French-Japanese Symposium, Ifremer, Sète, France , 1-3 September 2010

How minimizing the footprint of aquaculture and fisheries on the ecosystem?

Proceedings

Prof. Takeshi Yamane, Dr. Jacques Sacchi, Dr. François Poisson
Co-Convenors

Acknowledgements

The first symposium organized by the University of Kinki and Ifremer on the interactions between fishery, aquaculture and environment was held in Sète in September 2010.
The intention of this symposium was to provide a forum for the researchers, delegates of the aquaculture and fishing industries and managers, to come together to share ideas, update information and report on the progress of the most recent experiences on the reduction of negative impact of aquaculture and fishing activities on the environment.
This symposium was also the opportunity to encourage the development of cooperation on ecosystem approach between scientists from Japan and France and other partner countries for a better sustainable exploitation of marine resources. Researchers' participation of 9 countries among which Canada, Croatia, France, Italy, Japan, the Philippines, Slovenia, Spain and Tunisia underlined the international dimension of this issue. This conference received the wide support of our institutions, local and regional Assemblies of elected representatives and the representatives of the aquaculture and fishing industries of the Gulf of Lions.
Thank you again for your participation and your help to have made of this symposium a success.

Participants of the first symposium organized by the University of Kinki and Ifremer, September 2010, Sète, France

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André Carpentier: Chercheur biologiste halieute, Responsable du Département Halieutique Manche Mer du Nord, Ifremer Boulogne sur mer.
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Jean-Marc Fromentin : Responsable programme thon rouge, Ifremer Sète.
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Takeshi Yamane: Professor, University of Kinki.

National and Local Organizing Committee

Jacques Sacchi, Takeshi Yamane, François Poisson, Gérard Riou, Lisa Koenig, Jacques Vichery, Jacques Dietrich, Patricia Gontier, Erick Buffier.

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[1] Centre Halieutique Méditerranéen et Tropical Sète
[2] Commission Générale des Pêches en Méditerranée

A Brief History of Kinki University

The university dates its foundation back to the establishment of Osaka Technical College in 1925. Under the new education system, the university proper came into being in 1949 when the founder college merged with Osaka Science and Engineering University, which was established in 1943. The first President was Koichi Seko. Initially there were just two schools, the School of Engineering and the School of Commerce (which has since grown to become the School of Business and Economics).
Always sensitive to the latest developments in the world, Kinki University has constantly focused on the future prospects of its alumni. After the war, when food was in short supply, the university turned its attention to opening up the field of marine resources in order to assist in the resolution of that problem. The Marine Research Centre was opened in 1948 in Shirahama-cho, Wakayama Prefecture and is still going strong today as the Fisheries Laboratory. This was the first time that research into marine fish farming was carried out in Japan. Other pioneering projects include, along with the opening of the Atomic Energy Research Institute, establishing the first private nuclear reactor facilities in 1960. Kinki University has constantly maintained an approach to education that is both practical and proactive.

A school culture that's open to the new and possesses substantial facilities

When Masataka Seko became the head of Kinki University in 1965, he effectively used his energy to fill out and improve the curricula and environment. In 1974 the School of Medicine was opened, followed, just a year later, by a teaching hospital. Besides these new departures, existing university buildings were reconstructed and laboratories and other facilities were improved and expanded.
One aspect of his vision "Education comes from the environment" that there would be more greenery on campus has also been realized.

Even greater activity towards a more comprehensive university

Coming into the 1990s, more radical changes were in store. In 1989, breathing new life into a university that had hitherto concentrated on science and technology, the School of Literature, Arts and Cultural Studies was opened. At the same time, the School of Agriculture was relocated to a campus in Nara Prefecture which was more conducive to allowing students to pursue more rewarding studies concerned with our natural environment.
In 1993, the School of Biology-Oriented Science and Technology was opened in Uchita-cho, Wakayama Prefecture. It attracted public interest as the first center in Japan to concentrate on this new field concerning superior functions possessed by organisms.
As a comprehensive institute of learning that comprises 11 schools and 44 departments in all and which, moreover, has a School of Medicine that runs three general hospitals, Kinki University covers many fields of research. And the contribution this university makes to world has been rising with every passing year.

Centre de Recherche Halieutique Méditerranéenne et Tropicale (CRH) - Sète, France.
Wednesday 1st September 2010 to Friday 3rd September 2010

Kinki University
Nakamachi 3327-204
Nara 631-8505
Japan

Ifremer Sète and the Centre de Recherche Halieutique Méditerranéenne et Tropicale (CRHMT).

CRHMT develops integrated and multidisciplinary studies in the Mediterranean and tropical areas to study the effect of climate change and overexploitation on marine ecosystems. The objectives are to develop knowledge, tools, and models to contribute to the EAF. CRHMT is keen at collaborating and developing projects with European, Mediterranean and tropical countries and becoming a training and 'think tank' centre with the help of scientific network such as Eur-Oceans Consortium.

The fisheries thematic of Ifremer is aimed to obtain, within 10 years, the scientific means and methods which will ensure the maintenance of the fisheries in an sustainable state and the preservation of habitats, ecosystems and biodiversity.
In the very dynamic context of the Mediterranean during this period, the actions of the fisheries department are oriented in three main directions:

- the actions oriented towards the gathering of observations on the fisheries resources (biological parameters, exploitation patterns, population dynamics) and on the environment, and the production of diagnosis and advices directed to the fisheries national and international management bodies,
- the Ecosystemic Approach of the Fisheries, which general goal is to allow the integration of a number of parameters which are not yet taken into account in most of the fisheries management processes (multispecificity, species interactions, natural anthropic effects on the environment…)
- and the study of trophic webs which is integrated in a research programme on the fate of contaminants in the sea water masses.

The research field of the department covers the demersal species as well as the small and large pelagics, exploited by various fishing techniques operated by small scale fishermen, trawlers and purse-seiners

Centre de Recherche Halieutique Méditerranéenne et Tropicale (CRH) - Sète, France.
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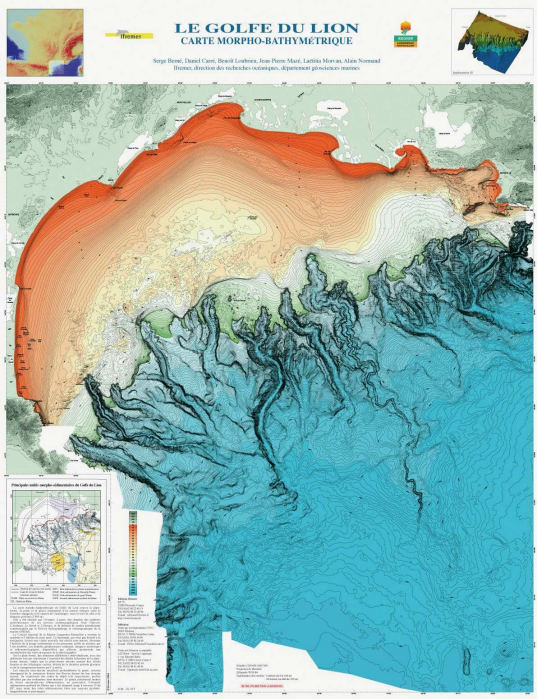

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Etang de Thau et Sète

How minimizing the footprint of the aquaculture and fisheries on the ecosystem?

Centre de Recherche Halieutique Méditerranéenne et Tropicale (CRH) - Sète, France.
Wednesday 1st September 2010 to Friday 3rd September 2010

Themes and Agenda

The participants were invited to present current knowledge on disciplines related to the themes of the symposium, and exchange information and experiences within these four following main themes:

1 - Interaction between aquaculture, fisheries and ecosystem

- biology, technology, economic and social implications for exploited species and species of conservation concern ;
- mutual benefits, seasonality and space conflicts and challenges ;
- market and other anthropogenic activities effects.

2 - Mitigating measures and good practices in fishing and aquaculture activities

- selective fishing techniques, alternative harvesting methods ;
- new technologies for sustainable aquaculture, feed manufacturing ;
- artificial reefs and restricted fishing area ;
- fish welfare, fish health and fish quality, training.

3 - Integration of Fisheries and Aquaculture industries into planning and management

- dissemination of scientific advices to stakeholders ;
- scale of stakeholders involvement in management ;
- banned fishing techniques and switching gears issue ;
- preservation of traditional and local uses.

4 - Governance system

- multi-scale governance mechanisms ;
- the human dimensions of the ecosystem approach to fisheries ;
- integrating knowledge for adaptive management ;
- integrating environmental and fisheries policies into ICOM ;
- penalties and incentives for compliance to regulations ;
- ethical obligations to the natural environment: concepts and values.

Wednesday 1st September 2010

Oral Session

8:00 **Registration**

9:00 **Welcome**

9:30 TOPIC 1 : INTERACTION BETWEEN AQUACULTURE, FISHERIES AND ECOSYSTEM

Moderators: *Z. Suzuki / P. Prouzet*

P. Addis
The effects of mining extraction on the Atlantic bluefin tuna (*Thunnus thynnus*) trap fishery of Sardinia (Western Mediterranean)

C. Chaboud
Interactions between industrial shrimp fisheries with other fisheries and the environment. Biological and bio-economic aspects, the examples of Madagascar and French Guyana

A. Fiandrino
Escherichia coli Maximum allowable daily loads (MADL): an environmental management tool for improving the microbiological quality of the Thau lagoon water (French Mediterranean coast)

P. Guillotreau
Climate oscillations and tuna-dependent economies

10:30 **Coffee break**

M. Kadota
An optimization problem of aquaculture and fisheries product

R. Le Boucher
Can genetic improvement in aquaculture reduce the impact on fisheries? The case of European sea bass (*Dicentrarchus labrax*) fed on a totally plant-ingredient based diet.

Z. Suzuki
Harmonizing aquaculture, fishery and management, challenges in Pacific bluefin tuna

12:30 **Lunch**

Oral Session

14.00 CONTINUING TOPIC 1 : INTERACTION BETWEEN AQUACULTURE, FISHERIES AND ECOSYSTEM

M. Tada
Regulation on bluefin tuna catch in the Mediterranean sea and the market expansion for the full cycle farmed tuna

S. Voisin
Methodology for Comparing the Environmental and Socio-Economical Impacts of the Fishery and aquaculture Supply Chains: from wild fish in the water to protein on the consumer plate

TOPIC 2 : MITIGATING MEASURES AND GOOD PRACTICES IN FISHING AND AQUACULTURE ACTIVITIES

R. Babaran
Measurement of the resonant vibrations of bamboo used for fish aggregating devices

J.-L. Coeurdacier
Is global serum protein a good indicator for stress and welfare in reared sea bass

C. Fauvel
Control of bluefin Tuna reproduction: a condition for self sustained aquaculture

16:00 **Coffee break and Poster Session**

16:30

H. Fukuda
Ontogenetic changes in schooling behaviour and transmission of behaviour between individuals of Pacific bluefin tuna juveniles.

G. Moreno
Fishers´ echo- sounder buoys to study fish aggregations around drifting FADs

T. Yasuda
Estimating the rate of energy expenditure in red sea bream *Pagrus major* using an acceleration logger

M. Nalovic
Reducing the effects of shrimp trawling on the Guyana's plateau ecosystem

Thursday 2nd September 2010

Oral Session

8:30 TOPIC 2 : MITIGATING MEASURES AND GOOD PRACTICES IN FISHING AND AQUACULTURE ACTIVITIES

Moderators: *T. Takagi /J. Sacchi*

D. Priour
Numerical method for energy optimization of bottom trawl

B. Séret
«MADE» Project: Methods to release Elasmobranches from purse seine

S. Shirakashi
Parasitic infections observed in artificially bred Pacific bluefin tuna, *Thunnus orientalis*

T. Takagi
Dynamic analysis in the development of offshore net-cage aquaculture system for bluefin tuna by using computer simulation system NaLA

10:30 **Coffee break and Poster Session**

11:00 **S. Torisawa**
Three-dimensional monitoring of free-swimming Pacific bluefin tuna cultured in a net cage using a digital stereo-video camera system

Y. Tsuda
Visibility range of juvenile Pacific bluefin tuna, *Thunnus orientalis*, related to the turbidity and the color sensitivity in the net-cage

12:00 **Lunch**

TOUR

Friday 3rd September 2010

Oral Session

8:30 TOPIC 3 : INTEGRATION OF FISHERIES AND AQUACULTURE INDUSTRIES INTO PLANNING AND MANAGEMENT

***Moderators**: M. Kadota /C. Chabout*

L. David
Synthesis of scientific studies undertaken during six years on the Mediterranean "thonaille" fishery: bycatch and solutions

G. Fabi
Artificial reefs as fisheries management tools in the northern Adriatic Sea

H. Farrugio
A Fisheries restricted area in the Gulf of Lions (France)

M. Goujon
Actions of the French purse-seine industry to reduce its footprint on the tropical pelagic ecosystem

O. Guyader
Moored Fishing Aggregating Devices exploitation by Small-Scale Fleet in the Caribbean: Review and Outlook after 20 years

10:30 Coffee break and Poster Session

11:00 R. Parker
Ecological footprint and life cycle assessment of Antarctic krill fishery products

D. Sauzade
Mediterranean marine ecosystems: an economic valuation

TOPIC 4 :GOVERNANCE SYSTEM

***Moderators:** M. Tada / Y. Henocque*

B. Cazalet
Indeterminacy of waters under the jurisdiction in the Mediterranean

J.-M. Fromentin
Overfishing : the Atlantic bluefin tuna case

12:30 Lunch

Oral Session

14:00 CONTINUING TOPIC 4 : GOVERNANCE SYSTEM

Y. Henocque
What makes the difference between the ecosystem approach to fisheries and integrated coastal zone management in the Mediterranean: it's the economy, stupid!

S. Miyashita
Seedling Production of the Pacific Bluefin Tuna.

S. Pioch
Toward a new coastal development: the 4 dimensional uses of the sea

16:00 Coffee break and Poster Session

16:30 Conclusions

Session Poster

TOPIC 1 : INTERACTION BETWEEN AQUACULTURE, FISHERIES AND ECOSYSTEM

D. Banaru
Food web and fisheries interactions in the Gulf of Lions

V. Cikes
Reproductive cycle and minimal length at sexual maturity of *Scomber japonicus* (Houttuyn, 1782) in the Middle eastern Adriatic Sea

F. Grati
Interaction in coastal waters: A roadmap to sustainable integration of aquaculture and fisheries – the COEXIST project

I. Isajlovic
Preliminary results of the south Adriatic deep sea fauna investigation

Y. Kunimune
Acoustic telemetry study on seasonal migration patterns of the endemic crucian carp Nigorobuna and Gengoroubuna in Lake Biwa, Japan

O.Serais
Investigating an avian source of shellfish microbial contaminations on Thau in dry weather conditions

N. Staglicic
Temporal changes in littoral fish assemblages along the eastern Adriatic coast

B. Zorica
Growth, age - otolith weight and length relationship of garfish in the eastern Adriatic Sea

TOPIC 2 : MITIGATING MEASURES AND GOOD PRACTICES IN FISHING AND AQUACULTURE ACTIVITIES

J.-L Coeurdacier
A first approach to investigate alterations, within physiological limits, in serum protein of sea bass (*Dicentrarchus labrax*)

N. Di -Meglio
Endangered species and fisheries in the Western Mediterranean: Which strategy to mitigate the interaction?

J. Franco
New Designs of Drifting Fish Aggregating Devices to avoid passive catches of sea turtles and sharks

T. Kojima
Estimation of fish struggle energetics using branch line movement in longline

K. Komeyama
Measuring the swimming behaviour of a cultivated pacific bluefin tuna in an aquaculture net cage

K. Nagamatsu
Investigation of submersible net cage movement using a model Orientation changes due to asymmetric surplus buoyancy

M. Pinault
Artificial reefs as a tool to supply artisanal fishery in Reunion Island: Implementation and scientific evaluation

T. Šegvic Bubic
Wild fish population around the sea-cages of the eastern Adriatic tuna farms

F. Poisson
Incidental catches of thresher sharks in the Gulf of Lions (Mediterranean Sea)

Topic 2 : Mitigating measures and good practices in fishing and aquaculture activities

T. Yamane
Effects of currents and the induced net deformation on set-net fishery, experimental and numerical approach

T. Yamane
Human impact on the catch composition of traditional set-net operated in the south–basin fishing ground of Lake Biwa

T. Yamane
Relationship between the discards and catch-diversity of the set-net fishery

T. Yamane
How to minimize the discards from set-net fishery

Topic 3 : Integration of Fisheries and Aquaculture industries into planning and management

B. Cazalet
Reflections on the management methods of artificial reefs

F. Claro
GTMF (Groupe Tortues Marines France) an appropriate tool for sea turtle conservation

Topic 4 :Governance system

J. Barde
Fisheries Data Integration for Ecosystem Approach to Fisheries

A. Carpentier
The Charm Project: Defying the Channel's loss by facing environmental challenges across borders

H. Farrugio
Monitoring Mediterranean fish stocks and fisheries management measures

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The effects of mining extraction on the Atlantic bluefin tuna (*Thunnus thynnus*) trap fishery of Sardinia (Western Mediterranean)

P. Addis*

Department of Animal Biology and Ecology, University of Cagliari Viale Poetto 1, I-09126 Cagliari, Italy

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Abstract

The aim of this paper is to investigate on possible effects caused by past mining activities on migrating pathways of the Atlantic bluefin tuna, Thunnus thynnus, in south-western Sardinia (W Mediterranean). We have studied catch variability in three neighbouring traps which are sited progressively far-away from a mining hot spot. Historical records were analysed with a Before/After and Control/Impact design (BACI) in order to detect a) proximity effect with the impacted site and b) beginning of impacts. Furthermore, using time series analysis, we have investigated relationships among catch data and the explorative variable Run-off. Results have indicated: 1) a proximity effect in the inshore trap of Porto Paglia and no-proximity effect in the offshore trap of Isola Piana and Portoscuso; 2) a time split Before-After identified in late 1880 during which mechanized mining processes started; 3) a negative major trend in the captures for all traps; 4) a secondary oscillating pattern "synchronous" between catches of the impacted trap and Run-off. Our final statement asserts the condition for a "pulsing boundary" since the coastal zone was supplied by mine wastes related to the variable "Run-off" which caused an exclusion of the inshore tuna pathway. We also assumed that this process is still active endangering the habitat fit for bluefin tuna migrating.

Key words: Bluefin tuna / Impact / Migration pathways / Trap fishery / Mediterranean Sea

Introduction

The evaluation of potential impacts to fishery populations is a difficult and mystifying problem depending by a combination of stressors or environmental factors and the availability of significant historical datasets. Furthermore, fishery scientist generally study the impacts on fish species considering the biological approach considering marine species and habitats as watertight compartments missing the perspective for a ecosystem-based management approach.

Most of species important to commercial fisheries are dependent upon nearshore and estuarine habitats for the achievement of their life histories (Elliott et al., 2002). For this reason the interaction occurring in the interface land-seawater (for example the quality and quantity of freshwater inflow into the coastal areas) are important factors maintaining to the nearshore productivity of fishery spawning zone and to the

stability of coastal shelf where the migration for reproductive purposes take place. Therefore the modification of these habitats can be harmful to the production and recruitment to fishable stocks with negative change in fishery yield. The coastal area of south-western Sardinia have had a long history of contaminant inputs associated to processes of development and abandon of the mining activities. Deposits of Zn-Pb were exploited since pre-Roman times (Cidu et al., 2009), with much exploratory activity in the period from 1850 to 1970 (Boni et al., 1999). This coastal area is also a key-zone for the reproductive migration of the Atlantic bluefin tuna, Thunnus thynnus (Addis et al., 2008). The aim of this paper is to investigate on possible sources of environmental alteration which may have been cause of the loss of habitats suitable for the coastal migration of bluefin tuna. At the present, little is known about the effects of past mining activities and abandoned sites on the local commercial fisheries. We only know anecdotal information and historical documents on recurring events of cloudy water inflows reported by trap fishermen in concomitance of low or absence of tuna catches.

We predict that bluefin migratory patterns show a marked concordance in their trajectories toward neighbouring traps, unless a perturbation occurs. In this sense the objective of this work is to explore the statistical interaction over spatial and time scale of one dependent variable, tuna captures from three nearest traps, and to identify possible relationships with explorative variables depending from mining activity.

Materials and methods

Data collection

Three different variables were considered for the analysis: catches of three traps in the period 1825-1970 (number of tunas, transformed Log X + 1) (IP = Isola Piana; PS = Portoscuso; PP = Porto Paglia); mining production (M) of the local mining district expressed by tons of Zn and Pb in the period 1832-1979 (n = 147); Run-off (RO), an index of the hydrological processes of outflow from the local watershed into the shore face of the trap area in the period 1920-1973 (n = 53). This index has been calculated on a basis of a time series of data from a local rain gauge network (RAS, 1998). Inflow-outflow data were modelled in a linear stochastic model better known as Box e Jenkins model.

Data Analysis: BACI design to detect perturbation and interaction of Run-off with Capture

We applied a Before, After, Control, Impact design to detect a statistical interaction between the differences in the mean of captures (Underwood, 1991). We elected the trap site PP as Impact site because its proximity to the Mining Hot Spot. On the contrary the sites of PS and IP were chosen as Control sites as they are farther the Mining Hot Spot. Asymmetrical ANOVA was performed considering the following source of variation: Before vs. After; Impact vs. Controls.

Auto Correlation Functions (ACF) were calculated for mining-related variables and tuna catches and to detect trends or cyclical patterns. The cyclical patterns of data were studied using single spectral analysis (Platt and Denman, 1975) which is a method that cannot account for missing values and it requires that the series be stationarized with a sequence of transformations (Legendre and Legendre, 1998).

Results

The best fit for a split Before/After was identified in the period 1825-1880 as Before and 1881-1970 as After. The final data shaped with the Control/Impact and Before/After design are reported in Fig. 1.

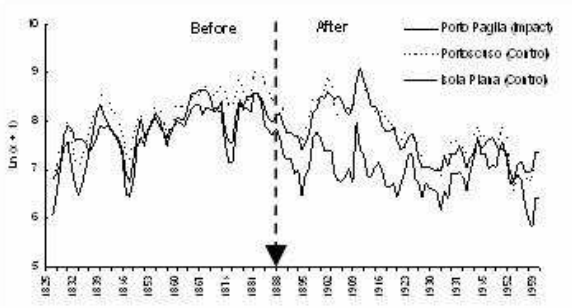

Figure 1. Historical records of captures (transformed) for three Sardinian traps. Data are shaped to detect impacts in a BACI design. Data are sampled at several times in a single Impacted location (Porto Paglia trap) and two Controls (Isola Piana and Portoscuso traps) Before and After the disturbance of the mechanized mining or the time split of pre and post-industrial revolution (at the time indicated by the arrow).

The asymmetrical analysis of variance showed significant differences in the Before vs. After ($p<0.01$) and Control vs. Impact comparison ($p<0.01$). The post-Hoc test of Schaffé, which considers all pairwise combinations, provided the following results: Before Impact vs After Impact ($p<0.001$); Before Controls vs. After Controls (p= n.s.); Before Impact vs. After Controls (p=n.s.); Before Controls vs. After Impact ($p<0.001$); After Controls vs. After Impact ($p<0.001$).

The ACF plots for traps data and the environment variables are reported in Fig. 2.

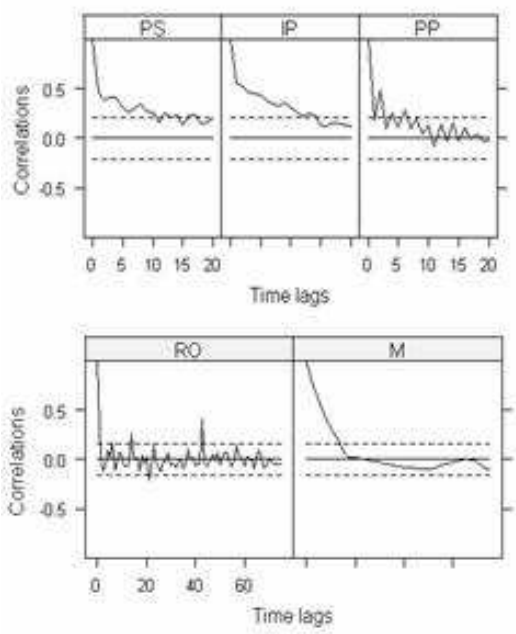

Figure 2: Auto Correlation Functions for three trap series and the explorative variables.

The trap series showed a marked negative trend pattern for Portoscuso (PS) and Isola Piana (IP). The impact site of Porto Paglia (PP) shows a main trend negative and a secondary oscillating shape. The explorative variables Mining (M) didn't reveal any relationship with catch data e it was excluded by following analysis.

These preliminary results pointed out as only Run-off index and PP variables were suitable for single spectral analysis. They revealed a match between two oscillation periods, estimable approximately at about 7 years as also confirmed by the Bivariate Fourier analysis (Fig. 3).

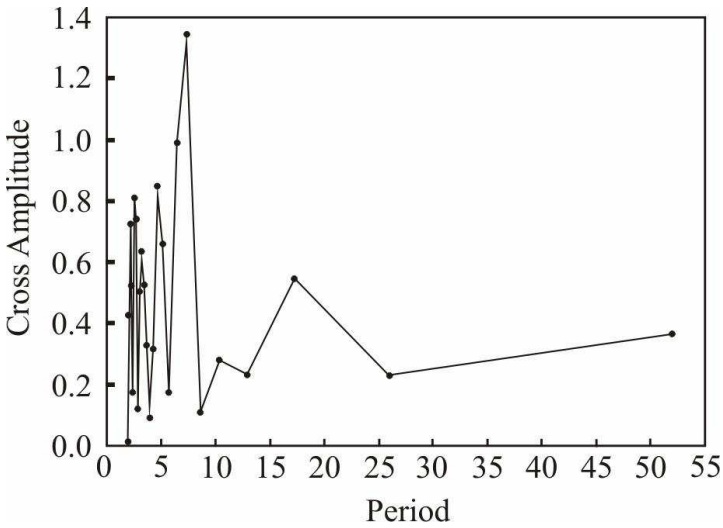

Figure 3. Plot of the cross spectral analysis (bivariate Fourier analysis) testing for synchronicity of the Porto Paglia and Run-off series. Major peak of the cross amplitude correspond to a cycle of 7 years.

Discussion

In this work we have attempt to explain the source of variability in the abundances of bluefin tuna captured by traps in the pre and post-industrial period. We have identified the beginning of environmental disturbance in concomitance of the activation of mechanized mining and corresponding to a notable increase in mining production during the "industrial revolution" of late 20th century. As we have assessed as the cyclical pattern of captures in one trap was related to the same pattern with an environmental index related to runoff processes.

We think that the high ecological value of tuna pathways→ trap grounds → trap fishery, would be preserved with an appropriate integrated coastal management strategy. The risk of losing these habitats is quite high and it could have serious consequences both in terms of economy and traditions. We assert that it is imperative to protect threatened species with environmental policies based on applying rigorous science, but it is also necessary to protect the environment where species spend part of their biological life cycle. In order to mitigate impacts on the trap grounds, we proposed the following pragmatic actions:

- the activation of a seasonal no-entry zone with different level of protection with the aim to reduce any dynamic maritime activity as commercial traffic, anchoring and trawl fishing during the migration of bluefin tuna;

- exclude any operation concerning physical impacts in the coastal zone and sea bottoms as new harbour excavations, activation of offshore fish farming, wind energy farms and oil explorations;
- the urgent activation of the Rehabilitation plan expected by the Italian Ministry for the Environment (DCPM/23.04.93) in the local watershed and the coastal zone;
- to develop a network for environmental controls in the coastal zone including multidisciplinary approaches and recent technologies (fallout in the trophic web, remote sensing technology, transport-dispersion modelling of surface water).

References

Addis P., Dean J.M., Pesci P., Locci I., Cannas R., Corrias S., Cau A., 2008, Effects of local scale perturbations in the Atlantic bluefin tuna (Thunnus thynnus L.) trap fishery of Sardinia (W. Mediterranean). Fish. Res. 92, 242-254.

Boni M., Costabile S., De Vivo B., Gasparrini M., 1999, Potential environmental hazard in the mining district of southern Iglesiente (SW Sardinia, Italy). J. Geochem. Explor. 67, 417-430.

Caredda A.M., Cristini A., Ferrara C., Lobina M.F., Baroli M., 1999, Distribution of heavy metals in the Piscinas beach sediments (SW Sardinia, Italy). Environ. Geol. 38, 91-100.

Cidu R., Biddau R., Fanfani L., 2009, Impact of past mining activity on the quality of groundwater in SW Sardinia (Italy). J. Geochem. Explor. 100, 125-132.

Elliott M. and Hemingway K.L., 2002, In: M. Elliott and K.L. Hemingway, Editors, Fishes in Estuaries, Blackwell Publishing, Oxford, 636 pp.

ICCAT, 2007, Report of the standing committee on research and statistics (SCRS) , Madrid, Spain, October 1 to 5, 2007. 1–216. 2007. ICCAT, Madrid, Spain.

Legendre P., Legendre L., 1998, Numerical Ecology, Second English Edition. Elsevier, Amsterdam, The Netherlands.

Pereira H.M., Leadley P.W., Proença V., Alkemade R., Scharlemann J.P.W., Fernandez-Manjarrés J.F., Araújo M.B., Balvanera P., Biggs R., Cheung W.L., Chini L., Cooper H.D., Gilman E.L., Guénette S., Hurtt G.C., Huntington H.P., Mace G.M., Oberdorff T., Revenga C., Rodrigues P., Scholes R.J., Sumaila U.R., Walpole M., 2010, Scenarios for Global Biodiversity in the 21st Century. Science DOI: 10.1126/science.1196624.

Platt T., Denman K.L., 1975, Spectral analysis in ecology. Ann. Rev. Ecol. Syst. 6, 189-210.

RAS, 1998, Nuovo studio dell'idrologia superficiale della Sardegna. Regione Autonoma Sardegna, Assessorato della Programmazione, Bilancio ed Assetto del Territorio, Ente Autonomo del Flumendosa, Cagliari, (in Italian).

Interactions between industrial shrimp fisheries with other fisheries and the environment. Biological and bio-economic aspects, the examples of Madagascar and French Guyana

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Introduction

Tropical shrimp fisheries are known for their impacts on ecosystems and biodiversity due to the by-catch of industrial trawlers. Their impacts generate important costs for society and other fisheries. Mitigation actions exist to limit these impacts and their economic evaluation must be known. Impacts of tropical shrimp fisheries and mitigation actions are illustrated in the cases studies of Madagascar and French Guiana using a bioeconomic modelling. Interactions in shrimp fisheries are schematized (fig. 1) in the case of 2 fleets exploiting the same shrimp stock. Each fleet fishing effort and selectivity parameters affect total shrimp biomass, age structure and then revenues. In sequential fishing, frequently encountered in tropical shrimp fisheries, a fleet targets the first age classes, often with poorly selective gears, and impacts the fleet targeting adult shrimps. Non targeted species catches including emblematic species like turtles, are kept on board or discarded and impact fish fisheries and have a more general effect on marine ecosystems.

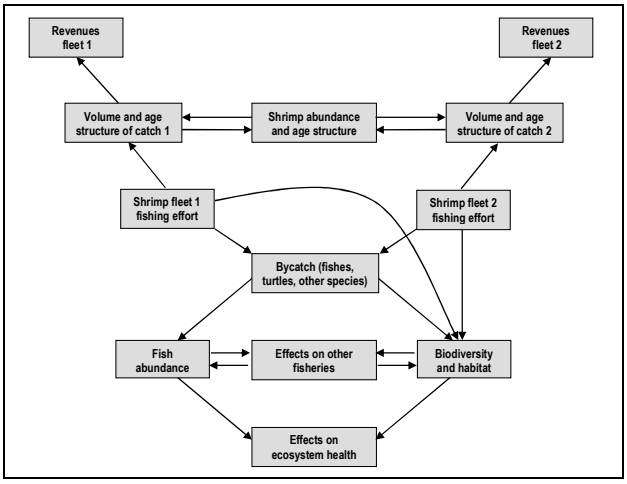

Figure 1 : Problematic of interactions in shrimp fisheries

Tropical shrimp fisheries are characterised by the greatest discard rate among world's fisheries. Their discards (9,511 Mt) represent 84 % of their total catch and 1/3 of world fisheries discards. NGO's and producer/consumer states like USA consider that the environment and societal costs of shrimp fisheries must be reduced. Turtle

Excluder Device (TED) aimed to reduce sea turtles' mortality, was experimented in the Gulf of Mexico and introduced in trawl fisheries in the 80's. Later, bycatch reducing devices (BRDs) were designed to reduce fish bycatches. Since 1998, US shrimp trawlers of the Gulf of Mexico and South Atlantic were required to use BRD and this device was progressively adopted in other countries. Better fishing selectivity through mitigation actions is often seen as a component of the ecosystem-based fisheries management.

The potential consequences of mitigation actions on catches, revenues, costs and profit are presented in figure 2. The use of mitigation improves shrimp and fish selectivities, and increases big shrimp share in catch. Decrease in fish bycatch improve fish biomass and biodiversity. Mitigation may allow a reduction in energy costs. The higher prices allowed by the consumers' willingness to pay for ecolabeled products and the market price differential for bigger individuals may also increase revenues from shrimp.

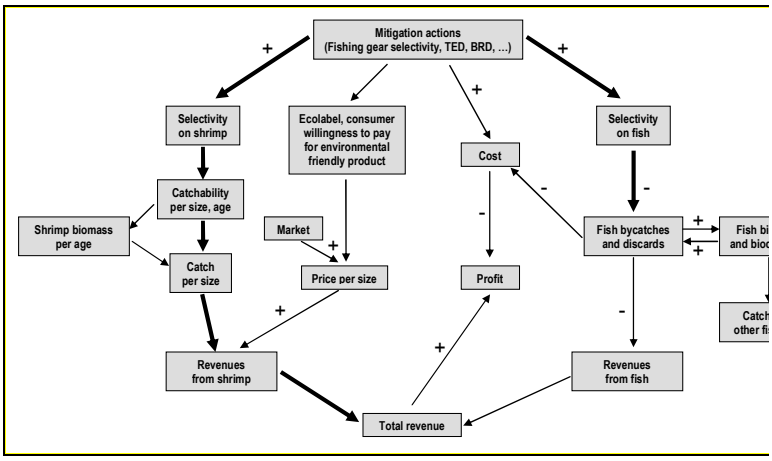

Figure 2 : Potential impacts of mitigation tools.

