efficiency, both of which are relative measures. Capacity utilization is the level at which the firm operates given its level of variable input usage, which may be less than possible under normal working conditions. Technical efficiency on the other hand is the degree to which the potential output is achieved given the amount of both variable and fixed inputs employed. For example, in the case of a fishery, differences in the catch of two boats of the same size may be due to a difference in the number of days fished (capacity utilization), or a difference in the ability of the skipper in harvesting the resource (technical efficiency). Therefore, in order to determine the potential output of a boat under normal operating conditions, these effects need to be separated out.

DEA is a non-parametric approach to the estimation of capacity and technical efficiency. An advantage of DEA is that it is able to incorporate multiple outputs directly in the analysis. Further, the technique does not require any pre-described structural relationship between the inputs and resultant output, which allows greater flexibility in the frontier estimation. A disadvantage of the technique, however, is that it does not account for random variation in the output(s), and so attributes any apparent shortfall in output to either capacity under-utilization or technical inefficiency.

The following example takes a two-output example to demonstrate DEA for the estimation of capacity and capacity utilization. The illustrated example describes five boats (*j = {A,B,C,D,E}*) targeting. In terms of fixed input use, the fleet is homogeneous. Therefore, the level of catch is determined by the extent to which the fixed inputs are fully utilized. Figure A.1 shows the catch ($u_{j,m}$) achieved by the boats for both species ($m = \{1,2\}$). The production possibility frontier is defined by boats A, B C and D, which as they lie on the frontier are assumed to be operating at full capacity. However, boat E is producing less of both species relative to the frontier and is therefore assumed to be operating at less than full capacity. The production potential of boat E can be found by expanding the output of both species radially from the origin until it reaches the frontier (point E*). OE*/OE is the expansion factor (θ) by which output of boat E could be increased. Capacity utilization of boat E is given by OE/OE* (i.e. 1/θ).

The shape of the frontier will differ depending on the scale assumptions that underlie the model. Two scale assumptions are generally employed: constant returns to scale (CRS) and variable returns to scale (VRS). The latter encompasses both increasing and decreasing returns to scale. However, there are generally *a priori* reasons to assume that fishing would be subject to variable returns, and in particular decreasing returns to scale. Figure A.2 shows the differences between these alternative measures for the five boats in the example above. In the analysis in this paper, the frontier is assumed to follow the form of a VRS model where zero inputs equate to zero outputs. Hence, the frontier would go through the points OBCD and would not be defined by the standard VRS envelope ABCD as shown.



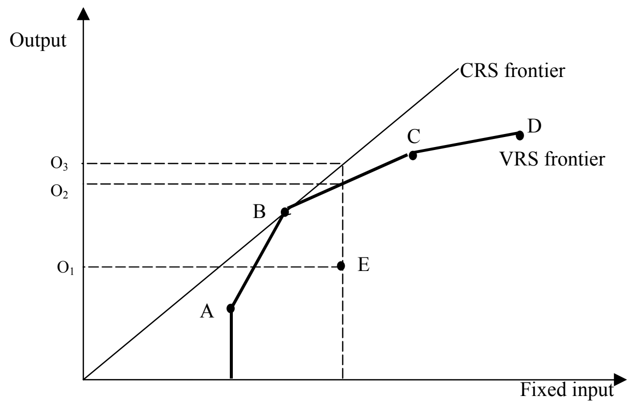


Figure A.1. Two output production possibility frontier. Figure A.2. CRS and VRS efficient frontiers.

The VRS DEA model is formulated as a linear programming (LP) model, where the value of θ for each vessel can be estimated from the set of available data. Following Färe *et al.* (1989, 1994) this DEA model of capacity output given current use of inputs is given as:

$$Max\,\theta_1$$

subject to

$$\begin{aligned}
&\theta_1 u_{0,m} \le \sum_j z_j u_{j,m} \quad \forall\, m \\
&\sum_j z_j x_{j,n} \le x_{0,n} \quad n \in \alpha \\
&\sum_j z_j x_{j,n} = \lambda_{0,n} x_{0,n} \quad n \in \hat{\alpha} \\
&\sum_j z_j = 1 \\
&z_j \ge 0, \quad \lambda_{j,n} \ge 0 \quad n \in \hat{\alpha}
\end{aligned} \tag{1}$$

where θ_1 is a scalar showing by how much the output of each boat can be increased, $u_{j,m}$ is the output m produced by boat j, $x_{j,n}$ is the amount of input n used by boat j and z_j are weighting factors that determine the influence of each vessel j on the potential output of the vessel being considered (i.e. $z_j = 0$ for boats not on the frontier, and $z_j \ge 0$ for the vessels on the frontier). The value of θ_1 is estimated for each vessel separately, with the target vessel's outputs and inputs being denoted by $u_{0,m}$ and $x_{0,n}$ respectively. Inputs are divided into fixed factors (i.e. set α) and variable factors (i.e. set $\hat{\alpha}$). The measure of capacity output is calculated by relaxing the bounds on the sub-vector of variable inputs, $x_{\hat{\alpha}}$. This is achieved by allowing these inputs to be unconstrained through introducing an input utilization rate ($\lambda_{j,n}$). This is estimated in the model for each boat j and variable input n (Färe *et al.,* 1994). The restriction $\sum_j z_j = 1$ allows for variable returns to scale[8]. Hence, capacity utilization (*CU*) is defined as:

$$CU = 1/\theta_1 \tag{2}$$

The measure of CU ranges from zero to 1, with 1 being full capacity utilization (i.e. 100 per cent of capacity).

Due to random variations in the catch being measured as under-utilization rather than stochastic error, the estimated capacity utilization may be biased downward (and capacity output biased upwards). Further, the observed outputs may not be produced efficiently (Färe *et al.,* 1994), and hence some of the apparent capacity under-utilization may be due to inefficiency (i.e. not producing the full potential given the level of fixed and variable inputs). If all inputs (both fixed and variable) are not being used efficiently, then it would be expected that output could increase without an increase in the level of variable inputs through the more efficient use of these inputs. By comparing the capacity output to the technically efficiency level of output, the effects of inefficiency can be separated from capacity under-utilization. As both the technically efficient level of output and capacity output can be upwardly biased due to random variability in the data, the ratio of these measures is a less biased (both statistically and theoretically) measure of capacity utilization.

[8] In contrast, excluding this constraint implicitly imposes constant returns to scale while $\Sigma z_j \le 1$ imposes non-increasing returns to scale (Färe *et al.,* 1989).

The technically efficient level of output requires an estimate of technical efficiency of each boat, and requires both variable and fixed inputs to be considered. The VRS DEA model for this technically efficient measure of output is given as:

$$Max\,\theta_2$$

subject to

$$\begin{aligned}
&\theta_2 u_{0,m} \leq \sum_j z_j u_{j,m} \quad \forall\, m \\
&\sum_j z_j x_{j,n} \leq x_{0,n} \quad \forall\, n \\
&\sum_j z_j = 1 \\
&z_j \geq 0
\end{aligned} \tag{3}$$

where θ_2 is a scalar outcome showing how much the production of each firm can increase by using inputs (both fixed and variable) in a technically efficient configuration. In this case, both variable and fixed inputs are constrained to their current level. In this case, θ_2 represents the extent to which output can increase through using all inputs efficiently. The technically efficient level of output (u^*_{TE}) is defined as θ_2 multiplied by observed output (*u*). As the level of variable inputs is also constrained, $\theta_2 \leq \theta_1$ and the technical efficient level of output is less than or equal to the capacity level of output (i.e. $u^*_{TE} \leq u^*$). The level of technical efficiency is estimated as:

$$TE = 1/\theta_2 \tag{4}$$

Consequently, the unbiased estimate of capacity utilization (*CU**) is estimated by:

$$CU^* = \frac{CU}{TE} = \frac{1}{\theta_1} \Big/ \frac{1}{\theta_2} = \frac{\theta_2}{\theta_1} \tag{5}$$

As $\theta_1 \geq \theta_2$, the unbiased estimate $CU^* \geq CU$. The unbiased estimate CU* has been shown to be relatively insensitive to random error in the data (Holland and Lee 2002). Further details on the use of DEA in estimating capacity utilization in fisheries can be found in Kirkley and Squires (1999).

6. References

Brooke, A.D., Kendrick, D. and Meerhaus, A. (1992) *GAMS: A User's Guide.* Scientific Press, California.

Food and Agriculture Organization of the United Nations (FAO). (1998) Report of the Technical Working Group on the Management of Fishing Capacity, La Jolla, California, United States, 15-18 April 1998, *FAO Fisheries Report* No. 586, FAO, Rome, 1998.

FAO. (1999) International Plan of Action for reducing incidental catch of seabirds in longline fisheries. International Plan of Action for the conservation and management of sharks.

International Plan of Action for the management of fishing capacity. Rome, FAO. 1999. 26 pp.

FAO. (2000) Report of the Technical Consultation on the Measurement of Fishing Capacity. *FAO Fisheries Report* No. 615 (FIPP/R615(En)). FAO, Rome.

Färe, R., Grosskopf, S. and Lovell, C.A.K. (1994) *Production Frontiers.* Cambridge University Press, UK.

Färe, R., Grosskopf, S. and Kokkelenberg, E.C. (1989) Measuring plant capacity, utilization and technical change: a non-parametric approach. *International Economic Review*, 30(3): 655-666.

Holland, D.S. and Lee, S.T. (2001) Impacts of random noise and specification on estimates of capacity derived from Data Envelopment Analysis. *Journal of the Operational Research Society*, 137(1): 10-21.

Hsu, T. (1999) Simple capacity indicators for peak to peak and data envelopment analyses of fishing capacity, FAO Technical Consultation on the Management of Fishing Capacity, Mexico City, Mexico 29 November – 3rd December, 1999.

Ignizio, J.P., and Cavalier, T.M. (1994) *Linear Programming.* USA: Prentice-Hall.

Kirkley, J.E. and Squires, D.E. (1999) Measuring capacity and capacity utilization in fisheries. In: Gréboval, D. (ed) Managing Fishing Capacity: Selected Papers on Underlying Concepts and Issues. *FAO Fisheries Technical Paper* 386. FAO, Rome.

Kirkley, J.E., Färe, R., Grosskopf, G., McConnell, K., Squires, D.E., and Strand, I. (1999) Assessing capacity and capacity utilization in fisheries when data are limited, FAO Technical Consultation on the Management of Fishing Capacity, Mexico City, Mexico 29 November – 3rd December, 1999.

Kirkley, J.E., Squires, D.E., Alam, M.F., and Omar, I.H. (1999) Capacity and offshore fisheries development: the Malaysian purse seine fishery, FAO Technical Consultation on the Management of Fishing Capacity, Mexico City, Mexico 29 November – 3rd December, 1999.

Pascoe, S. and Mardle, S. (2001) Optimal fleet size in the English Channel: a multi-objective programming approach. *European Review of Agricultural Economics*, 28(2): 161-183.

Tétard, A., M. Boon, *et al*. 1995. Catalogue International des Activities des Flottilles de la Manche, Approche des Interactions Techniques, Brest, France, IFREMER.

Tingley, D., Pascoe, S. and Mardle, S. Estimating capacity utilisation in multi-purpose, multi-métier fisheries. *Fisheries Research* (*in press*)

Vestergaard, N., Squires, D. and Kirkley, J.E. (1999) Measuring capacity and capacity utilization in fisheries: the case of the Danish gillnet fleet, FAO Technical Consultation on the Management of Fishing Capacity, Mexico City, Mexico 29 November – 3rd December, 1999.

Applicability of English Channel methodology to Mediterranean fisheries

Monica Gambino*[1]

Abstract

Data Envelopment Analysis (DEA) is applied to obtain a measure of the technical efficiency of Italian bottom trawl and mid-water pair trawl fleets of the Northern and Central Adriatic Sea. Both bottom and mid-water pair trawlers result to operate close to their capacity output level. Variable factors not considered in the analysis are discussed. Further comparison of DEA analysis with stochastic methods based on production function is suggested.

1. Introduction

In this study we have applied Data Envelopment Analysis (DEA) to some key fleet segments operating in Northern and Central Adriatic. The aim was to estimate a measure of technical efficiency of these segments using a quantitative approach. The methodology is similar to that employed for the analysis for English Channel fisheries (Pascoe *et al.*, this volume). This fishing area, as in the Northern and Central Adriatic, is characterised by multi-species and multi-gears fisheries. Following Pascoe's approach we have compared multi-output measures of capacity utilisation based on catches and on revenues.

2. Methodology

In simple terms, DEA is a non-parametric approach to frontier estimation because it assumes the production function of a firm is unknown. This method is a linear programming technique for considering optimum solutions relative to individual units rather than assuming, as in optimised regression, that a solution applies to each decision making unit (DMU).

The purpose of DEA is to construct a non-parametric envelopment frontier over the data points, such that all observed points lie on or below the production frontier. DEA measures efficiency by comparing each individual production unit against all other production units within its sample data. The efficiency of each unit is calculated by comparing output and input use with points on the production frontier (best observed practice). If the production unit is on the frontier (efficient point), it will be assigned an efficiency score of 1. On the contrary, if a unit is inside on the frontier (inefficient point) it will be assigned an efficiency score smaller than 1.

DEA can be input or output oriented: it depends upon the optimisation production process characterising the firm. The input oriented technical efficiency measure addresses the question: "By how much can input quantities be proportionally reduced without changing the

---

*IREPA ONLUS – Institute for Economic research on Fisheries and Aquaculture. Via San Leonardo, Traversa Migliaro – 84131 Salerno, Italy; Email: mgambino@irepa.org

[1] This study makes extensive use of studies undertaken on the subject by Sean Pascoe. However responsibility for the selection of material and its presentation in this document rests solely with the author.

output quantities produced?" The alternative output oriented measure asks the question: "By how much can output quantities be proportionally expanded without altering the input quantities used?"

In figure 1 the distance AA' represents technical inefficiency. That is, the amount by which outputs could be increased without requiring extra inputs. Hence a measure of output-orientated technical efficiency is the ratio: TE = OA/OA'

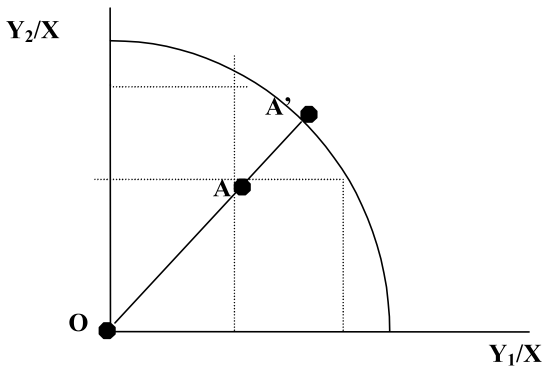


Figure 1. Technical Efficiency from an Output Orientation.

In synthesis DEA study provides:

- A best practice frontier represented by a piecewise linear empirical envelopment surface. The best practice units are those exhibiting the highest input/output relation.
- Specific targets or efficient projections onto the frontier for each inefficient DMU.
- An efficient reference set or peer group for each DMU defined by the efficient units closest to it. The peer DMU are observed to produce the same or highest level of outputs with the same or less inputs in relation to the inefficient DMU being compared.