Case studies

Two tropical shrimp fisheries case studies are presented in this contribution : Madagascar and French Guiana.

The Malagasy fishery exploit coastal shrimp for the 60's and develops until the middle of the 90's. The industrial boats number was close to 80. The shrimps are exploited also by artisanal small trawlers and traditional canoes. Since 2003, the fishery is facing serious difficulties: the mean year catch was 8300 t between 1995 and 2003 and fell under 4000 t. The fleet was reduced to 42 boats. In the last decade management measures tried to control fishing capacity and reduce bycatches. Industrial adoption of TED and BRD was decided in 2003. In 2005 the industrial bycatch ratio is estimated at 72 % and discards ratio at 48 % (fig.3).

Guianese shrimp exploitation began in the 1950's when the US shrimp fishery extended to the Guianas- Brazil continental shelf. US companies established in 1960 in French Guiana. Then Japanese boats entered the fishery. The implementation of Economic Exclusive Zones in 1977 gave resource control to the coastal states. French Guiana developed a national fleet in place of foreign vessels. In 10 years it reached 70 units. Since 1999 landings and fleet number are decreasing. French fleet

operated now in shallow waters, where the brown shrimp biomass is high but composed of small individuals.

The situation worsen in 2009, when only 15 boats operate. In 2005 the bycatch and discards ratios for French Guiana (fig.3) were respectively estimated at 85 % and 78 %.

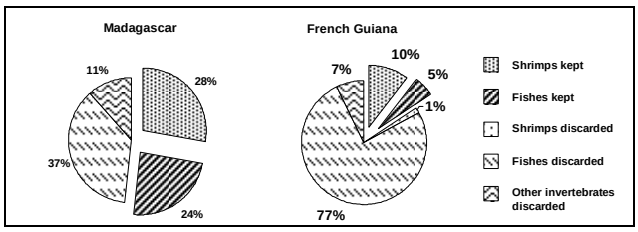

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Figure 3: Bycatch in tropical shrimp trawl fisheries – Madagascar and French Guiana

For these 2 case studies mitigation took place in a difficult economic context due to depressed international shrimp prices and increasing energy costs.

Methodology : models specifications and objectives

Specifications

Bioeconomic models were used to assess the viability of the fisheries and to produce different mitigation and management scenarios. These models are based on the same general structure (fig.4), a central module including the shrimp and fish population dynamics and current economic results calculation, fed by 3 exogenous modules : (1) management decisions; (2) labor and inputs costs; (3) international shrimp market parameters.

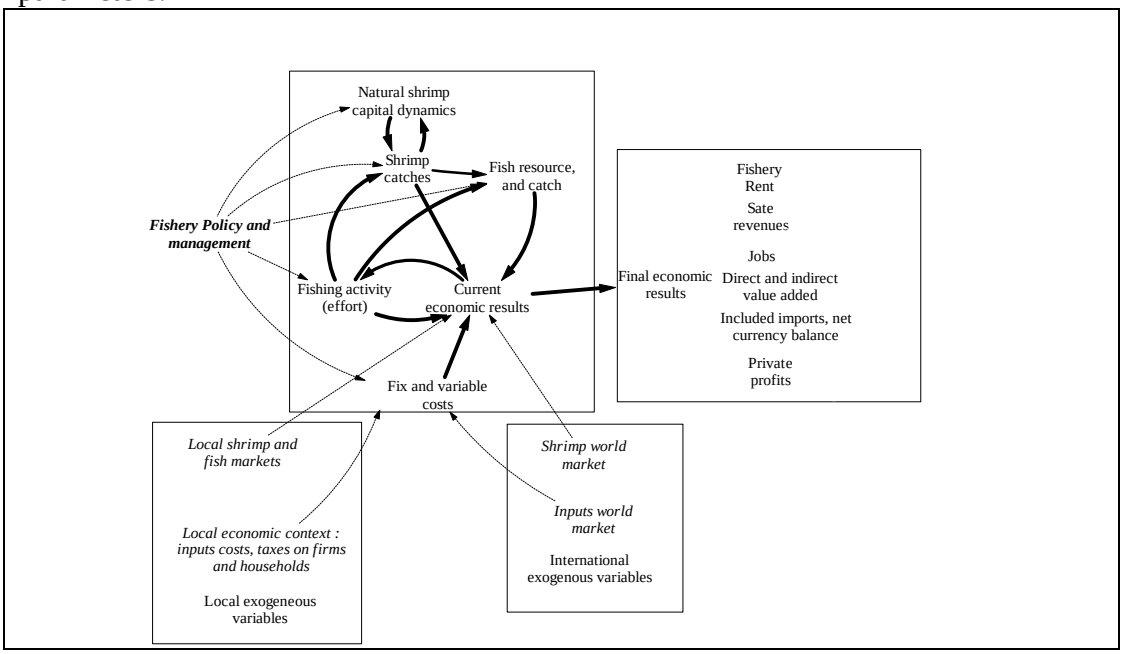

Figure 4 : General structure of bioeconomic models

The Malagasy model produces one year simulations ; the Guianese model long term simulations until ten years. The parameters values are kept constant during the

simulation in the one year model. In the Guianese model they can be modified during the projection period.

Simulation objectives

The two models assess the impact of mesh size increase and migration devices adoption (TED and BRD) on shrimp and fish biomasses, catches and fisheries economic results from the points of views of private boats owners (firms) and of the society. The mesh size increase simulations use the shrimp selection curves for 3 mesh sizes (40, 45, 50 mm) in French Guiana and rebuilt curves for 2 L_{50} (21.5 and 24 mm cephalotoracic length) in Madagascar. For the two fisheries, different simulations on TED and BRD adoption were carried on, using three sets of hypothesis :

	Hypothesis 1	Hypothesis 2	Hypothesis 3
Effect on shrimp catchability	-5 %	-5 %	-5%
Effect on fish bycatch	-38 %	-38 %	-38%
Effect on fuel cost	0 %	- 5 %	0 %
Effect on market price	0 %	+ 5 %	+ 5 %

Parameters values for catchabilities come from experiments made by Ifremer's fisheries technologists in the two countries with the collaboration of professional fishers.

Results

Consequences of mesh size changes

The improvements in shrimp biomass are significant. In Madagascar, the shrimp biomass is increased by 21 % at the end of the simulation year. In French Guyana, at the end of the ten years projection period, the improvements in biomass are respectively of 21 % and 30 % for the 45 and 50 mm mesh compared to the results obtained for the initial 40 mm mesh. These results underline the contribution of selectivity measures to resource sustainability.

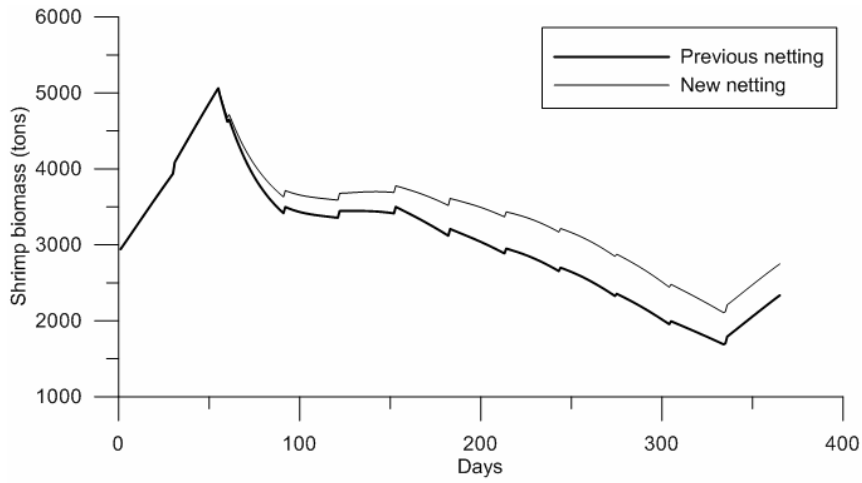

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Figure 5 : Impact of a mesh size change on shrimp biomass in Madagascar

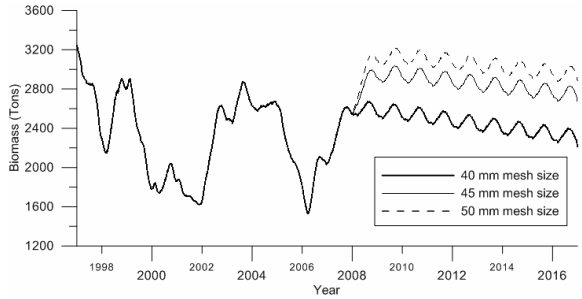


Figure 6 : Impact of a mesh size changes on shrimp biomass in French Guiana

In Madagascar, the mesh increase induces a slight reduced total shrimp catch (-1.35 %). In value the reductions for industrial fleet are offset by the improvement for artisanal and traditional fleets. In French Guiana, the adoption of the 45 mm mesh lead to better results than with the 50 mm one. Despite the decrease in catch, an improvement in revenues and profits is observed, due to the better valorization of bigger landed shrimps. The contribution of small commercial grade shrimp (less than 40 to 60 individuals per kg) is less important for the two countries after mesh size change.

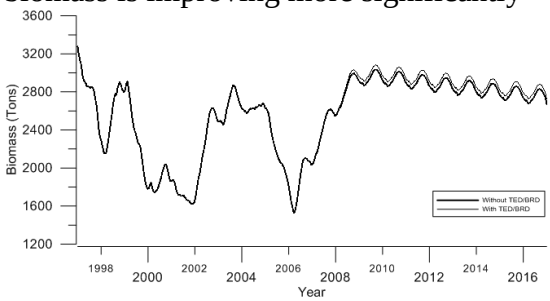
Madagascar			
L_{50} (mm)	21,5	24	
	value	*value*	*Δ (%)*
Shrimp catch (T)	11 860	11 699	
Total firms revenues (M MGA)	90 842	91 734	+ 1
- Industrial	*68 157*	*66 596*	*- 2*
- Artisanal	*8 307*	*9 389*	*+ 13*
- Traditional	*4 318*	*4 561*	*+ 6*
Total private profits (M MGA)	- 3 842	- 3 717	+ 3
- Industrial	*- 6 351*	*6 871*	*- 8*
- Artisanal	*- 973*	*2 565*	*+ 28*
- Traditional	*505*	*588*	*+ 16*
State revenues (M MGA)	11 046	11 022	+ 2
Economic rent (M MGA	7 091	7 575	+ 7
Valorisation per kg (MGA/kg)	6 530	6 676	+ 2

(M MGA : millions of Malagasy Ariary)

French Guiana					
Mesh size	40 mm	45 mm		50 mm	
	value	*value*	*Δ (%)*	*value*	*Δ %*
Shrimp catch (T)	2 500	2 300	- 8	2 000	- 20
Firms revenues (10^3 €)	14 800	15 700	+ 6	15 100	+ 4
Private profits (10^3 €)	1 450	2 011	+ 39	1 600	+ 10
State revenues (10^3 €)	- 1 627	- 1 155	+ 20	- 1 109	+ 32
Economic rent (10^3 €)	- 783	- 285	+ 375	62	+ 108
Valorisation per kg (€/kg)	5,6	6,6	+ 18	7,0	+ 25

Consequences of TED and BRD adoption.

The shrimp biomass is very slightly improving in the two case studies, but the fish biomass is improving more significantly



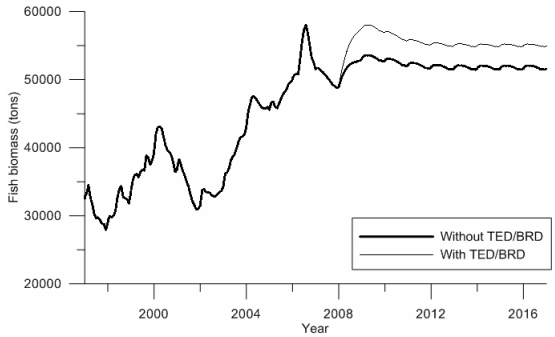


Figure 7: Impact of TED/ BRD adoption on shrimp biomass (left) and on fish biomass (rigth) in French Guiana

When TED and BRD adoption has only catchability effects, private profits are always decreasing. In Madagascar, artisanal and traditional sub sectors profits improve due to positive changes in fish and shrimp biomass. For hypothesis 2 and 3, all fleets have better economic results. It underlines the role of positive market response to support mitigation initiatives. For the two countries, state revenues and rent improve with hypothesis 2 and 3.

Discussions

Concerning mesh size, a critical assumption is the survival of shrimp escaping through larger meshes. If we retain the alternative assumption of a higher mortality for escaped shrimps, then mesh size changes results could be reconsidered. A second point is selectivity efficiency when high yields per tow may create the plugging of coddend meshes.

Concerning mitigation impact, some questions are not addressed by our bioeconomic models, such as the consequences of reducing shrimp fisheries bycatch, taking in account the trophic relationships between species impacted by shrimp fishing. The mitigation effect on shrimp biomass may be negative if shrimp predators are a significant component of bycatch.

A last discussion point concern the cost and of shrimp fishing and potential benefits of mitigation. In our bioeconomic models only direct monetary (or markets) costs are considered. The shift from optimizing the economic yield of a fishery (like most bioeconomic models do) to sustainable development objectives should imply to include externalities and non market costs or benefits. Some species like sharks, ray, and turtles are, or are becoming, emblematic and have a high existence value, attested by the international effort to protect them, but still not estimated. Thus, we have to considerer that some benefits for mitigation are under evaluated in our models.

Conclusion

The economic feasibility of better gear selectivity and mitigation devices adoption in industrial trawl fishery has been demonstrated. The possibility of costs reduction and price increase make a slight improvement of profits possible. Where subsectors are in competition for the resource, some profits redistribution may favor of fishery segments unconcerned by mitigation. From the societal point of view, direct economic results are always improved by mitigation. However, these results don't take in account some possible important feedback effects, like the increase of predation on shrimps when predators removal through bycatch is reduced by mitigation. The incorporation of ecosystemic feedback effects could be then a next step to a better evaluation of mitigation. The mobilization of environmental evaluation economic methods in addition to more traditional bioeconomic approaches may also contribute to go farther in the evaluation of the contribution of selectivity and mitigation tools to the sustainable management of tropical shrimp fisheries.

References

Alverson L.A., Murawski S.A., Pope J.G., 1994. A global assessment of fisheries, bycatch and discards. *FAO Fisheries Technical Paper*. n° 339, Rome, FAO, 233 p.

Caverivière A. Chaboud C., Rafalimanana T., 2008. Les crevettes côtières de Madagascar. Biologie, exploitation, gestion. Ed. Sci. Caverivière A., Chaboud C., Rafalimanana T, Marseille, IRD Ed., 362 p.

Kelleher, K., 2008. Les rejets des pêcheries maritimes mondiales. Une mise à jour. FAO *Doc. Tech. Pêches*. No. 470. Rome, FAO, 147p.

Vendeville P., Rosé J., Viéra A., Blanchard F., 2008. Durabilité des activités halieutiques et maintien de la biodiversité marine en Guyane. Rapport final de convention, Conv. 05/1215640/F - 05/1215614/F. *Rapp. Ifremer Guyane*. DCM/HMT/RHGUY 2008-1, 316 p.

Escherichia coli Maximum Allowable Daily Loads (MADL): an environmental management tool for improving the microbiological quality of the Thau lagoon water (French Mediterranean coast)

A management tool to attain microbial shellfish and water sanitary standards in Thau lagoon (Mediterranean, France)

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Introduction

With production up to 13,000 tons of oysters and 2,500 tons of mussels every year, the Thau lagoon (75 km²) is the main Mediterranean shellfish harvesting area. Thau lagoon is a "B-class" area according to European health regulations. During dry weather or after heavy rainfall, the Thau lagoon shellfish are regularly subjected to microbial pollution of faecal origin exceeding health standards, leading authorities to restrict the shellfish harvest area, and in some cases suspend production. Moreover, shellfish from Thau lagoon have been involved in several foodborne disease outbreaks of viral origin, during winter gastroenteritis epidemics in the local population (Barataud et al., 2003; Le Saux et al., 2009).

To improve the water quality, and in the face of increasing population pressure around the lagoon, the OMEGA Thau project was initiated in 2006. The aim of this project was to develop an Environmental Management Tool, to guide local authorities in infrastructure improvements and urban planning so as to achieve optimal water quality consistent with European standards for shellfish harvesting areas.

This management tool was developed in five steps: (i) inventory of the watershed pollution sources; (ii) simultaneous measurements of microbial quality in the watershed and the lagoon; (iii) development and validation of mathematical models, both on watershed and on the lagoon, to understand the processes involved; (iv) use of these models to determine E. coli Maximum Allowable Daily Loads (MADLs), above which shellfish microbial quality falls below public health safety thresholds; and (v) comparison of MADLs to real inputs from inlets, to determine priority interventions concerning the watershed.

The Five steps of the OMEGA-Thau project

Step 1: inventory of pollution sources

The first step of the OMEGA approach consisted in the identification and localization of the main sources of microbial contamination and the critical points on the Thau watershed. This first step enabled the identification of the most critical sub-basins. The inventory showed that the main *E. coli* sources in the watershed were: i) in dry weather conditions: faecal matter from seabirds and private wastewater treatment facilities; ii) after rainfall events: overflows from wastewater pumping stations, storm overflows and urban runoff.

Step 2: monitoring of watershed and lagoon

The watershed and the lagoon were monitored simultaneously for 18 months (from September 2007 to February 2009) to enable: (i) the validation of the inventory of pollution sources in dry weather and after rainfall events; and (ii) data acquisition for the calibration and validation of the models of faecal pollution transfer, from the source on the watershed to the shellfish harvest areas.

The results of watershed monitoring confirmed the main sources identified during the first step: urban and rural runoff and overflows from pumping stations due to connections between storm drainage and sewage networks. The results of step 2, however, showed that the levels and durations of *E. coli* discharges from waste water treatment plant (WWTP) after rainfall, had been under-estimated in step 1. Step 2 led to the identification of the most critical sub-basins and wastewater pumping stations.

Field investigations in dry weather in Thau lagoon and its watershed showed that there was substantial faecal contamination of shellfish with no significant input from the watershed (Derolez *et al*., 2010). These investigations suggest (but need to be confirmed) the contribution of an avian source to shellfish contamination during dry weather.

Step 3: calibration and validation of models

Data collected during step 2 were used to develop, validate and calibrate a modelling tool to simulate the transfer of microbiological contaminants from their source of production in the watershed to the shellfish production areas in the lagoon. This tool consists of two models: a watershed model that provides the freshwater and *E. coli* loads; and a lagoon model that simulates the dynamics and the biological processes of *E. coli* in the lagoon.

The watershed model is based on hydrological and water quality models previously developed (Mockus, 1957; Nash, 1958; INSA-Valor and SOGREAH, 1999). This model simulates rainfall events at a less-one-hour time step and provides freshwater and *E. coli* loads at each of the 20 sub-basin outlets of Thau watershed. Specific processes were implemented in this model during OMEGA project: overflows from wastewater pumping stations (separate and combined sewers), WWTP discharges, urban and rural wash-off and salting-out of *E. coli* accumulated in river sediments during dry period (Tournoud *et al*., 2008; Chu, 2006; Raymond, 2010).

Impact of these freshwater and *E. coli* loads in seawater and on shellfish contamination are estimated using the hydrodynamic Model for Application at Regional Scale (MARS-3D) (Lazure and Dumas, 2008), coupled to a model for *E. coli* mortality using a constant decay-rate factor .

This model simulates *E. coli* mortality processes in seawater and transport and dispersion of *E. coli* plume from the river mouths to the shellfish farming areas, mainly due to wind-induced water circulation into the lagoon (Fiandrino *et al.*, 2010).

Step 4: evaluation of Maximum Allowable Loads (MADLs)

To evaluate the impact of *E. coli* loads in the lagoon, we used a downstream - upstream approach and developed the concept of Maximum Allowable Daily Loads (MADLs). The MADL is the lowest *E. coli* load, above which shellfish microbiological quality is altered. This definition requires the determination of a level of *E. coli* in shellfish farming area not to exceed. In association with stakeholders, water quality for shellfish farming is considered to be altered if *E. coli* concentrations in shellfish are above the B-class health threshold (4 600 *E. coli* / 100 g of flesh) for a period of more than 2 hours.

MADLs were calculated for the meteorological conditions giving the greatest risk of shellfish contamination. Thus, the conditions used were those associated with the most critical water and *E. coli* loads and those favouring both *E. coli* survival in seawater (T90 = 48 hours) and the rapid transfer of *E. coli* from the plumes at river mouths to the nearest shellfish farming area. Two types of watershed inputs were simulated: (i) dysfunction of pumping stations lasting 4 hours in dry weather; (ii) a rainfall event of 2-years return period (76 mm in 24 hrs).

Step 5: determination of priority works

For each sub-basin, simulated *E. coli* loads were compared to MADLs to identify areas critical for shellfish quality, in dry weather conditions or after rainfall (Figure 1). This comparison allowed evaluation of the reduction targets for *E. coli* loads, necessary to attain the previously defined quality target (*E. coli* levels under the B-class health threshold).

The pollution sources causing the MADLs to be exceeded are shown in Table 1. The avian source, highlighted during step 2, was not taken into account in the watershed model although it was shown probably to contribute significantly to shellfish contamination during dry weather.

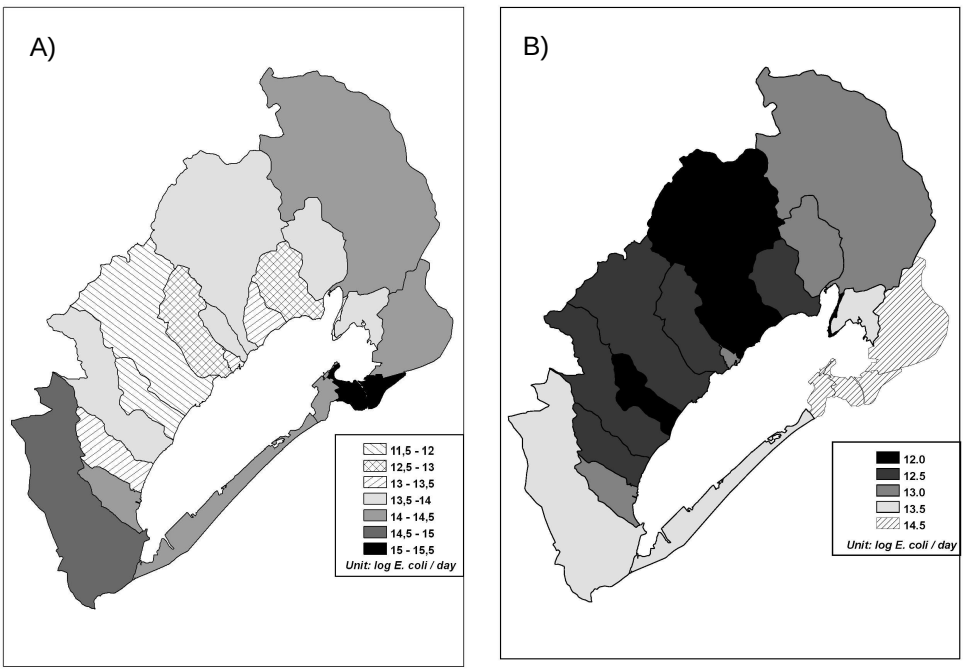

Figure 1: A) E. coli daily loads simulated for a 2-years return period rainfall event. B) Maximum Allowable E. coli Daily Loads (MADLs) calculated for a 2-years return period rainfall event on Thau lagoon's 20 sub-basins.

To attain the previously defined quality objective, preventive and corrective actions should be implemented with priority for wastewater system networks, especially wastewater pumping stations and sewer overflows, more than a half of which are critical. Priority interventions for these structures should consist of diagnosis, enhancement of both reliability and security, or rehabilitation.

Concerning urban runoff, the actions planned include recommendations for better practices in management and prevention of the accumulations of animal waste (covering collection, public education, street and networks cleaning, and large-scale plans for the whole territory involved).

Table 1: E. coli load reduction factors (= simulated E. coli load / E. coli MADL, expressed in E. coli.day-1 units) for the main pollution sources and number of watershed affected (maximum 20) with respect to the quality objective.

	Dry weather			2-years return period rainfall		
	Average reduction factor	Maximum reduction factor	Number of watersheds	Average reduction factor	Maximum reduction factor	Number of watersheds
Combined and separate sewer overflows or accidental discharges	3 to 10	10 to 100	7	3 to 10	10 to 100	10
Individual wastewater treatment facilities				3 to 10	3 to 10	7
Urban runoff				3 to 10	3 to 10	1
Total	**3 to 10**	**10 to 100**	**7**	**3 to 10**	**10 to 100**	**15**

Conclusion and perspectives

The calculation of MADLs requires a good knowledge of microbial sources and clear understanding of the processes of pollution transfer from the watershed to shellfish growing areas. On the Thau lagoon, this necessitated the collection of large amounts of data and the implementation of watershed and lagoon models. The MADLs can help guide local authorities in infrastructure improvements and urban planning, so as to attain optimal water quality consistent with European standards for shellfish. Indeed, these values will be taken into account by the local government authorities as part of the water management plan (SAGE), to determine priority issues to be addressed in the watershed over the next 6 years.

The water-quality based management tool developed as part of the OMEGA-Thau project is versatile and could be implemented for the management and control of recreational water areas, for other types of pollution (notably pesticides or eutrophication). It could also be adapted for the management of other coastal zones.

References

Barataud D., Doyle A., Gallay A., Thiolet J.M., Le Guyader S., Kholi D. and Vaillant V., 2003. Toxi-Infections Alimentaires collectives à Norovirus, liées à la consommation d'huîtres de l'étang de Thau, France, décembre 2002, *Bulletin Epidémiologique Hebdomadaire*, 38/2003, 177-179.

Chu Yin, 2006. Flux de polluants en crue sur des petits bassins versants côtiers méditerranéens. Sources, estimations et modélisation. PhD Thesis. Université de Montpellier 2, 166 p.

Derolez V., Serais O., Caprais M.-P., Le Saux J.C., Messiaen G., 2010. Investigating an avian source of shellfish faecal contaminations in the Thau lagoon (Mediterranean, France). Proceedings of the 7th International Conference on Molluscan Shellfish Safety (ICMSS), Nantes, 14–19 June 2009. http://www.symposcience.org/exl-doc/colloque/ART-00002553.pdf

Fiandrino A., Cesmat L., Derolez V., Jeannée N., Lemarchand O., Serais O. and Laugier T., 2010. Assessment of *Escherichia coli* contamination in the Thau lagoon (France): Combined use of physically based modelling and geostatistics. Proceedings of SimHydro 2010 Conference: Hydraulic modeling and uncertainty, 2-4 June 2010, Sophia Antipolis.

INSA-Valor and SOGREAH, 1999. CANOE : logiciel d'hydrologie urbaine, conception et évaluation de réseaux d'assainissement, simulation des pluies, des écoulements et de la qualité des eaux. Manuel de l'utilisateur. 469 p.

Lazure P. and Dumas F., 2008. An external-internal mode coupling for a 3D hydrodynamical model for applications at regional scale (MARS). Advances in Water Resources, 31, 233-250.

Le Saux J.C., Serais O., Krol J., Parnaudeau S., Salvagnac P., Delmas G., Cicchelero V., Claudet J., Pothier P., Balay K., Fiandrino A, Pommepuy M. and Le Guyader S., 2009. Evidence of the presence of viral contamination in shellfish after short rainfall events. Proceeding of the 6th International Conference on Molluscan Shellfish Safety (ICMSS); The Royal Society of New Zealand (Eds), 2009. Miscellaneous Series, 71, 256-262.

Mockus V., 1957. Use of storm and watershed characteristics in synthetic hydrograph analysis and application. U.S. Dept. of Agriculture. Soil Conservation Service, Washington, D.C.

Nash J.E., 1958. The form of the instantaneous unit hydrograph, IUGG Gen. Assembly, Toronto Vol. III, IAHS, Gentbrugge. Publ. 45, pp. 114–121.

Raymond M., Delichère S., Boudong C., Fang Z-X., 2010. Innovative development for a modelling approach of the microbiological pollutant sources in the watershed of the Thau lagoon. Proceedings of the 7th international conference on sustainable techniques and strategies in urban water management (Novatech), Lyon, France, June 27th – July 1st 2010. http://www.hydropraxis.com/?p=461

Tournoud M.G., Perrin J.L., Salles C., Got P., Caro A., Picot B., Rodier C., Grillot C., Chu Y., 2008. Impact of the hydrological behaviour on pollutant in an intermittent Mediterranean river (Vène, France). 13th World Water Congress, Montpellier, France – IWRA Proceedings.

Climate oscillations and tuna-dependent economies

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Context and goal of the study

Climate variability operates on seasonal, inter-annual or decadal time scales and affects numerous biological and ecological processes, as well as fisheries. El Niño Southern Oscillation (ENSO) events impact ecosystem processes across the globe and are the major phenomena driving inter-annual ocean climate variability. The ENSO signal propagates in the

Indian Ocean and is manifested as sea surface temperature and heat storage anomalies. Interannual climate variability in the Indian Ocean also results from coupled ocean-atmosphereland interactions that operate independently of the ENSO forcing that originates in the Pacific. The Indian Ocean zonal dipole mode is a "basin-scale pattern of surface and subsurface temperature that seriously affects the inter-annual climate anomalies of many nations around the Indian Ocean rim". The positive or negative IOD events may occur in the same years as ENSO, such as in 1998, or in its absence. ENSO and IOD processes have a profound effect on tuna fisheries in the region. Of major concern to the tuna economy of Seychelles is the prediction that ENSO anomalies may increase in frequency and severity in relation to climate change. The importance of tuna to the Seychelles economy has been enhanced through expansion in tuna canning capacity. Presently the cannery (Indian Ocean Tuna Ltd) is one of the biggest in the world, representing a major employer of the domestic economy with 1,975 workers in March 2007 (i.e 19% of the formal employment in the private sector, and more than 90% of national exports). Most canned tuna exports are destined for Europe and Seychelles accounted for a 13% share of the European market in 2007.

The aim of this study is to assess the impacts of climate variability on the tuna-dependent economy of Seychelles. This assessment is achieved by crossing scientific knowledge on the linkages between climate and fisheries with economic models and several statistical methods (cluster analysis, cointegration, Markov-switching Vector Error Correction Model) to analyse the relationships between climate indices and available economic data relating to the purseseine tuna fleet and fisheries-related industries.

Methodology

We employed several climate indices in the analyses, of which: (1) the Dipole Mode Index DMI), the east-west temperature gradient across the tropical Indian Ocean; (2) the Indian Oscillation Index (IOI), the difference in sea level pressure standardized

anomalies between Seychelles and Darwin; (3) the Southern Oscillation Index (SOI), the difference in sea level pressure standardized anomalies between Tahiti and Darwin, and (4) the Western Tropical Indian Ocean sea surface temperature index (WTIO), the surface temperatures in the region 50°E -70°E, 10°S - 10°N. The spillover effects of the purse-seine tuna fleet in Seychelles were estimated from an original dataset of economic expenditures at Port Victoria, and using an input-output model and a multiplier approach. The expenditure of fishing vessels landing or transhipping in Port Victoria is partly flooding into the national economy through the revenue transferred as wages or dividends (to shareholders) to Seychellois households that is not saved or spent on imported goods. In addition to the direct (fleet) and indirect (cannery, government) expenses, a looping effect induced by the household expenditure can be estimated. The standard multiplier impact is obtained by dividing the sum of direct, indirect and induced expenditure by total expenditure of the purse-seine tuna fleet. To determine the economic effects of changes in landings and transhipment, it was necessary to assess whether a cause-effect relationship existed. While numerous expenses incurred by the vessels in Port Victoria are expected to be largely independent of landings and transhipment, cargo handling costs should be strongly related. The relationship between cargo handling costs (CHC) and landings/transhipment was therefore tested statistically in order to study causality between the variables. Having confirmed causality between landings/transhipment and expenditure related to CHC, and with the PCA identifying the existence of two seasonal and periodical regimes in the expenditure data, we then examined the effects of climate variability on the relationship between fishing effort and landings/transhipment. Following a standard typology of shipping costs, the purse-seine tuna vessel expenditures could be divided into CHC and the vessel or voyage costs, of which the bunker costs represented 86% on average. As a first step, the equilibrium between fishing effort and landings/transhipment was analysed through cointegration, with gasoil expenditure (bunker costs) used as a proxy of fishing effort. We then applied a Markov-Switching VECM (MS-VECM) method to model the probability of shifting between two regimes (high and low) of landings/transhipment in relation to climate oscillations.

Results

Using the average 2006 exchange rate (1€ = 6.93 Seychelles Rupees, SR) and excluding the cannery in a first step, the annual total (constant) expenditure of the tuna fleets valuing 240 million (M) SR2001 (i.e. 35 M€; average 1992-2006) gives an average induction effect of 1.99. In terms of direct fleet expenditure (203 MSR2001, i.e. 29 M€), the spillover (indirect and induced expenditures) was estimated at 231 MSR2001 (33 M€). Thus, a net induced contribution represents more than twice the initial inflow for the rest of the economy. When IOT expenditures and their spillover effects were included in a second step, the coefficient of induction rose to 2.94. In other words, every 100 SR spent by the purse seine tuna fleet in Port
Victoria leads to a final amount of nearly 300 SR for the Seychelles economy. Interestingly, all types of effects show an inflexion point in 1998, year of the main impacts of the 1997-98 warm events (ENSO+IOD) in the WIO. In 1998, the direct, indirect and induced effects declined by 58%, 26% and 35% (42% decrease overall), respectively, compared with a yearly growth trend of 19%, 3% and 5% (10% increase overall) for the same effects, respectively. In projecting expenditure data as

a factorial plan in a PCA, 1998 is isolated from other years and clusters with the second quarter patterns of low expenditure and extreme values of two climatic indices, the IOI and the WTIO. This suggests that anomalous ocean-climate conditions produce a similar response in expenditure to that typically observed during the second quarter of the year. Cluster analysis of seasonally adjusted quarterly expenditure data yielded an optimal of 5 clusters and isolated 1994 and 1998 from the recurrent seasonal pattern, clustering most quarters from those years (55% of observations in the cluster compared to an average of 13%) and rejecting the null hypothesis of a random distribution. The level of tuna landings/transhipment in this cluster was 53% lower than average and can be considered as the seasonally adjusted impact of the 1997-1998 warm event on the Seychelles tuna economy.

There was bidirectional causality between CHC and landings/transhipment. CHC increased by

116 SR when total landings/transhipment in Port Victoria increased by 1 tonne (t). On average, with a standard level of 61,632 t landed/transhipped per quarter (mean 1992:1-2008:2), the estimated CHC expenditure would be 8,376,092 SR2001. Other things being equal, a 40% cut of landings/transhipment caused by a warming event as extreme as that of 1997-1998 would result in a 34% loss of CHC expenditure for the local economy.

Concerning the Markov-switching VECM model, two regimes were identified and constitu d

the higher level of landings/transhipment occurring during the third and the fourth quarters (regime 1), and the lower levels of the second quarter and, sometimes, the first quarter (regime 2). The lowest values of p* (regime 2) occur mainly during the second quarter when the vessels usually land in other regional ports. While not defined by 3 quarters entering the low regime, 2007 was the only year since 1998 for which there were two consecutive quarters

in regime 2. The best OLS model attempting to explain p* was obtained with the IOI, the other indices exhibiting a lower level of significance. In terms of the IOI index, any deviation of the square IOI value from average values decreases by nearly 10% the probability of being in a normal (high) landing reg me. Severe deep mixed-layer depth anomalies, which are known to reduce catchability of tuna, occurred only in late/early 1991-92, 1997-98 and 2006-07. Large variations in the climate index can therefore have a depressing influence on landings/transhipment in Seychelles.

To conclude, the potential impacts of climate variability and change on the Seychelles economy are severe. Similar to many small island developing states situated in productive tuna fishing zones, Seychelles has come to rely heavily on a ‘tuna economy’ as world demand

for tuna has grown steadily. The multiplier approach demonstrated the importance of this industry for domestic wealth. Stakeholders of the tuna industry, including the cannery, generally perceive climate variability to be a relatively unimportant threat compared to changes in trade regimes, piracy, regional competition and overfishing, and the industry has demonstrated a degree of resilience to recent warm events. However, this situation may change given the predicted interaction of background warming on the occurrence of the central Pacific El Niño and changes in the distribution and magnitude of fisheries resources caused by climate change. The incorporation of climate variability in population and bioeconomic fisheries models will be important for fisheries assessment and management, as well as for building adaptive capacity

An optimization problem of aquaculture and fisheries product

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Introduction

Recent aquaculture product has grown impressively. Some people believe the growth of aquaculture product could be an answer to the growing problem of world food supply problem. However fish supply prospects will depend to large extend on the effectiveness of fishery management. Further development of aquaculture could threaten a number of factors such as water pollution and ecosystem. For example cultivating fish like tuna does not help the food supply problem because they need to eat more fish product from other fish. To produce one ton of farmed tuna, products from 10 to 15 tons of sardines are needed to caught to feed them. As farming industry expands, it will continue to require more wild fish for feed. Unfortunately farming species such as cod, salmon and snapper is likely to have the same environmental impacts as tuna farming. Therefore it is important to understand how far aquaculture product needs to expand. In this study we seek the proper aquaculture supply within theoretical framework.

Model of fishery and aquaculture system

Our primarily goal of this section is to simplify the fishery system, and construct the mathematical model which describe the total product as a sum of catch fishery and aquaculture product. Then answering the next question is an ultimate goal: how much percentage of catch product should be used as fish-meal in the aquaculture in order to maximize fishery product?

Model formation

For ease of reference, a list of the principal symbols used is given below.

Y_c product due to catch fishery
Y_a product due to aquaculture
Y_t total fishery product
α a ratio of capture fishery product used for fish-meal in aquaculture
f aquaculture system as a function. Input of this function f is amount of fish-meal,
and output is aquaculture product.

Systematic diagram of the system we concern is shown in Figure 1. Therefore total fishery product Y_t can be expressed as

$$\begin{aligned} Y_t &= (1-\alpha)Y_c + Y_a \\ &= (1-\alpha)Y_c + f\left(\alpha Y_c\right) \qquad (1) \end{aligned}$$

We also define a function describing the relation fish-meal and aquaculture product as
a logistic function of the next form

$$Y_a = f(\alpha Y_c)$$
$$= A(1 - e^{-\beta \cdot \alpha Y_c}) \qquad (2)$$

where A is the limited value of Y_a. The largest value that the aquaculture product can reach given infinite fish-meal. And β defines the increase rate of aquaculture product. The value of the rate β represents production increase of the Y_a in one million tons of fish-meal. These values of parameters A=40 and β-0.04 are estimated from the FAO statistical data.

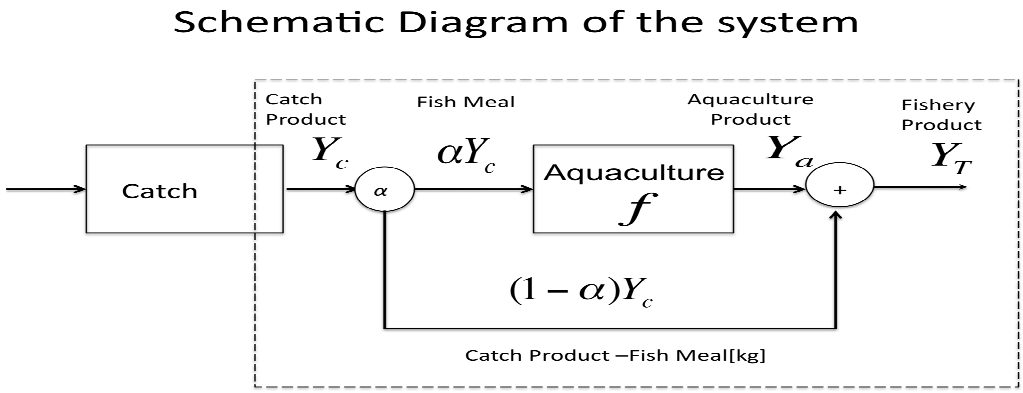

Figure 1: The systematic diagram of the product flow in the fishery system. The total fishery product Y_t is the sum of (the catch fishery product - fish meal) and (the aquaculture product). Therefore it can be expressed as $Y_t=(1-\alpha)Y_c+Y_a$

Maximizing fishery product

Replacing Y_a in the right hand side of equation (1) by (2),

$$Y_t = (1-\alpha)Y_c + A(1 - e^{-\beta \cdot \alpha Y_c}) \qquad (4)$$

Total fishery product is expressed as a function of fish meal α. The maximum point of total fishery product respect to fish-meal can be determined by taking the first derivative of the nonlinear equation (4) respect to α and setting it equal to zero($\frac{dY_t}{d\alpha}$=0), which yields

$$\alpha' = \frac{\log(A \cdot \beta)}{\beta \cdot Y_c} \qquad (5)$$

Further it is possible to estimate the ideal aquaculture product as

$$Y_a^{ideal} = A(1 - e^{-\beta \cdot \alpha' Y_c}) \qquad (6)$$

Ideal aquaculture product estimated by equation (6) is a function of Y_c,

Results

Estimation of α and Y_a^{ideal}

The proper amount of fishmeal, and aquaculture product Y_a^{ideal} of each year(2002-2006) was calculated based on equation (5) and (6). These results are shown in Table.1.

Table.1 Yc and Ya are total capture and aquaculture products in million tones. These data are from FAO SOFIA(2006). α and Yaideal was calculated based on equation (5) and (6).

	2002	2003	2004	2005	2006
Y_c	76.7	73.7	77.7	77.1	74.9
Y_a	12.6	13.8	15.3	16.1	17.2
α	0.153	0.159	0.151	0.154	0.157
Y_a^{ideal}	15.0	14.5	14.9	15.1	15.0

Discussion

In this study we undertake an optimization problem of aquaculture and fisheries product from the viewpoint of effective use for finite aquatic resources. Our goal is to maximize the total fishery product by controlling the ration of aquaculture and catch fishery products. The simple mathematical model is constructed to describe the total fishery product as sum of capture fishery product and aquaculture product. Thus this model does not account for any economical aspect, but only focus on product flow. Aquaculture and capture fishery products interact in the model through the parameter α, which is defined as the ratio of capture fishery product turned into bait in aquaculture. It was assumed there is logistic curve relationship between amount of bait used in aquaculture and aquaculture product, and also assumed that any of aquaculture product is not used as bait in aquaculture or capture fishery. Within this framework, the total product is critically dependent on this parameter α. We also analyzed FAO data (non-food uses, aquaculture, capture product data are used). Our results indicate the total fishery product is maximized if the amount of the bait used in the aquaculture is limited to about15% of catch fishery product. Our sensitivity analysis (not shown) also indicates the upper bound of α needs controlled to be less than 18.9% in order to maximize the total fishery product. Although it is difficult to verify whether these values of α and Y_a^{ideal} are how realistic, it should be important to pay attention to these suggested values as warning to a remarkable increase of recent aquaculture product.

Reference

FAO (2006): SOFIA – The State of World Aquaculture, Rome

Can genetic improvement in aquaculture reduce the impact on fisheries? The case of European sea bass (*Dicentrarchus labrax*) fed on a totally plant-ingredient based diet

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Introduction

Facing the finite size of fisheries resources, the important increase of aquaculture production during the last decades has led to the evolution of feed composition with an increasing substitution of fish meal and fish oil with terrestrial plant products. During the same period, selective breeding has been developed in fish and major improvements were achieved on growth, resulting in 4 to 20 % gain per fish generation (Olesen et al., 2003; Chevassus et al., 2004).
Recent and fast co-evolution of these two major parameters of fish production raises issues about the consequences of feed composition changes on fish breeding, and on the possibility of selecting for growth with plant-based feed. To date, several authors already found significant genetic variability of growth traits with plant-based diets. But only Pierce et al. (2008) and Quinton et al. (2007) gave precise estimates of heritability, respectively for rainbow trout and European whitefish. The major problem would result in the existence of genotype-diet interactions because feeding fish, formerly selected with marine diets, on plant-based diets would lead to family re-ranking and hence loss of genetic gain. Presently, results on the subject are quite uneven, e.g., in rainbow trout, Palti *et al*. (2006) and Quinton et al (2007) found no genotype-diet interaction conversely to Pierce *et al*. (2008) and Dupont-Nivet *et al*. (2009). For the first time, we estimated genetic parameters in a context of marine products substitution in European sea bass, and showed reranking of family performances with extremely contrasted diets in this species.

Material and methods

784 fish from 328 families were reared together and microsatellites were used to assign parentage. Fish were individually tagged and DNA sampled. When fish weighted 192 g ± 54 g, they were distributed in 4 tanks. Two tanks were fed with marine diet (M), mainly based on fish meal (FM) and fish oil (FO), while the other two were fed with a plant-based diet (PB: FM: 0% and FO: 0%). Body weight (*BW*) was measured 7 times at regular intervals until 850 days post fertilization (dpf). At each date, fillet lipid content was assessed using a Fish Fatmeter and corrected by the logarithm of the body weight (*CorrFat*) Traits were analyzed with a linear model associated to ANOVA or to restricted maximum likelihood (REML) methodology using SAS and ASREML (Gilmour *et al.*, 2002) software.

Results

No difference between final weight and fillet lipid content after 269 days of trial were observed (P=0.06) with PB diet. Sire*diet interaction was significant on *BW* and *CorrFat (P <0.05)* Heritability estimates of BW differed significantly from zero (PB: 0.37 ± 0.18(SE); M: 0.47 ± 0.24 (SE)). Genetic correlations were between 0.51 and 0.87 and tended to decrease over time, showing genotype*diet interaction for *BW* and *CorrFat* (Table I).

Table I: Genetic correlations between diets and heritability (± standard errors) for Plant Based, Marine and both diets. Ages of the fish are indicated before the period number.

BW		**Genetic correlation**	h^2 **(PB) (± SE)**	h^2 **(M) (± SE)**	h^2 **(total) (± SE)**
(588)	**0**	**0.99** ± 0.00	**0.07** ± 0.01	**0.52** ± 0.04	**0.32** ± 0.13
(605)	**1**	**0.99** ± 0.00	**0.14** ± 0.01	**0.52** ± 0.04	**0.32** ± 0.13
(647)	**2**	**0.81** ± 0.38	**0.21 ±** 0.16	**0.54** ± 0.24	**0.31** ± 0.13
(679)	**3**	**0.64** ± 0.35	**0.29** ± 0.17	**0.51** ± 0.24	**0.31** ± 0.13
(736)	**4**	**0.51** ± 0.34	**0.36** ± 0.18	**0.48** ± 0.24	**0.30** ± 0.13
(787)	**5**	**0.51** ± 0.34	**0.36** ± 0.18	**0.47** ± 0.24	**0.30** ± 0.13
(850)	**6**	**0.62** ± 0.35	**0.36** ± 0.18	**0.37** ± 0.22	**0.29** ± 0.13
CorrFat					
(588)	**0**	**0.99** ± 0.00	**0.46** ± 0.1	**0.60** ± 0.08	**0.63** ± 0.19
(605)	**1**	**0.99** ± 0.00	**0.62** ± 0.6	**0.68** ± 0.08	**0.63** ± 0.19
(647)	**2**	**0.99** ± 0.00	**0.19** ± 0.01	**0.19** ± 0.11	**0.61** ± 0.18
(679)	**3**	**0.99** ± 0.09	**0.70** ± 0.22	**1.02** ± 0.29	**0.78** ± 0.21
(736)	**4**	**0.87** ± 0.16	**0.59** ± 0.22	**0.83** ± 0.27	**0.60** ± 0.18
(787)	**5**	**0.80** ± 0.16	**0.57** ± 0.22	**1.10** ± 0.29	**0.65** ± 0.19
(850)	**6**	**0.83** ± 0.17	**0.56** ± 0.22	**0.94** ± 0.23	**0.65** ± 0.19

Conclusion

From this trial, we conclude that family ranking for BW and CorrFat is not consistent among marine and plant-based diets, that heritability estimates are moderate to high for both traits which confirms that sea bass is a good candidate for selection on these traits, in PB diet as well. Still, this has to be confirmed in larger experiments, over a longer time period and complementary results are currently analysed and will be shown.

References

Chevassus B., E. Quillet, F. Krieg, M.G. Hollebecq, M. Mambrini, L. Labbe, J.P. Hiseux, M. Vandeputte. 2004. Enhanced individual selection for selecting fast growing fish: the "PROSPER" method, with application on brown trout (*Salmo trutta fario*). Genet. Sel. Evol. 36 : 643-661.

Dupont-Nivet M., F. Médale, J. Leonard, S. Le Guillou, F. Tiquet, E. Quillet, and I. Geurden. 2009. Evidence of genotype-diet interactions in the response of rainbow trout (*Oncorhynchus mykiss*) clones to a diet with or without fishmeal at early growth. Aquaculture 295: 15-21.

Gilmour A.R., B.J. Gogel, B.R. Cullis, and S.J. Welham. 2002. User Guide Release 1.0.

Olesen I, T. Gjedrem, H.B.Bentsen, B. Gjerde and M. Rye. 2003. Breeding programs for sustainable aquaculture. Journal of Applied Aquaculture 13 :179-204.

Palti Y., J.T.Silverstein, H. Wieman, J.G. Phillips, F.T. Barrows, and J.E. Parsons. 2006. Evaluation of family growth response to fishmeal and gluten-based diets in rainbow trout (*Oncorhynchus mykiss*). Aquaculture 255: 548-556.

Pierce L.R., Y. Palti, J.T. Silverstein, F.T. Barrows, E.M. Hallerman, and J.E. Parsons. 2008. Family growth response to fishmeal and plant-based diets shows genotype x diet interaction in rainbow trout (*Oncorhynchus mykiss*). Aquaculture 278, 37-42.

Quinton C.D., A. Kause, J. Koskela, and O. Ritola. 2007. Breeding salmonids for feed efficiency in current fishmeal and future plant-based diet environments. Genetics selection evolution 39:431-446.

Harmonizing aquaculture, fishery and management, challenges in Pacific bluefin tuna

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Introduction

Management of the Atlantic buefin tuna drew wide attention when the species was proposed to be listed as CITES List 1 and that the COP held in Doha in March 2010 rejected the proposal. Regarding to the management of bluefin tuna, recent progress in complete bluefin aquaculture could give revolutionary impacts to the fishery and management of this species. Japan will be the first country in the world that has to face this potential but real impacts derived from rapid progress of bluefin aquaculture technique. In this regard, it is necessary to take a holistic approach of the management of the Pacific bluefin tuna with harmonization of captive fishery and aquaculture. The presentation covers briefly Pacific bluefin fishery including aquaculture, fishery, biology and stock status followed by major challenging issues foreseen such as sustainable use of the stock for wild fishery and aquaculture, stock enhancement and researches for comprehensive management.

Historical back ground of Japanese tuna farming

After the World War II, Japanese tuna longline fishery started to extend rapidly its operation from the Japanese waters to rest of the Pacific, then Indian and Atlantic Ocean. This resulted in remarkable increase of the tuna catches. However, the Japanese tuna production showed a sign of decrease for the first time in the 1960s. Fisheries Agency of Japan (FAJ)started a research program entitled ”Large scale aquaculture experimental project for useful fishes” in 1970 in hope of stopping the decline of the tuna catch. During 1980-1989, FAJ started another research project, so called “Marine ranching project” aiming at stock enhancement of the Pacific bluefin tuna (PBFT). However, those two projects were not successful until the time Kinki University succeded in complete aquaculture of PBFT in 2002. Tuna farming in Japan started around 1980 with wild juveniles of 20 cm in fork length (FL) and gradually increased up to some 10,000 tons in 2009 (recently some farms started to grow large adult fish).

Fisheries, stock status and management of Pacific bluefin tuna

There is a lot of similarity in the bluefin fishery between the Mediterranean and Pacific stocks. First, the bluefin has been caught for a long time dating back to historic time more than 10 centuries. Second, variety of fishing gears are used including trap, jig, handline, longline, purse seine, baitboat. However, purse seine and jig fisheries have been major fisheries that produced major part of the total Japanese catch of PBFT. Those various fishing gears were employed by various sized boats ranging from very small boats operated by one man to modern industrial

boats mostly operated within the Japanese EEZ. The total catch of the PBFT fluctuated widely without trend between 9,000 and 40,000tons with an average 22,000tons. Japan has been dominant in the catch followed by the USA and Mexico. The PBFT fishery is characterized by a large catch of juvenile bluefin tuna. Biology of the PBFT has also very similar to that of the Mediterranean bluefin tuna. They tart spawning at 3-year old and make trans-oceanic migration between the Japanese waters and waters off Calfornia and Mexico. This stock shows a typical large stock size fluctuation during the past 100 years (Muto et al., 2009). It seems that the large scale stock size fluctuation is caused by environmental changes.

Stock status of the Pacific bluefin is summarized as follows (WCPFC, 2009): 1. Recruitment has fluctuated without trend over the assessment period (1952-2006), and does not appear to have been adversely affected by the relatively high rate of exploitation. 2. Spawning stock biomass (SSB) fluctuated widely for the past 50 years without increasing or decreasing trends. The SSB estimates for 2005 are above the median level over the assessment period (1952-2006). If the future fishing mortality rate (F) continues at the current F level, the short-term projections (2009-2010) indicate SSB will decline. In the longer term, SSB is expected to attain levels comparable to median SSB levels over the assessment period. 3. No relationship between SSB and recruitment is apparent over the range of "observed" SSB from the assessment. 4. Management measures currently applied to the Pacific bluefin tuna is that no increase of overall F from the recent year level with targeting the reduction of F for ages 0-2 juveniles.

Challenges in the future

Supply of cultured juveniles for tuna farming

Bluefin aquaculture in Japan has a long history started around 1980s and increased steadily up to around 10,000 tons in 2009 while Mexico started the aquaculture around 2000 and produced about 6,000 tons. South Korea is interested in taking part in the aquaculture very soon. Complete aquaculture of bluefin tuna succeeded by Kinki University in 2002 now produces the 3rd generation. This university alone able to produce some 30 thousands of 3month old juveniles for commercial sale to private aquaculture companies in 2009.

However, the supply of seed fish for the Japanese tuna farming is unstable because of dependency of the seed fish from wild fish that show a large annual fluctuation. It is estimated that currently some 0.5 millions seed fish have been annually taken from the wild fishery. On the other hand, observed wild population size corresponding to farm seed fish (20 cm FL) is estimated, on an average , 10 millions (minimum level 5 millions). Therefore, now, some 5-10% wild fish are used for tuna farming

Increase for demand of the seed fish for tuna farming is expected due to catch reduction of the Atlantic BFT catch. As previously mentioned, F for juveniles is recommended to be reduced by the regulatory measures by the Western and Central Pacific Fisheries Commission (WCPFC). In this regard, it is considered that more supply of aquacultured seed fish (now, able to produce about 10% of demand) has potential for contributing in reducing F as well as stabilizing the supply for farms.

Shifting management objective from MSY to observed minimum SSB

Pacific BFT stock is hard to manage based on MSY or its related concepts because the stock has never been in stable condition, concept of virgin stock dose not fit to

this stock and even if MSY exists, adjusting catch/effort to rapid and large changes of the MSY is hard. In addition, maximizing the catch is not necessarily target, keeping diversity of BTF fisheries in a sustainable way would be more important. Although both ICCAT and WCPFC define the management objective is to keep the stocks at the level of MSY, there is growing concern to use the MSY as management objective because the MSY is hard to estimate reliably in addition to the reasons mentioned before. Along with concept proposed by Hilborn and Stockes, 2010), minimum SSB observed instead of the MSY is under consideration of the management reference point for the PBFT. In the future, potential exists for stock-replenishing in low recruit period when SSB projected to be below observed minimum. Stock-replenishing already in practice in Japan for red sea bream and flounders that contribute the stability of catch.

Cooperative works between tuna farming and captive fisheries

Up to present time, the Pacific bluefin has been sustainably fished. However, as specified by current management measures, there is concern about taking too much juvenile fish, about 95% of catch in number of fish caught is ages 0-2 juveniles, with respect to future sustainability of the stock. In addition to heavy dependence of wild fishery on the juveniles, aquaculture production of this species has been increasing steadily as previously noted. Since aquaculture for Pacific bluefin depends mainly on juveniles caught by jigboats, there is potential threat of further increase of F for the stock and competition over the use of juveniles between wild and aquaculture fisheries. At this moment, Kinki University is able to provide one tenths of the aquaculture demand to seed fish in Japan. If the complete aquaculture improves the techniques further, it is possible to provide all necessary amount of seed fish to aquaculture, without taking it from the wild population, that alleviates to reduce F for the juveniles. Further, this technique may able to contribute the restocking of the wild population when the recruitment continued to be in a very low level for a long period, by releasing juveniles artificially raised. There are several unknowns to be known such as when, where and how many juveniles have to be released for restocking without disturbing biodiversity and ecosystem.

Collaboration between aquaculture and wild fish studies would be mutually beneficial. For example, information about prey species or food variety of the larval and juvenile fish brought from the researches on wild population will be useful for aquaculture and detailed experiments in the laboratories provide information about food requirement, growth and mortality that is actually measured. Various other subjects could be studied collaboratively that include, potential differences in quality of eggs produced by young and old adults, skipping of annual spawning event and environmental stimulation to trigger the spawning etc.

Literature cited

Hilborn Rey and Stokes, Kevin, 2010. Defining overfished stocks: Have we lost the plot?, Fisheries, Vol 35, no. 3, 113-120.
Muto, F., Y. Takeuchi, K. Yokawa, S. Ochi and M. Taguchi, 2009. Pacific bluefintuna fisheries in Japan and adjacent areas before the mid-20th Century. Coll. Vol. Sci. Pap. ICCAT, 63: 238-240.
WCPFC 2009, Summary Report of the 6th Northern Committee of the Western and Central Pacific Fisheries Commission (WCPFC), 42pp.

Global regulation of the Bluefin Tuna Catch and the market expansion for the Full cycle farmed Tuna

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Abstract

Catch control on bluefin tuna is just about to be strengthened globally due to very scarce resource levels. Following the very strict catch quota on Atlantic bluefin tuna adopted by the International Commission for the Conservation of Atlantic Tunas (ICCAT), catch quota on bigeye tuna in the Pacific Ocean and tentative catch regulations on bluefin tuna were adopted by the Western and Central Pacific Fisheries Commission (WCPFC). The industrialization of reproductive tuna farming is thus anticipated with improvements in industrial profitability due to price increases. Under these situations, this paper tries to analyze 1) the extent to which prices of bluefin tuna will rise due to a supply shortage of wild tunas and juveniles for farming, and 2) the expected market size expansion for full cycle farmed tuna.
To estimate the price levels at the time of the implementation of the present regulation plans, we constructed an econometric price determination model for bluefin and bigeye tunas. As a result, the wholesale price of bluefin tuna in the Japanese market was estimated to rise by 31% from a recent 2,972 yen/kg to 3,896 yen/kg, while the price rise would be mitigated by 7.5% with a double in farmed tuna production. This implies that farmed tuna industries applying full cycle farming technology face opportunities for further development.

Key words: bluefin tuna / bigeye tuna / catch regulation / full cycle farming technology / price / market size

Purpose and background

Catch control on bluefin tuna is just about to be strengthened globally due to very scarce resource levels. Following the very strict catch quota on Atlantic bluefin tuna adopted by the International Commission for the Conservation of Atlantic Tunas (ICCAT), catch quota on bigeye tuna in the Pacific Ocean and tentative catch regulations on bluefin tuna were adopted by the Western and Central Pacific Fisheries Commission (WCPFC). In addition, action plans for conserving Pacific bluefin tuna resources are currently under consideration by the Japanese government.

The industrialization of full cycle tuna farming is anticipated, and the profitability of the industry is expected to improve due to price increases. Under

these situations, this paper tries to analyze 1) the extent to which prices of bluefin tuna will rise due to supply shortages of wild tunas and juveniles for farming, and 2) the expected market size expansion for full cycle farmed tuna.

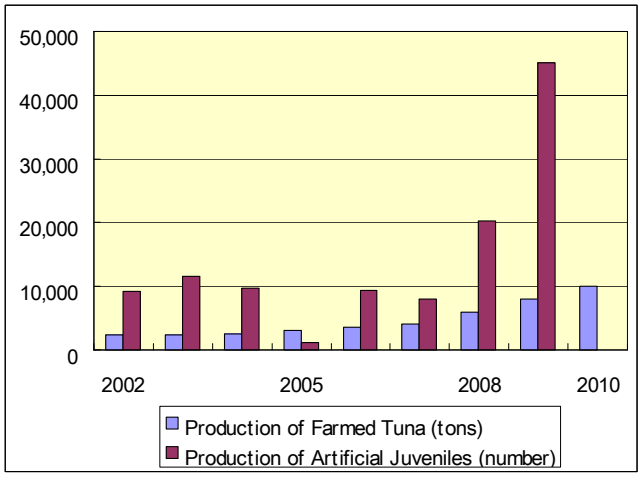

Figure 1: Supply of bluefin tuna to the Japanese market and prices : Sources: 1) Production of farmed tuna: Lou (2004) and Torii (2008), 2) Production of artificial seedlings: Fisheries Laboratory, Kinki University.
Note: Production of farmed tuna in 2010 is the predicted record.

Supply of tunas to the Japanese market

The supply of bluefin tuna to the Japanese market is composed of three parts; local landed wild tuna, imported and locally farmed tuna (Fig. 1). After the mid-1980s, import of Atlantic bluefin tuna began to increase due to the Japanese bubble economy, currency appreciation, supply limitation of Pacific bluefin tuna, and the proportion of farmed tuna in the imports, produced mainly in the Mediterranean countries, has also risen due to the prevalence of farming technology.
At the same time, supplies of bigeye tuna and southern bluefin tuna (SBT), a substitutive species of bluefin tuna, have also increased. In addition, the supply of locally farmed tuna has been increasing recently (Fig. 2). The supply of locally farmed tuna exceeded the supply of farmed southern bluefin tuna in 2009, and it is possible that the supply of locally farmed tuna may also exceed the supply of farmed Atlantic bluefin tuna in 2010. Kinki University has succeeded in developing the full cycle farming technology in 2002, and began shipping full cycle farmed tuna and artificial seedlings in 2004 and 2007, respectively.

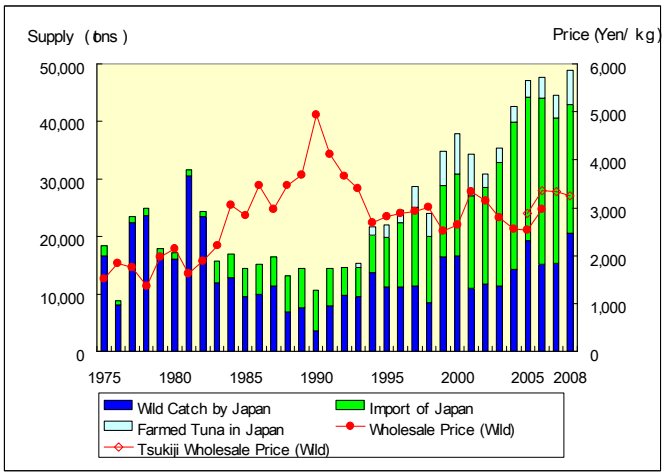

Figure 2: Production of farmed tuna and artificial seedlings in Japan
Sources: 1) Wild catch by Japan: Fisheries Research Agency (2008); 2) Import of Japan: Trade Statistics of Japan, Ministry of Finance (MOF); 3) Farmed tuna production in Japan: Lou (2004) and Torii (2008); 4) Wholesale price: Annual report of fishery distribution, Ministry of Agriculture, Forestry and Fisheries (MAFF); 5) Tsukiji wholesale price: Annual Statistics, Metropolitan Central Wholesale Market

From 1998 to 2002, the price of farmed bluefin tuna from Japan was higher than the prices of fresh and frozen wild bluefin tuna due to a strong demand for *toro* (a fatty meat of tuna) from *fast-food shushi* (conveyor belt sushi) restaurants. Market saturation for *toro* meat has caused prices of various types of bluefin tuna to reach similar levels as shown in Fig.3.

We constructed an econometric model composed of three species, which are Pacific and Atlantic bluefin tuna, southern bluefin tuna, and bigeye tuna, to estimate changes in tuna prices in the Japanese markets caused by the strengthened catch regulations, in which the price of fresh bluefin tuna is an indicator of various types of bluefin tuna.

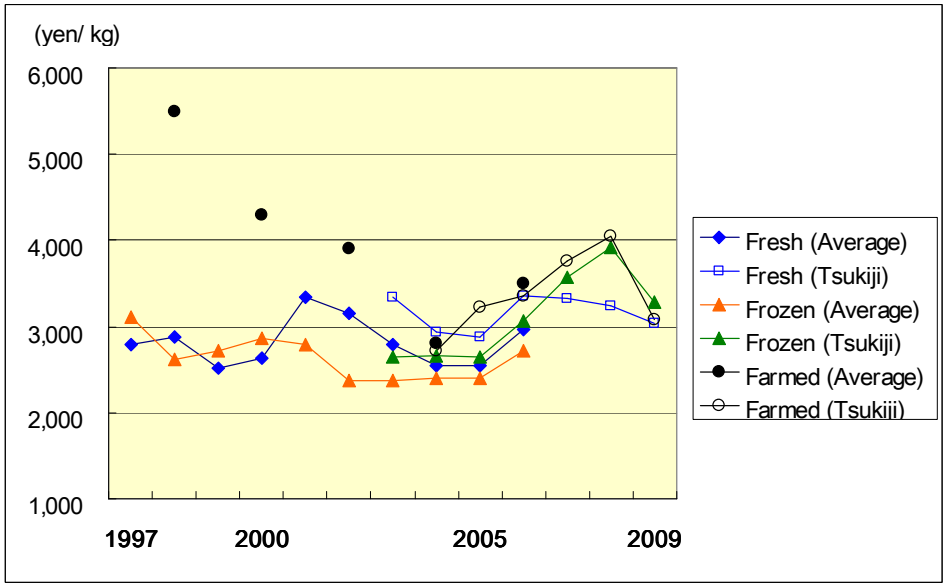

Figure 3: Prices of bluefin tuna in Japanese wholesale markets
Sources: 1) Fresh and frozen tuna price (average): Annual report of fishery distribution, MAFF; 2) Fresh and frozen tuna price (Tsukiji): Annual Statistics, Metropolitan Central Wholesale Market; 3) Fared tuna price (average): Torii (2008); 4) Fared tuna price (Tsukiji): Jiji Press Ltd. (2010).

Model structure and estimated results

We posed two assumptions for the model 1) the Japanese market is a price leader in the global tuna markets, while the consumption of *sushi* has been growing in other countries, and 2) bigeye tuna is a price leader in the Japanese market due to its dominant position in the sushi and *sashimi* (fresh raw seafood meat) markets.
The price of bigeye tuna in the Japanese wholesale markets is thus determined by the supply of the tuna and the per capita GDP of Japan, representing the supply and demand side factors, respectively. Due to a substitutive relationship, the price of bluefin tuna is determined primarily by the price of bigeye tuna. The price of bluefin tuna is also determined by supplies of bigeye and southern bluefin tunas. These relationships are presented in Fig. 4.

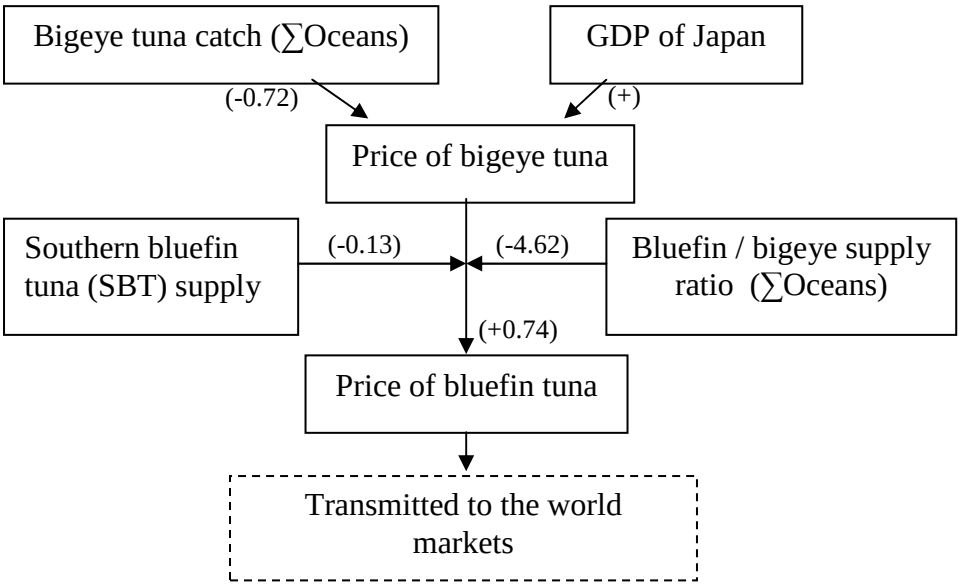

Figure 4. Flowchart of the econometric model of tuna price determination; Notes: 1) ( ) represents elasticity, which is % change in the dependent variable against a 1% or a 1-point change in the independent variable. 2) The elasticity of the price of bigeye tuna against the GDP of Japan is 0.45 (1980), 0.32 (1990), 0.29 (2000) and 0.27 (2006), respectively.