In this study, output orientated DEA is used to determine:

i) **<u>Capacity output</u>** given current use of inputs, where potential vessel output is estimated based on its fixed inputs (i.e. gross tonnage and engine power)

ii) **<u>Technically efficient measure</u>** of output where vessels' potential output is estimated also taking into consideration the efficient use of variable input (i.e. days fished)

The mathematical formulation of the DEA model of capacity output, given current use of inputs and with variable return to scale, is given as:

$$Max\,\theta_1$$

subject to

$$
\begin{aligned}
&\theta_1 u_{0,m} \le \sum_j z_j u_{j,m} \quad \forall\, m \\
&\sum_j z_j x_{j,n} \le x_{0,n} \quad n \in \alpha \\
&\sum_j z_j x_{j,n} = \lambda_{0,n} x_{0,n} \quad n \in \hat{\alpha} \\
&\sum_j z_j = 1 \\
&z_j \ge 0, \quad \lambda_{j,n} \ge 0 \quad n \in \hat{\alpha}
\end{aligned}
\tag{1}
$$

where:
θ_1 is a scalar showing by how much the output of each vessel can be increased,

$u_{j,m}$ is the output m produced by vessel j,

$x_{j,n}$ is the amount of input n used by vessel j

z_j are weighting factors measuring the distance vessel j is from the frontier.

The value of θ_1 is estimated for each vessel separately, with the target vessel's outputs and inputs being denoted by $u_{0,m}$ and $x_{0,n}$ respectively.

Inputs are divided into fixed factors (i.e. set α) and variable factors (i.e. set $\hat{\alpha}$).

The measure of capacity output is calculated by relaxing the bounds on the sub-vector of variable inputs, $x_{\hat{\alpha}}$. This is achieved by allowing these inputs to be unconstrained through introducing an input utilisation rate ($\lambda_{j,n}$). This is estimated in the model for each boat j and variable input n.

The restriction $\sum_j z_j = 1$ allows for variable returns to scale[2].

Hence, capacity utilisation (*CU*) is defined as:

$$CU = 1/\theta 1 \tag{2}$$

It estimates capacity utilisation as a function of fixed inputs only. The measure of CU ranges from zero to 1, with 1 being full capacity utilisation (i.e. 100 per cent of capacity).

The output oriented DEA model for technically efficient measure of output is given as:

$$Max\,\theta_2$$

subject to

[2] In contrast, excluding this constraint implicitly imposes constant returns to scale, while $\Sigma z_j \le 1$ imposes non-increasing returns to scale (Färe *et al.,* 1989).

$$\theta_2 u_{0,m} \le \sum_j z_j u_{j,m} \quad \forall\, m$$
$$\sum_j z_j x_{j,n} \le x_{0,n} \quad \forall\, n$$
$$\sum_j z_j = 1 \tag{3}$$
$$z_j \ge 0$$

where:
θ_2 is a scalar outcome showing how much the production of each firm can increase by using inputs (both fixed and variable) in a technically efficient configuration.
In this case, both variable and fixed inputs are constrained to their current level and θ_2 represents the extent to which output can increase through using all inputs efficiently.
The technically efficient level of output (u^*_{TE}) is defined as θ_2 multiplied by observed output (u).
As the level of variable inputs is also constrained, $\theta_2 \le \theta_1$ and the technical efficient level of output is less than or equal to the capacity level of output (i.e. $u^*_{TE} \le u^*$).
The level of technical efficiency (TE) is estimated as:

$$TE = 1/\theta_2 \tag{4}$$

It estimates technical efficiency as a function of fixed and variable inputs.
Consequently, the unbiased estimate of capacity utilisation (*CU**) is estimated by:

$$CU^* = \frac{CU}{TE} = \frac{1}{\theta_1} \Big/ \frac{1}{\theta_2} = \frac{\theta_2}{\theta_1} \tag{5}$$

As $\theta_1 \ge \theta_2$, the unbiased estimate $CU^* \ge CU$.

3. The Mediterranean Case Study

The case study refers to bottom trawl and mid-water pair trawl of the Northern and Central Adriatic Sea. This area as most of fisheries in Mediterranean is characterised by a multi-species, multi-gears and artisanal-type fishery.
The Central and North and Adriatic Italian fleet is classified into the following six segments: bottom trawlers, mid-water pair trawlers, purse seiners, dredges, small scale fisheries and multi-purpose trawling vessels.
With respect to 2001, this area covered 820 bottom trawlers, with a total of 28,467 GRT and 177,302 Kw, about 18% of the Central and North Adriatic fleet in terms of number and 55% in terms of gross tonnage. There were 112 mid-water pair trawlers operating in this area, covering almost the entire Italian fleet segment (132) even if they account only for 2% of the local fleet. In 2001, catches from bottom trawlers are estimated around 36,132 tonnes, representing 26% of the Northern and Central Adriatic by weight and 40% by value. In the same period catches of mid-water pair trawl were around 33,300 tonnes, the 24% in terms of

weight and only 7% in terms of value. The low value of mid-water pair trawl landings is due to the low weight of high value species, such as marine crustaceans.
The landings of bottom trawl include a wide range of species. In 2001 the 48% of bottom trawl landings refer to the groups of finfishes and demersal fishes. For mid-water pair trawl about 90% of total volume of landings are composed by anchovies and pilchards.

The data set was constructed from the Irepa Observatory. It included monthly observations for 95 bottom trawlers and 21 mid-water pair trawlers, operating from 2000 to 2001. DEA was also run separately for bottom trawlers with greater overall length than 18 meters and bottom trawlers less than 18 meters in length (Table 1). In fact the differences between these vessels under physical and output points of view could influence the analysis (Table 2).

Table 1. Consolidated data sets used in the analyses.

Gear	Boats	Number of Obs.
Bottom trawl (total)	95	1,157
Bottom trawl (overall length <=18m)	39	374
Bottom trawl (overall length >18m)	56	783
Mid-water pair trawl	21	279

Source: Irepa Observatory

The key inputs used in the analysis were days fished as variable input, gross tonnage and engine power as fixed inputs. CU was estimated using multiple output (Table 2). For the multiple output measures, the top species were used individually, with the other species aggregated into a composite "other" category[3]. The "other" catch category (in weight terms) was derived using revenue shares while the revenues of 2000 were inflated to 2001 values using a Fisher price index. A different price index was estimated for each fleet segment, representing the different combination of species in the catch.

Table 2. Outputs and Inputs used in the analyses (Average per boat per month).

Gear	Catch (Kg)	Revenue (€)	Days fished	Gross tonnage (GRT)	Engine power (KW)
Bottom trawl (total)	3,692	16,479	14	43	238
Bottom trawl (overall length <=18m)	2,097	9,110	13	15	158
Bottom trawl (overall length >18m)	4,877	22,102	15	64	298
Mid-water pair trawl	28,704	29,408	16	66	334

Source: Irepa Observatory

[3] The main target species of bottom trawl are hake, red mullet, octopus, cuttlefish, Norway lobster and spottail mantis.
The main target species of mid-water pair trawl are anchovy, pilchard, mackerel, grey mullet and jack and horse mackerel.

The results were produced using a linear programming model developed in GAMS[4] by Sean Pascoe. This program has four main characteristics:

i) It considers unbalanced panel data because the number of boats varied from 2000 to 2001. In addition mid water pair trawlers did not operate in August.

ii) It runs the model with all outputs together (main species and "other" category) because it estimates multi-output measures of CU. This has the effect of reducing the influence of random fluctuations on the comparative process, so providing more accurate results[5]. In fact a boat may catch more of one species than another. If in the DEA analysis we use a single output measure (running the model for separate species), the CU results of lower species will appear under-utilised, while the boat is fully utilised when all the activity is considered.

iii) It was also run separately for four fleets (total otter trawlers, otter trawlers desegregated by two vessel length categories and mid-water pair trawlers).

iv) As data on stock abundance were not available, the model was run separately for each month so that only boats that fished in the same month would be compared. It is assumed that stock levels were relatively constant over the month; hence a stock variable cannot be included in the analysis. Spatial variations in catch composition are also not included. It is assumed that species abundance does not vary substantially across this area.

The CU biased and unbiased average scores of fleets considered are shown in Table 3. It is interesting to note the similarity between the catch and revenue based measures.
The results show that capacity utilisation (CU) varied between bottom trawlers and mid-water pair trawlers for both measures. Between bottom trawlers CU scores for vessel equal or less than 18m in overall length were inferior to CU scores of vessels greater than 18m. However, much of this under-utilisation of capacity arose out of using the inputs inefficiently rather than not using enough variable inputs. If the inputs had been used efficiently, then unbiased capacity utilisation (TE CU) for both medium-sized vessels and large vessels have been greater than 94%.

For mid-water pair trawlers capacity utilisation levels (unbiased) are always over 94%: in particular both unbiased catch and revenue-based measures of capacity utilisation (TE CU) are close to 100%.

[4] GAMS 2.0 (General Algebraic Modeling System). GAMS Development Corporation.
[5] S. Mardle, S. Pascoe, D. Tingley. "*Trends in capacity utilisation in the English Channel*". XII Conference of the European Association of Fisheries Economists, Salerno, Italy.

Table 3. Estimated capacity output and capacity utilisation.

Gear	Observed output	Capacity output	CU (1/θ1)	TE (1/θ2)	TE CU (θ1/θ2)
Multiple outputs based on weights (tonnes)					
Bottom trawl (total)	4552	5840	0.78	0.81	0.96
Bottom trawl (overall length <=18m)	784	953	0.82	0.86	0.94
Bottom trawl (overall length >18m)	3766	4480	0.84	0.87	0.96
Mid-water pair trawl	8073	8522	0.95	0.96	0.98
Multiple outputs based on revenues (€'000)					
Bottom trawl (total)	21219	25610	0.83	0.86	0.96
Bottom trawl (overall length <=18m)	3853	4453	0.87	0.90	0.95
Bottom trawl (overall length >18m)	17356	19656	0.88	0.90	0.97
Mid-water pair trawl	8551	9130	0.94	0.95	0.99

The degree of capacity utilisation is also reflected in the variable input utilisation rate (λ), which says how much variable inputs need to increase in order to operate at full capacity. Mid-water pair trawlers were operating at their optimal number of days in over 80% of observation (Figure 2). In contrast, about 60% of bottom trawlers observations were at their optimal number of days fished.

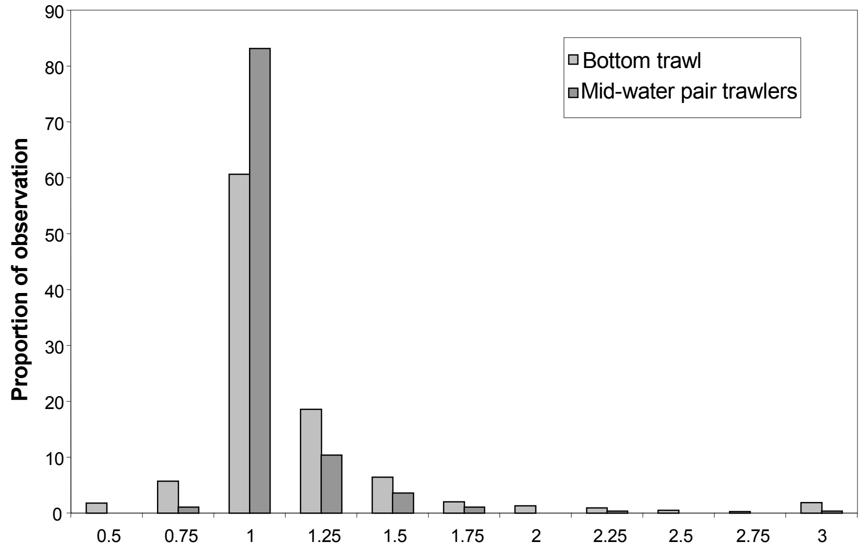


Figure 2. Variable input utilisation rate (λ).

Finally, it is interesting to observe the trend of average CU scores throughout the period considered. The average CU results tend to decrease between 2000 and 2001 for all bottom trawlers and for bottom trawlers less than 18m in overall length whilst large bottom trawlers (greater than 18m in overall length) appear to have constant scores. In average, only CU unbiased scores based on revenue of mid-water pair trawl tend to increase from 98% to 99% over the period considered.

Table 4. Average CU results by year.

Gear	CU (1/θ1)		TE CU (θ1/θ2)	
	2000	2001	2000	2001
Multiple outputs based on weights				
Bottom trawl (total)	0.80	0.77	0.97	0.95
Bottom trawl (overall length<=18m)	0.91	0.78	0.97	0.93
Bottom trawl (overall length>18m)	0.85	0.84	0.96	0.96
Mid-water pair trawl	0.95	0.95	0.98	0.98
Multiple outputs based on revenues				
Bottom trawl (total)	0.86	0.81	0.97	0.95
Bottom trawl (overall length<=18m)	0.92	0.84	0.99	0.93
Bottom trawl (overall length>18m)	0.90	0.87	0.97	0.97
Mid-water pair trawl	0.93	0.94	0.98	0.99

4. Conclusions

In this empirical analysis we have evaluated the efficiency of multi-output or multi-species fisheries using a non-parametric method such as Data Envelopment Analysis (DEA). Results indicate that both bottom trawlers and mid water pair trawlers operate close to their capacity output level. On average, the unbiased capacity utilisation levels of all fleet segments examined are over 94% for both catches and revenues measures. Mid-water pair trawlers appear to be operating more efficiently than bottom trawlers and between bottom trawlers larger boats have higher capacity utilisation scores than the smaller boats.

In these applications, the DEA methodology doesn't seem to give additional information about the economic performance of fleets examined because the results of the empirical analysis appear very similar. Almost all vessels sampled appear efficient. There are few differences between boats with different fishing gears and between bottom trawlers with different physical features. Probably the results are limited by the quality of variables included in the analysis and all these considerations suggest that other important factors have been ignored.

The DEA technique evaluates capacity establishing deviations from "best practice" performance, taking all types of fishing effort inputs into account, and comparing the resulting measures to those considering only the use of capital inputs, unconstrained by the availability of variable factors. The problem with the application to the Mediterranean case arises from the structure of fleet segments analysed, which is very homogenous. For example, if we observe the variable input, we can notice that days fished are very similar for both fleet segments considered because they are regulated by the same temporal withdrawal.
In our case it could be more interesting to analyse the characteristics of fishing activity of the vessels. For example, bottom trawlers usually follow the same fishing routes and for this reason their productivity is more influenced by the fishing area rather than by their capacity. This suggests the need to include a variable related to the fishing area in the model.

Finally the fundamentally random nature of the fishing processes under consideration suggests that stochastic methods could be preferable for estimation of efficiency. Hence future works shall compare DEA analysis with stochastic methods based on production functions.

5. References consulted

Brooke, A., Kendrick, D., Meeraus, A. & Raman, R. (1998) *GAMS A User Guide.* GAMS Development Corporation, Washington.

CEMARE. (2000) *Technical efficiency in EU fisheries: implications for monitoring and management through effort controls: "TEMEC*", University of Portsmouth on behalf of the TEMEC project partners. EU funded project QLK5-CT1999-01295.

Coelli, T., Rao, D.S.P. & Battese, G.E. (1998) *An introduction to Efficiency and productivity analysis*, Kluwer Academic Publishers, Boston/Dordrecht/London.

Coglan, L., Pascoe, S. & Mardle, S. (2000) *Physical versus harvest based measures of capacity: the case of the UK vessel capacity unit system*, IIFET 2000 Proceedings.

Färe, R. Grossokopf, S. & Kokkelenberg, E.C. (1989) *Measuring plant capacity, utilization and technical change: a non-parametric approach*. International Economic Review.

Farrell, M. (1957) The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society, Series A*, General.

IREPA. (2001) *Osservatorio economico sulle strutture produttive della pesca marittima in Italia.* Franco Angeli Eds. Milano, Italy.

Tingley, D., Pascoe, S. & Mardle, S. (2001) *Trend Utilisation in the English Channel*, XII Conference of the European Association of Fisheries Economists, Salerno.

Example of capacity assessment of a Mediterranean fishery and relevant bio-economic indicators

Evelina Sabatella*, Corrado Piccinetti**

Abstract

This paper, beginning with a definition of fishing capacity, reports on a case study which aims to assess trawl fishing capacity in the Central and North Adriatic (GFCM geographical sub-area 17), a preliminary description of which is also given.
Over the last four years, the fleet analysed has been affected by a constant decrease in all technical parameters, partly due to the capacity management policies adopted by the European Commission through the Multi-Annual Guidance Plans (MAGPs). Moreover, during the period under consideration, the trawl fleet has also undergone some significant variations following the application of national regulations on fishing days. In order to obtain a concise measurement of the capacity employed, fishing effort has been calculated; this was obtained by multiplying the capacity indicator (gross tonnage) by that of activity (average fishing days).
Indicators of capacity, activity and effort, used to measure the impact of the fishery sector on natural resources, have been completed by CPUE analysis so as to assess the impact of capacity management policies on the state of resources. The CPUE analysis was carried out for four target species of the trawl fleet in the area being studied. The biomass indices of these species were compared to the catch per unit effort. The joint use of economic (CPUE) and biological (biomass indices) indicators produced interesting conclusions and therefore should be positively considered as an effective means of analysing the effects of fishing effort management policies.
Finally, to describe further elements of complexity in the management of capacity and effort in the Adriatic Sea (such as the presence of shared stocks), distribution maps for the five species analysed have also been included.

1. Introduction

This paper, beginning with a definition of fishing capacity, reports on a case study which aims to assess the capacity of one Mediterranean fishery.

Partly to put the case study into context, this paper begins with the definitions of capacity both from a technical and an economic point of view, some clarification of the most commonly used measurement methods are also provided as taken from literature and used in the framework of management.
The case study was carried out on trawl fishing in the Central and North Adriatic (GFCM geographical sub-area, GSA, 17), a preliminary description of which is given. As well as the

* IREPA Onlus – Institute for Economic Research on Fisheries and Aquaculture. Via S. Leonardo, Traversa Migliaro; 84131 Salerno, Italy; Email: rsabatella@irepa.org.
** University of Bologna, Laboratory of Marine Biology and Fisheries of Fano. Viale Adriatico 1/N, 60132 Fano (PS), Italy; Email: cpiccinetti@mobilia.it.

assessment of the capacity of the fishery in question, an analysis will be carried out of the legal and management measures which aim to control fishing capacity and effort. In the light of these measures the trends in fishing capacity from 1997 to 2001 will be studied.

Furthermore it will be interesting to evaluate whether fishing capacity and effort management have had a noticeable biological impact on the resources. In order to do this, the trends of some biological parameters will be studied in the light of the trends of capacity indicators.

Analysis of other biological data will be performed to define problematic aspects of fishing capacity management in the Central and North Adriatic.

2. The concept of fishing capacity and its measurement

Among the most important topics concerning fisheries that are under discussion at national and international level, the excess of fishing capacity, the over exploitation of resources and the relative management issues can certainly be included. Nonetheless, the definition of fishing capacity and its measurement are obscure and not unequivocal concepts. According to the point of view (economic, biological or technical), several definitions and ways of measuring capacity have been proposed some of which are conflicting. These definitions and measurements have often been adopted in order to correspond to the aims of those involved in fisheries management.

Capacity is often expressed in terms of variables which are simple and easy to monitor; such as number of vessels, physical characteristics, fishing time, fishing gear and methods used. However capacity is defined more accurately in terms of catch (output) or in economic terms (capital costs).

In its most common application, fishing capacity is often identified with capital stock. Specifically fishing capacity is defined as "*the maximum available capital stock in a fishery that is fully utilized at the maximum technical efficiency in a given time period given resource and market conditions*" (Kirkley and Squires, 1998).

FAO suggests using a definition of fishing capacity in terms of output, the proposed definition is: "*fishing capacity is the maximum amount of fish over a period of time that can be produced by a fishing fleet if fully utilised, given the biomass and age structure of the fish stock and the present state of the technology*" (FAO, 1998, p 10).

Capacity measured at the level of single enterprises, vessels, vessel classes, ports or regions can be aggregated to obtain a measurement of total capacity. This measurement of total capacity can thus be compared to the target capacity or reference point.

The concept of *capacity utilisation* (CU) represents the available part of capacity which is utilized. CU is usually defined as the relationship between effective output and one of the measures of capacity. In the approach adopted by FAO, full CU represents full capacity and CU cannot exceed 1. Capacity utilization lower than 1 indicates that the fishing enterprises have the potential for higher production without having to incur any further expense for new capital or equipment.

Capacity and capacity utilisation are strictly short-term concepts, defined or measured on the basis of a stock of fixed capital and of the state of technology. In the long term, capital can be modified on the basis of changes in economic conditions, or there could be technological changes and therefore capacity and capacity utilisation can also alter.

An *excess of capacity (overcapacity)* occurs when an enterprise or industry has the potential to produce more than is actually produced. To express this in greater detail, an excess of all inputs is present – including work, capital, and other fixed factors – in order to produce a given set of output. Therefore *overcapacity* is present when the output of capacity (or the maximum possible output) is greater than the desired target capacity levels.

FAO (1998) proposed a general description of *target capacity*: "*target fishing capacity is the maximum amount of fish over a period of time that can be produced by a fishing fleet if fully utilized, while satisfying fishery management objectives designed to ensure sustainable fisheries*".

Estimation of *overcapacity* allows fishery managers to define a series of significant adjustments of the fleets with the purpose of rebalancing the fleet's capacity with the availability of resources.

2.1 The measurement of fishing capacity by the European Union

Fishing capacity in the EU has historically been measured in terms of two vessel characteristics, gross tonnage and engine power. These two characteristics have been measured, monitored and registered as fishing capacity indicators by most member states, as defined in EC Regulation n. 2930/86 and have been considered the most relevant parameters to express the fishing capacity of fleets with active gear.

The number of kilowatts of an engine (total of continued maximum power) is a relatively clear measurement, although different measuring procedures among member states has caused some complication. There have been problems concerning de-rating practices, the exclusion of auxiliary engines as well as different measurement in terms of official kilowatts (kW) and maximum effective kW (Lindebo, 2000).

Calculation of gross tonnage has, however, proved to be less linear. Historically tonnage has been measured as Gross Registered Tonnage (GRT), defined by the Oslo Convention of 1947. Progressively the EU has introduced a standard, common measurement of tonnage, a volumetric quantification known as Gross Tonnage (GT) defined by the International Convention on Tonnage Measurement of Ships, 1969. However the registration of fleet tonnage for many member states still includes a combination of measurements due to the slow and complicated conversion process, this has limited the transparency of the results of fishing capacity reduction initiatives. The re-measurement process should be concluded by the end of 2003.

The EU has used the concept of fishing capacity to define a further term known as fishing effort. Both terms have been used in parallel since 1992 to achieve the desired fleet reduction. Lassen (1996) states that fishing effort can be considered to be composed of two separate elements: an element of capacity (characteristics of the vessel and the gear) and an element of activity (utilisation of the capacity, fishing time etc). In other words:

Fishing effort = capacity (vessels) * capacity (gear) * activity

The EU has adopted a measurement of fishing effort per fleet segment, in terms of aggregate tonnage, engine power and fishing activity (EC Regulation n. 2091/98):

$$\text{Fishing effort (tonnage)} = \sum_{t=1}^{n} a_t J_t$$

$$\text{Fishing effort (engine power)} = \sum_{t=1}^{n} a_t P_t$$

Where n is the number of vessels in the segment, a_i is the number of days at sea in the period of observation, J_i e P_i are respectively the average tonnage per vessel and the average engine power in each segment and during the period of observation.

It is easy to see that, as in all cases, estimation of fishing effort is difficult and the objectives can therefore be manipulated.

3. Description of the area and the fleet which are the focus of the case study

The morphological characteristics of the Adriatic allow for a straightforward differentiation of the three basins: the deep southern one, the central one and the northern one (Figure 1). The morphology and the physiographical nature of the northern basin are such that it is significantly different from the two basins further south.

The most relevant aspects are:

- The lower average depth.
- The absence of marked irregularities on the sea bottom, which slopes progressively towards south-east.
- The presence of several of the largest rivers of the area along its coast, which convey the flow-off from the Po valley and from the slopes of the Alps and Apennines which surround the area.

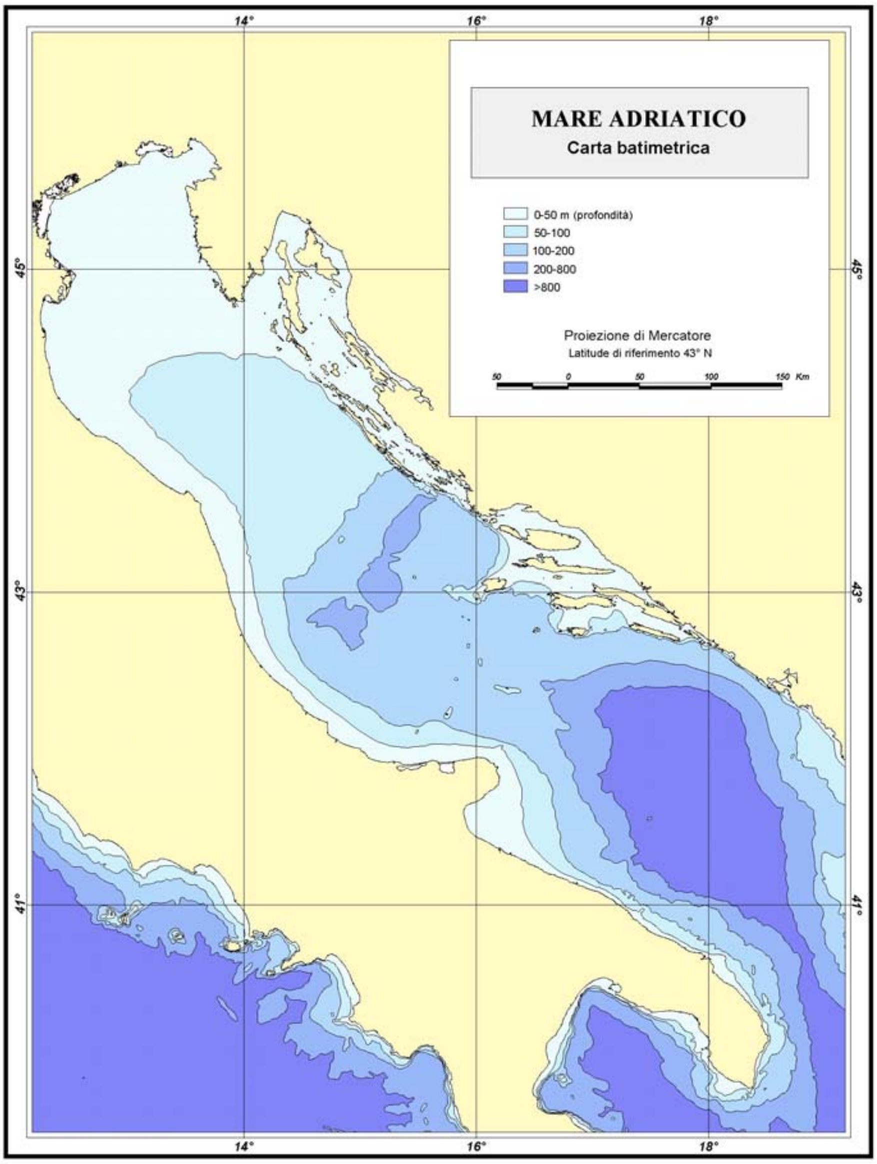


Figure 1. Bathymetric map of the Adriatic Sea.

On a geological scale, these elements have had a direct influence on the morphological modelling of the seabed as it is now and, in the short term, are very important for the determination of the structure of the density of the water contained in the basin, as well as of the chemical and physical properties of the water and the various processes which occur there.

The shallowness of the water, the considerable quantity of nutrients which these areas receive, above all from the freshwater run-off from the rivers, together with the distinctive processes of sedimentation, accumulation and decomposition of the organic silt on the sea bed are the fundamental components for the development of an extremely rich and diverse trophic chain.

Marine waters are significantly influenced by variations in temperature that occur during the changes in the seasons, and the temperature range is appreciable due to the very fact that the water is shallow. The water mass warms up and cools down more quickly than in basins which contain a larger mass. In particular, summer temperatures accelerate the bio-geo-chemical cycle of the mineral elements, making them more available to the trophic chain and more quickly.

The Central and North Adriatic is therefore an environment characterised by many elements which define its peculiarity and above all interact to determine the biological richness and the availability of fishery resources. In particular, the moderate slope and soft sea bottom which covers a large area going away from the coast and is for the most part sandy, muddy and alluvial, have made the Adriatic particularly suitable for trawl fishery, both bottom and beam trawling for demersal species, mid-water pair trawl for small pelagic fish and dredgers for clams. The fishery activities requiring this environment therefore flourish, from the coastal fishing valleys to the open sea.

In general, among the various techniques present in the fishery sector, trawl fishery is the most widespread since it guarantees technical and economic yields which are higher on average than those obtained using other methods. The trawl net is not a highly selective gear, targeting medium to high value demersal fish stocks, in accordance with the times and procedures permitted in the fishing area and within the limits of prevailing regulations.

The study area covers 764 km of coast on the Adriatic Sea and for administrative purposes is divided into 11 ports of registration (maritime districts).

In 2001 in the regions of the Central and North Adriatic, 502 vessels operating with trawl nets were registered in the Archive of Fishing Licences in the segment 4H2 (coastal, trawl), with a gross tonnage of 17659 GRT and an engine power of 109960 kW. The category MAGP 4H2 does not cover all vessels using trawl nets, as part of them are classified for MAGP purposes as 4H6 (coastal, polyvalent) and 4H7 (Mediterranean, bottom and mid water trawl). This study, however, looks exclusively at segment 4H2 where fishing capacity is concerned, whereas effort and CPUE data refer to the entire trawl fleet in GFCM GSA 17.

4. EC capacity adjustment policy

Control of the fleet's fishing capacity comes under the jurisdiction of the EC regulations and is governed by the Multi-Annual Guidance Plans (MAGPs). These plans aim to bring fishing effort into line with the volume of resources available. They allow the development of each member state's fishing fleet to be planned, establishing objectives concerning the reduction of tonnage and engine power, which have to be achieved within the set time limits.