The estimated equations by the ordinary least squares method are

$$\ln(JBETP/JCPI) = -0.720 \ln(WBETQ) - 1.151*10^{6} / JGDP + 11.95 \quad \text{[Eq. 1]}$$

(–4.52) (–1.71) (5.41)

R^2: 0.64, DW: 1.62, Estimated period: 1975–2006

$$\ln JBFTP = 0.738 \ln JBETP - 0.127 \ln WSBTQ - 4.620 (WBFTQ/WBETQ) + 4.80 \quad \text{[Eq.2]}$$

(5.37) (–2.05) (–5.99) (4.18)

R^2: 0.84, DW: 1.56, Estimated period: 1975–2006

( ): t-value of the estimated coefficients,

where JBETP is the price of bigeye tuna in Japan (frozen), JBFTP is the price of bluefin tuna in Japan (fresh), WBETQ is the worldwide supply of bigeye tuna, WBFTQ is the worldwide supply of bluefin tuna, WSBTQ is the worldwide supply of southern bluefin tuna, JGDP is the real GDP of Japan, and JCPI is the consumers price index of Japan.
Based on our estimation, the price of bigeye tuna rises 0.72% with a 1% decline in supply, and rises 0.27% with a 1% increase in the real GDP of Japan. The price of bluefin tuna rises 0.74% and 0.13% with a 1% rise in the bigeye tuna prices and a 1% decline in southern bluefin tuna supply, respectively, and a 1-point increase in the bluefin/bigeye supply ratio leads to a 4.62% decline in price.

Yellowfin tuna is globally used for producing canned tuna, and high grade parts of the species are used for *sashimi* in Japan. Since the influence of yellowfin tuna supply on bluefin tuna price was very slight, it was eliminated from the model for avoiding complexity.

We can then get estimated prices for bigeye and bluefin tuna in the Japanese markets by giving exogenous values to catch and farmed amounts for the species in each ocean. To estimate price at the time when present catch regulation plans are implemented by Regional Fisheries Management Organizations (RFMOs), we prepared three alternative scenarios to compare against the 2006 base line case.
Scenario A assumes that the latest ICCAT agreement will be implemented in the Atlantic Ocean. The transition of Total Allowable Catch (TAC) and other regulations for Atlantic bluefin tuna, including farming regulations, is summarized by Mylonas et al. (2010).
Scenarios B-1 and B-2 assume that the latest agreements by WCPFC and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) and ICCAT will be implemented, in which Japan produces more farmed tuna in Scenario B-2 than in Scenario B-1. Scenario C assumes that full cycle farming technology, which would apply artificial seedlings, will be available at current prices to farms in order to compensate for the supply shortage of bluefin tuna.
Regarding Scenario A, the catch amount of bluefin tuna decreases by 28% worldwide from 59,865 to 42,890 tons due to a drastic 53% decrease in the Atlantic Ocean, and the price would rise by 20% to 3,562 yen/kg compared to 2,972 yen/kg in the baseline case.

For Scenario B-1, the reduction in supplies of bluefin, bigeye and southern bluefin tuna is more drastic, and the price of bluefin and bigeye tuna would rise by 31% and 9%, respectively compared with the baseline case. Regarding Scenario B-2, however, sharp price rises would be mitigated by an increase in Japanese farmed tuna production, which increases from 3,500 to 10,000 tons between 2006 and 2010.

Scenario C assumes a quantitatively limitless for the supply of artificial seedlings in Japan. Therefore, farmed tuna would be supplied as long as the price compensates for the operation cost of farmed tuna. The supply of 20,000 tons of farmed tuna, which is produced from both wild juveniles and artificial seedlings, would cover the operation costs at a price of 3,193 yen/kg (Table 1).

Table 1 Simulation of tuna catches and prices

		2006 (*) baseline	Scenario A	Scenario B-1	Scenario B-2	Scenario C
			TAC by ICCAT	TAC by ICCAT, WCPFC and CCSBT	TAC by ICCAT, WCPFC, CCSBT and JPN farm expansion	Artificial seedlings available
Bluefin Tuna						
Catch	Pacific	24,090	24,090	**20,130**	20,130	20,130
	Atlantic	32,275	**15,300**	15,300	15,300	15,300
Farm	Japan	3,500	3,500	3,500	**10,000 (**)**	**20,000**
	Total	59,865	42,890	38,930	45,430	55,430
SBT	**Total**	12,572	12,572	**9,449**	9,449	9,449
Bigeye Tuna	Pacific	254,829	254,829	**204,999**	204,999	204,999
	Indian	111,611	111,611	111,611	111,611	111,611
	Atlantic	66,251	66,251	66,251	66,251	66,251
	Total	432,691	432,691	382,861	382,861	382,861
Price						
Bluefin Tuna	Yen/kg	2,972	3,562	3,896	3,602	**3,193 (***)**
Bigeye Tuna	Yen/kg	915	915	999	999	999

* Market average price data are unavailable after 2006.; ** 10,000 tons of production is forecasted for 2010; *** The price of 3,193 yen/kg is equivalent to 2006 operation costs of farmed tuna, (Ono (2010)).

Conclusion

Japanese production of farmed tuna is rapidly increasing, whereas production in the Mediterranean countries and Australia is stagnant due to resource limitations. Catch control on wild bluefin tuna will likely be very strict, creating opportunity for a full cycle tuna farming industry to emerge. The number of artificial seedlings equaled roughly 10% of the number of wild juveniles used in Japanese tuna farming in 2009 (Kumai (2010)).

Based on our econometric estimations, prices of bluefin and bigeye tuna in the Japanese markets will rise by 31% and 9%, respectively, when the latest catch regulation plans of ICCAT, WCPFC and CCSBT are implemented. If the artificial seedlings can be produced at current prices, the market size of farmed bluefin tuna would expand from a current 10,000 tons to 20,000 tons. In this case, the price of bluefin tuna would be approximately 3,200 yen/kg, which is equivalent to 2009 prices as shown in Fig.3.

The above analyses assume that Japan can produce farmed tuna by applying full cycle farming technology limitlessly so long as tuna prices are greater than operation costs, and do not assume any physical constraints such as adequate farming spaces. If such physical constraints are realistic, the transfer of full cycle farming technology to overseas farms may be an appropriate solution.

Methodology for Comparing the Environmental and Socio-Economical Impacts of the Fishery and aquaculture Supply Chains: from wild fish in the water to protein on the consumer plate

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The debate is ragging between tenants of fisheries and tenants of aquaculture regarding global food-security in future. This debate is exacerbated by the recent concern about environmental and economical sustainability of these activities. Fisheries defenders claim that despite the relative conversion efficiency of many aquaculture systems cycling fishmeal and oil through other species is not as effective a means of providing highly nutritious animal protein to humans than the direct human consumption (DHC) of fresh forage fish. In addition, substantial energy inputs are required throughout the meal / oil mediated supply chain when inputs to fish harvesting, reduction, transport etc. are accounted for (Pelletier, 2008; Pelletier *et al*., 2009). Aquaculture defenders claim that the overall ‘‘fish - in to fish - out’’ (FI / FO) ratio for fed species was reduced from 1.05 in 1995 to 0.65 in 2007 (Naylor *et al*., 2009), and expected “progress” in genetics, physiology and feeding practices will likely continue to reduce this ratio into the future. The counter-argument is that greater use of alternative protein sources like soya meal also has an environmental impact linked to agricultural practices and related emissions (e.g. mechanical traction, production of fertilizers and pesticides, deforestation). Another claim of aquaculture defender is that in the wild, the equivalent of FI / FO ratio for carnivorous fish species is always higher than in fish farming, due in part to the higher metabolic energy demands associated with the foraging behaviour of wild fish in contrast with the industrial energy inputs to supply feed to farmed fish. The counter-argument of fishery defenders is that energy flows in marine ecosystems occurs within a complex food web with many different trophic levels and that the benefit of aquaculture versus fishery is not so obvious.

It appears that without a proper quantification of the numerous sources of environmental and socio-economical impacts, one must be cautious before pointing to supposedly bad practices (e.g. Pelletier and Tyedmers, in press). Rather than pitting aquaculture against fisheries, we consider that both activities urgently need further research for integrated management and sustainable development. A proper

integrated, quantitative and comparative study of food supply chains founded on forage fish is needed. Indeed a fishery is one of the nodes of a larger network that includes up and downstream processes or activities such as fluxes of energy and biomass in marine (and terrestrial) ecosystems, boat and gear construction, fuel provision, fish processing, marketing and transport, aquaculture uses and impacts, etc. Often impacts of these other activities are easily overlooked.

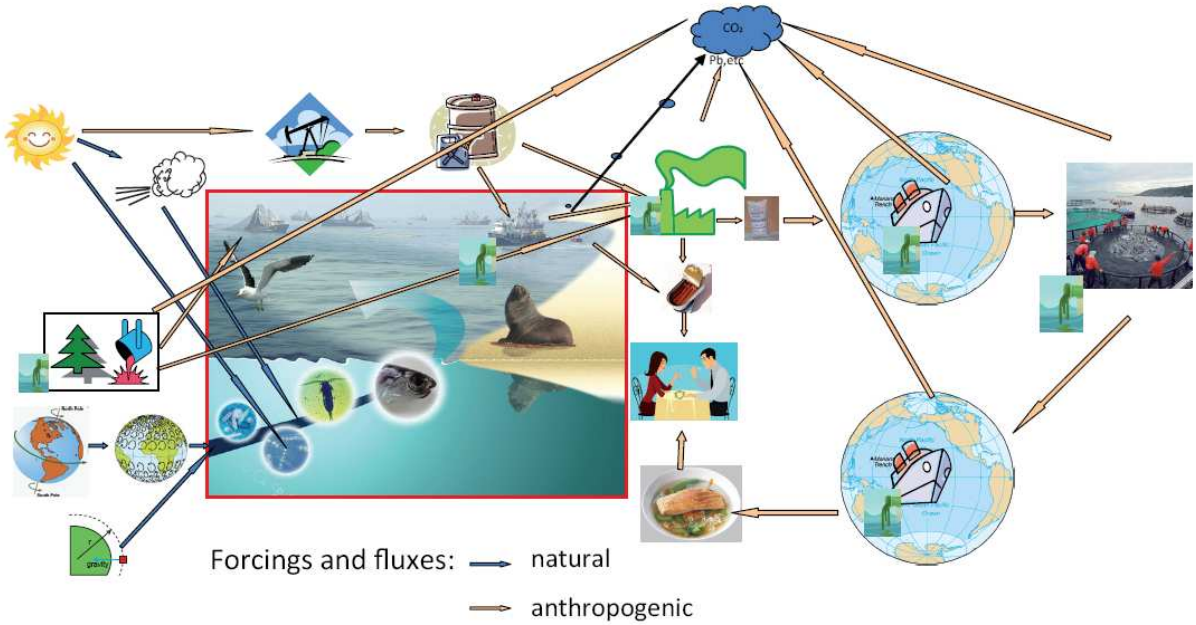

Figure 1: Simplified diagram of the functioning and environmental impact of the Peruvian anchoveta supply chain. The large composite image with a red frame in the diagram represents the Peruvian Marine ecosystem whereas items surrounding it in the far left and upper parts of the diagram represent natural forcing (sunlight, wind, Coriolis and gravity forces) and "exosomatic" input such as construction materials (wood, mineral) and domesticated energies (fuels). Items on the right hand side of the diagram represent transformation of anchoveta for direct or indirect human consumption, for instance through carnivorous fish cultivated in Asia.

A new research project on environmental and socio - economical impacts of the Peruvian anchoveta supply chains was launched at the end of 2009 by IRD (French Institute of Research for Development) and IMARPE (Instituto del Mar del Peru), within the framework of the International laboratory DISCOH (Dynamics of the Humboldt Current system) and with the input of external experts in various fields. The aim of the study is to quantify and compare the environmental and socio - economical impacts of the Peruvian anchoveta supply chains for direct and indirect human consumption, from end to end (Fig. 2).

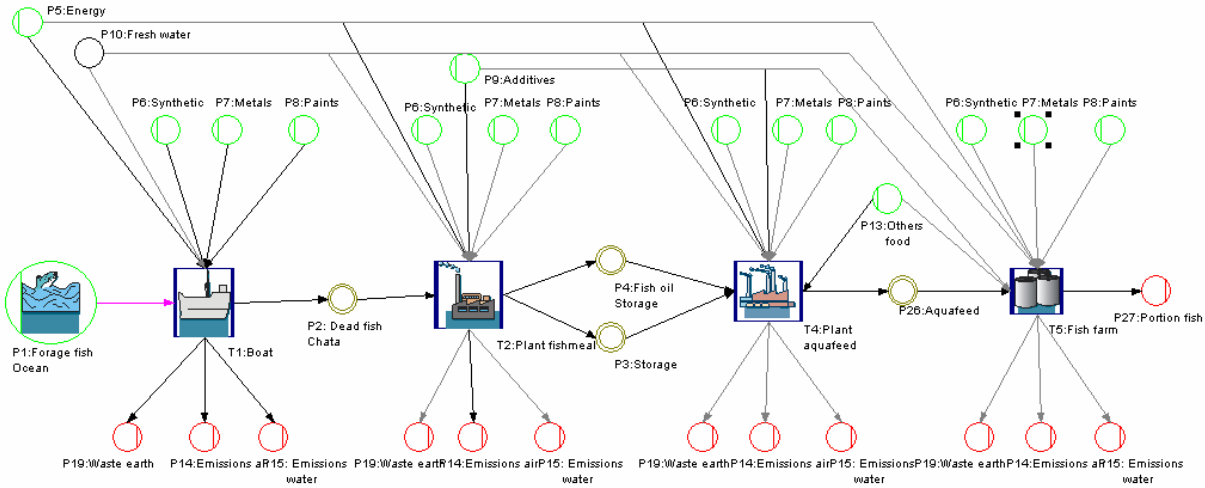

Figure 2: Simplified Petri diagram of the flow of energy and materials in a forage fish supply chain. For simplification, transport is not explicitly represented, nor the marine trophic flows. Green circles represent inputs, red circles outputs.

The first step will be a comparison of impacts resulting from the extraction phase according to the type and size of boat. Life cycle assessments of the extraction phase will be performed, along with analyses of employment (direct and indirect) and economical rent in order to provide decision makers with a broader and multidimensional understanding of this complex sector. A similar study will be undertaken for the transformation phase (fishmeal and fish oil production, canned fish, frozen fish, fresh fish and cured fish) both locally in Peru and abroad (for example in Asia). This will help to identify sustainable fishery systems that better align with policies aimed at addressing climate change (Driscoll and Tyedmers, in press) and social welfare (Pelletier et al., 2007). This type of analysis is especially important at this juncture, where over - exploitation and collapse of several fish stocks (FAO, 2007), increasing fuel prices, concerns over greenhouse emission contributions to climate change and ocean acidification and related issues have combined to increase consumer concern regarding how and where their food is produced (Deere, 1999; Jacquet and Pauly, 2007). This project should help in the definition of criteria and good practices for certification of pelagic fisheries and supply chains in order to promote incentives for a more environmental friendly exploitation of natural resources.

Life Cycle Assessment (LCA) is a tool which provides a useful framework to identify potential contributions to a wide range of global scale environmental concerns that result from various production systems. It will be used to inventory the physical inputs, production materials, energy requirements along with the resulting emissions (to air, land, fresh water and oceans) associated with each stage of each production chain: from anchovy capture through production, transport, use and disposal. The process will be facilitated by the use of the SimaPro software package by Pre Consultants that allows various indices of environmental impacts to be derived. Material Flow Analysis and conventional micro - economics approaches will be used to complement LCA and study rents and employment (but not environmental costs). The Umberto software will facilitate this approach.

This study will provide direction on how to best support people dependent on fisheries as it will assess and compare the socio - economic implications of each stage of the anchovy production system in terms of indirect and direct jobs, and use of the rent and wealth redistribution. Together with other studies of the whole artisanal and industrial fisheries undertaken by IMARPE and IRD, this work will provide indications on the vulnerability of Peruvian fisheries to global changes such as climate change, globalisation of the markets, human population growth, global economical growth and the associated increasing demand for animal proteins. Quantifying natural resource use, together with the social and environmental factors of the industry represent a novel approach which could lead to improvements of the management and a more environmentally and socio - economic sustainable anchovy industry. It aims at providing stakeholders and policy makers with a basis upon which to jointly decide further research and development perspectives in the sector and generate the necessary information to inform consumers about the aggregated environmental impacts of each anchovy derived product, in addition to socio - economics aspects.

References

Deere C.L. 1999. Eco - labelling and sustainable fisheries. IUCN, Washington, D.C. and FAO, Rome. 36 pp.

Driscoll J. and P. Tyedmers. 2010. Fuel use and greenhouse gas emission implications of fisheries management: the case of the New England Atlantic herring fishery. Marine Policy 34(3): 353 – 359.

FAO. 2007. State of the world´s fisheries a aquaculture 2006. Food and Agriculture Organization of the United Nations, Rome. http: / / www.fao.org / docrep / 009 / A0699e / A0699e00.htm.

Jacquet J. and D. Pauly. 2007. The rise of seafood awareness campaigns in an era of collapsing fisheries. Marine Policy 31: 308 – 313.

Naylor R.L., R.W. Hardy, D.P. Bureau, A. Chiu, M. Elliott, A.P. Farrell, I. Forster, D.M. Gatlin, R.J. Goldburg, K. Hua and P.D. Nichols. 2009. Feeding aquaculture in an era of finite resources. Proceedings of the National Academy of Sciences 106(36): 15103 – 15110.

Pelletier N. 2008. Environmental performance in the US broiler poultry sector: Life cycle energy use and greenhouse gas, ozone depleting, acidifying and eutrophying emissions. Agricultural Systems 98: 67 – 73.

Pelletier N., N.W. Ayer, P.H. Tyedmers, S.A. Kruse, A. Flysjo, G. Robillard, F. Ziegler, A.J. Scholz and W. Sonesson. 2007. Impact categories for life cycle assessment research of seafood production systems: review and prospectus. International Journal of Life Cycle Assessment 12(6): 414 – 421.

Pelletier N., P. Tyedmers, U. Sonesson, A. Scholz, F. Ziegler, A. Flysjo, S. Kruse, B. Cancino and H. Silverman. 2009. Not all salmon are created equal: life cycle assessment (LCA) of global salmon farming systems. Environmental Science and Technology 43(23): 8730 – 8736.

Exploited marine ecosystem of the Gulf of Lions

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Abstract

The objective of the present study was to analyse the structure and the functioning of the food web in the Gulf of Lions and to estimate the impact of fisheries on the food web compartments using Ecopath with Ecosim mass-balance model.

Key words: Gulf of Lions, Ecopath with Ecosim, fisheries impact, food web

Introduction

Fishing has been proposed as the main major human disturbance to coastal area, within an ecosystem context where target and non-target species interact establishing complex relationships. The Gulf of Lions represents a highly productive system because of the Rhone River inputs, bottom morphology and water circulation. In this area marine resources are intensively exploited on the continental shelf and upper slope by French and Spanish fleets using multispecific artisanal gears like trawlers, purse seines, gillnets and other small gears.

Methods

The Ecopath and Ecosim (EwE) modelling approach version 6 (www.ecopath.org) was used to ensure energy balance of the model. In this study the EwE model represents an average annual situation (2000-2009) of the gulf of Lions between 0 to 2500 m covering a total area of 20400 km2 (Fig. 1).

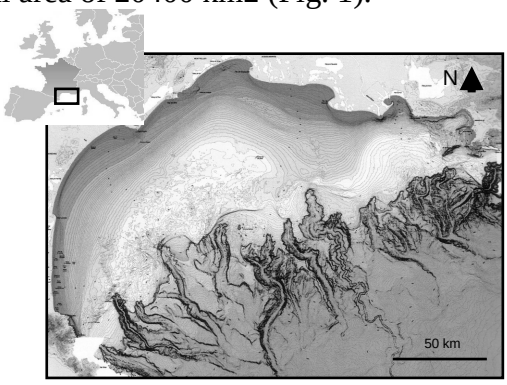


Figure 1: Study area situated in the south of France (modified from Berné et al., 2001).

The model is composed of 39 functional groups, including 5 groups of primary producers, detritus and discards, 12 groups of invertebrates, 17 groups of fish,

seabirds and 2 groups of cetaceans. Seven multi-species artisanal fleets operating in this area were included in the model. Inputs were based on two landings data sources, aerial, acoustic and bottom trawl surveys, stock assessment working groups, stomach analyses, satellite data and published information.

Results and discussion

Functional groups were organised into five trophic levels with the highest one represented by dolphins, anglerfishes, Atlantic bluefin tuna, hake and European conger (Fig. 2). Fishes like Atlantic mackerel, blue whiting, European pilchard, fishes (feeding on benthic crustaceans), as well as some invertebrates (bivalves-gastropods, benthic crustaceans, mesozooplankton, macrozooplancton and echinoderms) had high relative total impact on the entire food web.

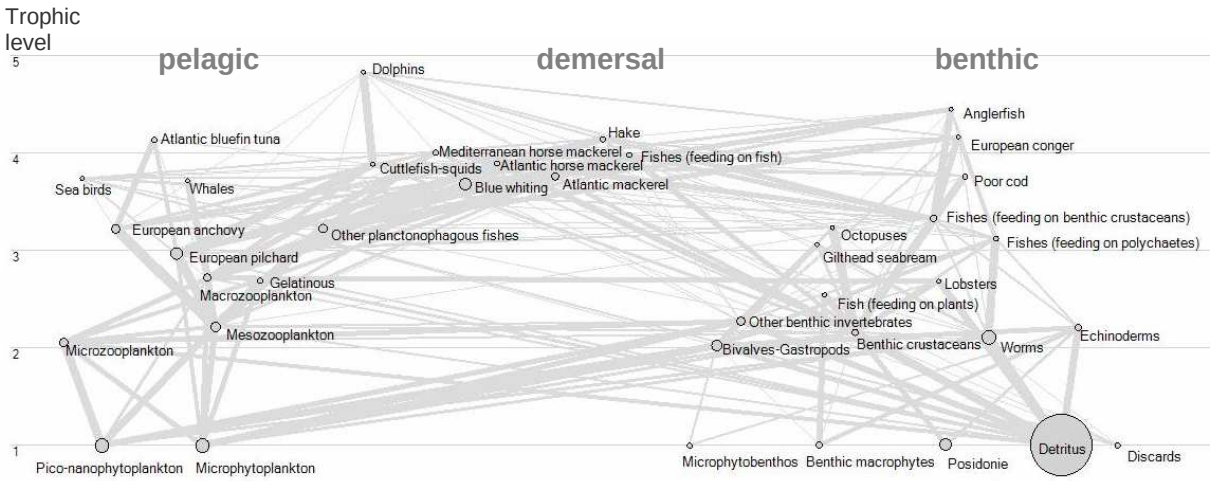


Figure 2: Structure of the pelagic, demersal and benthic food web. The links between the different compartments are proportional with the trophic flows. Large arrows show coupling between pelagic, demersal and benthic compartments through consumption.

There is a high coupling between pelagic, demersal and benthic compartments through consumption (Fig. 2). The main flows between trophic levels are represented in the Fig. 3.

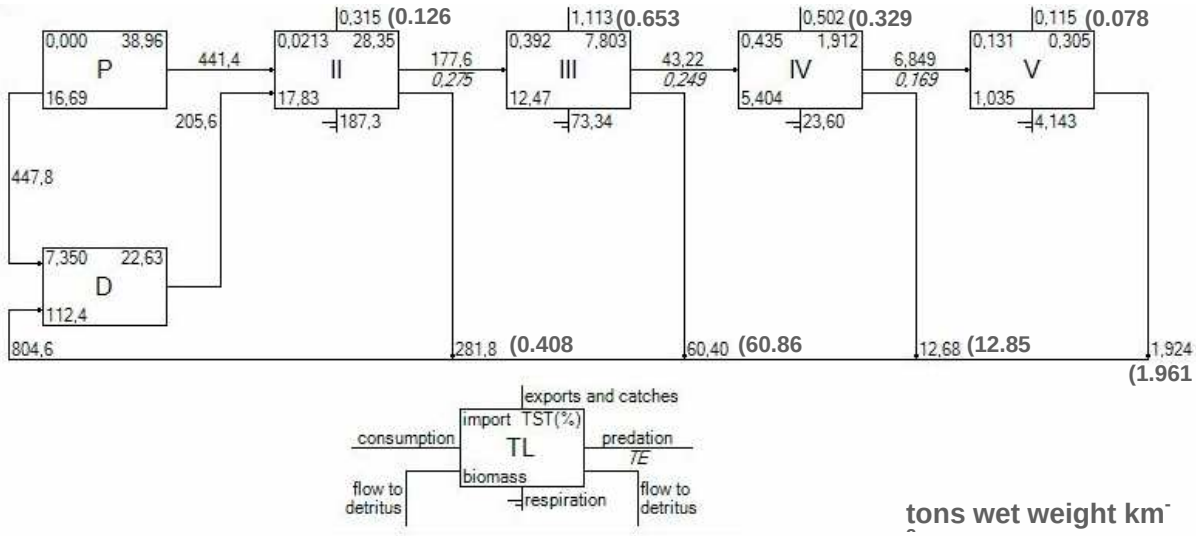
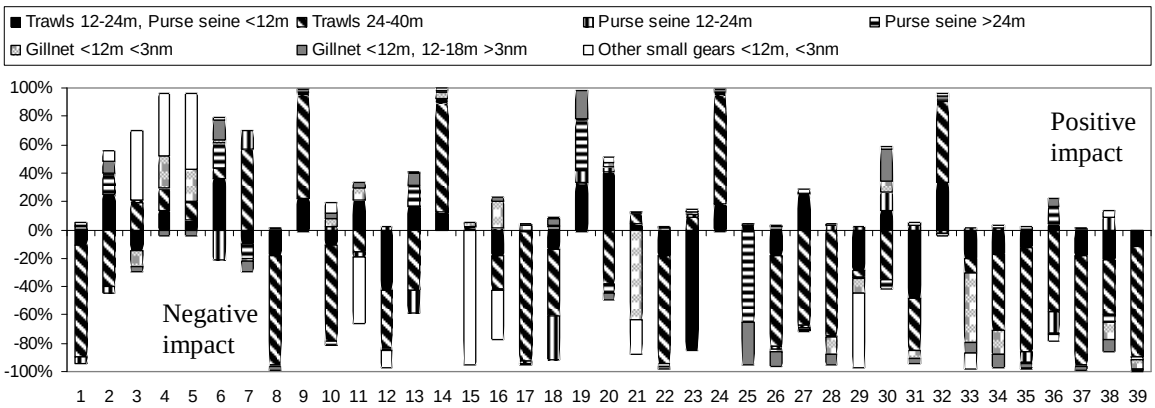


Figure 3: Lindeman spine: flows between trophic levels. Catches are different according to the data sources (Demaneche et al., 2009; FIS, Ifremer auction sales).

Fisheries were operating at mean trophic levels situated between 2.5 for small artisanal boats, 3.2-3.8 for gillnets, 3.3-3.4 for trawls, 3.0 for purse seine (12-12m) for and 4.1 for purse seine (24-40 m). Large trawl (24-40 m) had the highest impact on most of the considered groups, while purse seine > 24m had the lowest one (Fig. 4).



1 Pico-nanophytoplankton
2 Microphytoplankton
3 Microphytobenthos
4 Posidonie
5 Benthic macrophytes
6 Microzooplankton
7 Mesozooplankton
8 Macrozooplankton
9 Gelatinous
10 Worms
11 Bivalves-Gastropods
12 Octopuses
13 Cuttlefish-squids
14 Benthic crustaceans
15 Lobsters
16 Echinoderms
17 Other benthic invertebrates
18 European pilchard
19 European anchovy
20 Other planctonophagous fishes
21 Fishes (feeding on plants)
22 Atlantic mackerel
23 Mediterranean horse mackerel
24 Blue whiting
25 Atlantic bluefin tuna
26 Hake
27 Atlantic horse mackerel
28 Anglerfish
29 European conger
30 Poor cod
31 Fishes (feeding on fish)
32 Fishes (feeding on benthic crustaceans)
33 Gilthead seabream
34 Fishes (feeding on polychaetes)
35 Sea birds
36 Dolphins
37 Whales
38 Detritus
39 Discards

Figure 4: Impact of the fisheries on the different functional groups induced by direct or cascade effect.

Conclusion

The present model constitutes the first mass-balance model constructed to characterise the exploited system of the gulf of Lions and it represents an important effort to integrate the available data. Deficiencies in available biological and landings data sources have been identified. Preliminary results highlighted also the importance of these data sources for Ecosim and Ecospace scenarios.

References

Berné S., Carré D., Loubrieu B., Mazé J.-P., Normand A., 2001. Carte morpho-bathymétrique du Golfe du Lion. Ifremer, direction des recherches océaniques, département géosciences marines.

Demaneche S., Merrien C., Berthou P., Lespagnol P., 2009. Rapport R3 Méditerranée continentale, échantillonnage des marées au débarquement. Méthode d'élévation et évaluation des captures et de l'effort de pêche des flottilles de la façade Méditerranée continentale sur la période 2007-2008. Programme P6 AESYPECHE "Approche écosystémique de l'halieutique" Projet Système d'Informations Halieutiques SIH, IFREMER, France, 54 pp.

Fisheries Information System - Ifremer auction sales (www.ifremer.fr/sih/)

www.ecopath.org

Acknowledgements: D. Bănaru is titular of a post-doc fellowship co-funded by the ANR "AMPED" and IFREMER, France.

Reproductive cycle and minimal length at sexual maturity of *Scomber japonicus* (Houttuyn, 1782) in the Middle Eastern Adriatic Sea

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Introduction

The chub mackerel, *Scomber japonicus* Houttuyn (1782), is widely distributed in moderate and warm waters of Atlantic, Pacific and Indian Ocean. It is also rather widely distributed thought the Mediterranean and Adriatic Sea. This middle-sized pelagic fish species has been located in the deeper waters during the colder part of the year whereas during warmer part of the year its schools were settled in the coastal waters; where they spawn and feed. Subsequently, spawning season is depended on water temperature (15 to 20 °C) (Collete and Nauen, 1983). Despite chub mackerel abundance and economical importance in the Adriatic Sea, the biology and population dynamics of this species is still insufficiently known. So, the aim of the present study was to determine reproductive cycle, length-weight relationship and length at first maturity of *S. japonicus* from catch samples realized in the Middle Adriatic Sea.

Materials and methods

Monthly representative samples of chub mackerel were collected from the commercial purse seine catches realized during January 1998 - December 2008, in the eastern Middle Adriatic Sea. Fork lengths of the fresh fish were measured to the nearest mm and the weighted to the nearest mg. Sex was determined macroscopically considering shape, appearance and gonad structure. Relationship between fork length (*LF*) and weight (*W*) of chub mackerel was estimated by GM functional regression (Ricker, 1975) for each sex separately and overall. The maturity stages were determinate according to the empiric scale described by Sinovcic (1978), and then modified into 4 stages. Reproductive period of the chub mackerel was determined by monthly changes in gonosomatic index (*GSI* = 100 x gonad weight/ total body weight), gonad weight and stages of gonad. Sex ratios were compared to the 1:1 proportion by using _2 test. Length at sexual maturity was determined by logistic model P*LF*=a/(1+e(b+c*LF*)) where P*LF* was ratio between matured and non matured specimens, *LF* size class, and *a*,*b* and *c* constants.

Results

Fork length of all analysed specimens (*N*=4157) ranged from 10.1 to 39.1 cm (x =23.8±4.68 cm). Males (*N*=1085) ranged from 17.9 to 38.8 cm (x =26.0±3.83 cm) and females (*N*=1620) from 14.9 to 39.0 cm (x =25.3±3.45 cm). Sex ratio was determined to be ♂/♀=0.68 in total and it was significantly different from expected 1:1 ratio (_*2*=102.62; *P*<0.001).

The length-weight relationships was calculated to be *W*=0.0061 *LF*3,1836 (*N*=1085, *r2*=0,922) for males, *W*=0.0057 *LF*3,1936 (*N*=1620, *r2*=0,910) for females, and *W*=0.0052 *LF*3,2238 (*N*=4157, *r2*=0,969) for overall specimens. The hypothesis of isometric growth of males and females for this species was discarded, as the obtained allometric index value (*b*) was significantly different from 3 (Student's *t*-test; *P*<0.05) for both sexes (*t*=0.713; *t*=0.961) but not for the overall specimens (*t*=0.317, *P*>0.05), which was in accordance with most of the studies of this species (Moutopoulos i Stergiou, 2002).

According to the monthly percentage composition of gonad maturity stages chub mackerel spawned from April to August with the peak in the June (90.3% males, 77.6% females). Obtained spawning season was in accordance with studies earlier reported in Adriatic Sea (Mužinic,1979). Seasonal alternations in mean monthly gonadosomatic indices as well as mean monthly values of gonad weight of males, females and overall (Fig. 1) analysed chub mackerel specimens followed and confirmed that of maturity stages of gonads. Minimal length at first sexual maturity was obtained as the length at which 50% of chub mackerel were matured. For males that length was 16.8 cm (P*LF*=104.33/(1+e3.63-0.21*LF*); *r2*=0.695), for females 20.4 cm (P*LF*=99.43/(1+e9.26-0.46*LF*); *r2*=0.852), and for the whole material 18.3 cm (P*LF*=102.86/(1+e4.78-0.26 *LF*); *r2*=0.789). The whole population (100%) of chub mackerel males was matured at 28.0 cm and females at 26.0 cm.