Subsequently, according the criteria fixed by the Council, the member states set up four- or five-year adjustment plans for their fleets. To make the measures more suitable for each type of fishery, the fleets have been divided into groups or "segments" which correspond to the main fishery activities carried out. It is then a question of calculating the reduction in effort necessary in each segment for each national fleet, using a specific means of calculation.

The MAGP applicable to the period considered in this paper is MAGP IV which was in force from 1997 – 2001. The aims established by the EC for the fourth MAGP with reference to the segment concerning trawl fishery, scheduled a reduction in capacity, expressed both in terms of tonnage and in terms of engine power.

The fishing capacity of the trawl fleet can be contained by blocking the concession of new licences and also by binding the construction of new vessels to the withdrawal of the old vessel (demolition, sale to non EU countries, passage to another destination) on the condition that the old vessel is 120% of that to be built.

5. National regulations regarding fishing capacity and effort

In order to achieve the objective identified by the EC of limiting the effort exerted by the fleet on the fishery resources, the national administration uses another tool which is to reduce the number of days at sea. The interruption of fishing activity constitutes a protective measure for the resources, in particular during the recruitment period and it is applicable to vessels with licences for bottom and with pelagic trawling.

The prohibition of access to the fishing zone for a consecutive period is employed at different times according to the management areas concerned. From 1997 to 2001 the periods of interruption to fishing activity in the Central and North Adriatic took place in several ways in the different years (Table 1) and were further conditioned by unexpected events which had a strong impact on the normal, regular fishing activity.

Table 1. Periods and typology of the interruptions to fishing activity in the Central and North Adriatic in the years 1997 – 2001.

Year	Periods and typology of the interruptions in the Central and North Adriatic	Duration in days
1997	31 July - 13 Sept. (Obligatory)	45
1998	20 July - 2 Sept. (Obligatory)	45
1999	14 May - 3 June (Voluntary - war)	20
	4 June - 15 July (Obligatory)	41
	16 July - 31 Aug. (Facultative)	46
2000	- 19 July (Facultative)	
	20 July - 1 Sept. (Obligatory)	44
2001	1 -30 August (Obligatory)	30

Knowledge of national regulations concerning technical interruption of activity will be useful for a correct interpretation of some of the indicators referred to hereafter. Furthermore, although fishing effort is a separate concept from fishing capacity, as we have already seen, "the management of fishing capacity closely relates to many issues and concepts of conventional fisheries management and conservation. In general terms, issues raised are often quite similar to those relating, for example, to the management of fishing effort." (FAO, 1998).

6. Assessment of fishing capacity and effort for the bottom trawl fleet in the Central and North Adriatic.

6.1 Capacity

In Italy, as in most EU countries, fishing capacity in identified by the quantity of capital and is often associated with the variables gross tonnage (GRT) and engine power (expressed in kW). These and other variables are analysed in this paper in order to provide a complete picture of the trend in capacity of the bottom trawl fleet in the Central and North Adriatic relative to the period 1997 – 2001 and to be in a position to evaluate the impact this fleet's activity had on the fishery resources.

The analysis is carried out considering the total values of each single variable per vessel, as this allows for a better description of the evolution of the structure of the fishing fleet considered. Data concerning the dimensions of the fleet are taken from the Archive of Fishing Licences, while data on activity and production are from the IREPA database produced in the context of the programme "Economic observatory on the productive structures of Italian marine fisheries".

In the course of the last four years, the fleet under analysis has been affected by a constant decrease in all technical parameters (Table 2). The downward trend is most consistent where gross tonnage is concerned, compared to the indications in the multi-annual guidance plan this parameter has suffered a more marked reduction than those found for the other technical characteristics of the vessels.

Table 2. The bottom trawl fleet* in the Central and North Adriatic (Source: Archive of Fishing Licences).

	1997	**1998**	**1999**	**2000**	**2001**
Number of vessels	661	642	584	548	502
Gross tonnage (1000 GRT)	25	24	22	20	18
Engine power (1000 Kw)	137	135	124	120	110

* the vessels which, according to MAGP classification, are in segment 4H2 have been considered.

Total tonnage (Figure 1) decreased by 30% from 1997 to 2001, going from 25 thousand tons to 18 thousand. In terms of average tonnage per vessel, there was a reduction of 8%; in 1997 a trawl vessel had an average tonnage of 38 t whereas in 2001 this value was 35 t.

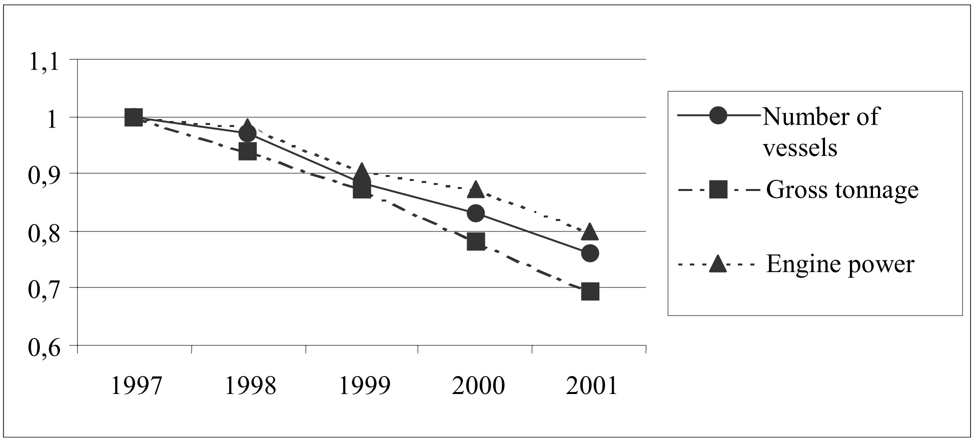


Figure 1. Trends of the bottom trawl fleet (POP 4H2) in the period 1996-2001. Source: Archive of Fishery Licences.

Engine power shows similar behaviour to tonnage, but at lower rates. Engine power decreased constantly in the period analysed for a total of about 27 thousand kW. Contrary to tonnage, average engine power per vessel increased slightly, going from 208 kW in 1997 to 219 kW in 2001.

The differing behaviour of the two variables can be explained with reference to the objectives of the multi-annual guidance plan to reduce effort and the regulations which followed this. The aims of reducing tonnage and engine power were pursued by blocking the issue of licences and by limiting the construction of new vessels by imposing the withdrawal of old vessels to a total of 120% of those being built. The latter measure clearly brought about a reduction of the average tonnage of bottom trawlers, however the reduction did not have such strong repercussions on engine power.

Tonnage and engine power are the variables which are most directly influenced by the measures set out to achieve a reduction in capacity; however, at the same time they are remote from the definition of capacity given in paragraph 2. Fishing capacity as proposed by FAO is a measure of output and refers to the full utilisation of the fleet. Kirkley and Squires' definition, expressed in terms of capital stock, refers to a fully utilised fishing fleet. Capacity expressed in terms of tonnage or engine power certainly cannot be considered fully utilised, on the other hand it is not easy to find capital stock that corresponds to this requisite. Capacity management policy cannot be limited to a consideration of capacity as such, but should also associate a measurement of its real utilisation. Even if consideration of "full utilisation" is not limited exclusively to the temporal aspect, this latter is certainly an indispensable element in defining the degree of real utilisation of the capacity. In the case study in question, the activity of the trawl fleet has been analysed in terms of average fishing days per vessel.
During the period considered, the activity of the trawl fleet underwent some significant variations. These variations were due to both the effect of the regulation of its activity and also to the occurrence of some exceptional events, such as the beginning of the Balkan conflict and the phenomenon of mucilage. In particular, following a relatively stable period from 1997 to 1998, the conflict of 1999 caused a reduction of total fishing days of over 18% (Figure 2).

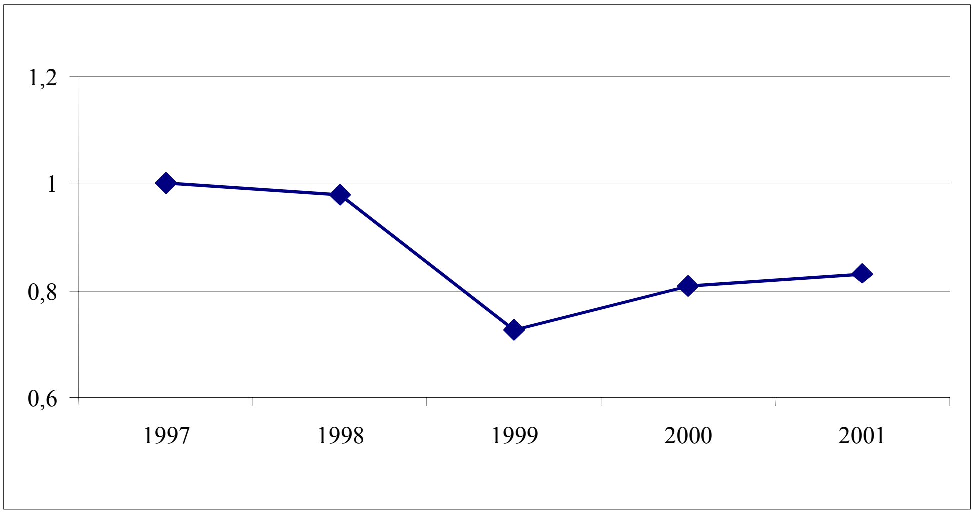


Figure 2. Total fishing days in the period 1997-2001. Source: IREPA Observatory.

In the following two years a substantial recovery was observed. In 2000 the increase was partially slowed down by the presence of mucilage, but in spite of this the number of fishing days was able to return to the levels seen before the period of war. In 2001 there was further growth with a rise of over 2% compared to the previous year. This increase was mainly due to a reduction in the number of days of the closed fishing period, which went from 45 days the previous year to just 30 days.

The analysis of the indicator of activity allows for a clearer picture of the capacity which is actually employed by the vessels of the fleet under examination. For example, this allows us to reveal how in 2000, compared to 1999, in spite of a considerable reduction in tonnage, the fishing effort of each single vessel remained virtually the same as the previous year. Moreover, if the capacity in terms of gross tonnage decreased by 17.5%, its level of use in terms of days of activity grew by almost 19%. Concise measurement of the capacity employed can be obtained by multiplying the capacity indicator (gross tonnage) by that of activity (average fishing days). This measurement is also used to estimate the fishing effort exerted on the resources. In any case, it is necessary to consider that the calculation of the number of fishing days is affected by the fact that the fleet has numerous small vessels, thus the duration of each fishing days is highly variable. Small fishing vessels operate for 8-10 hours a day, while for medium and large vessels the fishing day is between 22 and 24 hours. This indicates that there is a significant margin of the fleet's fishing capacity which is not utilised. Another aspect which is linked to the partial utilisation of the fishing capacity is the engine power available which is actually used for towing the nets. Generally this is less than 50% of the power available.

6.2 Fishing effort

As with capacity, effort does not have an unequivocal definition, consequently there is no single measurement method, however in empirical studies present in literature, several measurements of effort have been proposed. For example, Gulland (1983) measured fishing effort in terms of

vessel length, tonnage and engine power, whereas Beverton and Holt (1957) only in terms of gross tonnage.
A decidedly economic method was applied by Placenti *et al.*, (1992) who employed the composite index *"vessel tonnage*vessel engine power*fishing hours"* in a bioeconomic model applied to Italy. This formula can be considered a synthesis of the two measures predominantly adopted by the EU *"vessel tonnage*fishing hours"* and *"engine power*fishing hours"*.
Sabatella (2000) concluded that to measure capacity in fisheries (a measure of capital) it was necessary to develop investment time series.
In this case study, it was deemed preferable to use a simpler formula, obtained from the product of vessel tonnage and fishing days. Figure 3 demonstrates an initial decline of this parameter until 1999, followed by a slight increasing trend until 2001.

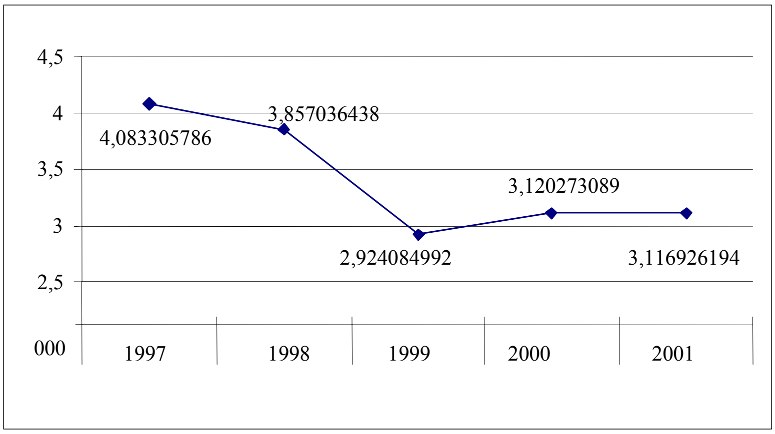


Figure 3. Total effort, trawler fleet (GSA 17) 2001. Source: IREPA Observatory.

The most marked reduction (-24%) occurred in 1999 and was chiefly due to the reduction of fishing days for the risks connected to the Balkan conflict. The following year effort began to increase slowly. This trend, as has already been stated, was the result of a significant reduction in tonnage, almost entirely compensated by an increase in days of activity.

7. Catch per unit of effort

Capacity, activity and effort indicators are used to measure the impact of the fishery sector on natural resources. These indicators are necessary, although certainly not sufficient, to assess the state of the resources in a given geographical area. The information obtained from these indicators needs to be completed by that which derives from the total of the catches, that is, from the output of the productive process. In this sense, one of the most widely used indicators is the catch per unit of effort (CPUE). CPUE is extensively used by biologists to determine variations in biomass and by economists as a measure of the efficiency of the fleet (van Hoof *et al.*, 2001).
Consider a simple model for the fishery sector, where catches are defined as:

$$C = EqB \qquad (1)$$

where C are the catches expressed in kg, E represents fishing effort as previously defined (gross tonnage*fishing days), q is the catchability coefficient and B is the biomass level.

CPUE is therefore defined as the relationship between total catches and total fishing effort in a given period of time:

$$U = C / E \tag{2}$$

where U represents the CPUE.
From (1) and (2) it follows that CPUE can be connected to biomass:

$$U = qB \tag{3}$$

As stated previously, CPUE can be used to measure variations in biomass level.
Consider the variations of the indicator:

$$C_t / E_t = \alpha (C_{t-1} / E_{t-1}) \tag{4}$$

where *t-l* and *t* represent the two consecutive time periods. α is a coefficient linked to biomass development:

$$q_t B_t = \alpha (q_{t-1} B_{t-1}) \,. \tag{5}$$

If the catchability coefficient is assumed to be constant, CPUE variations can be considered a good proxy of the variations which arise in the stock.
Figure 4 shows the trend of this indicator in relation to the trawl fishery system in the Central and North Adriatic. Until 1999, the indicator is subject to slight oscillations.