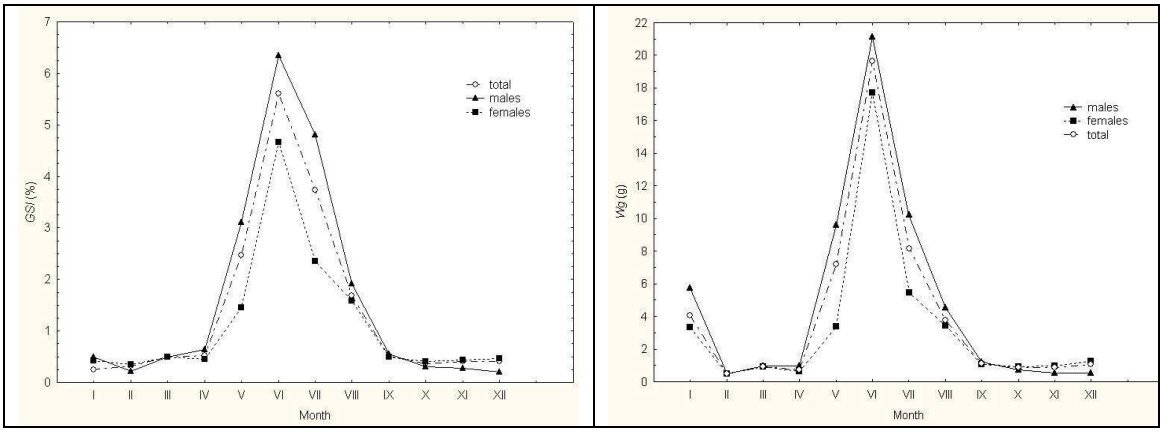

Figure 1: Monthly fluctuations of (a) gonadosomatic index - *GSI* and (b) gonad weight – *Wg* for male, female and overall chub mackerel specimens, Adriatic Sea, 2003-2008.

References

Collete B. B., Nauen C. E. (1983). FAO species cataloque, vol. 2. Scombrids of the world, Anotated and illustrated cataloque of tunas, mackerels, bonitos and related species known to date. FAO Fish Synop 125: 2-137

Houttuyn M. (1782). Beschryving van eenige Japansce visschen, en andere zee-schepzelen. Ver Holl Wet Haarlem 20(2): 311-350

Moutopuulos D. K., Stergiou K. I. (2002). Length-weight and lenght-lenght relatioships of fish species from Aegean Sea (Greece). J Appl Ichtyol 18: 200-203

Mužinic R. (1979a) Neka opažanja o ekologiji plavice (Scomber japonicus, Houtt.) u srednjem Jadranu. Acta biologica 8(1-10): 115-122

Ricker W. E. (1975). Computation and interpretation of biological statistic of fish populations. Bull Fish Res Board Can 191: 382 p

Sinovcic G. (1978). On the ecology of anchovy, *Engraulis encrasicolus* (L.), in the Central Adriatic. Acta Adriat 19 (2): 32

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Interaction in coastal waters: A roadmap to sustainable integration of aquaculture and fisheries – the COEXIST project

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Abstract

Coastal areas are subject to an increase in competing activities and protection and are a source of potential conflict for space allocation. The maintenance and/or, the development of small scale coastal fisheries and aquaculture highly depend on the availability and accessibility of appropriate sites. Besides fisheries and aquaculture, coastal activities also include tourism, wind farms, Marine Protected Areas, etc. There is good reason to believe that the competition in the coastal zone will increase, emphasizing the need for improved management tools supporting policies for space allocation along the entire European coastline.

COEXIST is a multidisciplinary project with thirteen partners from ten European countries coordinated by the Norwegian Institute of Marine Research. It is aimed to evaluate these interactions with the ultimate goal to provide a roadmap to better integration, sustainability and synergies among different activities in the coastal zone. The main steps of the project are:

- To study the interactions between capture fisheries and aquaculture and evaluate mutual benefits, existing conflicts and possible bottlenecks for concomitant development of these activities in the coastal zone within the context of the ecosystem approach to management.

- To evaluate the efficiency of current spatial management tools (zoning, closed areas, etc.), to propose different forms of coastal aquaculture and fisheries at different scales (e.g. local, regional), and to exploit mutual opportunities (e.g. artificial reefs, protected areas, wind farms, tourism, etc.) within a context of competition for space by multiple users.

- To address differences in acceptance of activities (fisheries, aquaculture, and other uses of the coastal zone) by the society.

Preliminary results of the south Adriatic deep sea fauna investigation

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Introduction

In the framework of FAO AdriaMed international project, investigation of deep sea fauna was conducted in the poorly investigated area of the deepest part of Adriatic Sea (1100-1200 m depth) during the August 2008. The aim of this investigation was to identify adequate gear and methods for sampling demersal fauna and to preliminary describe qualitatively and quantitatively its assemblages.

Material and methods

Sampling was conducted using different fisheries gear types. Bottom longlines of 300 hooks were used mainly for catching demersal selachians. Small pelagic fish and cephalopods were used as bait. Crustaceans and cephalopods were sampled by different types of traps, bated by small pelagic fish for catching crustaceans or with plastic strips which cephalopods use for laying their eggs. Demersal organisms were also collected using scientific bottom trawl net GOC 73, with 10 mm code end mesh size, specially designed for the MEDITS surveys, and towed by research vessel at the speed of 2.6 knots. Duration of each tow was 2.5 hours.

Results and discussion

Preliminary analysis showed relatively low quantity of biomass and small number of species. This is to be expected for depths of 1200 m where sampling was conducted. Selachian *Galeus melastomus* was predominantly represented in the longline catch although its total catch was relatively poor. Sampling with traps did not obtain almost any samples and was determined as not adequate sampling gear for this area. Bottom trawl net showed low abundance of demersal organisms in the catch. Total list of recorded species is provided in table 1. Fish *Polyacanthonotus rissoanus* (De Filippi & Verany, 1857) were recorded for the first time in the Adriatic Sea. Large quantity of waste, predominantly plastics materials, was noticed in samples from bottom trawl and quantity of which was often larger than quantity of caught demersal organisms.

Investigation of deep sea fauna of the Adriatic Sea has not been provided systematically until now. Further on, data from commercial fishery in this area are mostly unavailable or insufficient because this is not a main fishing ground for Adriatic fisheries. Therefore detailed knowledge about biological characteristics of those organisms is limited. This situation is a serious obstacle in preparation of conservation and management plans especially because the deep sea fauna, which

constitute particular ecological zone, is sensitive to the influence of potential increase fishery pressure or other anthropogenic influence.

Table 1. List of recorded species during investigation of deep sea fauna of southern Adriatic pit.

Pisces	**Cephalopoda**
Argyropelecus hemigymnus	*Chiroteuthis veranyi*
Bathyopterois dubius	*Ctenopteryx sicula*
Benthosema glaciale	*Galiteuthis armata*
Chauliodus sloani	*Heteroteuthis dispar*
Chimaera monstrosa	*Histioteuthis reversa*
Coelorhynchus mediterraneus	*Onychoteuthis banksi*
Diaphus sp.	*Todarodes sagittatus*
Etmopterus spinax	
Galeus melastomus	**Crustacea**
Lampanyctus crocodilus	*Aristaeomorpha foliacea*
Lampanyctus pusillus	*Aristeus antennatus*
Lepidion lepidion	*Geryon longipes*
Lobianchia dofleini	*Pasiphaea sivado*
Melanostigma atlanticum	*Pasiphea multidentata*
Mora moro	*Polycheles typhlops*
Nettastoma melanurum	*Ponthopilus spinosus*
Nezumia aequalis	
Notacanthus bonaparte	
Polyacanthonotus rissoanus	
Raja batis	
Stomias boa	
Symbolophorus veranyi	
Trachyrhynchus trachyrhynchus	
Vincigueria poweriae	

References

Isajlović I., Piccinetti C., Vrgoč N., Dulčić J., 2009. First record of the smallmouth spiny eel, Polyacanthonotus rissoanus for the Adriatic Sea. Cybium, 33(2): 169-170.

Iwamoto T., Ungaro N., 2002. A new Grenadier (Gadiformes, Macrouridae) from Mediterranean. Cybium, 26(1): 27-32.

Lipej L., Dulčić J., 2004. The current ststus of Adriatic fish biodiversity. In: Balkan biodiversity. (Griffiths H.&Kryštufek B., eds). Pp. 291-306. Amsterdam: Kluwer.

Ungaro N., Marano G., Rivas G., 2001. Notes on ichthyofauna of the deep basin of the Southern Adriatic Sea. Sarsia, 86: 153-156.

Vrgoč, N., Arneri E., Jukić-Peladić S., Krstulović S., Mannini P., Marčeta B., Osmani K., Piccinetti C., 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 Termoli

Acoustic telemetry study on seasonal migration patterns of the endemic crucian carp Nigorobuna and Gengoroubuna in Lake Biwa, Japan

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The acoustic telemetry study was performed to determine the details of behavioural characteristics of two endemic crucian carp with an emphasis on spatial distribution in Lake Biwa, the largest lake in Japan and one of a few ancient lakes in the world (Fig. 1). It is an important habitat for endemic species such as nigorobuna *Carassius auratus grandoculis* Temminck et Schlegel and gengoroubuna *Carassius cuvieri* (Temminck et Schlegel), both moderate large Cyprinidae. The crucian carp population is experiencing a dramatic decrease. Despite active juvenile fish introduction and fishery regulations, the Japanese Ministry of Environment registered both species on the red list as threatened animals in 2007. The ecology of these fish, however, is not clearly understood.

Adult nigorobuna (N = 23) and gengoroubuna (N = 11) were used in this experiment. All fish were caught using set nets between April and May 2007. An acoustic transmitter (V13-1 L, 12 g in air, 13 mm in diameter, 36 mm long; Vemco Ltd., Canada) was surgically inserted into each fish. This transmitter emits a series of pings at 69 kHz called a pulse train, which contains identifying information for more than 450 days. The time between pulse trains randomly varied from 30 to 90 s to ensure that other transmitters had an opportunity to be detected by the receivers. Surgical implantation into the fish was conducted under anaesthesia using 0.05% 2-phenoxyethanol. After a recovery time of 3 h or more, the fish were released at the Wakamiya fishing port near the set nets. Fish locations were identified by 23 acoustic receivers (VR2; Vemco Ltd.) installed around Lake Biwa (Station 1 to 23: St. 1 – 23, Fig. 1), with an emphasis on the south basin. In this experiment, the maximum detection zone was a circle with a radius of about 200 m. The recorded data were manually downloaded every 3 to 4 months.

Distance-based analysis (DA) was used to determine where these species chose as their seasonal habitat. DA is a matrix containing the theoretical distances of a set of points. The distance from the detection St. to St. $_i$ was labelled U_i in this experiment. The average theoretical distance, R_i, which is the expected distance under the null hypothesis, was obtained for each St. using DA, and the distance ratio (D_i) was obtained using the equation,

$$D_i = U_i/R_i.$$

If the distance ratio was equal to 1, the fish did not have a preference for the given St.. The smaller the distance ratio, below 1.0, was, the more preferred the St. was for that species. If the distance ratio was much larger than 1.0, the species tended to avoid the area. A Kraskal Wallis test was performed at $\alpha = 0.05$ with the null hypothesis of $D_i = 1$. If the null hypothesis was not rejected, then this would suggest

that the fish had no selection for the habitat. With Kruskal-Wallis test, it could not identify which St. fish chosed. Therefore, a Shefè's F test was used for pairwise habitat comparisons when the null hypothesis was rejected. The DA was performed over a period of 3 months. Instead of using conventional seasons, the experiment was divided into five periods based on the spawning behaviour of nigorobuna and gengoroubuna (April–June, July–September, October–December in 2007, January–March, April–June in 2008). The appearance ratio at each station can be expressed as the following percentage,

Appearance ratio (%) = [number of recorded fish] / [number of released fish] × 100.

The seasonal distribution patterns of both nigorobuna and gengoroubuna during the five experimental periods are indicated as appearance ratios and illustrated on a map of Lake Biwa (Fig. 2, A–E). Average distance ratios, D_i, for each station and each period are summarised in Fig. 3, A–E. The Kruskal-Wallis test revealed that both nigorobuna and gengoroubuna intentionally selected habitats ($P < 0.001$) in all experimental periods. Two closely related endemic species, nigorobuna and gengoroubuna, have different seasonal migration patterns. Adult nigorobuna chose the south basin of Lake Biwa as their main habitat throughout the year. However, some nigorobuna that migrated to the north basin during the non-spawning season returned to the south basin for the next spawning season. This finding indicates that nigorobuna individuals are consistently present around the spawning area, even during the nonreproductive period. On the other hand it is suggested that gengoroubuna uses the north and south basin seasonally. Gengoroubuna inhabited the south basin during the spawning season (April–June), but made less appearance in the south basin and moved to and stayed in the north basin for most of the year (July–December). Gengoroubuna might use the south basin primarily as a spawning ground and the north basin as its main habitat.

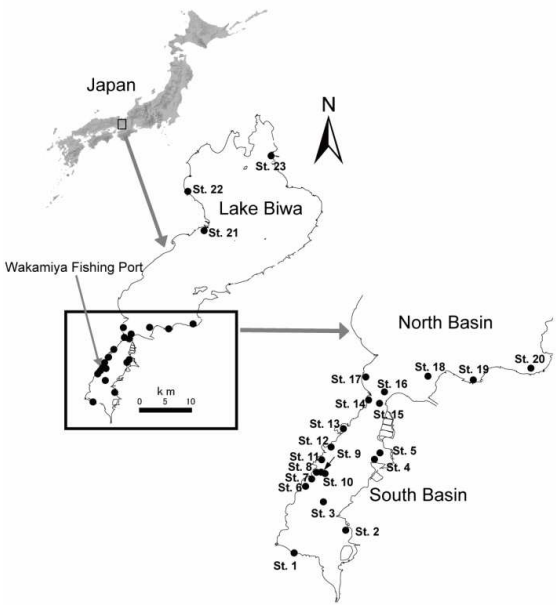

Figure 1. Study area. Each solid circle indicates a station (St.) where a receiver was installed.

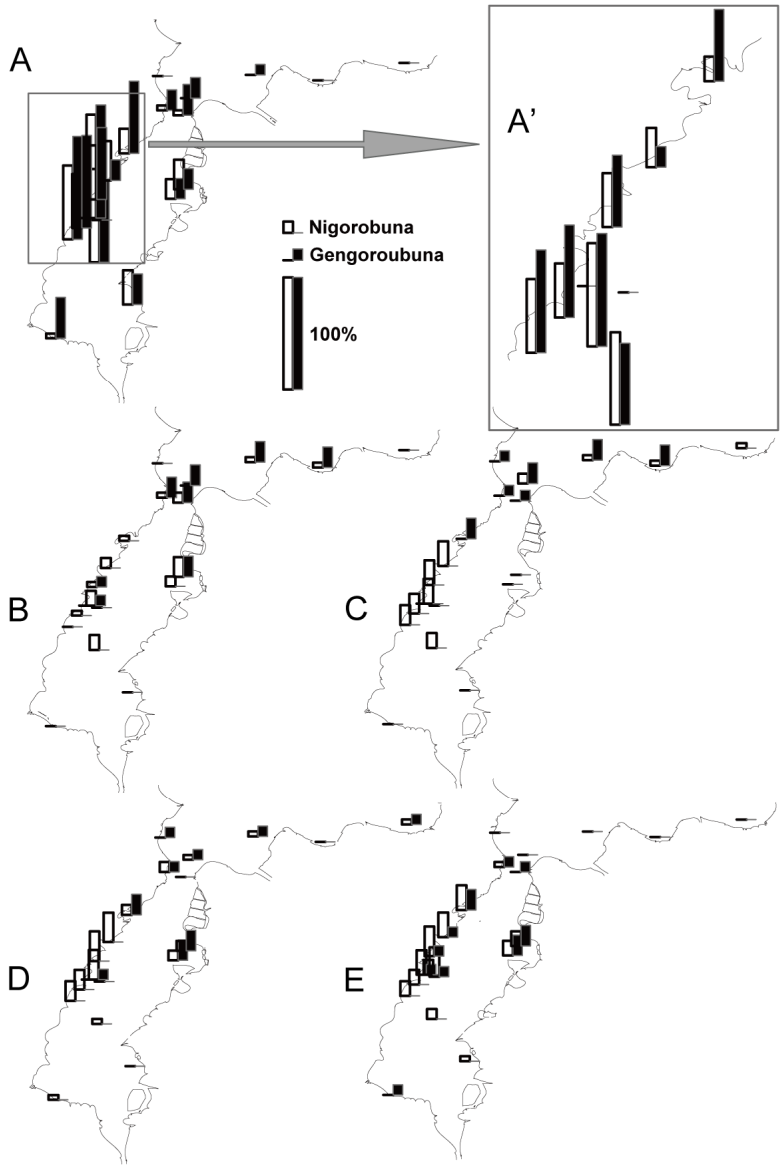

Figure. 2. Seasonal distribution patterns for both nigorobuna (open bar) and gengoroubuna (solid bar) during the five experimental periods. Each bar indicates percentage of appearance ratio (% = [number of recorded fish] / [number of released fish] × 100). A, A': Apr.–June 2007, B: July–Sept. 2007, C: Oct.–Dec. 2007, D: Jan.–Mar. 2008, E: Apr.–June 2008. A' is a close-up of the area enclosed by the square in panel A.

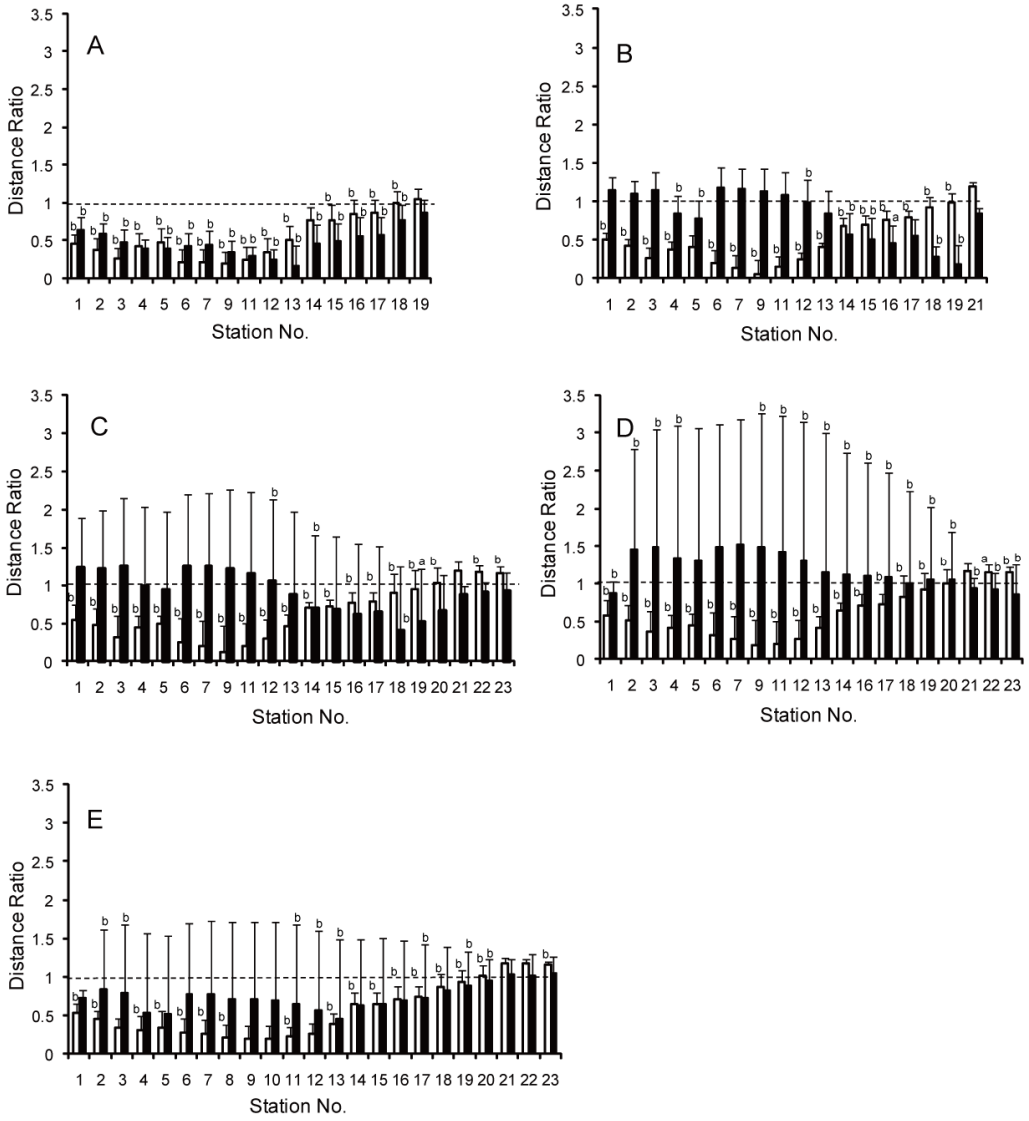

Figure 3. Habitat preferences of nigorobuna (open bar) and gengoroubuna (solid bar) in each season from distance-based analyses (Mean distance ratio + SD). Broken line indicates the prediction from the null hypothesis. The smaller the average distance ratio, below1.0, is, the more preferred the station is for the species; the larger the distance ratio, above 1.0, the station is less preferred by the species. A: Apr.–June 2007, B: July–Sept. 2007, C: Oct.–Dec. 2007, D: Jan.–Mar. 2008, E: Apr.–June 2008. a, b: significantly different from the next preferred station by Scheffè's F-test at $P < 0.05$ (a), $P < 0.01$ (b).

Investigating an avian source of shellfish microbial contaminations in the Thau lagoon in dry weather conditionsin dry weather conditions

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Introduction

With up to 13 000 tons of oysters and 2 500 tons of mussels marketed every year, the Thau lagoon is the main Mediterranean shellfish harvesting area. Due to frequent faecal pollution, it is a "class B" area, according to European sanitary regulations; shellfish thus have to be depurated before they are marketed. Between 1997 and 2007, 18% of the analyses carried out during dry weather showed more than 230 *Escherichia coli* / 100 g of bivalves, leading the administration to introduce restrictive measures in the contaminated shellfish harvesting areas, including temporarily suspending production.

An inventory of *Escherichia coli* sources, compiled in 2007 for the Thau drainage area, showed that private wastewater treatment facilities, avian populations and industries may constitute the main pollution sources in dry weather. Many studies have shown the effect of seabirds on the microbial degradation of water quality (Edge *et al*., 2007; McLellan *et al*., 2003; Levesque *et al*., 2000; Benton *et al*., 1983). This study aims to clarify the contribution of seabirds roosting at night on the Thau lagoon shellfish growing frames to shellfish faecal pollution in dry weather.

Materials and methods

Thau is a 75 km² lagoon in the South of France, with a drainage area of 230 km², connected to the Mediterranean Sea via two outlets (Figure 1). The Thau lagoon and its drainage area were monitored in dry weather over four periods in 2008. The Marseillan zone was monitored on three occasions (referred to as periods): 1) 14th and 15th of March; 2) 27th and 28th of March and 3) 30th and 31st of July. The zone of Bouzigues was monitored for the last period: 4) 26th and 27th of August.

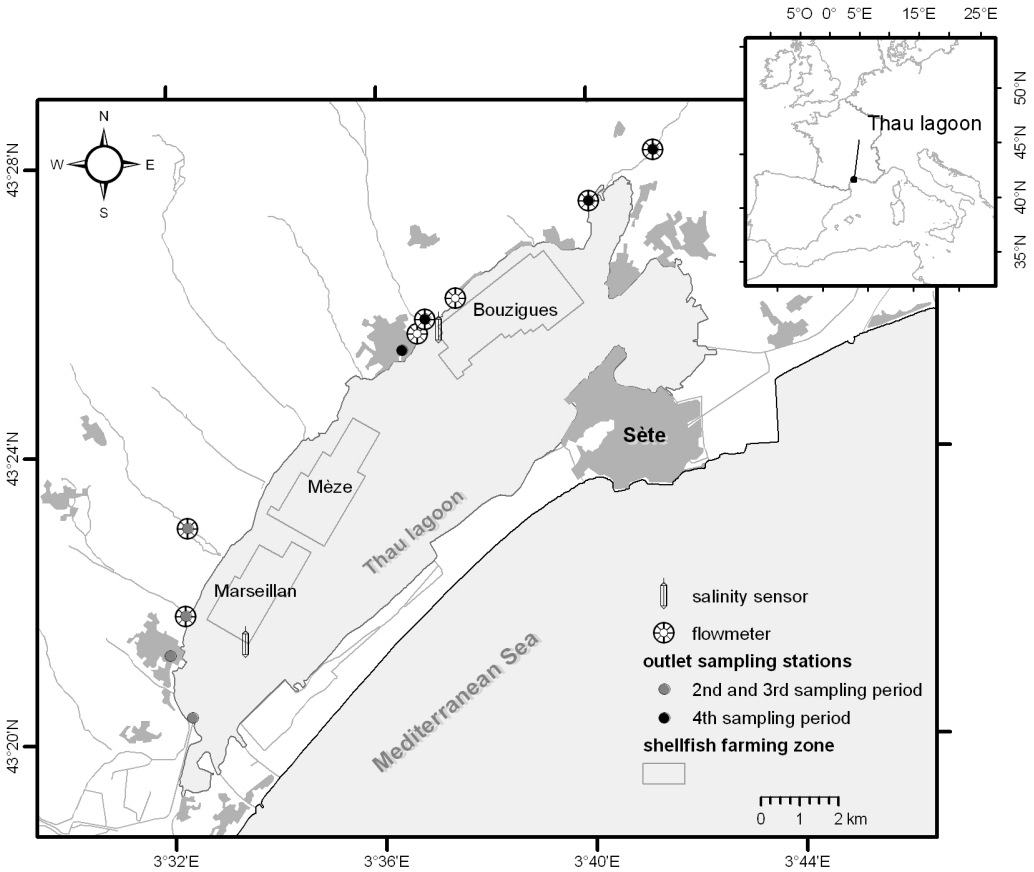

Figure 1. Thau lagoon and its three shellfish farming zones: Bouzigues, Mèze and Marseillan. Location of salinity sensors, flowmeters and water sampling sites on the main drainage area outlets.

Bird counts and sampling

At dusk, seabirds roosting on shellfish structures in areas of interest were counted from boats circulating between the shellfish farming structures. Species were identified with the naked eye, or in some cases with the help of binoculars. The shellfish structures were observed 2 hours before to 30 min after sunset for the purpose of counting and identification.

The seven main tributaries were equipped with flowmeters to monitor possible drainage area input (Figure 1). Salinity of the lagoon was monitored at the surface and the bottom of the water column by two high-frequency sensors.

For periods 2, 3 and 4: in the afternoon, before the bird counts, samples of water were collected at the outlets of the main potential faecal sources (Figure 1). Water and oyster (*Crassostrea gigas*) samples were collected under the shellfish structures, using a sampling strategy with 12, 15 and 11 initial surface sampling stations respectively (-1 m below the surface).

For each of the four periods, the day following the bird counts, water and oyster samples were collected at dawn under shellfish breeding structures. These were defined as “roosting structures” if more than 30 seabirds were counted in an area of radius 100 m from the sampling location, or “control structures” if less than 30 birds were counted. The total number of samples collected at the surface during the four periods under the “roosting structures” was 34 for both water and oysters, with 7, 6, 12 and 9 samples respectively for each period. Under the “control structures”, a total of 35 samples, with 7, 10, 11 and 7 samples were collected respectively for the four sampling periods.

Microbial analyses

Levels of *Escherichia coli* (*E. coli*) were analysed in all the water and shellfish samples collected during the sampling periods. Water samples were analysed using the NF EN ISO 9308-3 standard method, *i.e.* the Most Probable Number (MPN), scaled down for inoculation into liquid culture medium (Afnor, 1999). Samples of oysters were analysed using the NF V08-106 standard method (Afnor, 2002).

F-specific RNA bacteriophage (FRNAPH) analyses were carried out at various times on shellfish collected during periods 1 and 2, and on seabird dropping samples (Caprais *et al*., 2009) to identify whether contamination was of human or animal origin. FRNAPH counts were performed using the double agar layer method, ISO NF 10705-1 (ISO, 1995). FRNAPH genotyping was performed according to published methods (Schaper and Jofre, 2000; Gourmelon *et al*., 2007; Beekwilder *et al*., 1996).

Results

During the four sampling periods, rainfall was low (<12 mm on the four previous days), *E. coli* input from the drainage area was negligible ($<10^{11}$ *E. coli*.day^{-1}), and no lagoon water freshening was detected, thus contamination by freshwater input could be excluded.

At dusk, large mono-species groups of seabirds were observed on the shellfish structures. During the four sampling periods, a total of 600 to 1 100 yellow-legged gulls (*Larus michahellis*), 330 to 2 200 common black-headed gulls (*Larus ridibundus*) and Mediterranean gulls (*Larus melanocephalus*), 60 terns (*Sterna sandvicensis*) and 150 great cormorants (*Phalacrocorax carbo*) were roosting in the Marseillan area, and about 4 400 yellow-legged gulls and 1 000 common black-headed gulls in the area of Bouzigues.

Regarding sampling periods 2, 3 and 4, the numbers of *E. coli* in lagoon shellfish (N=36) and water (N=38) samples collected at the surface from the roosting and control structures at the same sampling stations were significantly higher after nocturnal bird resting than before the arrival of the seabirds (Wilcoxon signed rank test, $p = 0.012$).

The combined results for the four periods showed that the levels of *E. coli* in shellfish samples collected at dawn, from the surface under roosting structures (N=33) were significantly higher than in those collected under control structures (N=35) (Mann-Whitney test, $p = 0.024$) (Figure 2A).

Regarding periods 1 and 2, the levels of F-specific RNA bacteriophage in shellfish samples collected at dawn from the surface under roosting structures (N=11) were significantly higher than in those collected under control structures (N=18) (Mann-Withney test, $p = 0.001$) (Figure 2B). FRNAPH genotyping was performed on 21/43 shellfish samples, collected at the surface, at dawn on 15th and 28th of March. Group I was most frequently detected of the four genogroups (56 to 100%), indicating faecal contamination of animal origin (Hsu *et al*., 1995 ; Noble *et al*., 2003 ; Long *et al*., 2005).

A

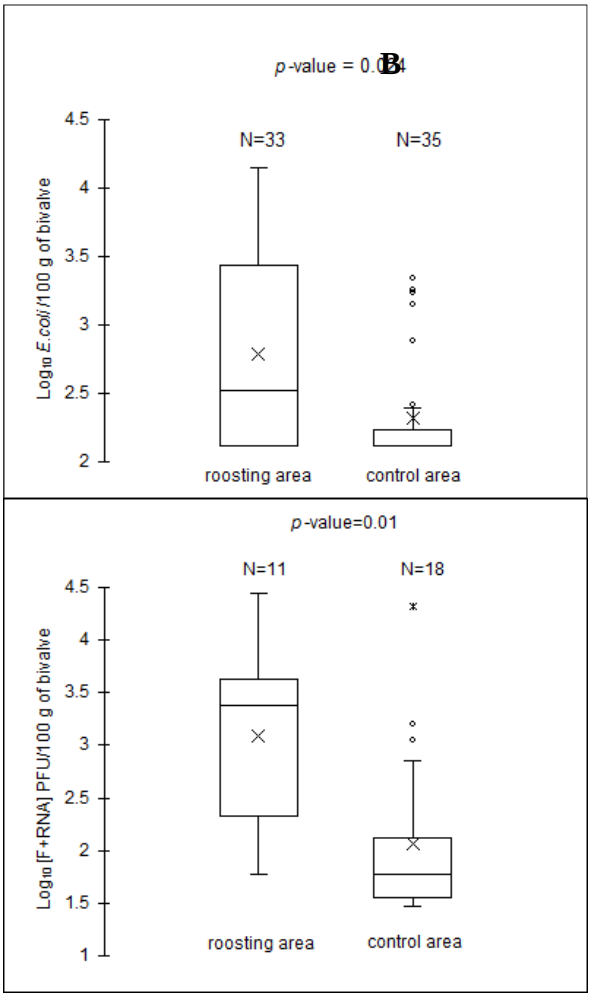

Figure 2 : *Escherichia coli* (A) and F+ specific RNA bacteriophage counts (B) in shellfish samples collected at dawn from surface, under roosting and control areas. Results in (A) are from all four periods and in (B) from the first two. Numbers of samples (N) and p-values calculated using the Mann-Whitney test are indicated.

Conclusion

The results from four periods of sampling carried out in the Thau lagoon in dry weather showed that high faecal contamination levels in shellfish were reached, with no significant drainage area input. At dusk, large populations of seabirds were observed on shellfish structures. *Escherichia coli* and F+ specific RNA bacteriophage levels were significantly higher under roosting structures than under the control structures.

Initial results of FRNAPH genotyping in shellfish suggested contamination of animal origin. However, the notion that an avian source contributes to shellfish contamination during dry weather needs confirmation using Microbial Source Tracking methods in seabird droppings and shellfish.

References

Afnor, 1999, Norme NF EN ISO 9308-3, Mars 1999. Qualité de l'eau. Recherche et dénombrement des *Escherichia coli* et des bactéries coliformes dans les eaux de surface et résiduaires. Partie 3 : méthode miniaturisée (NPP) pour ensemencement en milieu liquide. 21 p.

Afnor, 2002, Norme NFV08-106, Janvier 2002. Dénombrement des *Escherichia coli* dans les coquillages marins vivants. Technique indirecte par impédancemétrie directe.

Beekwilder J., Nieuwenhuizen R., Havelaar A.H., van Duin, J.,1996. An oligonucleotide hybridization assay for the identification and enumeration of F-specific RNA phages in surface water, *Journal of Applied Bacteriology*, 80, p. 179-186.

Benton C., Khan F., Monagha, P., Richars W.N., Shedden C. B., 1983. The contamination of a major supply by gulls (*Larus sp.*): a study of the problem and remedial actions taken, *Water Research*, 17, p. 789-798.

Caprais M.-P., Le Mennec C., Pommepuy M., Le Saux J.-C., Gourmelon M., 2009. Occurrence of F+ RNA specific bacteriophage in French shellfish. What about a use for the discrimination of faecal pollution? *Submitted to Aquatic Living Resources*.

Edge T. A., Hill S., 2007. Multiple lines of evidence to identify the sources of fecal pollution at a freshwater beach in Hamilton Harbour, Lake Ontario, *Water Research*, 41, p. 3585-3594.

Gould D.J. and Fletcher M. R., 1978. Gull droppings and their effects on water quality, *Water Research*, 12, p. 665-672.

Gourmelon M., Caprais M. P., Segura R., Le Mennec C., Lozach S., Piriou J.,Y., Rince A., 2007. Evaluation of two library-independent microbial source tracking methods to identify sources of fecal contamination in French estuaries, *Applied Environmental Microbiology*, 73, p. 4857-4866.

Hsu F.C., Shieh Y.S., Van Duin J., Beekwilder MJ., Sobsey MD., 1995. Genotyping male-specific RNA coliphages by hybridization with oligonucleotide probes, *Applied Environmental Microbiology*, 61, p. 3960-3966.

ISO, 1995. Detection and enumeration of bacteriophages. Part 1: Enumeration of F specific RNA bacteriophages. ISO 10705-1. International Standardisation Organisation, Geneva, Switzerland.

Levesque B., Brousseau P., Bernier F., Dewailly E. and Joly F, 2000. Study of the bacterial content of ring-billed gull dropping in relation to recreational water quality, *Water Research*, 34(4), p. 1089-1096.

Long S., El Khoury SS., Oudejans SJG., Sobsey MD., Vinje J., 2005. Assessment of sources and diversity of male specific coliphages for source tracking, *Environmental Engineering Science*, 22, p. 367-377.

McLellan S. L., Salmore A. K., 2003. Evidence for localized bacterial loadings as the cause of chronic beach closings in a freshwater marina, *Water Research*, 37, p. 2700-2708.

Noble RT., Moore DF., Leecaster MK., Mc Gee CD., Weisberg SB., 2003. Comparison of total coliform, fecal coliform, and enterococcus bacterial indicator response for ocean recreational water quality testing, *Water Research*, 37, p. 1637-1643.

Schaper M., Jofre J., 2000. Comparison of methods for detecting genotypes of F-specific RNA bacteriophages and fingerprinting the origin of faecal pollution in water samples, *Journal of Virological Methods*, 89, p. 1-10.

Temporal changes in littoral fish assemblages along the eastern Adriatic coast

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Abstract

Littoral fish assemblages were monitored by experimental trammel net fishing up to six times per year, within the warm period – May to September, at four locations along the eastern Adriatic coast between 1993 and 2009. Analyses were performed on total fish abundance and biomass, diversity indices and multivariate abundance and biomass structure of fish assemblages. The results revealed spatially consistent increasing trends of total fish abundance and biomass growing at an average rate of 15 and 14% per year, respectively. Of the diversity indices analysed, the same pattern of variability was observed for Shannon diversity, while Pielou evenness and average taxonomic distinctness measures Δ* and Δ+ showed spatial variability with no obvious temporal trends. Multivariate fish assemblage structure in terms of both abundance and biomass underwent a directional change displaying a similar pattern through time for all the locations. Temporal pattern of assemblage change was general and attributable to a relatively large and different pool of species in each of the locations. However, increasing trends of *Mullus surmuletus*, *Scorpaena porcus* and *Symphodus tinca* were spatially consistent. The observed changes are likely to have resulted from a more restrictive artisanal fishery management that has progressively been put in place during the study period.

References

Fisheries Research Agency, 2008, Status of global fisheries resources, http://kokushi.job.affrc.go.jp/H21/H21_all.pdf (in Japanese).
Jiji Press Ltd., 2010, Jiji Fishery Information Service (in Japanese).
Kumai H., 2010, Retrospect, current status and perspective of tuna farming industry, In Kumai, H. (Eds.) Full cycle farming of bluefin tuna, Tokyo, Seizando Press, pp.1-21, (in Japanese).
Lou S., 2004, Demand-supply relations of tunas and the market structure, In: Ono S. (Eds.) Science of tunas, Tokyo, Seizando Press, pp.302-327 (in Japanese).
Mylonas C., Gandara F., Corriero A. and Rios A. B., 2010, Atlantic Bluefin Tuna (*Thunnus Thynnus*) Farming and Fattening in the Mediterranean Sea, Reviews in Fisheries Science, 18(3), pp.266-280.
Ono S., 2010, Issues in tuna farming industry, In: Kumai H. (Eds.) Full cycle farming of bluefin tuna, Tokyo, Seizando Press, pp.190-219, (in Japanese).
Torii T., 2008, Trend of farmed tuna production and big businesses, Aquaculture, September, pp.25-27 (in Japanese).

Growth, age-otolith weight and length relationship of garfish in the eastern Adriatic Sea

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Abstract

Otoliths of 468 garfish specimens (28.3>*TL*>75.4 cm; mean *TL*=42.5±10.44 cm), caught in the eastern part of the Adriatic Sea from January 2003 to December 2008, were studied to provide information on their age and growth pattern. Estimated von Bertalanffy growth parameters were: L_∞=106.0cm, K=0.11 year^{-1}and t_0= - 0.682. Otoliths were also weighted and power relationship was obtained between otolith weight and total somatic length ($Wo=0.0012TL^{2.189}$, r^2=0.9047) and otolith weight and garfish age ($Wo=0.568t^{1.486}$, r^2=0.9944).

Keywords: Garfish, age, growth, otolith weight, Adriatic

Introduction

Garfish, *Belone belone* (Linnaeus, 1761), is an epipelagic migratory species, widely distributed in the north-eastern Atlantic, Mediterranean, Adriatic and Black Sea (Whitehead et al., 1986.). The purpose of this study was to provide the information on age, growth, otolih weight – total length and otolith weight – age relationship of garfish from the eastern part of the Adriatic Sea.

Materials and methods

A total of 468 garfish specimens were obtained from commercial catches in the eastern part of the Adriatic Sea during a six year period (2003–2008). Total lengths (*TL*) of the specimens were measured to the nearest 0.1 cm in the laboratory Garfish age was determined using the sagittae otolith reading. Broad opaque and narrow hyaline zones of garfish otoliths alternated outwards the ototlith nucleus. The total number of hyaline zones was recorded and considered as annuli. Out of 468 otoliths, 440 were successfully aged. The relationship between age and length was adequately described by the von Bertalanffy growth equation. The weights of undamaged and cleaned otoliths were measured on a Mettler analytical balance (to the nearest 0.01 mg). The relationship between otolith weight - total length and age were analysed using the power function.

Results and discussion

Overall, garfish total length ranged from 28.3 to 75.4 cm (mean *TL*=42.5±10.44 cm). Out of 468 dissected otoliths, 440 were successfully aged. Annuli on garfish otholiths indicated the presence of eight age classes, while the dominant age class was 3+ (45.91%). The relationship between age and length was adequately described by the von Bertalanffy growth parameters: L_∞=106.0cm, K=0.11 year^{-1}and t_0= -

0.682. The estimated growth parameter *K* in the present study was in accordance with the results reported by Fehri-Bedoui and Gharbi (L_∞=61.4 cm, *K*=0.10 year^{-1}; 2004) and Samsun et al. (L_∞=74.64 cm, *K*=0.13 year^{-1}; 2006) for garfish inhabiting Mediterranean and Black Sea, respectively. The garfish asymptotic length of mentioned authors was lower than reported in this paper probably caused by the differences in the length frequency distribution; in this study the length range was the wider reported till now for garfish collected in the area of Mediterranean and its adjunct seas. Garfish otolith weight varied between 1.261 (*TL*=28.2 cm) and 18.12 mg (*TL*=73.6 cm). The mean otolith weight was 4.66±2.886 mg. Power relationship was obtained between otolith weight and total somatic length ($Wo=0.0012TL^{2.189}$, r^2=0.9047; Fig. 1a) and otolith weight and garfish age ($Wo=0.568t^{1.486}$, r^2=0.9944; Fig. 1b); otolith weight increased significantly with the length and age of garfish specimens. Concerning a high coefficient of determination in the above mentioned relationships, it could be assumed that otolith weight provided further quick, reliable and efficient way to estimate age for this pelagic fish species, which is especially important for its stock size assessment.

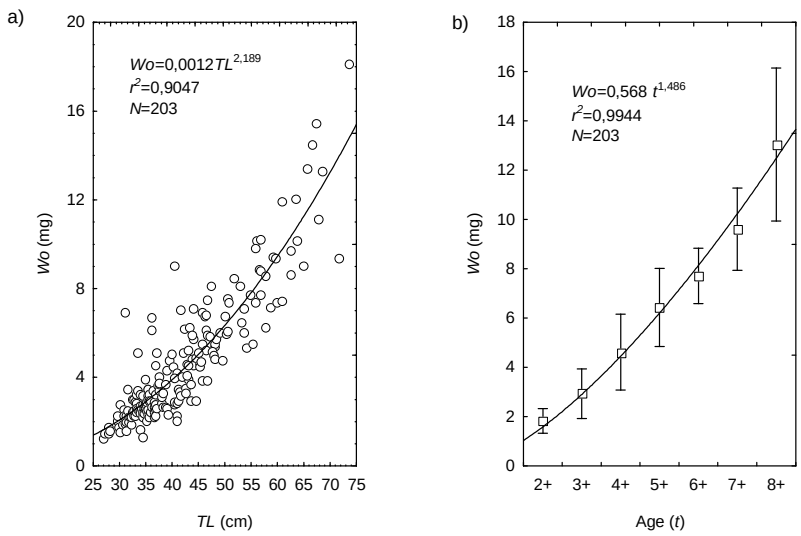

Figure 1: Garfish, *Belone belone*, relationship of total length (*TL*) and otolith weight (*Wo*) –a as well as relationship of mean otolith weight (*Wo*) and age (*t*) – b for individuals collected from the eastern Adriatic Sea, 2003-2008

References

Fehri-Bedoui R., Gharbi H. (2004) Contribution a l'etude de la croissance et l'age de *Belone belone* (Belonidae) des côtes Est de la Tunisie. Rapp Comm int Mer Médit 37: p 352

Samsun O., Samsun N., Bilgin S., Kalayci F. (2006) Population biology and status of exploitation of introduced garfish *Belone belone euxini* (Günther, 1866) in the Black Sea. J Appl Ichthyol 22: 353-356.

Whitehead P. J. P., Bauchot M.L., Hureau J.C., Nielsen J., Tortonese E. (1986) Fishes of the North – eastern Atlantic and the Mediterranean. UNESCO, Paris, 2: 604-607

Mitigating measures and good practices in fishing and aquaculture activities

Measurement of the resonant vibrations of bamboo used for fish aggregating devices

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Anchored fish aggregating devices (FADs) or payao depend on bamboo rafts to keep the structure afloat, and these are commonly used in the Philippines to capture tuna, small pelagic fish, and juveniles of *Seriola dumerilli*, which are valuable species for fish culture. The ability of payao to attract fish is believed to be partly due to its vibrations. Recent field experiments confirmed that the vortices generated by the anchor rope cause the payao to vibrate. In a separate experiment, the motions of palm leaves, which are usually suspended underneath the raft, apparently produce distinct low frequency signals. It is now apparent that sound recorded near payao is probably due to vortex-induced vibrations of the payao. However, all possible sources of these vibrations are not yet full established. Specifically, the vibrations of the bamboos used to construct the raft are not yet explored until now. This study seeks to address this information gap on the acoustic properties of payao and its parts.

In this study, the experiments were conducted using a bamboo pole (average ϕ = 5.4 cm) similar to those normally used for constructing the raft of anchored fish aggregating devices in the Philippines. The bamboo initially had a length of 3.5 m. A strain gage was glued directly at its center and connected to a data logger; the strain gage was covered with VM tape and wrapped further with electric tape to protect water penetration. Four sets of experiments, corresponding to bamboo lengths of 2.0 m, 2.5 m, 3.0 m, and 3.5 m, were conducted. For each experimental condition, the bamboo was gradually reduced by cutting 0.25 m from both ends and was dropped horizontally from different elevations (0.25 m – 1.00 m) in still water. Several trials were usually attempted for each condition, but those with potentially unfavourable results due to uneven level of the bamboo, were excluded from the analysis. The sampling rate was preset 500 Hz for all experimental conditions. Meanwhile, the cutoff frequency for the low pass filter was 200 Hz since the expected signals were below 100 Hz from previous recordings of payao vibrations. A total of 10,000 data points were preset for data collection from each experimental run, but the vibrations only last about 4 s; therefore, all data sets were visually examined before data analysis. Linear spectra were calculated using 1024 points beginning near the point where recorded bamboo vibrations were clearly visible. A total of 512 points were used for the Fast Fourier Transforms. For each condition, the mean spectrum was averaged from the results of 1000 data sets with each data set shifted by 1 point.

The resonant frequencies of the bamboo occurred between 12 Hz and 43 Hz. For a bamboo of constant length, the dominant vibrations occurred consistently within a narrow frequency range and were apparently unaffected by the elevation from which

it was dropped; for all lengths tested, the amplitude of the vibrations generally increased with dropping elevation. The frequency of the first dominant signal clearly varied inversely with length. Although the recorded amplitudes also generally decreased as the bamboo was cut into shorter lengths, this relationship is not as evident especially when the bamboo was dropped from higher elevations.

The raft of a payao is usually constructed with 32 pieces of 10 m long bamboos arranged in 2 layers. These bamboos are rigidly held by bamboo braces, which effectively partition the raft unevenly into 3 to 4 sections. Therefore, the length range of the bamboo that was tested during the experiment adequately represents similarly varied bamboo sections of the raft. The raft moves under the influence of surface waves but is pulled from the bottom by the anchor rope. Payao vibrations apparently include signals corresponding to those generated by the raft.

Potential energy increases with elevation and correspondingly influences vibration amplitude in bamboo. This explains the more intense sound generated by the raft that is normally perceptible even in air during rough weather. The frequency of bamboo vibrations varies inversely with its length, but for a given bamboo length, the elevation from which it is dropped does not affect vibration frequency. This implies that the raft of payao apparently emits a fixed set of sound signals depending on its construction. Moreover, since the amplitude of the vibrations gets smaller with shorter bamboos, the space affected by the signals is probably limited within the vicinity of the raft. This condition likely influences the ability of the payao to attract fish under different sea states.

The characteristics of vibrations generated by objects depend on their material properties. The type and size of bamboos used to construct the raft of payao are never the same; therefore, their vibrations are also probably different. Moreover, since bamboo is not the only material used as floating material for anchored FADs, it is most likely that the vibrations of different floating devices are also different; this may be the subject of future research on payao vibrations.

Total serum protein a good indicator for welfare in reared sea bass (*Dicentrarchus labrax* L, 1758)

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Introduction

Despite continuous improvements of diagnoses, sanitary controls, proactive treatments and methods such as vaccinations, the health and welfare of farmed fish still remains a major problem for the European aquaculture industry. The causes are to be found in environmental conditions and husbandry practices. The "Welfare and Health in Sustainable Aquaculture" (WEALTH) project aimed to present a holistic view of how the health and welfare of farmed fish can be maximized. Its final goal was to develop and validate an operational husbandry protocol management for the aquaculture industry. Reared sea bass were submitted to six stressful situations: hyperoxia, with or without hypercapnia, stocking density in open flow and in recirculating system, transfer to another tank and Nodavirus injection. Previous publications about ours experiments (Sammouth *et al.*, 2008; Taranger, 2008; Roque d'Orbcastel *et al.*, 2010) shown the negative impact their life. It was investigated using 9 water parameters and 19 fish parameters including total serum protein (TSP). TSP was already used to evaluate stress. The present study investigates TPS to determine its potential use as a routine indicator to assess welfare and eventually stress in sea bass reared in farm.

Material and methods

This paragraph gives specific information; the main information on materiel and methods of experiments is already published. Details of methods and results of experimentations were described in Sammouth et al., 2008; Taranger, 2008; Roque d'Orbcastel et al., 2010. Specific information for Nodavirus injection: 140 Fish (230±5g) were individually tagged, 105 were intramuscularly inoculated with a nodavirus suspension of 9 105 PFU/fish. The control group (35 fish) was injected with sterile SSN1 cell culture solution. Water temperature was 25°C in place of 20°C. Total morbidity and fish showing abnormal swimming behaviour were daily recorded for 3 weeks.Blood samples (0.5 ml) were collected from 30 fish at the middle and the end of experiment. They were starved 24 h before sampling. Blood was taken from the caudal vein on 10 fish anaesthetized for 3 min at 4°C in seawater and sampled within 5 minutes of fish capture to avoided TSP modification by handling stress. Serum was separated by centrifugation (15,000 rpm, 5 min, 4°C) and stored at - 20°C until analysis. A Max Mat Hycel autoanalyzer determined TSP, based on principle of the biuret reaction. Bovine serum albumin was used as standard and data were expressed in mg ml-1.

Results and discussion

Erratic TSP alteration by hyperoxia or/and hypercapnia

In the current experiment O_2 and CO_2 affect levels of TSP but erratic alterations were unworkable, probably because they are normal components of the fish environment and become toxic only by dose increase.

TSP decrease when stocking density increased

Stocking density induces differences ($P<0.05$) on TSP at the middle of the experiment between high densities and lowest. At the end of experiment the general tendency was conserve but with not significant difference. In similar experimental conditions to ours, an effect on the level of gene expression was found. Furthermore our investigations by 2D gel and proteomic analysis on MS-MS showed a significant difference in panels of serum protein with apparition of proteins involved in inflammation (Coeurdacier extended summary in this book). In the case of stocking density TSP is at the limit of its discriminating power.

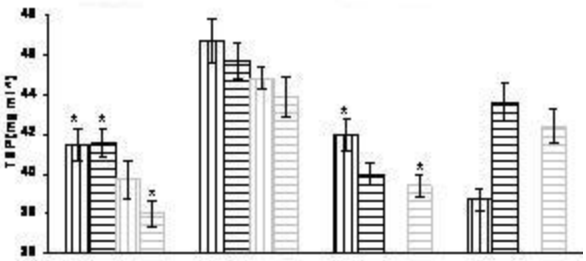

Figure 1: TPS increases when stoking density increases. Kg m3: 100(III); 70(=); 40(III); 10 (=), n=30; *P>0.05

TSP decreases after transfer to another tank

Around 1300 samples were analysed and data treated using TSP alteration or Protein Percentage Alteration (PPA). We present 2 representative cases (expressed in mg ml^{-1}±SE) and a global evolution (expressed in PPA) of all results.

TSP decreases in transferred and increase in unmoved fish.

The TSP of unmoved fish keeps on increasing but TSP of transferred fish stopped in first (day 7) and then decreased (day 27) maximizing the deficit in serum proteins versus unmoved fish.

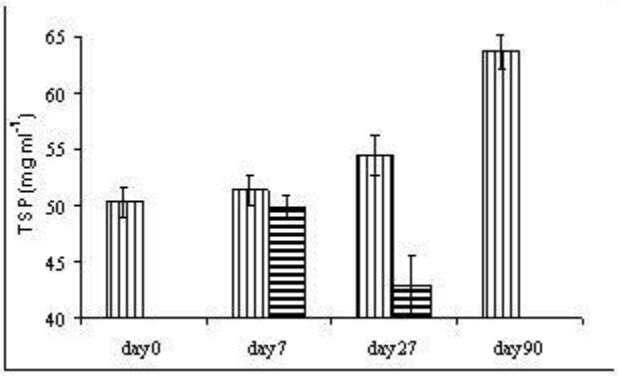

Figure 2: TPS decreases in transferred (=) an increase in unmoved fish (III), n=30; P>0.05

Global evolution after a single transfer

The Fig. 3 gives an overview of global evolution during 10 weeks after a single transfer. PPA decreases drastically during the second and third weeks after transfer

with a deepest at day 20 then it increases during 2 weeks to reach and overtake calculated TSP (0.2% by day); after a compensative overproduction (6th and 7th weeks), it fluctuates mildly to calculated TSP, before jointing it back on the ninth week. The graph is of interest by its general design and it was obtained by compilation of 1300 results on PPA.

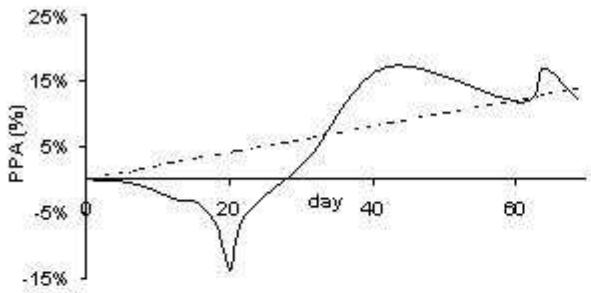

Figure.3: TPS alteration last 9 weeks after a single transfer (—). Calculated TPS, 0.2% day-1 (---), n=1300

TSP alteration due to multiple transfers

Multiple transfers to other tanks induced decrease in TSP (Fig.4) with cumulative effect. In parallel, unmoved fish increased with a ratio close to theoretic progression. TSP evolution presents similar pattern as those observed with single transfer in the decreasing but with a longer recovery period, (11 weeks instead of 4) showing that multiple transfers have a cumulative effect. After the second transfer the animals had to react rapidly by overcompensation to survive, and then production slowed down because reserve involved increased and/or break point level moved away.

Actually it seems that two different mechanisms are involved; the former is a normal compensation of protein consumption induced by the first transfer, the latter works urgently to keep the fish alive after 2° transfer. The latter probably activated all mechanisms of stress and, when the vital prognosis is averted, a feed-back control stops protein overproduction to resume to the former mechanism. In the case of single or multiple transfers TPS is a good discriminating parameter; its variation is significant and lasts for a long time.

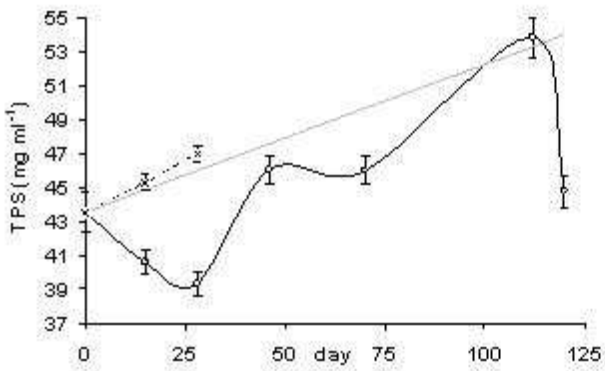

Figure 4 Cumulative effect after multiple transfers. First part of the group was unmoved (--x--) and the second part transferred 3 times at day 0, 15 and 112. Calculated TPS, 0.2% day-1 (—), n=30, P< 0.05

Nodavirus injection alters TSP

Electronic tagging of fish enabled individual comparison. (i) Dying fish PPA increased sharply due to over-production of protein involved in unspecific defences and inflammation, then decreased dramatically before death. (ii) Whirling fish group,

comprising fish that will die which PPA decreased and fish that will survive which PPA increased by developing specific immunity. (iii) Asymptomatic fish with 2 groups; the former close to control probably insensitive to Nodavirus, like the sea bas broodstocks, and the latter witch develops defences. In the case of Nodavirus infection TPS is good discriminating parameter.

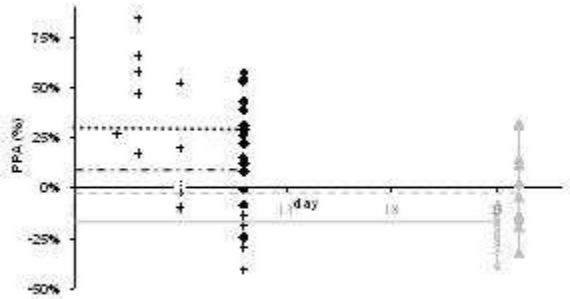

Figure 5: PPA versus health state of each fish. Dying fish (+; mean ····), whirling fish (♦; mean — · — · —) and asymptomatic fish (▲; mean — — —). Control fish (○; mean ——) Means (horizontal line) are different (P<0.05) than control except asymptomatic (n=35)

Conclusion

Fish showed different TSP responses in relation to living conditions: unworkable differences in TSP in response to hyperoxia and hypercapnia, low decrease in response to stocking density, sharp and significant alteration in response to transfer to another tank and nodavirus injection. All modifications of rearing conditions experimented during this program are less stressful for the fish than one transfer which is common practice. Actually it is a confirmation of well-known fish farmer opinion on bad effect of handling fish.

How to use TSP in farm? Every month or when necessary 30 fish can be sampled to follow TSP, which should normally increase slowly, when fish grows. TSP should be used as routine analysis, because only a variation give workable information and regular increase can attest a correct welfare of fish. If it decreases or increases sharply fish had or have a problem. For sharp increases, infection is probable, for decrease other stress factor should be investigated. Everywhere it is easy to find a facility to analyze total serum protein, with the condition to include a standard (BCA 50 mg ml^{-1}) and the price is 1-2€ in standard lab and 4-5€ in medical laboratory.

TSP is a non destructive, global, robust, easy to realize every-where and cheap parameter, to follow a global welfare of fish by its regular increase. But, it can be used only as a “warning” with obligation of further investigations to discriminate stress or health disorder.

References

Roque d'Orbcastel E., G. Lemarié, G. Breuil, T. Petochi, G. Marino, S. Triplet, G. Dutto, S. Fivelstad, J.-L. Coeurdacier,J.-P. Blancheton, 2010, Effects of rearing density on sea bass (*Dicentrarchus labrax*) biological performance, blood parameters and disease resistance in a flow through system. Aquat. Living Resour. 23(1), 109-117.

Sammouth S., E.R. d'Orbcastel, E. Gasset, G. Lemarie, G. Breuil, G. Marino, J.L. Coeurdacier, S. Fivelstad, J.P. Blancheton, 2008, The effect of density on sea bass (*Dicentrarchus labrax*) performance in a tank-based recirculating system. Aqua. Eng. 40(2), 72-78.

Taranger G.L., 2008, Welfare and health in sustainable aquaculture (WEALTH). Coordinator: Geir Lasse Taranger, Final report. E.U Project no. N501984, http://wealth.imr.no/

Control of Bluefin Tuna reproduction: a condition for self sustained aquaculture

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Among the possible solutions to sustain tuna availability, aquaculture has been evoked for decades over the world and has been investigated in the past ten years in Europe. The Bluefin Tuna (BFT) showed a remarkable capacity to grow and fatten in captivity giving rise to a capture based aquaculture which has increased the pressure on wild stocks., Japan had invested in the long term management of captive Pacfic bluefin tuna (PBFT) in order to obtain reproduction in captivity through both national and local programs implemented by universities and later on, in collaborations with private companies. The first spawn was collected in 1979 by Kinki University in Amami Island and this led to the first trials of larval rearing (Kumai, 1998). During the following years, spawns were irregular in both terms of occurrence and number of collected eggs. This was compensated by the settlement of broodstocks in different geographical areas and the increased size of the broodstocks (Masuma et al, 2008). Then, the availability of eggs was sufficient enough to progress rapidly in fry production. This large effort of Japanese scientists, private companies and authorities was awarded by the first F1 generation in 2002 (Sawada, 2005). Nowadays, the nine existing Pacific bluefin tuna broodstocks give rise to a fisheries disconnected commercial production of tuna born in captivity (Miyashita, 2010).

The analyses of spawn conditions revealed this event to be highly dependent on temperature level and variations around 23°C during a relatively restricted period of time. (Masuma, 2008). However the lack of reliability of broodstock which impairs production schedules as well as the low ratio of females responsible for egg production remain an important concern.(Masuma 2010) .

Since Atlantic bluefin tuna (ABFT) stocks have been decreasing probably due to overfishing, and in order to prevent further collapse of the fisheries, the European community invested into 2 consecutive programs aiming at the development of a self sustained tuna culture. These programs, REPRODOTT and SELFDOTT, investigated the reproductive potential of captive ABFT and the possibility to control spawning. The comparative study of gametogenesis process of wild captive and hormonally stimulated captive bluefin tuna (Corriero et al, 2007) and the analysis of of the spatial-temporal pattern of gonad maturation throughout the Mediterranean Sea (Heinisch et al, 2008) led to the faith in reproduction in the available fattening sites based in South East Spain (Cartagena) and Malta. After the first success in Puerto de Mazarron, Spain, in 2005 (Mylonas et al 2007) which provided some larvae obtained by artificial fertilization of gametes from sacrificed fish, the protocols of hormonal stimulation were refined and applied to broodstocks held in cages in 2 different programs, SELFDOTT (European program involving the private companies Ricardo Fuentes and Malta Fishfarming) and ALLOTUNA (an Italian regional program with the contribution of Mare Nostro private company). They were also used to stimulate broodstock held in tank in an internal program of Cleanseas an Australian private company in, with the initial participation of European researchers. Concomitantly, in 2006, a Croatian private company (Kali Tuna) created a 800 piece broodstock in order to obtain eggs and to close the tuna life cycle in farming operations.

Following hormonal inductions in European experiments, several spawns per season of at least 20 millions eggs each, have been obtained for 3 consecutive years (2008-2010) in the Italian site of Vibo Valentia from a 90 fish broodstock held in a single cage (De Metrio et al, 2010; Mylonas et al, 2010). According to press releases Cleanseas also claimed egg production for 3 consecutive reproductive seasons from the broodstock held in a tank, unfortunately, no information is available concerning the number of breeders and the number of collected eggs. During this period, the use of hormones was successful in Spain (2009) where a broodstock of only 35 fish produced at least 140 millions of eggs within 17 days and, in a lower extent in Malta (2010), where only 250,000 eggs were collected within the frame of SELFDOTT. Moreover, the Spanish broodstock spontaneously spawned in 2010 (Mylonas et al., 2010). Finally, Gordoa et al. (2009) reported spontaneous spawnings in towing cages belonging to the Company Balfegó Grup, in 2008 in Balearic waters (Spain(2)). This company also observed spontaneous spawnings in 2009 and 2010. The captive tuna reproduction performances that were confirmed in Europe and Australia are summarized in the following table (Table 1).

Conclusions

Although the data are fragmentary, incomplete and coming from various types of media from scientific publications to press releases, the control of tuna reproduction is improving. The Japanese research and industry laboratories have opened the track of tuna life cycle completion in captivity for 30 years. The European laboratories recently brought their contribution by a better control of tuna reproduction through adequate hormonal stimulation of broodstock that can be applied in cages as well as in tanks for a more regular annual production of eggs. Moreover, the last three year European experience shows that stocks with restricted number of breeders can provide large amounts of eggs which may fulfil in a short term, the requirements for self sustained aquaculture. The use of tanks and hormonal stimulation may allow scheduling gametogenesis and spawning and, in a short term, it may provide gametes

out of natural periods of reproduction. These improvements of broodstock management and performances allow to progress from capture based to self sustained tuna aquaculture.

Table 1: Synoptic view of induced and spontaneous spawns of captive broodstocks of bluefin tuna. (Bold type indicates hormonally controlled spawns ; Spain(2) concerns the towing cages of recently captured individuals; *From broodstocks held in tank; ** the number of collected eggs only come from the cage with 35 individuals. Spawns may have occurred spontaneously in the other cage but they were not recorded According to press releases, the Croatian broodstock of Kali company spontaneously spawned in 2009.

	Broodstock capture (number/cage)	2008(number of eggs collected)	2009(number of eggs collected)	2010(number of eggs collected)
Italy	2007 (90)	**Spawn (20 10^6)**	**Spawn (40 10^6)**	**Spawn (100 10^6)**
Australia	2006 (?)	**Spawn***	**Spawn***	**Spawn***
Spain	2007(35 and 25)		**Spawn (140 10^6)****	Spawn (70 10^6)
Spain(2)	current year (hundreds)	Spawn	Spawn	Spawn
Malta	2007			**Spawn (25.10^4)**

Acknowledgments

This work was performed in the frame of the European Union Project SelfDOTT (From capture based to SELF-sustained aquaculture and Domestication of bluefin tuna, *Thunnus thynnus*, research grant number 212797).

References

Corriero, A., A. Medina, C. C. Mylonas, F. J. Abascal, M. Deflorio, L. Aragon, C. R. Bridges, C. A. Santamaria, G. Heinisch, R. Vassallo-Agius, A. Belmonte, C. Fauvel, A. Garcia, H. Gordin, and G. De Metrio, 2007. Histological study of the effects of treatment with gonadotropin-releasing hormone agonist (GnRHa) on the reproductive maturation of captive-reared Atlantic bluefin tuna (*Thunnus thynnus* L.). *Aquaculture*, **272:** 675–686.

De Metrio,G., C. R. Bridges, C. C. Mylonas, M. Caggiano, M. Deflorio,N. Santamaria, P. Zupa, C. Pousis, R. Vassallo-Agius, H. Gordin,and A. Corriero, 2010. Spawning induction and large-scale collection of fertilized eggs in captive Atlantic bluefin tuna (*Thunnus thynnus* L.) and the first larval rearing efforts. *J. Appl. Ichthyol.*, **26:** 596–599.

Gordoa, A., M.P. Olivar, R. Arevalo, J. Viñas, B. Moli and X. Illas, 2009. Determination of Atlantic bluefin tuna (Thunnus thynnus) spawning time within a transport cage in the western Mediterranean. ICES J. Mar. Sci. **66** (10): 2205-2210.

Heinisch, G., A. Corriero, A. Medina, F. J. Abascal, J. M. de la Serna, R. Vassallo-Agius, A. Belmonte Rıos, A. Garcıa, F. De la Gandara, C. Fauvel, C. R. Bridges, C. C. Mylonas, F. S. Karakulak, I. K. Oray, G. De Metrio, H. Rosenfeld, and H. Gordin, 2008. Spatial-temporal pattern of bluefin tuna (*Thunnus thynnus* L. 1758) gonad maturation across the Mediterranean Sea. *Mar. Biol.*, **154:** 623–630.

Kumai, H. 1998. Studies on bluefin tuna artificial hatching, rearing and reproduction. *Nipp. SuisanGakk.*, **64:** 601–605. (in Japanese, with English abstract).