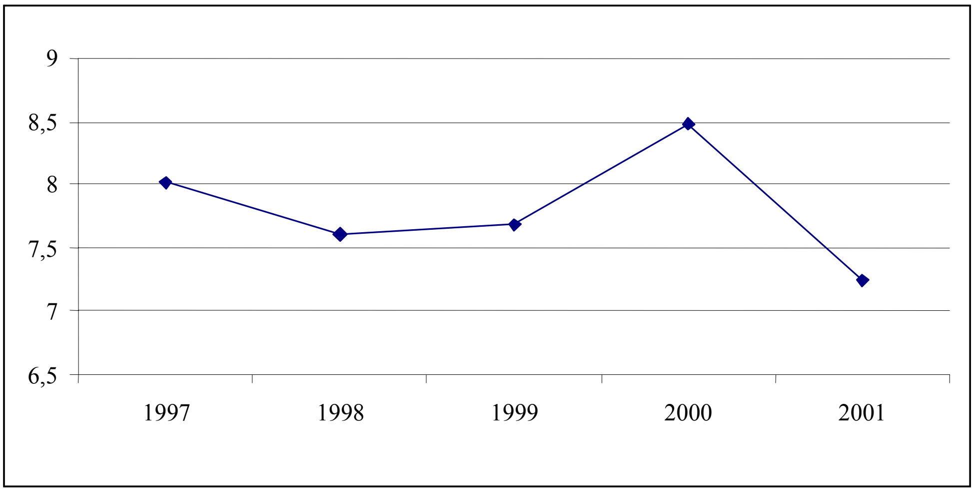


Figure 4. Total catch per unit of effort. Source: IREPA Observatory.

In 1998, CPUE was equal to 7.6 kg per GRT unit daily and this level was also maintained in 1999. More significant variations were registered in the last two years. In 2000 a considerable increase, over 10%, highlights a rise in biomass probably due to the prolonged closed period in the previous year which allowed the fishery stocks to build up. Finally, in 2001, with a reduction of 14.5%, CPUE reached its lowest level for the entire period being studied (7.2 kg). This figure, which indicates a significant decrease in total stock, is probably the consequence of the constant increase in the days the Adriatic fleet spent at sea in the period 1999 – 2001.

8. Indices of biomass and CPUE for some target species of trawl fishery

The biomass index is a biological indicator which measures the abundance of a species, it is calculated on the basis of scientific assessment surveys at sea and expresses an index of the quantity in kg per species per square kilometre. Among the most important species for Adriatic trawl fisheries, the following have been considered:

- European hake (*Merluccius merluccius*)
- Norway lobster (*Nephrops norvegicus*)
- red mullet (*Mullus barbatus*)
- horned octopus (*Eledone cirrhosa*)
- musky octopus (*Eledone moschata*)

The biomass indices for these species were compared to the catch per unit effort, for the two *Eledone* species only one CPUE measurement is available because this indicator is calculated on commercial catches and it is not commercially possible to distinguish between horned and musky octopus. The biomass indices and the catch per unit effort have been reported for the years from 1999 – 2001 in Table 3.

Table 3. Biomass indices and CPUE.

			1999	**2000**	**2001**
European hake	*Merluccius merluccius*	biomass index (kg km^2)	32,25	19,36	17,62
		CPUE	0,84	0,52	0,46
Norway lobster	*Nephrops norvegicus*	biomass index (kg km^2)	2,66	1,18	1,25
		CPUE	0,47	0,35	0,38
Red mullet	*Mullus barbatus*	biomass index (kg km^2)	51,20	10,70	13,47
		CPUE	0,61	0,67	0,55
Musky octopus	*Eledone moschata*	biomass index (kg km^2)	18,84	7,47	18,64
Horned octopus	*Eledone cirrosa*	biomass index (kg km^2)	1,43	5,34	8,26
		CPUE	0,33	0,34	0,66

In the case of the hake, the tendencies of the biomass index and CPUE in the three-year period considered, follow the same downward trend (Figure 5). The catch per unit of effort passed from 0.84 kg per unit of effort in 1999 to 0.46 kg in 2001. For both indicators, the decrease was most marked between 1999 and 2000.

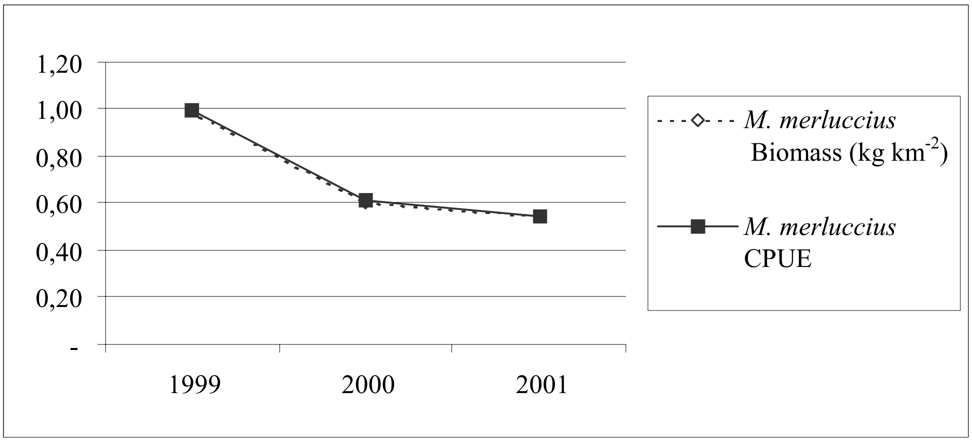


Figure 5. Bio-economic indicators, base year 1999 (*Merluccius merluccius*). Source: IREPA Observatory and MEDITS.

Passing on to an analysis of the bio-economic indicators of Norway lobster (Figure 6), a decline in both biomass index and CPUE can be noted between 1999 and 2000, with cautious recovery in 2001.

Between 1999 and 2000 catch per unit of effort reduced by 24% while the biomass index decreased by 56%. The increase in catch per unit effort in 2001 compared to the previous year can be put down to the albeit slight recovery of the state of the resources, as the increase in biomass proves.

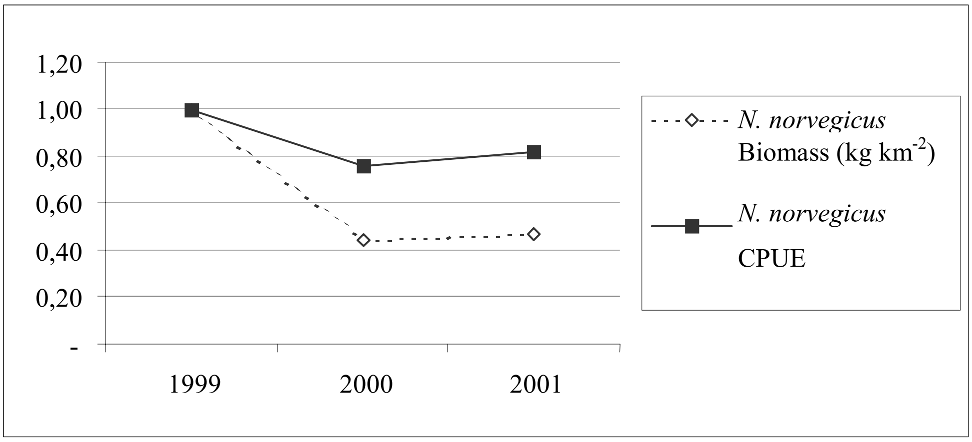


Figure 6. Bio-economic indicators, base year 1999 (*Nephrops norvegicus*). Source: IREPA Observatory and MEDITS.

The red mullet is the only species for which the trends of CPUE and biomass indices are not in agreement (Figure 7). Between 1999 and 2000 CPUE increased from 0.61 to 0.67 kg, while the biomass index decreased from 51.2 kg per square kilometre to 10.7 kg. Between 2000 and 2001 this trend reversed: the biomass index increased (taking it to 13.47 kg) while the CPUE decreased (taking it to 0.55 kg). This trend is, however, justifiable if the meaning of the two bio-economic indicators is analysed better.

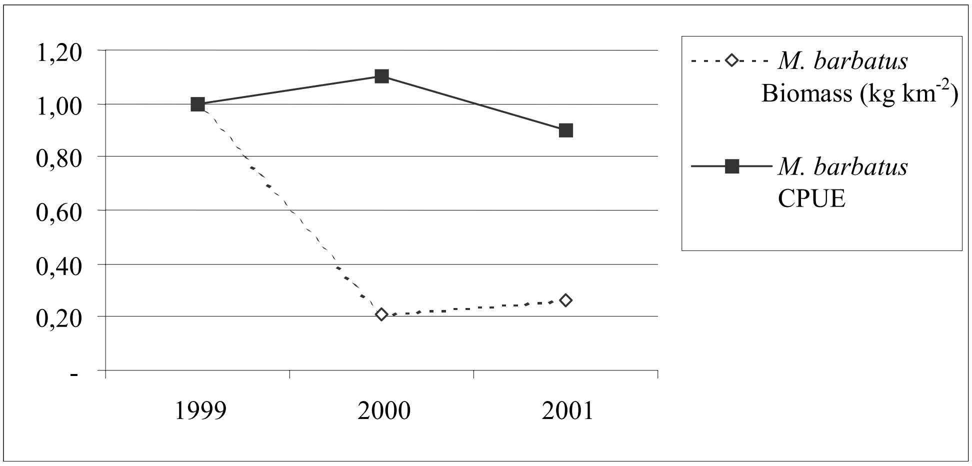


Figure 7. Bio-economic indicators, base year 1999 (*Mullus barbatus*). Source: IREPA Observatory and MEDITS.

The CPUE indicator refers to commercial catches achieved in a year's fishing, in relation to the effort exerted in the same year. The biomass index, in the other hand, refers to resource abundance at the moment in which the appraisal survey is carried out at sea. These biological surveys are carried out in late spring, which is the reproduction period of the red mullet. The life cycle of the species in question can explain the difference; the red mullet grows quickly and in the months of September and October the largest quantities of mullet are landed which were born from the June reproduction. To summarise, the two trends are in contrast because the biomass index is calculated at the moment of reproduction and therefore only counts the individuals which have "survived" a year's exploitation, while the CPUE indicator refers to an entire year of activity and is influenced by the recruitment of the young mullets. This example suggests that, for species with a short life cycle, it would be better to compare the two indicators over a shorter time period (month or three-month periods).

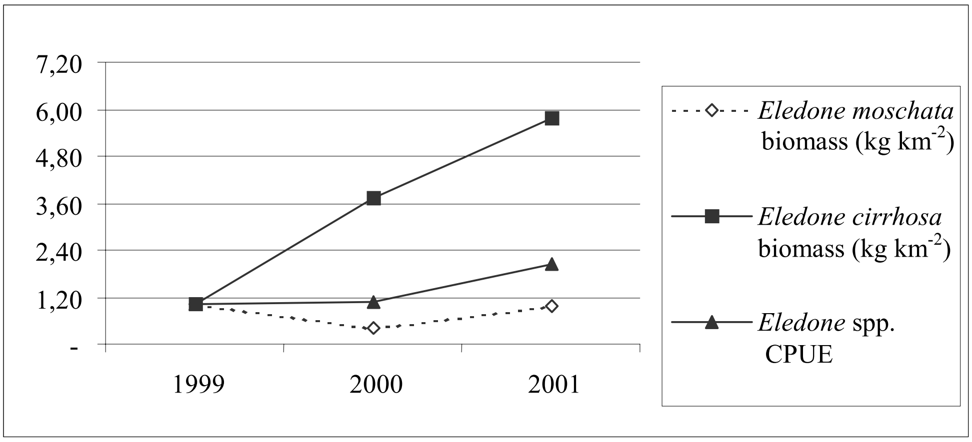


Figure 8 Bio-economic indicators, base year 1999 (*Eledone moschata, Eledone cirrhosa*). Source: IREPA Observatory and MEDITS.

Lastly, analysis of horned octopus (*E. cirrhosa*) and of musky octopus (*E. moschata*) was performed. The catch per unit effort index was calculated considering the sum of both species because commercial catch statistics do not report them as two species. Two separate biomass indices are, however, available. As can be observed in Figure 8, the tendencies of the indicators using 1999 as the base year show the CPUE trend is the same for both species, whereas the biomass index for *E. cirrhosa* shows a different trend for the years considered. This situation can be explained if we consider that the prevailing species in the study area is *E. moschata* of which a far higher quantity is caught, it is therefore justifiable that the biomass index of *E. moschata* is correlated with the indicator constructed on the basis of fishery activity and production.

As a conclusion to this analysis, it can be stated that biological and economic statistics allow for joint analysis and the integrated use of biological and economic indicators, as well as being possible, is highly recommendable as a tool for the analysis of the effects of fishing effort management policies.

9. Distribution maps

Management of fishing capacity and/or fishing effort should consider spatial distribution of species in order to have an effective result on resources. Reduction of capacity in one port could have no effect whatsoever on a particular species, if that species is distributed in different areas to those of the fleet from the port in question. For small fishing vessels the fishing area is very limited.

In order to describe this element of complexity in the issue of management of fishing capacity and fishing effort in the Adriatic Sea, hereafter follow the distribution map of *Mullus barbatus* (Figure 9), *Merluccius merluccius* (Figure 10), *Nephrops norvegicus* (Figure 11), *Eledone chirrosa* (Figure 12) and *Eledone moschata* (Figure 13).

The maps emphasize how the areas of distribution differ greatly according to the species. However, also considering the same species, distribution also changes according to the length class. An example can be seen in Figures 14, 15, and 16 which show the distribution maps for *M. merluccius* for three different length classes (less than 12 cm total length, from 12 cm to 20 cm, and greater than 20 cm, respectively).

The distribution maps highlight another important aspect of fisheries in the Adriatic Sea: the presence of shared stocks. In this context, the application of all encompassing management plans is unavoidable for effective fisheries management; unilateral efforts to control fishing capacity could otherwise be futile.

The example described in this paper considers only the fishing capacity and fishing effort of Italian vessels operating with bottom trawl nets, the same resources are also targeted by the fishing vessels of countries on the other side of the Adriatic, in particular from Croatia, as well as fishery using other types of gear.

To obtain reliable indications, it is essential to be aware of the variations in abundance of the resources and the variations in total fishing effort applied to all the species by all the fishing units that operate in the area.