Masuma,S., S. Miyashita, H. Yamamoto and H. Kumai, 2008.Status of bluefin tuna farming,broodstock management, breeding and fingerling production in Japan. *Rev. Fish. Sci.*, **16:** 385-390.
Masuma, S., T. Takebe, Y. Sakakura, 2010. A review of the broodstock management and larviculture of the Pacific northern bluefin tuna in Japan. *Aquaculture (* in press).
Miyashita S., 2010 Seedling production of the pacific bluefin tuna. Abstracts of the French-Japanese symposium, Ifremer, Sète, France (1-3 september 2010)
Mylonas, C. C., C. R. Bridges, H. Gordin,A. Belmonte Ros, A. Garcia, F. De la Gandara, C. Fauvel, M. Suquet, A. Medina, M. Papadaki, G. Heinisch, G. De Metrio, A. Corriero, R. Vassallo-Agius, J. M. Guzman, E.Mañanos, and Y. Zohar, 2007. Preparation and administration of gonadotropin-releasing hormone agonist (GnRHa) implants for the artificial control of reproductive maturation in captive-reared Atlantic bluefin tuna (*Thunnus thynnus thynnus*). *Rev. Fish. Sci.*, **15:** 183–210.
Mylonas, C. C., De la Gandara, F., Corriero, A. and Belmonte Rios, A.,2010. Atlantic Bluefin Tuna (Thunnus thynnus) Farming and Fattening in the Mediterranean Sea. *Rev. in Fish.Sci.* 18(3):266–280.
Sawada, Y., T. Okada, S. Miyashita, O. Murata, and H. Kumai, 2005. Completion of the Pacific bluefin tuna *Thunnus orientalis* (Temmich et Schlegel) life cycle. *Aqua. Res.*, **36:** 413–421.
websites
http://sites.google.com/site/selfdottpublic/

Ontogenetic changes in schooling behaviour and transmission of behaviour between individuals of Pacific bluefin tuna juveniles

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Abstract

Schooling was first observed at 21–24 d after hatching (22.7–32.3 mm total length) in the Pacific bluefin tuna Thunnus orientalis. At this time, the fish exhibited momentary parallel swimming. The latency period of time for the transmission of behaviour between individuals in the school decreased from this point with growth.

Introduction

Bluefin tuna aquaculture is carried out in many countries such as Mediterranean countries, Mexico, Australia, and Japan because of its high commercial value. However, as most of these aquaculture industries are dependent on wild captured juvenile tuna, the negative impacts of aquaculture on the management of this stock have been reported. Recently, the Fisheries Laboratory of Kinki University (FLKU) developed a hatchery for Pacific bluefin tuna Thunnus orientalis in order to establish a stable supply of juvenile fish for aquaculture and also to enhance fish stocks. The creation of this hatchery has also enabled evaluation of *T. orientalis* at all stages of the life cycle under suitable conditions. In this paper, we studied the ontogenetic changes in schooling behaviour and transmission of behaviour between individuals of T. orientalis to develop the biological knowledge of this species, which has been understood little information on their early life history.

Materials and Methods

The *T. orientalis* used in the present study were hatched in the Oshima station of the FLKU. We studied the behaviour of fish of 7 different ages that ranged from 15 to 45 d after hatching (dah). To regulate the experimental conditions such as lighting and water temperature, the behavioural experiments were conducted in circular tanks placed in a room partitioned with black curtains. We observed the behaviour of 4 individuals for 20 min by using a high-speed digital video camera (EX-F1; CASIO, Tokyo, Japan), which enabled to record at 300 frames per second. Positions of the snout and the midpoint between pectoral fins of each individual fish were digitized as a 2-dimendional coordinate data in a time series at 5 ms intervals. To evaluate the behaviour of each fish, two schooling indices of nearest neighbour index (INN; Fukuda et al., 2010) and separation swimming index (ISS; Nakayama et al., 2003), and swimming speed were calculated. Furthermore, latent period of time for the

transmission of behaviour between individuals in a school was measured as response latency.

Results and Discussion

The growth of *T. orientalis* was better than that reported by Miyashita *et al.* (2001). The metamorphic change from the larval to juvenile stage was considered to occur between 15 and 24 dah (11.0–32.3 mm Total length [L_T]). I_{NN} and I_{SS} were relatively constant before metamorphosis. At 24 dah (32.3 mm L_T), however, the I_{SS} was significantly lower than the expected value for randomly swimming fish, and both the decrease in I_{NN} and I_{SS} from 21 dah (23.2 mm L_T) onwards suggested the onset of schooling. At this time, the fish exhibited momentary parallel swimming with neighbouring fish, and the transmissions of behaviour were also observed between individuals (Fig. 1).

Figure 1: Superimposed picture which captured a transmission of behaviour between two individuals of *T. orientalis*.

The mean response latency for the transmission of behaviour between individuals was more than 1 s at 24 dah when it was right after the onset of schooling. With growth of *T. orientalis*, the mean response latency decreased to approximately 0.5 s. After the decreasing of the response latency, the compactness and polarity of the fish schools progressively improved. This change in the response latency was considered to be necessary for *T. orientalis* to form the polarized schools.

References

Fukuda, H. *et al.* (2010). Ontogenetic changes in schooling behaviour during larval and early juvenile stages of Pacific bluefin tuna. *Journal of Fish Biology* 76, 1841–1847.

Miyashita, S. *et al.* (2001). Morphological development and growth of laboratory-reared larval and juvenile. *Fishery Bulletin* 99, 601–616.

Nakayama, S. *et al.* (2003). Effect of prey items on the development of schooling behavior in chub mackerel in the laboratory. *Fisheries Science* 69, 670–676.

Fishers´ echo- sounder buoys to study fish aggregations around drifting FADs

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Abstract

Drifting Fish Aggregating Devices (DFADs) are used in tropical purse seiner fisheries targeting tuna. These DFADs occur in remote areas where tuna and other species are usually attracted to floating objects. In spite of the importance of this fishing modality on industrial fisheries - half of the tuna catch in the world is fished around DFADs - and the fact that DFADs may affect tuna behavior and pelagic ecosystems, few studies have addressed their impact, mainly due to the fact that they are difficult to monitor in remote areas.
Within SELECTUN (a research project funded by ANABAC (Spanish fleet owner association)) and MADE European programme (Mitigating ADverse Ecological Impacts of open ocean fisheries), a new observational instrument is being tested to study this pelagic ecosystems: an echo-sounder buoy used by fishers.
The aim is to use these echo-sounder buoys (i) to remotely discriminate by-catch around DFADs and (ii) to understand the effects of DFADs on tunas and other associated species, eventually building the basis for future observatories of pelagic ecosystems.

Key words: FAD, instrumented buoy, by-catch, tuna, pelagic ecosystem.

Introduction

Drifting Fish Aggregating Devices (DFADs) are extensively used in tropical purse seine fisheries to attract tunas. One of the main concerns on the use of DFADs is that other species such as wahoo (*Acanthocybium solandri*), dolphinfish (*Coryphaena hyppurus*), triggerfish (*Canthidermis maculatus*), sharks, turtles and small tunas are also attracted to DFADs (Parin and Fedoryako 1999; Castro et al. 2002; Girard 2005; Taquet et al. 2007).
Regional fishery management organizations (RFMOs) have all called attention to the need for better understanding of the effects of thousands of DFADs on the spatial dynamics and behavior of tunas; and the need to conduct studies to reduce by-catch around DFADs. However, few studies have monitored the dynamics of fish aggregations around DFADs mainly due to the fact that DFADs are difficult to access and monitor over time in offshore fishing grounds.
An alternative to the expensive research vessels was investigated during the FADIO European programme, where an instrumented buoy to study fish aggregations was designed (Dagorn et al. 2006). However, such sophisticated and expensive instrumented buoys cannot be deployed in large numbers on FADs used by fishers.

Purse-seining for tropical tuna is one of the most technologically advanced fisheries in the world. The rapid improvement in buoy technology utilized to monitor and relocate DFADs, provide fishing masters with remotely monitored biomass estimates beneath their DFADs (Moreno et al. 2007). During SELECTUN project (a research project funded by ANABAC (Spanish fleet owner association)), and MADE European programme (Mitigating ADverse Ecological Impacts of open ocean fisheries) fishers' echo-sounder buoys are being used with a double objective: to evaluate fishers´ buoys as a tool to remotely discriminate by-catch species around DFADs and to study fish aggregation's dynamics related to environmental variables in order to help understanding the impact of DFADs on fish habitat and behavior.

Selected echo-sounder buoy

Nowadays the Spanish fleet is using three different types of echo-sounder buoys. Interviews were conducted to Spanish fishing masters to help choosing the best buoy in terms of echo-sounder reliability. Likewise, manufacturers were contacted to know the technical specifications of each buoy as well as echo-sounder performance. From interviews and manufacturers contacts, one of the three models was chosen mostly due to the echo-sounder accuracy and the possibility to work with the manufacturer on specifications for data collection and data processing
Selected buoy is equipped with a Simrad ES10 echo-sounder which operates at a frequency of 190.5 kHz with a power of 140 w. Beam width is 40º and the range is from 3 to 115 m. The echo-sounder provides with ten different layers in depth with 11,2 m resolution. Raw acoustic signal is provided for each layer and converted into biomass in tonnes with an experimental algorithm. Acoustic data, buoy position, water temperature and buoy celerity is received for every hour, via satellite link.

On going research with fishers echo-sounder buoys

Echo-sounder buoys are being used to minimize the footprint of the fishery in the pelagic ecosystem, in two ways:

Remote discrimination of by-catch around DFADs

The effective by-catch mitigation measures to reduce (or eliminate) the by-catch caught by purse seining in DFAD fishing could be taken:

1. before setting the purse seine net (Avoidance strategy)
2. after setting the net but before hauling it (Releasing from net strategy)
3. after loading the catch (Releasing from deck strategy)

The first option, avoiding catches, is the safest and most desirable alternative for the survival of by-catch species, as there is no interaction with the fishing gear. However, few avoidance strategies have been explored besides area closures.

Fisher's echo-sounder buoys provide with remote biomass estimates that are given for all the species and sizes together without identifying the contribution of the different species and sizes to the acoustic signal. Within the MADE European project these buoys are being tested to see if remote discrimination of by-catch species can

be possible, both by acoustic means and by different behavioral patterns of the species around DFADs. This objective will be achieved through:

i) Comparing biomass estimates of the echo-sounder buoy with that of the EK60 scientific echo-sounder
ii) Comparing species vertical distribution by means of acoustic tagging with the vertical stratification provided by the echo-sounder buoy.
iii) Comparing biomass estimates of the echo-sounder buoy with purse seiner real catches

If we are able to improve remote discrimination of by-catch species and/or sizes this would prevent fishers from conducting long trips to areas with high percentages of by-catch species and eventually making a set that should not been done.

Effects of DFADs on fish behaviour

Marsac et al. (2000) first proposed that DFADs could act as ecological traps, e.g. that artificial DFADs might affect the movements or spatial distribution of tunas. Hallier and Gaertner (2008) provided results which tended to show that DFADs could in fact affect the biology and movements of tunas.
If the ecological trap hypothesis occurs, this implies that natural movements of tunas and other species as dolphinfish, rainbow runner and wahoo maybe altered. Subsequently, DFADs could take these species to areas where environmental conditions are not good enough for them. The ecological trap phenomenon may occur when fish make the choice of remaining associated to an artificial DFAD despite being in a low quality environment.

Within Selectun and MADE projects, echo-sounder buoys are being monitored in real time in Atlantic and Western Indian Oceans. For each buoy position and date, remote sensing environmental data will be extracted (Chlorophyll-a, Surface wind stress speed, Sea Level anomaly, Sea Surface Temperature and light intensity) with the aim of relating environmental conditions along the trajectory of monitored DFADs with biomass evolution under DFADs. This experiment would allow understanding how different environmental conditions can affect biomass presence and absence around DFADs and eventually working towards the validation or rejection of the ecological trap hypothesis.

Preliminary results show the potential of this tool to study the pelagic ecosystem in an extensive, safe, effective and low cost way.

References

Castro, J.J., Santiago, J.A., and Santana-Ortega, A.T. 2002. A general theory on fish aggregation to floating objects: An alternative to the meeting point hypothesis. Rev. Fish Biol. Fish. 11: 255-277.
Dagorn, L., Holland, K., Dalen, J., Brault, P., Vrignaud, C., Josse, J., Moreno, G., Brehmer, P., Nottestad, L., Georgakarakos, S., Trigonis, V., Taquet, M., Aumeeruddy, R., Girard, C., Itano, D., Sancho, G. New instruments to observe pelagic fish arouond FADs : satellite-linked acoustic receiver and buoys with sonar and cameras. *In* Lyle, J.M., Furlani, D.M., & Buxton, C.D. (Eds.). 2007. Cutting-

edge technologies in fish and fisheries science. Australian Society for Fish Biology Workshop Proceedings, Hobart, Tasmania, August 2006, Australian Society for Fish Biology.
Girard, C. 2005. Étude du comportement d'orientation d'espèces pélagiques tropicales vis-à-vis d'attracteurs. Thèse de Doctorat de lÚniversité de La Réunion, 250p.
Hallier, J.P., Gaertner, D., 2008. Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. Mar. Ecol. Prog. Ser. 353, 255-264.
Marsac, F., Fonteneau, A., and Menard, F. 2000. Drifting FADs used in tuna fisheries: an ecological trap? *In* Le Gall J.-Y., Cayré P. and Taquet M. (eds.), Pêche thonière et dispositifs de concentration de poissons, Ed. Ifremer, Actes de colloques. no. 28, pp. 537-552.
Moreno G., Dagorn L., Sancho G., Itano D., 2007, Fish behaviour from fishers' knowledge: the case study of tropical tuna around drifting fish aggregating devices (DFADs). Can. J. Fish. Aquat. Sci. 64, 1517–1528.
Parin, N.V., and Fedoryako, B.I. 1999. Pelagic fish communities around floating objects in the open ocean. Fishing for Tunas associated with floating Objects, International workshop. Inter-American Tropical Tuna Commission (11): 447-458.
Taquet, M., Sancho, G., Dagorn, L., Gaertner, J.C., Itano, D., Aumeeruddy, R., Wendling, B., Peignon, C., 2007. Characterizing fish communities associated with drifting fish aggregating devices (FADs) in the Western Indian Ocean using underwater visual surveys. Aquat. Living Resour. 30**,** 331-341.

Estimating the rate of energy expenditure in red sea bream *Pagrus major* using an acceleration logger

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Introduction

Rate of energy expenditure is fundamental to understanding their ecology suchas life-history decisions. In aquaculture, an interaction between the rate of energyexpenditure and the rate of feeding affects gross profits of fish. However, estimatingenergy expenditure in field-settings, even in net-cages for aquaculture, is difficult infishes. Recently, it is suggest that accelerations obtained by data loggers correlate withthe rate of energy expenditure in free-living animals. In this study, we tested validity ofan acceleration logger for estimating oxygen consumption rate of an economicallyimportant fish, Pagrus major, in laboratory experiments.

Materials and methods

We measured the surge acceleration along the long axis of the body and thesway acceleration along the orthogonal axis from side to side of the surge axes.Sampling rates was programmed 32 Hz. For external attachment of the logger, twosmall holes (ca. 2 mm diameter) were drilled near the dorsal fin, and the logger wasattached on the right side of the body using two plastic cable ties trough the holes. Fishwas then placed in the swimming chamber and left undisturbed overnight at a watervelocity of 20 cm s-1. Each experimental run consisted of a 10 min period at each of thedesignated water velocities (0.6-2.6 BL s-1). Dissolved oxygen (DO, mg l-1) wasmeasured with an interval of 10 s using the handy DO meter (OM-51-L1, HORIBA Co.Ltd., Japan). Fish MO2 (mg kg-1 min-1) was calculated using the last 8 min of a 10 minDO monitoring period.The accelerometer can measure both dynamic acceleration (e.g. propulsiveactivities) and static acceleration (e.g. gravity). High- and low- frequency componentswere divided by filtering process, which removed the high-frequency component basedon flipper beat strokes measured by the 1.1 Hz low-pass filter. To determine thedominant stroke cycle frequency of the fish, the periodic properties of the accelerationsignal were analyzed. Power spectral density was calculated from the dynamicaccelerations using a Fast Fourier Transform. The dominant stroke cycle frequency wasdefined as the value obtained at the peak power spectral density for each experiment.Dynamic accelerations of each axis were converted to absolute values (in g).Means of time integral values of the absolute g for 1 min were calculated and were usedas estimator for MO2 (partial dynamic body acceleration [PBDA]). To examine the bestindex for estimating MO2, 4 types of PBDA (i.e., PDBAsurge, PBDAsway, Sum ofPDBAsurgeand PBDAsway, Square

root of sum of PDBAsurge2and PBDAsway2) werecalculated, and MO2 was then regressed against each PBDA. The coefficient ofdetermination (R2) and Akaike's Information Criterion (AIC) were calculated for eachliner regression to compare the estimative power of each PBDA on MO2.

Results and discussion

There was little difference in estimation power among each index (Table 1).One axis recording, is able to achieve relatively long-term recording, may be useful infield researches. However, difference in attachment angle of the logger amongindividuals is then likely to become an important issue for estimating MO2. Addition ofrecording axis may decrease this affect and the advantage was shown in our results.Nonetheless, coordinate system of the logger is still determined by attachment angle foreach individual. Therefore, the square root of sum of squares of each axis is likely to bebetter predictor of MO2 (Table 1).

Table 1. Values of *R2*and AIC of linear regressions with MO2 as the dependent variable for red sea bream.

Index	n	R_2	AIC
$PDBA_{surge}$	59	0.7399	155.353
$PBDA_{sway}$	59	0.7394	155.489
Sum of $PDBA_{surge}$and$PBDA_{sway}$	59	0.7477	155.572
Square root of sum of $PDBA_{surge^2}$and $PBDA_{sway^2}$	59	0.7488	155.324

The French Guina shrimp fishery: The efforts undertaken to reduce ecological impact

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Introduction:

French Guiana is located on the northeast coast of South America between the frontiers of Suriname and Brazil, with a coastline of more than 350 km and a EEZ of about 130,000 km². Its waters are particularly rich in organic matter and sediments due to the influence of the Amazon Delta and other rivers that discharge the long of the Guyanese coast. The fishing sector holds a primordial place at a regional economic level since it places itself in third of place (for exports) after the space and gold mining industries (Insee, 2008). In French Guiana, three primary fishing sectors have developed: industrial shrimp trawling, red snapper hand line fishery, and a coastal artesian gillnet fishery. Total production by the shrimping sector for the year 2008 is 2,239 tons for a fishing effort of 4,732 days at sea. A study of the graph below shows that there is a progressive reduction of fishing effort and therefore total production in time. However, considering the reduction in effort, the observed reduction in production is inevitable. It even seems that the ships have adopted intensification techniques of their fishing activity that has allowed for an improved production, since the fleet has been more than halved since 2000 and production has not collapsed.

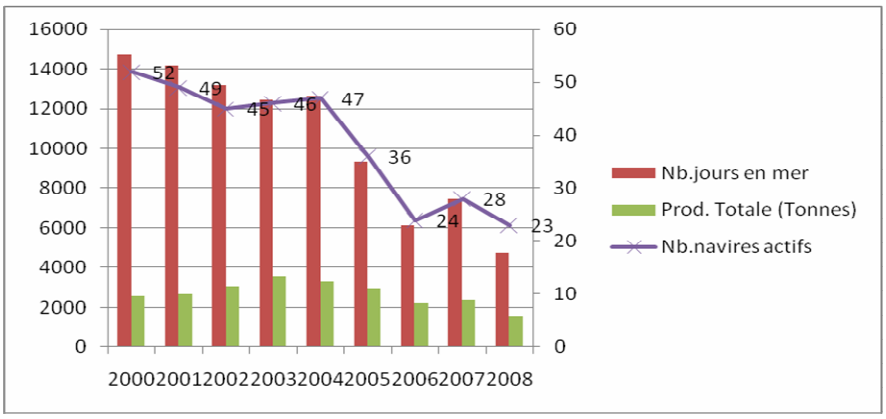

Figure 1: Evolution of the fishing effort and total production for the fishery from 2000 to 2008

The fishing boats are semi-industrial freezer trawlers. Their size varies between 23 and 22 m and their power ranges from 420 to 500 hp. The Guyanese trawlers have a capacity to hold 14 tons of shrimp in their freezers. This type of technique is called

"Florida-style twin rig bottom trawling". The bags of the nets have 45 mm mesh size, and they are reinforced with chafing gear of 90 mm around the bag.

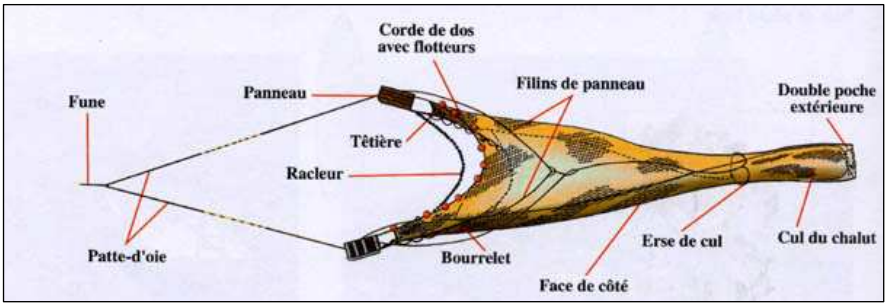

Figure 2: This drawing shows the different parts and characteristics of the shrimp trawl used in French Guiana (sources: Deschamps et al., 2003)

The fleet concentrates its effort on two primary species of shrimp: Brown (*Farfantepenaeus subtilis*) and Pink Spotted (*Farfantepenaeus brasiliensis*), both of which are present on the continental shelf. We can confirm that the fishery is mono-specific since 95% of the production consists of Brown shrimp. The shrimp of the continental shelf have been subject to European law since 1985. The principal characteristic of this regulation concerns a limitation of the TAC (Total Admissible Capture), the mesh size, and the fishing zone (Ifremer, 2006). In 2010 the TAC is set at 4,108 tones.

Global Impacts of Tropical Shrimp Fisheries:

Tropical shrimp trawling is generally considered one of the most nonselective fishing practices and having the most impact on the marine habitat. This document will evaluate some of the efforts put in place by different players within the fishing industry to attempt to minimize these impacts. First we will discuss environmental aspects and will follow with the socioeconomic impacts of the fishing industry. The fishing technique utilized by the shrimp industry is not selective (45 mm tail bag sweeping the seabed), and responsible for the capture of high levels of bycatch (up to 90% of the total catch). Seeing that the laws in place do not allow for the transformation of the bycatch and that much of the bycatch has no commercial value, the majority of bycatch is thrown back to sea. Ifremer performed a study in 2006 on the bycatch of the shrimp trawlers and evaluated the primary species comprising the bycatch. The four following species are often found in the bycatch: *Macrodon ancylodon, Ctenosciaena gracilicirrhus, Trichiurus lepturus, Herengula jaguana*. The use of bottom trawls for the capture of shrimp is also a major contributor the destruction of numerous marine habitats including the nursery grounds located in shallow waters between 5 to 15 m in depth. This phenomenon is particularly important in neighboring countries (Suriname and Guyana) that fish for Seabob shrimp (Xiphopenaeus kroyeri) in depths ranging from 5 to 25 m. This destruction may lead to the progressive exhaustion of the shrimp stock in the region. Oil changes at sea, the emptying of ballast water, and trash thrown to sea by the crew are other sources of pollutants that can affect the marine habitat, even if it doesn't only concern the shrimp fishery. In terms of ecological impacts and with the gradual increase of the price of fuel, filling up all the boats requires a considerable budget that may cause financial difficulties for the different companies present in French Guiana, especially since the price of fuel is the highest in the region, therefore the

companies do not send the boats fishing when the fesource is not present and less fuel is wasted looking for shrimp or to produce low yields of shrimp.

Measures Taken to Reduce the Impact of the French Guiana Fleet.

Following the results of studies conducted between 2005 and 2009 led in part by l'Ifremer (Institut Français de Recherché pour l'Exploitation de la Mer), in cooperation with the WWF (World Wildlife Fund), and later with the CRPMEM Guyane (French Guiana Regional Fisheries Committee), NOAA (National Oceanographic and Atmospheric Administartion), the DIREN (Direction Régional l'environement) and the French Guiana Region, a decree rendered obligatory the use of the TTED onboard all French Guyanese shrimp trawlers since the 1st of January 2010. The TED (Turtle Excluder Device) is a system that allows for the exclusion of marine turtles and also the capture of other mega fauna. Simply put, it consists of an inclined grill on which turtles slide to escape through an opening that is situated either towards the top or the bottom of the trawl. The opening is covered by a flap that prevents the escape of shrimp (Ifremer, 2006). The first TEDs were developed by the NMFS (National Marine Fisheries Service) of NOAA (National Oceanographic and Atmospheric Administration) in the 1980s. Since their creation the shrimping industry has invested it's time alongside the technologists to conceive new TED models with improved technical aspects (M. Nalovic, 2006). The first tests conducted by the CRPEME Guyane with different TED prototype led to the choice of the flat bar TED over the Pip-TED. The tests conducted in French Guiana follows the protocol described in the ICES manula of methods of measuring the selectivity of towed fishing gears. The tests were conducted under classic fishing conditions, the length of the toes and the fishing zones were chosen by the captain. For the last experiments three prototype TED's were tested. The prototypes were almost identical, only the spacing between the bars varied. These spacings were 43, 50 or 57 mm. The prototypes had the following characteristics:
TED Model = Supershooter TED, oval grill measuring 110 cm in width and 127 in length.
Bar type = aluminum and flat, with the rectangular section measuring 38mm and in depth and 6 mm in width.
This table is a summary of the results obtained for the three prototype TTEDs tested:

TTED spacing	Shrimp			Bycatch		
	In-shore	Offshore	Combinaison of both zones	In-shore	Offshore	Combinaison of both zones
43 mm	9%	-1,20%	2,97%	-27,21%	-30,33%	-27,98%
50 mm	2%	4%	2,51%	-3,14%	-26,55%	-8,50%
57 mm	2,70%	-1,90%	1,80%	-25,1%	-36,70%	-28%

Even though there is a difference in the results of the TED that had the bar spacing of 50 mm showing a reduction of only 3.14% bycatch, there is a tendency for the three prototypes evaluated. Not only is there a slight gain in shrimp production when combining the average from the different trials, but there is a reduction of bycatch ranging from 25 to 35%. The difference in the result for the trial of the TTED with 50 mm for the zone in-shore can be explained by the fact that the bycatch during this trial was comprised of small fish only. In fact, it can be noted that the three experiments were performed at different periods during the year 2008. Finally the TTED chosen by the industry to be installed on the Guyanese trawlers is the Flat-bar

supershooter TTED with 50 mm bar spacing. This system will allow the Guyanese shrimp fishery to reduce the sorting time and the risks associated with capturing sharks, stingrays, catfish and other non-desired bycatch.

Other Initiatives Taken to Reduce the Impact of the French Guiana Fleet.

There is a strict law that keeps shrimp trawlers from accessing the zone that is less than 30 m in depth. This law guarantees that the next generation of shrimp and fish are preserved. More recently in an attempt to reduce the fuel costs of the shrimp trawlers, some of the fleets have begun to equip themselves with more hydrodynamic doors, thereby reducing the drag of the doors and net, which in turn saves fuel and reduces the impact on the sea bed. To this effect the French Guiana fleet remains on the lookout for other developments in fisheries technologies that can improve the efficiency and reduce the impact of their activity.

Conclusion

In regard to the negative impact that the shrimping activity has on the marine ecosystem, it is apparent that the French Guianese fleet has gathered all of these efforts in an attempt to render the activity as least destructive as possible for the marine habitat and environments in general. It is crucial to maintain this activity because even though it may seem less important today in the economy of the region, it allows many families to make a living. These different projects put in place by the professionals will without a doubt help revitalize the shrimp fishery sector. In October 2010 the fleets decided to begin pre-evaluations to assess their capacity to acquire the MSC (Marine Stewardship Council) ecological label knowing that to this day no other tropical shrimp-trawling fishery has acquired this label. We would like to congratulate the industry on this additional effort aiming to recognize the different actions taken by the industry and its representatives to reduce the ecological impact of this industrial exploitation of shrimp in French Guiana. Finally during the last Marine turtle conference of the Guyana plateau; the Departments of fisheries of Surinam and Guyana have decided to evaluate the efficiency of TTED in their own tropical shrimp fisheries.

References

Anonyme. Pêcherie crevettière : vers une restructuration de l'activité. Antiane Guyane [en ligne]. Septembre 2008, N° 70. Disponible sur : http://www.insee.fr/fr/insee_regions/guyane/themes/ae_bilan/aes70gy/aes70gy_art09.pdf

Deschamp G. Les chaluts: IFREMER, Edition Quae 2003.

Baudrier J, Vendeville P, Rosé J, Achoun J. Evaluation du volume des captures accessoires et des rejets de crevettes par observateurs embarqués. Cayenne : Rapport final IFREMER, Mai 2006. 51p.

Nalovic M.A. Rapport destiné aux armements crevettiers de la Guyane Française sur l'utilisation actuelle de TED dans les Amériques. Cayenne : Rapport technique OPMG, Déc.2006. 20p.

Energy efficient optimisation method for bottom trawl

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Abstract

Drag substantially impacts bottom trawl energy efficiency. During fishing operations the swept area by the trawl plays also an important role not only in the determination of energy efficiency but also in the quantity of the fish caught. Introducing a model using a finite element method adapted to fishing nets, we have developed a constrained optimisation tool that starts from a reference design of the trawl and modifies it step by step by selecting the best one satisfying the best drag to swept width ratio.

Key words: Fishing gears; bottom trawl; modelling; optimisation; fuel consumption; drag; swept area.

Introduction

This work describes a numerical optimisation tool for the design of bottom trawl such that its panels are cut in order to decrease fuel consumption. With the help of a finite element method adapted to fishing nets, the constrained optimisation tool is tailored to proceed through a step by step route to modify the trawl design starting from some reference model. This means that for each design, we perform the full energy evaluation simulation and finally select the best result according to the resulting drag over swept width value. We show in the sequel how this tool offers potential saving in fuel consumption since it reduces drag. Moreover it leads to a moderate increase of catch volume while decreasing the number of fishing trips.

Method

The optimisation objective

The energy required annually during the hauls is due to the drag (D) and the annual distance of the hauls (L). If we accept that the efficiency of the propulsion system is known (□) as well as the heating capacity of the fuel (hf), the fuel volume (Vf) can be assessed by the following relation:

$$V_f = \frac{D\,L}{\eta\, h_f}$$

V_f: Fuel volume used per year (m^3),
D: Drag of the gear (N),
L: Towed distance per year (m),
η: Propulsion efficiency, often close to 0.1,
h_f: Heating capacity of fuel, around $36GJ/m^3$.

An improvement of fishing gear must be carried out without damaging the quantity of fish caught per year (F):

$$F = W\ L\ T_c$$

F: Fish caught per year (kg),
W: Swept width of the bottom trawl (m),
L: Towed distance per year (m),
T_c: Trawl catchability (kg/m^3).

The gear improvement is intended to decrease the ratio between the fuel consumed and the fish caught:

$$\frac{V_f}{F} = \frac{D}{W}\frac{1}{\eta\ h_f\ T_c}$$

Since it is expected that the parameters □, hf and Tc are constant, that means not affected by the optimisation process, the optimisation leads to a decrease of the ratio D/W where W is the swept width of the trawl and D its drag.

Optimisation process

Because the trawl drag is mostly due to the netting we have developed a novel Successive Optimisation Tool (SOT) which affects the panel cutting in order to reduce the D/W ratio and adapted to the bottom trawl problem. It works on the basis of successive structural modifications in the trawl design.
The optimisation tool modifies a parametric vector representing all the nodes of the net step by step until it finds the best solution that minimises an objective function.
The modifications involved are brought into the parameter vector components one by one in mesh units, leaving the other components unchanged and equal to their starting value. In addition, the modifications are applied with opposite signs successively on couples of vectors.
The optimization modification proceeds along the following strategy:
a- Starting from the reference model (Figure 3 and Figure 4), we perform a first optimisation with a given Modification Size (MS) [**Erreur ! Source du renvoi introuvable.**]. The latter defines the size of the horizontal/vertical modification with respect to the panel length (in mesh units) along the horizontal/vertical direction.
b- After the first optimisation, we perform another one with respect to the results found (and not with respect to the reference model). Thus MS varies according to the following set from which we select the best ratio (drag to swept width): 32%, 16%, 8%, 4%, 2% and 1%.

Bottom trawl

The design of the bottom trawl, which is used on a research vessel [**Erreur ! Source du renvoi introuvable.**], is displayed in Figure 3, the rigging is not represented. This trawl is used at a 80m depth with warps of 215m and bridles of 36.6 m. The towing speed is 1.69m/s. The swept width is defined here, as the mean spread between the bottom and the top wing ends.
The calculated drag of the reference trawl is 63 kN and the swept width is 22.3 m, which gives a drag per swept width equal to 2840 N/m. The shape of the reference trawl is on Figure 4.

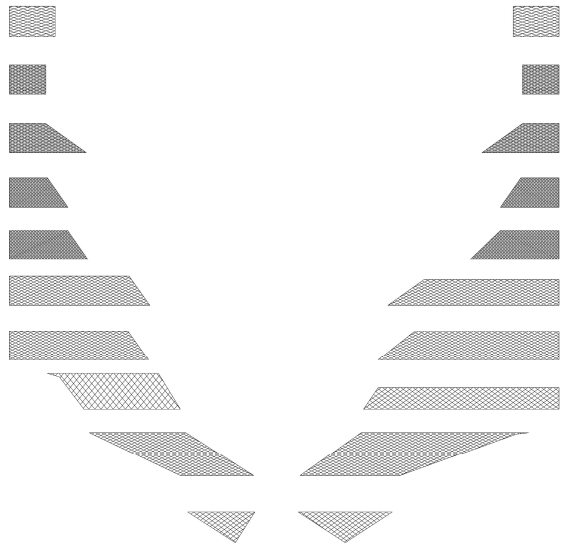

Figure 3. Netting panels of the reference bottom trawl. Due to the symmetry of the trawl only half parts of the back and the belly are presented. Due to the large number of twines only 1 twine out of 5 is drawn.