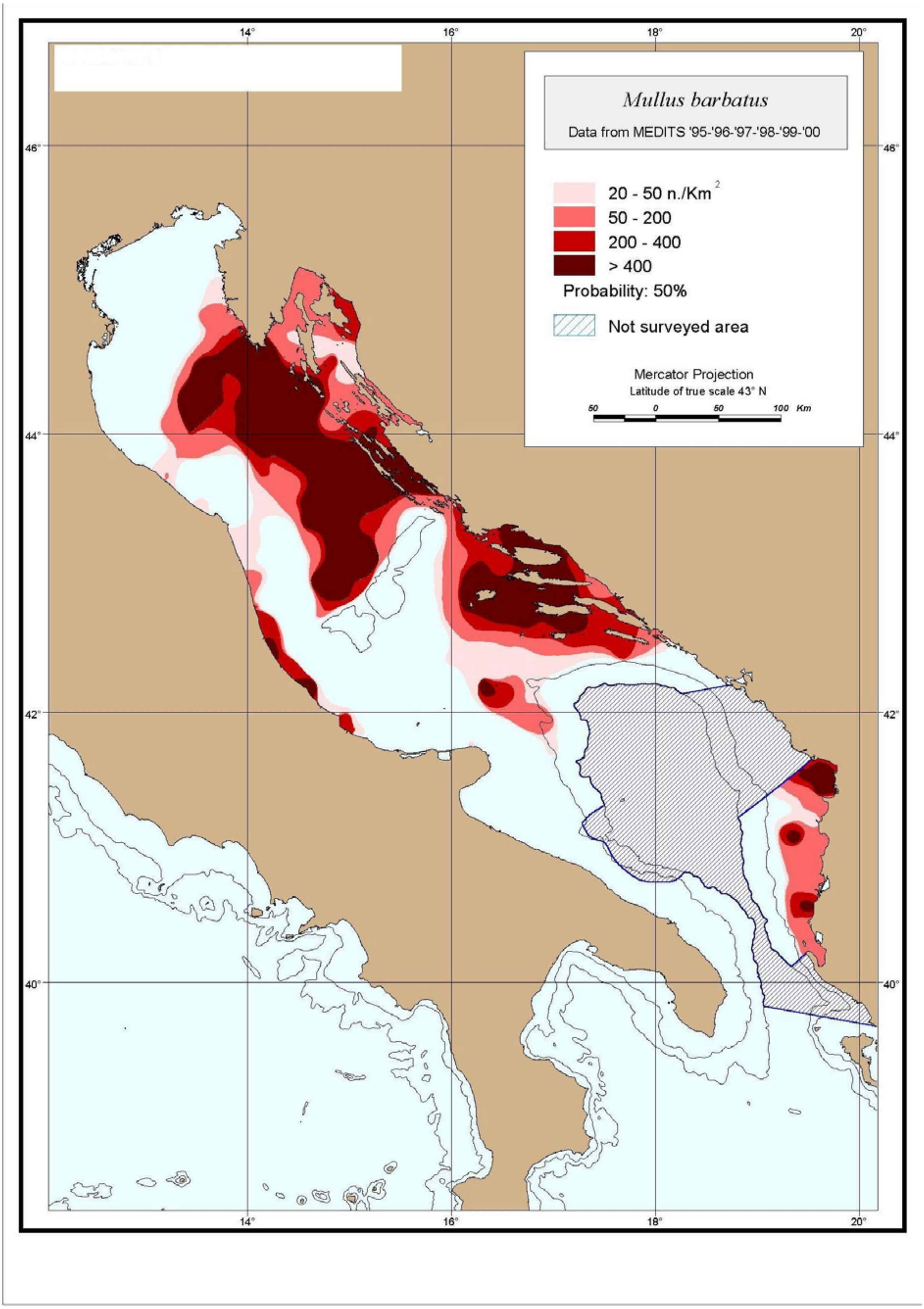


Figure 9. Distribution map of *Mullus barbatus.*

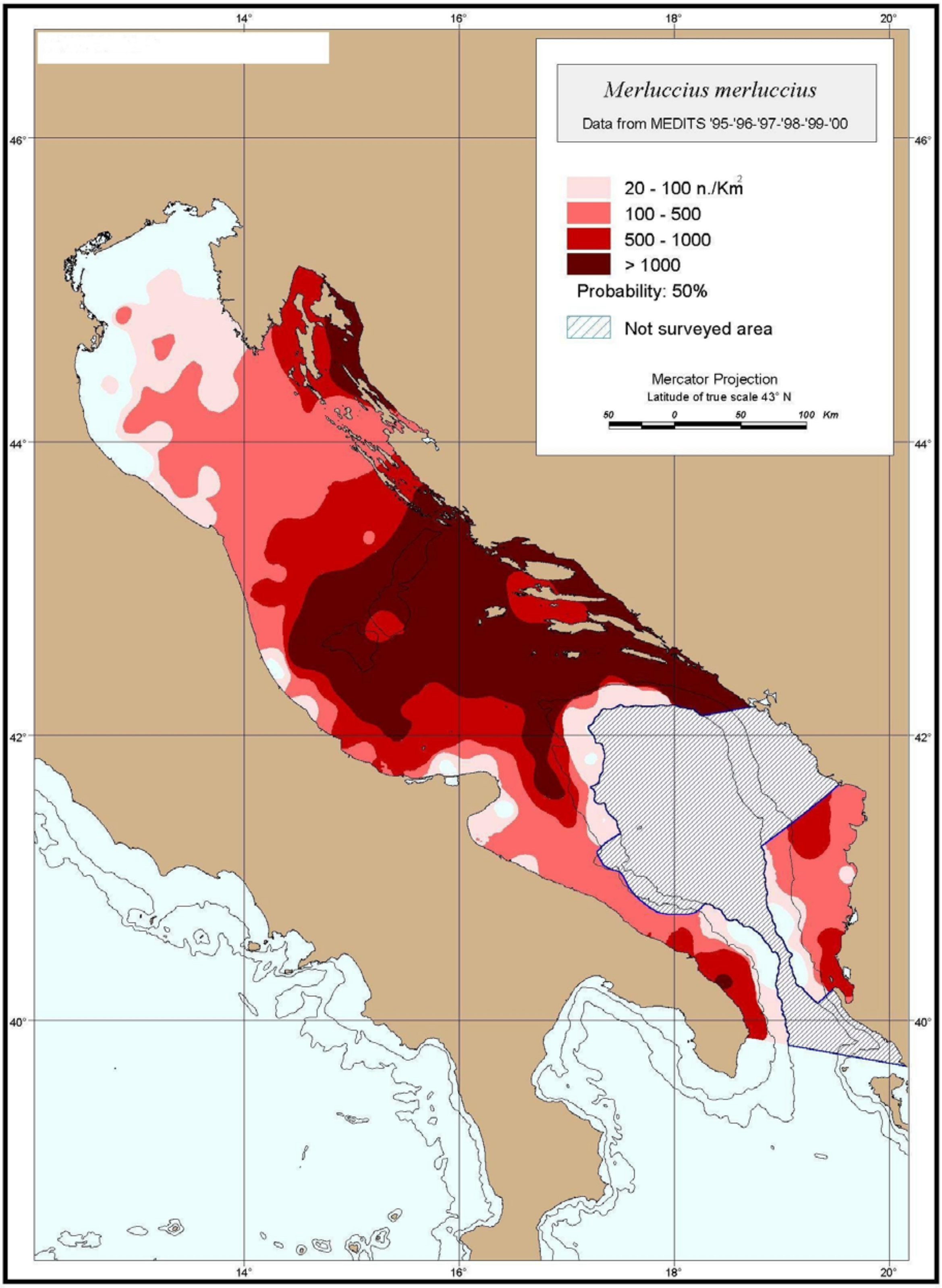


Figure 10. Distribution map of *Merluccius merluccius.*

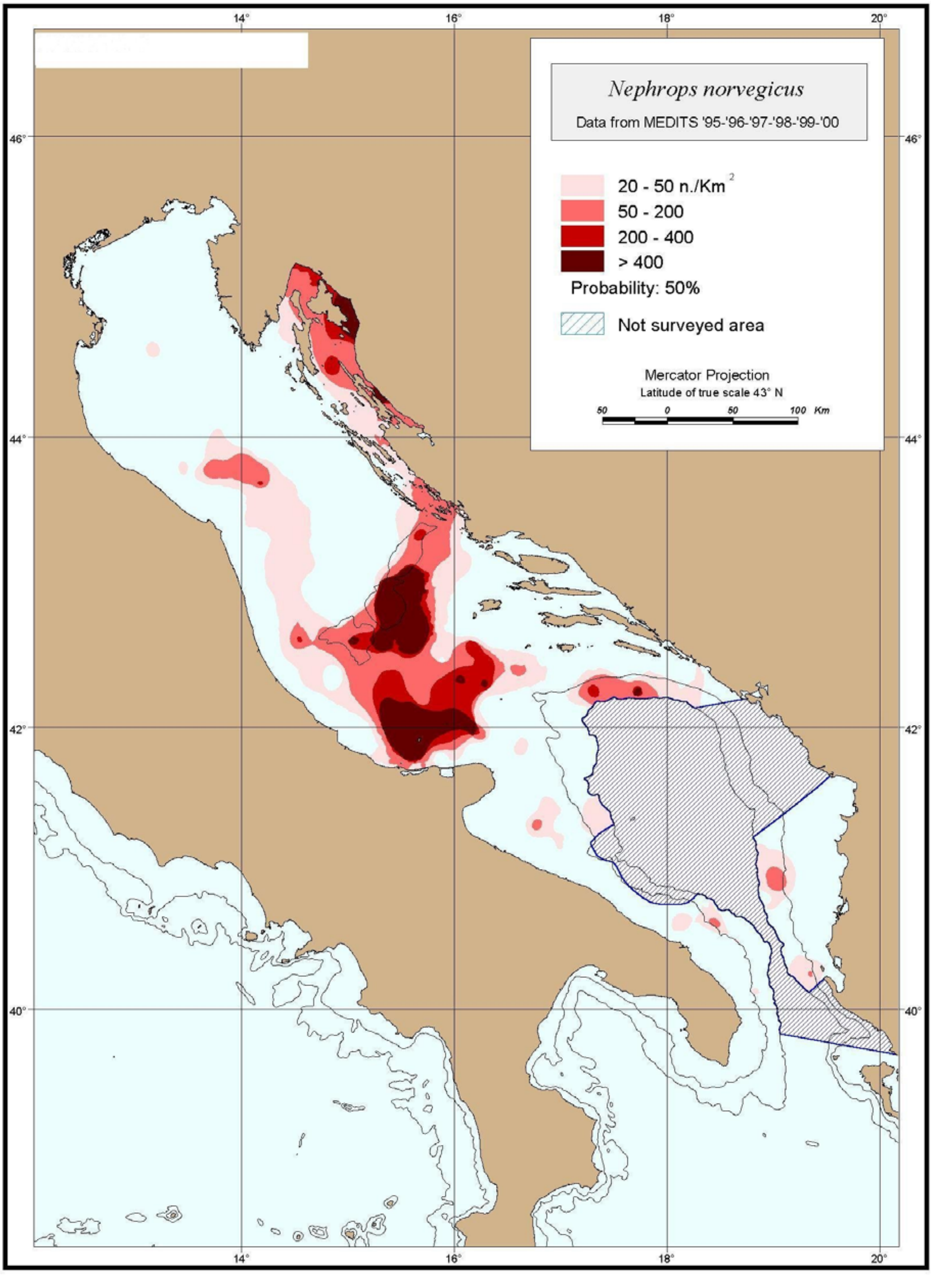


Figure 11.Distribution map of *Nephrops norvegicus.*

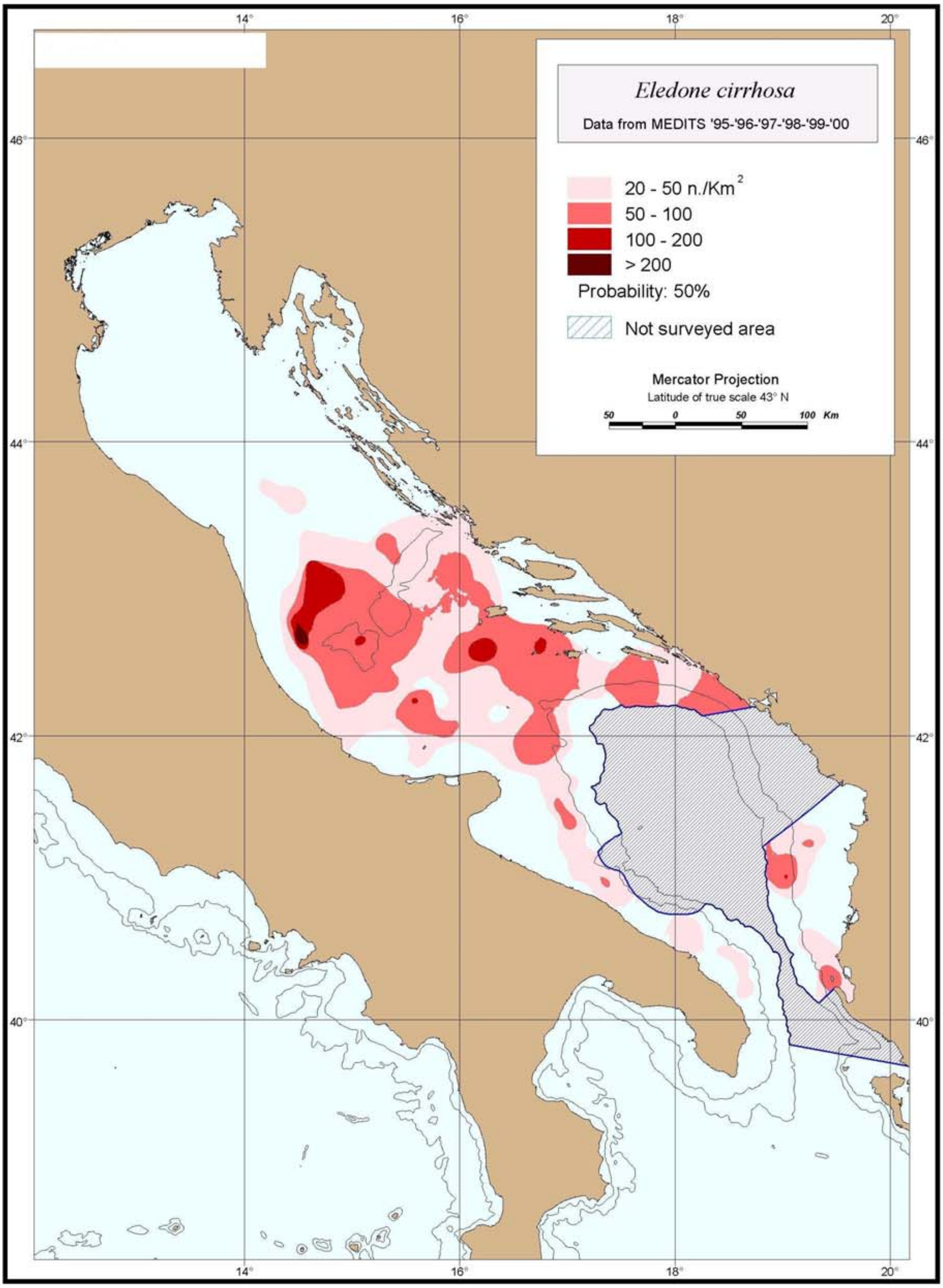


Figure 12. Distribution map of *Eledone cirrhosa.*

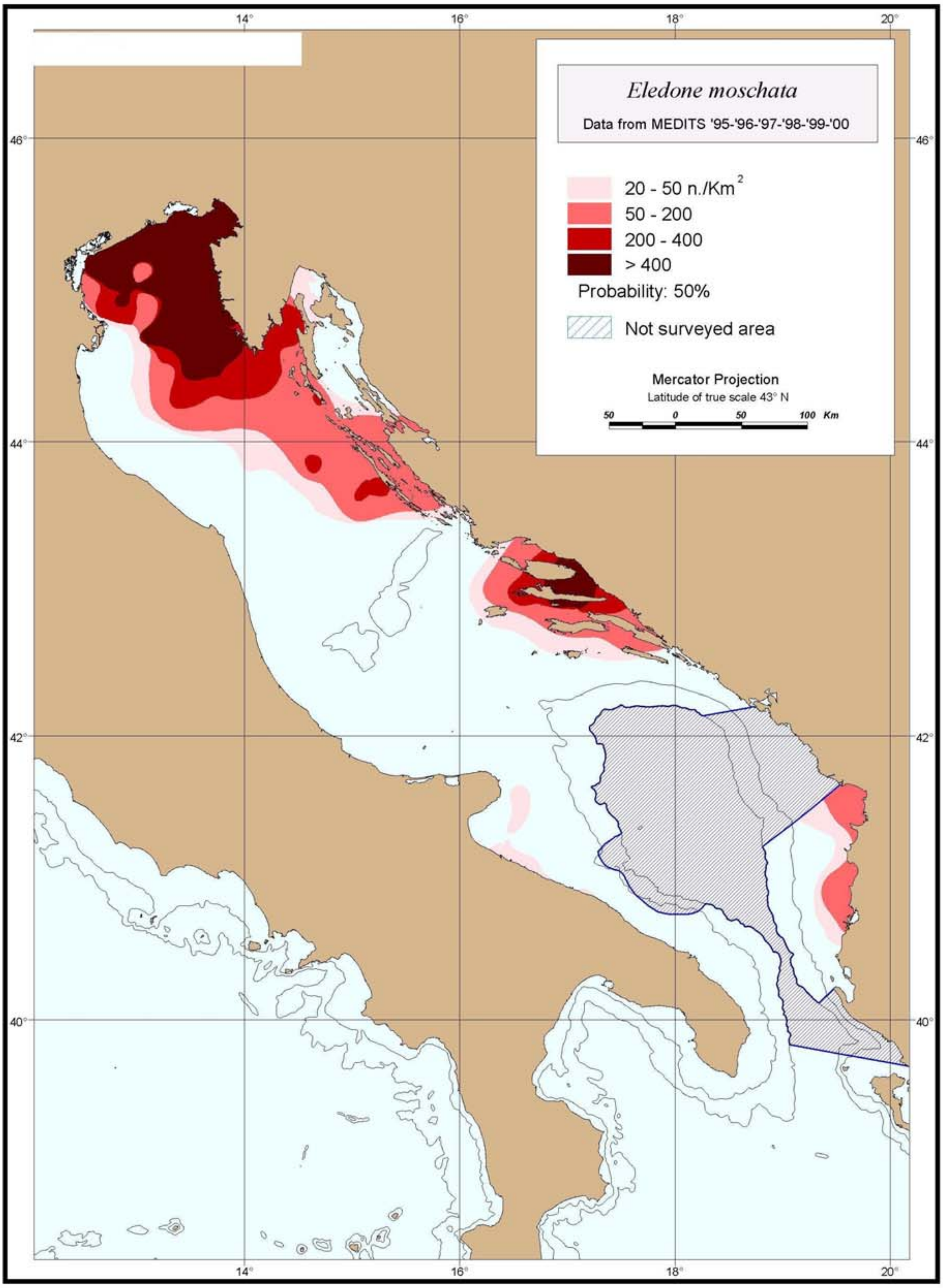


Figure 13. Distribution map of *Eledone moschata.*

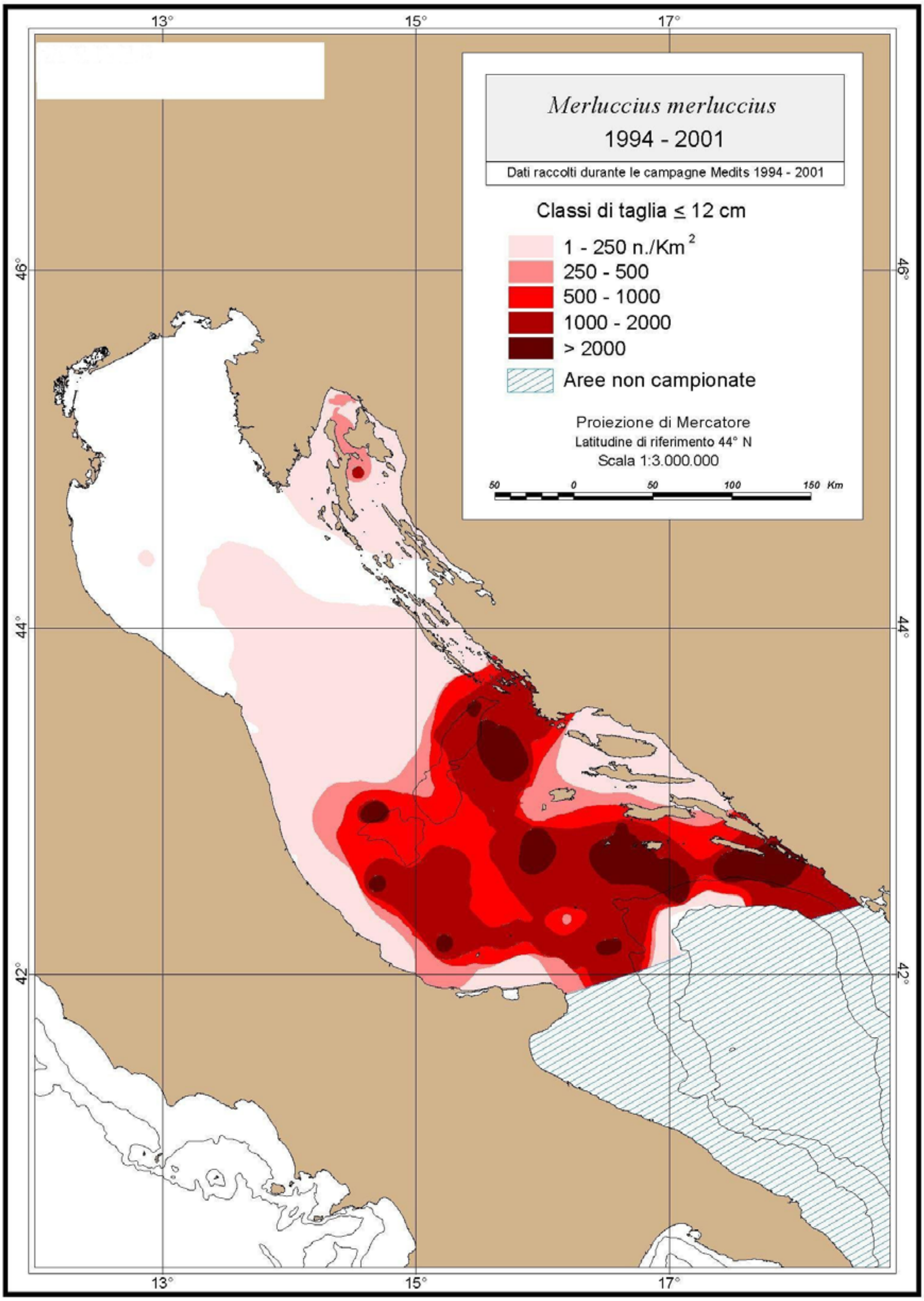


Figure 14. Distribution map for *M. merluccius* (less than 12 cm total length).

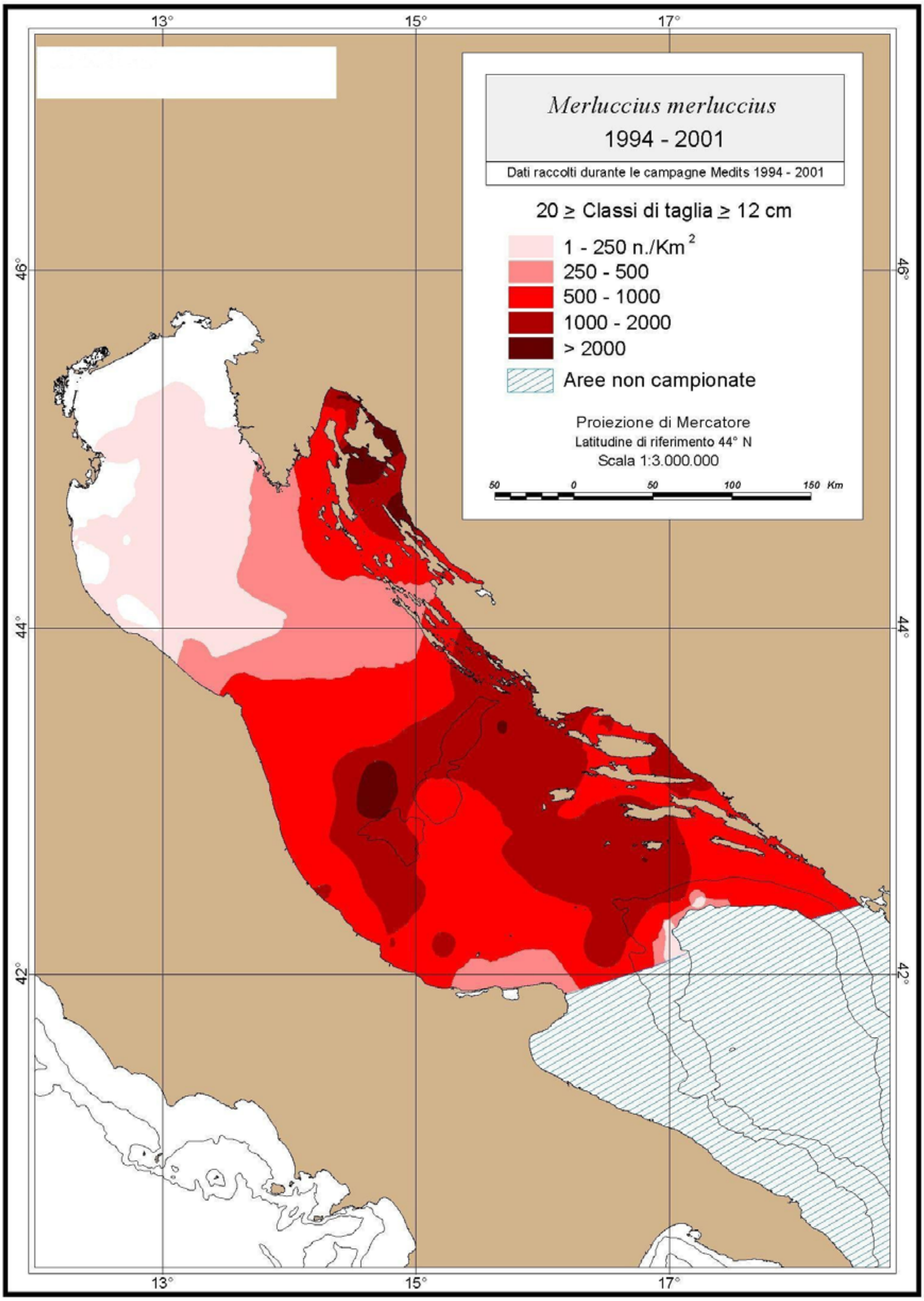


Figure 15. Distribution map for *M. merluccius* (from 12 cm to 20 cm total length).

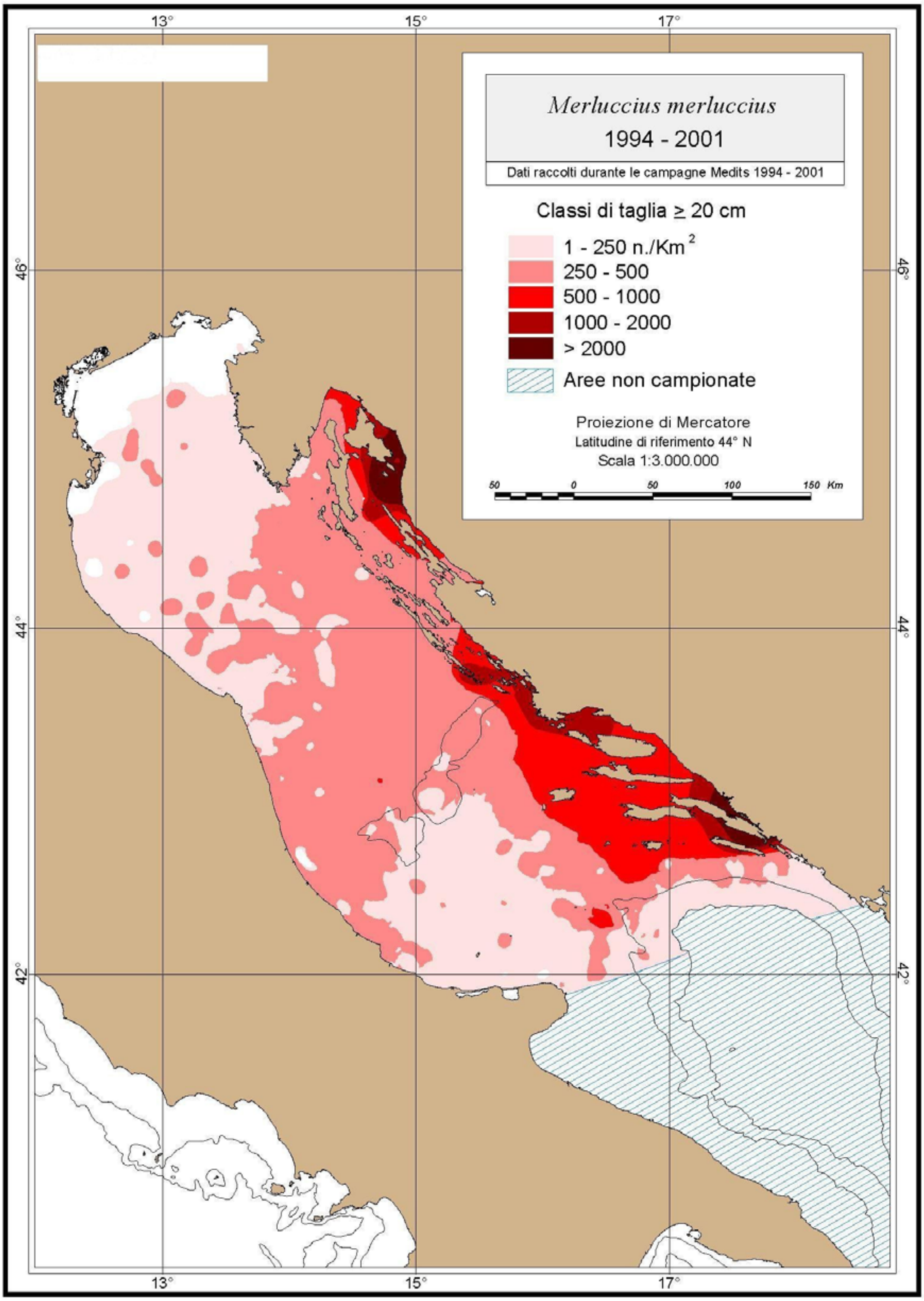


Figure 16. Distribution map for *M. merluccius* (total length greater than 20 cm).

10. Conclusions

The recent EC action plan for the conservation and sustainable exploitation of fishery resources in the Mediterranean states that management of fishing effort is necessary to achieve the objectives of the Common Fishery Policy. Fishing effort management must build upon experience already gained at local or national level, with the enforcement of simple rules such as the maximum allowable annual fishing days, the short week, a fishing ban during national holidays and the fixing of a maximum allowable daily time out of port or, in the case of longer than daily fishing trips, limitations of weekly fishing hours.

Among other tools, it is important to mention the introduction of collective property rights as in the case of clam management. This tool has proved to be particularly efficient both in biological and in economic terms.

Control of fishing capacity has been a task of the EU through the Multi Annual Guidance Programmes (MAGP). From an analysis of the official data relative to the area and fishery system studied from MAGP IV, for the period 1997 – 2001, it emerges that facing a 24% reduction in the number of vessels, gross tonnage fell by 28% and engine power went down by just 19%. This type of control, therefore, produced a fleet of vessels with lower tonnage but with more powerful engines.

The case study presented in this paper highlights, as in the case of the Mediterranean, that reduction of capacity must be accompanied by measures to control fishing activity. For example, it has been possible to reveal how in the year 2000, in spite of the large reduction in tonnage, the fishing effort of single vessels remained almost unchanged compared to the previous year. Indeed, if capacity in terms of average tonnage decreased by 17.5%, the level of utilisation in terms of days' activity grew by almost 19%.

Indicators of capacity, activity and effort are used to measure the impact of fishing on natural resources. However capacity and effort indicators are not sufficient to evaluate the state of the resources. From 1997 to 2001 the CPUE of the trawl fleet in the North and Central Adriatic decreased by 9.6% due to both a reduction in effort and a reduction in biomass available for fishing. The drop of CPUE represents a clear signal of deterioration of the state of the resources.

The management of fishing capacity should be conducted at local level in order to consider different distribution patterns and species size distributions. Moreover, the fishing of shared stocks should be subject to an EC and/or international regulatory framework, including effort limitation and technical measures.

11. References cited

Beverton, R.J.H., Holt, S.J. (1957) On the dynamics of exploited fish populations *Fish. Invest. Minist. Agric. Fish. Food G.B. (Sea Fish.)*, 19: 533 pp.

FAO (1998) Report of the FAO Technical Working Group on the Management of Fishing Capacity. La Jolla, United States of America, 15-18 April 1998. *FAO Fisheries Report*. No. 586. Rome, FAO. 1998.

Gulland, J.A. (1983) *Fish stock assessment: A Manual of Basic Methods*. John Wiley and Sons, New York.

IREPA (2002) *Osservatorio economico delle strutture produttive della flotta da pesca in Italia*, Ed. F. Angeli Milano, September 2002.

Kirkley, J., and Squires, D. (1998) Measuring Capacity and Capacity Utilization in Fisheries. Background paper Prepared for FAO Technical Working Group on theManagement of Fishing Capacity, La Jolla, USA, 15-18 April 1998, 160 pp. Forthcoming, *FAO Fisheries Report*.

Lassen, H. (1996) Report of the Group of Independent Experts to advise the European Commission on the Fourth Generation of Multi-Annual Guidance Programmes. DG XIV/298/96-EN, April 1996.

Lindebo, E. (2000) Capacity Development of the EU and Danish Fishing Fleets. Paper prepared for the XIIth Annual Conference of EAFE. Denmark, April 2000.

Piccinetti, C., Piccinetti-Manfrin, G. (1994) Considerazioni sullo stato di sfruttamento delle risorse demersali (Alto e Medio Adriatico). *Biol. Mar. Medit*., 1 (2): 77-87.

Placenti, V., Rizzo, G., Spagnolo, M. (1992) A bioeconomic model for the optimization of a multi-species, multi-gear fishery: the Italian case. *Marine Resource Economics* 1992, vol. 7 (4).

Sabatella E. (2000) Capacity Estimation: A Dynamic Approach - Depreciation On Capacity. Paper prepared for the XIIth Annual Conference of EAFE. Esbjerg, April 2000.

12. References consulted

Abella, A., Belluscio, A., Bertrand, J., Carbonara, P.L., Giordano, D., Sbrana, M., and Zamboni, A. (1999) Use of MEDITS trawl survey data and commercial fleet information for the assessment of some Mediterranean demersal resources. *Aquat. Living Resour*. 12 (3): 155-166.

Abellò P., Abella, A., Adamidou, A., Judic-Peladic, S., Maiorano, P., and Spedicato., M.T. (2002) Geographical patterns in abudance and population structure of *Nephrops norvegicus* and *Parapenaeus longirostris* (Crustacea: Decapoda) along the European Mediterranea coasts. *Sci. Mar*. 66 (Suppl. 2): 125-141.

Ardizzone, G. D. and Corsi, F. (Eds.) (1997) Atlas of Italian demersal fishery resources. Trawl surveys 1985 – 1987. *Biol. Marin. Medit*., 4(2): 568 pp.

Arneri, E., Jukic, S. (1986) Some preliminary observations on the biology and dynamics of Mullus barbatus L. in the Adriatic Sea. *FAO, Fisheries Rep*., 345: 79-85.

Arneri, E., Piccinetti, C., (1987) Evolution de l'effort de peche au chalut en haute et moyenne Adriatique. *FAO, Fisheries Rep*., 394: 230-233.

Belcari, P., Tserpes, G., Gonzales, M., Lefkaditou, E., Marceta, B., Piccinetti Manfrin, G., Souplet, A. (2002) Distribuition and abundance of *Eledone cirrhosa* (Lamarck, 1798) and *E. moschata* (Lamarck, 1798) (Cephalopoda: Octopoda) in the Mediterranean Sea. *Sci. Mar*., 66 (Suppl. 2): 143-155

Jukic, S., Piccinetti, C., (1979) Standing stock estimation and yield per exploitable biomass (YEB) forecast of the Adriatic edible demersal resources. *Inv. Pesq*., 43 (1): 273-282.

Jukic, S., Vrgoc, N., Dadic, V., Krstulovic-Sifner, S., Piccinetti, C., Marceta, B. (1999) Spatial and temporal distribuitions of some demersal fish populations in the Adriatic Sea described by GIS technique. *Acta Adriatica*, 40 (suppl.): 55-66.

Jukic, S., Vrgoc, N., Krstulovic-Sifner, S., Piccinetti, C., Piccinetti-Manfrin, G., Marano, G., Ungaro, N. (2000) Long term changes in demersal resources of the Adriatic Sea: comparison between trawl surveys carried out in 1948 and 1998. *Fisheries Research*, 1106: 1-10.

Luc van Hoof and Pavel Salz. Applying cpue as management tool. Paper prepared for the XIIIth Annual Conference of EAFE. Italy, April 2001

Orsi Relini, L., Papaconstantinou, C., Jukic-Peladic, S., Souplet, A., Gil De Sola, L., Piccinetti, C., Kavadas, S., Rossi, M., (2002) Distribution of the Mediterranean hake populations (*Merluccius merluccius smiridus* Rafinesque, 1810) (Osteichthyes: Gadiformes) based on six years monitoring by trawl-surveys: some implications for management. *Sci. Mar.,* 66 (suppl. 2): 21-38.

Tserpes, G., Fiorentino, F., Levi, D., Cau, A., Murenu, M., Zamboni, A. and Papaconstantinou, C. (2002) Distribuition of Mullus barbatus and Mullus surmuletus (Osteichthyes: Perciformes) in the Mediterranean continental shelf: implications for management. *Sci. Mar.* 66 (Suppl. 2): 39-54.

List of AdriaMed Publications

A. AdriaMed Technical Documents

Massa, F., Mannini, P. (eds). 2000. Report of the First Meeting of the AdriaMed Coordination Committee. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-01: 64 pp.

AdriaMed. 2000. Priority Topics Related to Shared Demersal Fishery Resources of the Adriatic Sea. Report of the First Meeting of the AdriaMed Working Group on Shared Demersal Resources. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-02: 21 pp.

Mannini, P., Massa, F., and Milone, N. (eds). 2001. Priority Topics Related to Small Pelagic Fishery Resources of the Adriatic Sea. Report of the First Meeting of the AdriaMed Working Group on Small Pelagic Resources. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents,* 3: 92 pp.

AdriaMed. 2001. Report of the Second Meeting of the AdriaMed Coordination Committee. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-04. *AdriaMed Technical Documents,* 4: 41 pp.

AdriaMed. 2001. Socio-economic aspects of the Adriatic Sea fisheries. Report of AdriaMed Meeting on Socio-Economic Aspects of the Adriatic Sea Fishery Sector. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-05. *AdriaMed Technical Documents,* 5: 53 pp.

AdriaMed. 2002. Adriatic Fishery Associations – First AdriaMed Meeting. Shoqatat e Peshkimit ne Adriatik-Takimi i Pare i AdriaMed-it. Jadranske ribarske udruge – Prvi sastanak AdriaMed-a. Associazioni della Pesca in Adriatico – Primo Meeting di AdriaMed. Jadranska ribiška združenja – Prvo srečanje v okviru AdriaMed-a. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-06. *AdriaMed Technical Documents*, 6: 168 pp.

AdriaMed. 2002. Report of the Third Meeting of the AdriaMed Coordination Committee. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-07. *AdriaMed Technical Documents, 7:* 34 pp.

Kolding, J. and Ubal Giordano, W. 2002. Lecture notes. Report of the AdriaMed Training Course on Fish Population Dynamics and Stock Assessment. GCP/RER/010/ITA/TD-08. *AdriaMed Technical Documents, 8:* 143 pp.

AdriaMed. 2003. Report of the Fourth Meeting of the AdriaMed Coordination Committee. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-09. *AdriaMed Technical Documents, 9:* 39 pp.

AdriaMed. 2003. Aspects of Fish Markets in the Adriatic Sea. Report of the AdriaMed Meeting on the Aspects of Fish Markets in the Adriatic Sea. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-10. *AdriaMed Technical Documents, 10:* 152 pp.

AdriaMed. 2003. Report of the Fifth Meeting of the AdriaMed Coordination Committee. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-11. *AdriaMed Technical Documents, 11:* 21 pp.

Vrgoč, N., Arneri, E., Jukić-Peladić S., Krstulović Šifner. S., Mannini, P., Marčeta B., Osmani, K., Piccinetti, C., and Ungaro, N. 2004. Review of current knowledge on shared demersal stocks of the Adriatic Sea. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-12. *AdriaMed Technical Documents, 12:* 91 pp.

AdriaMed. 2004. AdriaMed Seminar on Fishing Capacity: Definition, Measurement and Assessment. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-13. *AdriaMed Technical Documents, 13:* 119 pp.

B. AdriaMed Translations

AdriaMed (Botim.). 2000. Përkthim në shqip i Kodit te FAO-s te Drejtimit për një Peshkim të Përgjegjëshëm. GCP/RER/010/ITA/AT-01 40f. (Albanian Translation of the FAO Code of Conduct for Responsible Fisheries, 1995).

AdriaMed (Izdavac). 2000. Hrvatski prijevod FAO Kodeks Odgovornog Ribarstva. GCP/RER/010/ITA/AT-02 38str. (Croatian Translation of the FAO Code of Conduct for Responsible Fisheries, 1995).

C. AdriaMed Occasional Papers

AdriaMed. 2000. AdriaMed seminar on the preparation of the AdriaFISH project component (Adriatic Fishery Information System). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-01: 12 pp.

AdriaMed. 2001. The Geographical Management Units of the Adriatic Sea. Paper presented at the GFCM-SAC Working Group on Management Units (Alicante, 23rd-25th January 2001). FAO-

MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-02: 12 pp.

Ungaro, N., Vrgoć, N., and Mannini, P. 2001. The biology and stock assessment of *Merluccius merluccius* (L.) in the Adriatic Sea: an historical review by geographical management units. Paper presented at the GFCM-SAC Working Group on Demersal Species (Tunis, 13th -16th March 2001). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-03: 15 pp.

AdriaMed. 2001. A preliminary contribution to the Mediterranean Operational Units. Paper presented at the GFCM-SAC Working Group on Operational Units (Ancona, 18th -19th March 2001). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-04: 9 pp.

Massa, F., Mannini, P. 2001. The FAO-AdriaMed Project and its activities of interest to the SAP BIO Project. Paper presented at the First Meeting of the Advisory Committee of the project for the preparation of a Strategic Action Plan for the conservation of biological diversity (SAP BIO) in the Mediterranean Region (Tunis, 22-23 February 2001). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-05: 4 pp.

Cingolani, N., and Santojanni, A. 2002. Manual of the Recorder. AdriaMed Training Course on Small Pelagics Data Collection and Biological Sampling System. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-06. *AdriaMed Occasional Papers*, 6: 40 pp.

AdriaMed. 2002. Source and Accessibility of Socio-Economic data in AdriaMed member countries. Paper presented at the AdriaMed Meeting “Aspects of Fish Markets in the Adriatic Sea Fishery Sector”. (Ancona, 27th -28th June 2002). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-07. *AdriaMed Occasional Papers*, 7: 27 pp.

Giannetti, G., and Donato, F. 2003. Age Determination Manual. AdriaMed training course on fish age determination by otolith reading. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-08. *AdriaMed Occasional Papers*, 8: 14 pp.

Cingolani, N., Kariš, T., Sinovcić, G., Kapedani, E. 2003. Anchovy (*Engraulis encrasicolus*, L.) stock assessment in the Adriatic Sea: 1975-2002. Paper presented at the GFCM-SAC Working Group on Small Pelagic Species (Tangier, 12th-14th March 2003). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-09. *AdriaMed Occasional Papers*, 09: 12 pp.

Cingolani, N., Kariš, T., Sinovcić, G., Kapedani, E. 2003. Sardine (*Sardina pilchardus*, Walb.) stock assessment in the Adriatic Sea: 1975-2002. Paper presented at the GFCM-SAC Working Group on Small Pelagic Species (Tangier, 12th-14th March 2003). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-10. *AdriaMed Occasional Papers*, 10: 11 pp.

Osmani, K., Decolli, P., Ceriola, L., Ungaro, N., Mannini, P. 2003. Assessment of demersal resources by the Albanian trawl fishery: the case studies “hake” and “red mullet”. Paper presented at the GFCM-SAC Working Group on Demersal Species (Tangier, 12th-14th March 2003). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-11. *AdriaMed Occasional Papers*, 11: 13 pp.

Cingolani, N., and Santojanni, A. 2003. Manual of the Recorder. AdriaMed Training Course on Small Pelagics Data Collection and Biological Sampling System-Revision 1. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-06 (Rev.1). *AdriaMed Occasional Papers*, 6 (Rev.1): 53 pp.

Milone, N., Zeuli, V., Mannini, P. 2003. AdriaMed Trawl Survey Databank: User Manual. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-12. *AdriaMed Occasional Papers,* 12: 18 pp.

All the AdriaMed Publications are available from the Internet at http://www.faoadriamed.org/html/av_documents.asp

ADRIAMED

Corso Umberto I, 30 - 86039 Termoli (CB) - Italy
Tel: +39.0875.708252 / 0875.708240
Fax: +39.0875.720065
E-mail: faoadriamed@faoadriamed.org
URL: www.faoadriamed.org