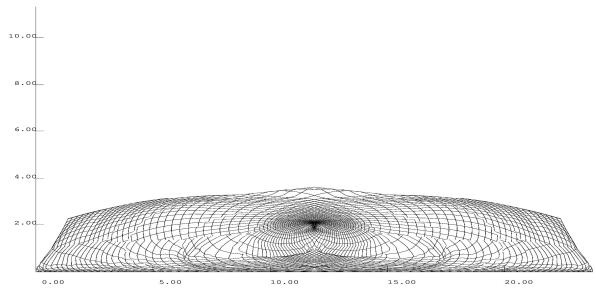

Figure 4. Front view shape of the reference trawl, we display in the figure only the netting. Only 1 twine out of 10 are drawn.

Potential time and money savings

The potential time and money savings generated by this optimisation are evaluated on the following assumptions:

(i) The quantity of fish caught per year with the optimised trawl is expected to be the same as that with the reference trawl, which means the same swept bottom surface for both trawls, on the assumption of a constant density of fish and a constant catchability.

(ii) The efficiency of the engine and propeller equals 10%, the energy per litre of fuel equals 10.70 kWh and the fuel costs 0.6€/l. These values may be considered as acceptable for 2010.

(iii) The duration of trawling of the reference trawl per year is 21h 36’ per day during 260 days. This duration is calculated from usual week trip where each haul consists in 3h of trawling and 20’ of hauling operations.

Results

Optimisation process

The best results are obtained for a modification of 32% from the objective function point of view and subsequent fuel consumption reduction (38%). Due to the vertical opening (1.8m) which is considered to be too small the case (32%) is rejected. For the same reason the 16% case is rejected (vertical opening of 3m) as well. Finally the 8% case is selected: Sizeable reduction of objective function (17%) and quite large vertical opening (3.8m). The corresponding shape is shown in Figure 6 and in 3D in Figure 7. The design is shown in Figure 5.

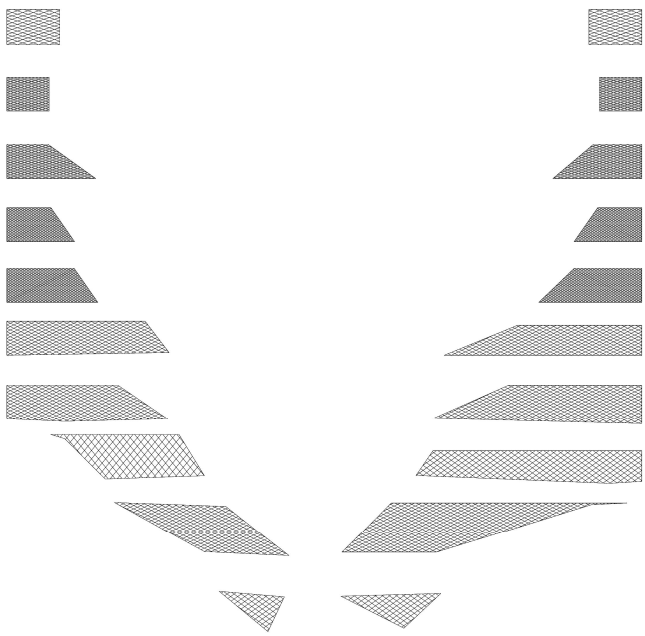

Figure 5. Design of optimised trawl. Only 1 twine out of 5 are drawn.

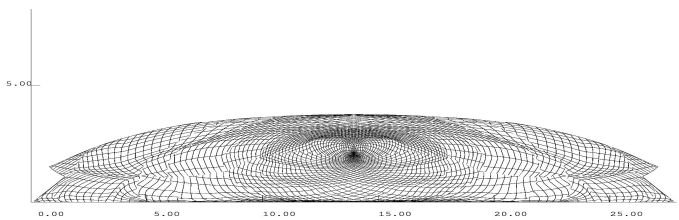

Figure 6. Front view shape of the optimised trawl, we display in the figure only the netting. Only 1 twine out of 10 are drawn.

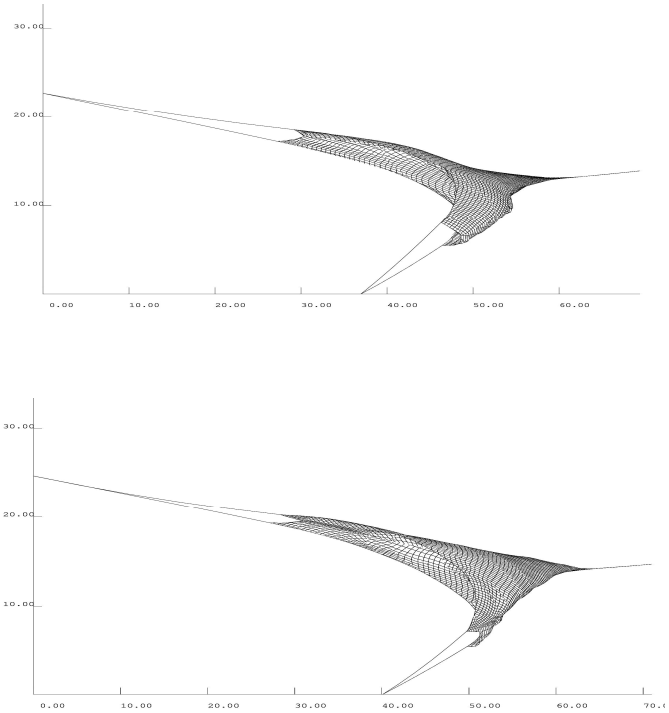

Figure 7: 3D aspects of the reference bottom trawl (top) and the optimised one (bottom). Only 1 twine out of 10 are drawn.

It can be seen on the design (Figure 5) that few panels have been modified relatively to the reference one (Figure 3). It is clear also that the shape of the optimised trawl (Figure 6) is close to the reference one (Figure 4).
The optimised trawl has a larger swept width (27 m) than the reference one (22.3 m), however. That means a potential increase of fishing catch leading to a decrease in the number of fishing trips.

Potential time and money savings

The main results, in terms of time and money savings, for the two bottom trawls (Shape of the reference trawl in Figure 4 and the optimised one in Figure 6) are displayed in Table 1. With the previous assumptions, and considering the same swept surface per year for both trawls, the duration per year is decreased by 45 days with the optimised trawl and the expected economy of fuel cost may amount to 54,000€ per year.

Table 1: comparison of the reference bottom trawl with the optimised one in term of time at sea and fuel cost.

	Reference trawl	Optimised trawl
Trawl drag (kN)	63	64
Trawl swept width (m)	22.3	27
Towing duration (days/y)	260	215
Towing distance (km/y)	34168	28222
Swept surface (km^2/y)	762	762
Drag energy (MWh/y)	598	502
Fuel volume (m^3/y)	559	469
Fuel cost (€/y)	335400	281400

Conclusion

In this work we describe a optimisation tool proper to bottom trawls based on a selective method targeting minimisation of drag to swept width ratio while keeping the same swept area per year. We find fuel consumption is improved by 17% with the optimisation tool.
Since fishing industry regulations impose quotas regarding the total quantity of fish caught during a well defined period of time as well as the optimisation tool (SOT) introduced in this work, temporal presence at sea should be reduced in order to have the same swept area per year between the reference trawl and the optimised one.

Acknowledgement: The authors would like to thank the European Fisheries Fund and the French Ministry of Agriculture and Fisheries for funding this field of research.

References

Priour, D., 2009. Numerical optimisation of trawls design to improve their energy efficiency, Fisheries Research, Volume 98, Issues 1-3, June 2009, Pages 40-50.
Anonymous, 2000. Development of predictive model of cod-end selectivity. Final report to the European commission of the RTD project Fair Program CT96 1555.

«MADE» Project: Methods to release Elasmobranches from purse seine

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Abstract

The primary objective of the MADE (Mitigating ADverse Ecological impacts of open ocean fisheries) project is to propose measures to mitigate adverse impacts of fisheries targeting large pelagic fish in the open ocean (purse seiners using Fish Aggregating Devices and longliners), through appropriate knowledge on the biology and ecology of species, and of the fisheries. A cruise onboard a commercial purse seiner was performed in the Atlantic Ocean in order to define the terms of reference of new methods and technologies to facilitate release after capture and ensure their survival. During the cruise conditions faced by sharks and rays were partially documented. The first observations of current practices on elasmobranches are presented and preliminary proposal of best practices to improve survival of released sharks are presented.

Introduction

The tropical and sub-tropical European pelagic fisheries constitute important components of European fisheries; they are performed by French, Spanish and Portuguese long-liners and purse-seiners in the Atlantic, Indian and Pacific oceans and in the Mediterranean (+ Greece and Italy). Beside the target species, these fisheries are responsible for by-catches of young tunas and sharks, particularly in purse seine fisheries using Fish Aggregating Devices (FAD). In the frame of responsible fisheries, a question arose: how to evaluate and reduce the impact of these fisheries on the environment?

The research programme MADE (Mitigating ADverse Ecological impacts of open ocean fisheries) was designed to answer this question by the means of increasing our scientific knowledge on the biology and ecology of these species and on the fisheries. MADE is the acronym for Mitigating adverse ecological impacts of open ocean fisheries. About 60 scientists from 13 institutions of 8 countries are involved in MADE. It is a 4-year programme with a budget of 3 millions Euros, managed by IRD.

The originality of the MADE research programme is the participatory approach. Indeed, scientists and stakeholders work together to share their mutual experiences. We have regular exchanges and workshops. The involvement of the fishing industry is also made thanks to joint actions with the International Seafood Sustainability Foundation or ISSF that is developing a similar initiative in the Pacific.

Observations at sea

Purse-seine fisheries use different strategies to catch tunas. They can set their seine on free-swimming school, or on schools associated with various floating objects that can be natural like tree logs or artificial.But these fisheries use more and more fish aggregating devices or FADs. Commonly a FAD is a raft made in bamboo with pieces of nets hanged underneath, and it is equipped with an echo-sounder buoy attached to the raft that transmit to the vessel estimates of the quantity of fish around the FAD.In attracting fishes, FADs modify their behaviour. That is why FADs have the greater impact on both target and by-catch species in these fisheries.Among sharks, the most commonly caught on FADs are the silky shark (*Carcharhinus falciformis*) and oceanic whitetip sharks (*C. Longimanus*).

Several cruises were scheduled to be done onboard French purse seiners in 2009 in the Indian Ocean but were delayed, then cancelled due to piracy risk (Somali pirates). However, a three week cruise was performed in the Atlantic Ocean this year (Feb-Mar 2010) in order to define the terms of reference of new methods and technologies to facilitate release after capture and ensure their survival. Conditions faced by sharks and rays during the different phases of the fishing operations, and catch processing were analyzed. The terms of references of new methods/strategies include the following points: avoiding the entrapment of elasmobranches in the purse seine, facilitating their release after the capture and reducing. their mortality after release.

During the fishing process, fishers interact with different “categories” of elasmobranches that range widely in sizes, weights and shapes, and exhibit various states of dangerousness for the crew. For these reasons, solutions would need to be considered carefully, on a case-by-case basis (Table 1).

Table I: Categories of elasmobranches captured by purse seiners, with corresponding risk for the crew.

Categories	Weight	Length	Width
Large whale sharks	300 kg-3 tons	4-9 m	-
Medium whale sharks	100-300 kg	3-4 m	
Large rays	~ 1 ton	-	> 2 m
Medium rays	30-70 kg	-	< 2m
Small rays (stingray)	~ 2 kg	-	-
Large sharks	>20 kg	>1.5 m	-

The first observations of current practices on elasmobranches are presented and best practices to improve survival of released sharks and rays are proposed. Also designs of devices to handle sharks and rays without damaging them and safe for the crew

were elaborated. These measures will be proposed to the fishermen, and those that will be retained, will be tested to be validated.
Also recommendations are done such as the ban of setting on whale sharks and not towing of sharks & rays to avoid damaging their vertebral column (Fig. 1).

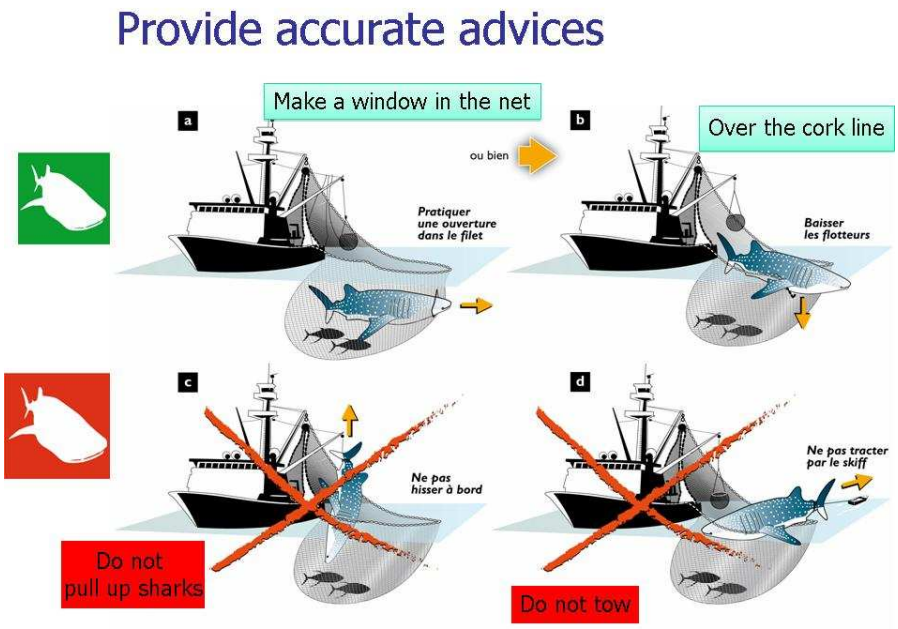

Figure 1: Best practices proposed to release whale sharks from the bunt.

Forthcoming researches include the estimate of the survival rate of released sharks using pop-up tags and the testing of the prototypes of the devices.These operations will be carry out on board of commercial purse-seiners and during the 24 month experimental cruise organised by the International Seafood Sustainability Foundation (ISSF).

Conclusion

MADE scientific programme performed in collaboration with the fishing industry shows that scientists and fishermen are strongly motivated to find methods and tools to mitigate the number of sharks killed by the tropical tuna purse-seiners.

Acknowledgements

We would like to express our deepest gratitude to the fishing company CMB, the skippers and crews who volunteered to allow us on board their vessels, and to all people involved in the preparation of the trips. These researches were supported by the European Commission (MADE programme)

Parasitic infections observed in artificially bred Pacific bluefin tuna, *Thunnus orientalis*

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Abstract

Growing interests in aquaculture of bluefin tuna have led to significant increase in tuna culture production worldwide. The establishment of complete culture of Pacific bluefin tuna at Kinki University further promotes the tuna culture industry in Japan. Following the increase of tuna farming, parasitic infections have become problematic, especially among juvenile tuna. At Kinki University, tuna seedlings were raised in specific pathogen free land based tanks for about a month and then transferred to cages in the open sea. In the past, there have been cases of mass mortality of juveniles due to parasite infections after the fish had been moved to the sea cages. In the present study, we investigate the parasites infecting cultured tuna in order to develop control measures against these pathogens. Juvenile tuna were checked for parasite infections on several occasions after fish had been transferred to the sea cages. After about one month in the sea cages, deposition of parasite eggs was observed in the gill lamellae, and adult sanguinicolid blood flukes were found in the afferent branchial arteries. This parasite was morphologically identified as *Cardicola orientalis*, a recently described blood fluke in Japan. Later in the season, a second species of blood fluke appeared in the heart ventricle. Based on the morphological and molecular analyses the second species is considered as a new species of the genus *Cardicola*. In addition, several myxozoan parasites were observed in cultured tuna. In the brain, *Kudoa yasunagai* infection was observed in nearly half of sampled fish. Besides, another *Kudoa* was observed in the brain and it was considered as a new species. There was a significant geographical difference in infection of these parasites. Possible pathogenicities, significance in tuna culture and possible control measures will be discussed.

Dynamic analysis in the development of offshore net-cage aquaculture system for bluefin tuna by using computer simulation system NaLA

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Abstract

It is necessary to develop new technologies to construct large offshore aquaculture facilities for blue tuna in Japan. An analysis system that is used for studying the loading and deformation of net structures is employed to develop an aquaculture facility; the system involves the used of a computer simulation system—NaLA—developed by the authors and the consideration of specific wave and current flow conditions. We also quantitatively determine the amount of accumulated periphyton on the net and rope. These values can be useful for the pragmatic estimation of large loads and large deformations at the facility through computational simulation. The apparent increase in the diameter of the net bar when it is soaked for 34 days is 75%. For a current flow rate of 40 cm/s, when the apparent area increase on the net is 75% due to the periphyton, the load is greater than that in the absence of the periphyton by 16%. However, the inner volume of the net cage is significantly affected; it is reduced by more than 40% due to the increase in the fluid force acting on the accumulated periphyton on the net.

Key words: bluefin tuna, net cage, aquaculture, numerical simulation, periphyton accumulation

Introduction

Since clear sea water and large space are essential for bluefin tuna cultivation, it is necessary to develop new technologies to construct large offshore aquaculture facilities for blue tuna in Japan. However, to construct a large aquaculture facility in an offshore area, it is necessary to develop a robust design so that the facility is resistant to waves and current flows. Thus, to develop a new submergible aquaculture facility that would be an improvement over the conventional one, we carried out dynamic analysis of how the wave and current flow influence the deformation and loading on the facility. For this, we used the numerical simulation system NaLA. NaLA is a computational simulation system used for designing fishing gear, and it can estimate the geometry and the loading on the gear underwater.

The aquaculture facility cannot avoid the accumulation of periphyton on the net and rope since the net is soaked for a long period. Periphyton accumulation leads to an apparent increase in the area, mass and volume of the net, therefore, the inertia force and fluid dynamic force on the facility can increase because of the accumulation. This can damage the facility under strong current flow and strong wave conditions. In the computer simulation, we determine the amount of periphyton that can be accumulated on the net cage, along with the associated increase in the area, volume, and mass from observed data *in situ*. Therefore, the dynamic impact on the aquaculture facility due to current flow and waves can be more realistically-estimated by using NaLA.

Figure. 1: Experimental site.

Material and Method

The prototype of an offshore net cage used in this study has raft frames that have diameters of 30 m and 50 m, and they will be set in the vicinity of Kahiwajima Island at the south-western end of Shikoku, Japan (Fig.1). Tuna aquaculture farming was conducted in the area a few decades ago. Some conventional types of aquaculture facilities for tuna have been constructed behind the island to avoid wave impacts. However, since the prototype net-cage will be set off the island, it is expected to be directly affected by wave impact resulting from the seasonal wind from the northern direction. The new facilities have a double-torus-shaped raft frame that hold the side panels of the net. The mooring lines are connected to the raft frame via shock-absorbing lines to avoid the impact force due to waves. Thirteen mooring lines, which are 36mm in diameter and 300 m in length, are firmly tied to a support. The raft frame can be submerged or brought to the surface by charge-discharging air in the raft frame by a air-compressor. The facility was numerically modelled using the lumped-mass method; the rope and net can be represented by many mass points and springs. The computational model can be expressed by the following equation:

$$\frac{1}{2}\sum_{j\in L(i)}\left(\mathbf{m}_{ij}+\mathbf{C}_{ij}\cdot\Delta\mathbf{m}_{ij}^{l}\cdot\mathbf{C}_{ij}^{T}\right)\ddot{\mathbf{x}}_i=\sum_{j\in L(i)}\left[\mathbf{T}_{ij}^{g}+\frac{1}{2}\left(\mathbf{C}_{ij}\cdot\mathbf{F}_{ij}^{l}+\mathbf{W}_{ij}^{g}+\mathbf{B}_{ij}^{g}\right)\right] \tag{1}$$

where $\mathbf{m}_{ij}$ is the inertial force term, $\Delta\mathbf{m}_{ij}$ is the additional mass force, $\mathbf{T}_{ij}$ is the tension force, $\mathbf{W}_{ij}$ and $\mathbf{B}_{ij}$ are the gravitational and buoyancy forces, and $\mathbf{F}_{ij}$ is the drag and friction force due to the fluid on the each element (Takagi et al. 2007). $\mathbf{C}_{ij}$ is the inertia transformation matrix used for transformation from the local to the global coordinate system. As the equation system is of the second-order ordinary differential type, the solutions can be obtained using a numerical integration scheme. The maximum wave height and the current flow speed data observed *in situ* can be specified as the numerical constraints to calculate the loading and determine the geometry of the facility.

To evaluate periphyton accumulation on the net cage, a rectangular net panel with dimensions 40 cm × 40 cm was set depths of 2 and 12 m, and its wet weight and the projected area were measured after it was soaked. The net panels were set both in the vicinity of the existing facilities in the coastal area and the prototype in the offshore area in June 2008. It is possible to use the increase in the projected area inferred from *in situ* measured data and caused by periphyton accumulation to estimate the apparent volume and mass; this volume and mass can then be used in the numerical simulation.

Results and Discussion

The maximum current speed and wave height were 0.54 m/s and 3.48 m, respectively, during the observation period. The direction of movement of both the current and wave was southeast. The computational results indicated that the maximum load on the mooring line and shock-absorbing line was 12 tf and 8 tf, respectively.

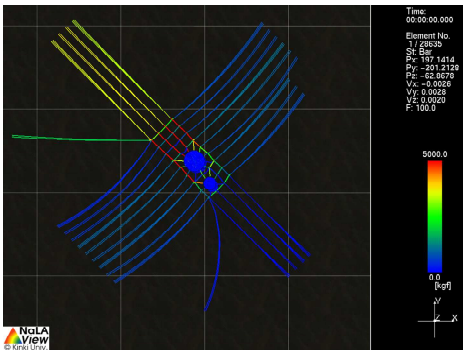

Figure 2: Top view of the prototype facility for tuna aquaculture constructed in the numerical simulation. The color indicates the magnitude of loading.

In case of coexistence of wave and current flow, although the loading on the mooring lines when the raft frame is submerged is less than that when it is at the surface, the load on the shock-absorbing lines when the raft frame is submerged is greater than that when it is at the surface. It is considered that the gravitational force on the net cage and raft frame is the reason for this. The lines with the largest loading force are determined by the current direction; the loading on the mooring lines on the upstream side is larger than that on the other lines. Thus, the computer simulation result indicates elements, which construct the facility, that should be reinforced or removed. The deformation of the net cage is affected more by the current than by the incident waves. The inner volume of the net cage of 30 m diameter raft frame was reduced by 20%.

The increase in the ratio *Ri*, which is the projected area of the soaked net cage divided by the initial area, are presented in Table 1. The apparent area of the net soaked after a period of 13 days at the depth of 2 m is 2.3 times the initial area in the coastal area and 1.3 times the initial area in the offshore area, due to periphyton accumulation. However, in the offshore area, the amount of periphyton accumulated on the net at the depth of 12 m is more than that in the coastal area. It is possible that net panel oscillations caused by waves lead to a lower amount of periphyton. The computer simulation for the 30 m net cage was carried out by taking into account the periphyton accumulation for *Ri* values of 1.45 and 2.23, determined from observations. The loading on the mooring line for *Ri* = 2.23 is larger by 19% compared to the initial condition for a current flow speed of 40 cm/s, but the inner

volume is remarkably reduced by 53%. This increases the possibility of the net cage impacting the cultivated tuna.

Table 1: Relationship between *Ri* and the soaking period of the net panel 2m and 12m depth.

Soaking period (days)	Increasing ratio *Ri*			
	Coastal region		Offshore	
	2m	12m	2m	12m
13	2.27	1.49	1.27	1.66
34	2.49	2.32	1.59	2.44

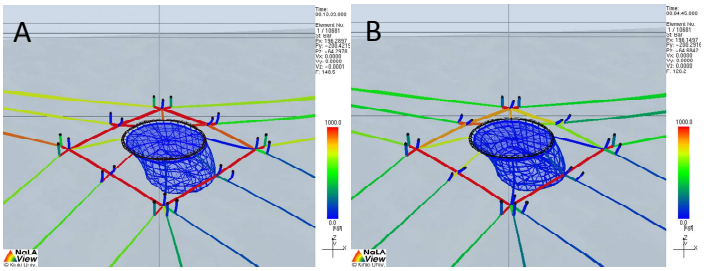

Figure 3: Net cage geometries at the tuna aquaculture facility for a current flow of 40 cm/s estimated using the simulation system. A indicates the absence of periphyton accumulation and B corresponds to *Ri* = 2.23.

Acknowledgements

We thank all the participants of the project for their contribution to the promotion of tuna aquaculture. This research was financially supported by Furuno Electric Co., Ltd., and the Association of Marino-Forum 21.

References

[1] T. Takagi, T. Shimizu and H. Korte, “Evaluating the impact of gillnet ghost fishing using a computational analysis of the geometry of fishing gear”, ICES Journal of Marine Science, **4** , 1517-1524, 2007.

Three-dimensional monitoring of free-swimming Pacific bluefin tuna cultured in a net cage using a digital stereo-video camera system

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Abstract

A digital stereo-camera system was used for 3-dimensional monitoring of cultured Pacific blufin tuna individuals, which were free-swimming in a net cage. Fork lengths, length frequency distribution and total countable number of tuna individuals in a net cage were estimated using the DLT (Direct Linear Transformation) method. The information of those obtained from stereo-images is required for the managers of fisheries industries to manage the cultivated fish during tuna culture. Although such methods have been too complicated and specialized, we are trying to develop the simple method of 3-dimensional measurements applied to the aquaculture, generally. Furthermore, we tried to develop and improve the simple and generalised method of 3-dimensional monitoring for free-swimming tuna in a net cage. This study is a first trial to develop monitoring cultured fish using a stereo-camera system, although the estimation using this tool helps to manage aquaculture. Considering the influence of wave and current in the sea during actual monitoring, we have to check the accuracy and precision of this measurement in the next step.

Key words: 3-dimensional monitoring, bluefin tuna, stereo-camera, aquaculture, DLT method

Introduction

The information of fish size and the frequency distribution, and total number of fish cultured in a net cage obtained from stereo-images is required for the managers of fisheries industries to manage the cultivated fish during tuna culture. Although such methods have been too complicated and specialised (Harvey et al., 2003), we are trying to develop the simple method of 3-dimensional measurements applied to the aquaculture, generally.

The problems and difficulties of 3-dimensional monitoring consist of the way of fixing the stereo-camera system in the sea (world coordinate system) and of distinguishing each individual, so that the essential problems are same among all methods. In other words, our simple method doesn't have a disadvantage in this point of view. Based on those issues, there have been no practical methods for counting the total number of free-swimming fish individuals in a net cage. The method for counting whole number of cultivated fish individuals can be applied only to the transfer of fish using a fish tunnel such that each fish passes through the recorded area once in a one-way swimming excluding going around and returning (Costa *et al*., 2009).

Therefore, we tried to develop and improve the simple and generalised method of 3-dimensional monitoring to measure fish size and total cultured fish numbers for free-swimming tuna in an aquacultural net cage. This study is a first trial to develop monitoring cultured Pacific bluefin tuna *Thunnus orientalis* using a stereo-camera system, although this estimation using this tool helps to manage aquaculture. Considering the influence of wave and current in the sea during actual monitoring, we have to check the accuracy and precision of this measurement in the sea near future.

Material and methods

We monitored tuna cultured in an ellipsoid net cage (length and width: 60m and 90m) on 26th June and 21st November 2009, using a digital stereo-video camera system, which is comprised two digital video cameras (HDC-SD100, Panasonic) in underwater housings mounted a steel frame as a stereo pair. Then the stereo-images of free-swimming tuna in the aquacutural net cage were recorded with 30 fps at 2, 4, 6 and 8-m depths for 5 minutes, respectively. Tilt and bearing angles and set depths of the system were also measured to check the stability of camera system, using the logger (DST-comp-tilt, Star-oddi). Light intensities at 0, 2, 12 and 22 m depths were simultaneously measured with Pendant-light loggers (Hobo).

At the beginning of recording stereo-digital images, calibrations were performed using a 60cm-length cubic calibration frame. Then we analysed three-dimensional positions of snouts and forks of tuna individuals from the stereo-images during stable stereo-camera system conditions, using DLT (Direct Linear Transformation) method. Ten time series data were used for the analysis at each depth [duration: 1.5 seconds (45 frames / 30 fps), interval: 15seconds].

Results and discussion

Based on the results of the calibration, mean and maximum errors of calculated 3D positions from the still stereo-images in June and November were 1.6 and 3.0 %, and 0.6 and 1.2 %, respectively, so that our estimated results using DLT method are sufficient to provide the information of fish size to fisheries industry.

During the first monitoring in June, tuna individuals showed typical free-swimming. However, during the second monitoring in November, the staffs of aquaculture industry were supplying the food to cultivated tuna, so that tuna individuals didn't show an ordinary swimming pattern. Consequently, the results of swimming characteristics are different among them. However, body lengths can be calculated, and then mean body length and standard deviations in June and November were determined as 760±110 mm and 1350 ±120 mm, respectively.

The relationships of swimming depths and body lengths were shown in Fig. 1 and 2.

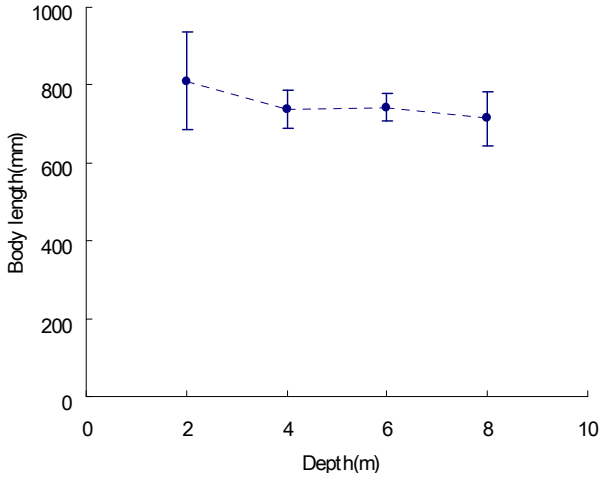

Figure 1: Relationship between swimming depths and body lengths (mean±SD) of cultured tuna in Jun. 2009

In June, larger size with large deviation tuna swam at the narrower depths and smaller tuna swam at shallower depths. On the contrary, such a tendency could not be shown during feeding in November.

Furthermore, size frequency distributions of tuna in both monitoring were obtained and shown in Fig. 3. In average size of 760mm tuna in June, the mode is 700-750mm and there is no fish smaller than 650mm. On the other hand, the range of tuna in November, mode of which is 1300-1350mm, widely spreads from 1100 to 1550mm. These results indicated that the tendencies of length frequency distributions are different during growth.

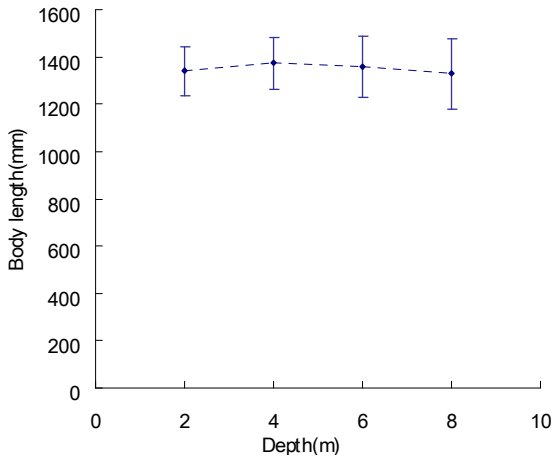

Figure 2: Relationship between swimming depths and body lengths (mean±SD) of cultured tuna in Nov. 2009

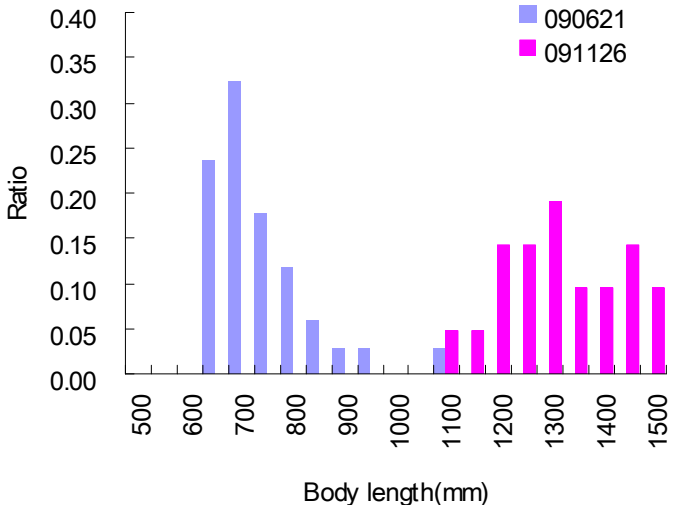

Figure 3: Relative frequency distributions of body lengths of tuna in Jun. and Nov. 2009.

Our results suggest that this monitoring system helps to manage appropriate fish aquaculture. In the next step, however, we have to determine the accuracy and precision of the calculated values under sea conditions.

References

C. Costa, M. Scardi, V. Vitalini and S. Cataudella (2009): A dual camera system for counting and sizing Northern Bluefin Tuna (Thunnus thynnus; Linnaeus, 1758) stock, during transfer to aquaculture cages, with a semi automatic Artificial Neural Network tool. Aquaculture 291, 161–167.

E. Harvey, M. Cappo, M. Shortis, S. Robson, J. Buchanan and P. Speare (2003) The accuracy and precision of underwater measurements of length and maximum body depth of southern bluefin tuna (Thunnus maccoyii) with a stereo–video camera system. Fisheries Research 63, 315–326.

Visibility range of juvenile Pacific bluefin tuna (*Thunnus orientalis)* related to the turbidity and the color sensitivity in the net-cage

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Abstract

Recently, culturing Pacific bluefin tuna in Kinki University is coming to the forefront of aquaculture. However, mass production remains out of reach due to the high mortality of bluefin tuna in larvae and juvenile stages. A major cause of this mortality is collision or contact between fish and the walls of the tanks. However, even after being moved to net cages, this phenomenon continues to be observed. Fish generally recognize an object by detecting the contrast in luminance between the object and its background. This luminance is reduced under conditions of turbidity. Therefore, the distance at which bluefin tuna can recognize the net may be affected by the turbidity of the water. However, the relationship between the visibility range of bluefin tuna and water turbidity has not been investigated. At the Fisheries Laboratory of Kinki University, using video camera as a substitute for fish eye. we investigated the relationship between the visibility range and water turbidity by transparency and measuring the extinction coefficient of luminance under ocean conditions. The visibility range was observed to decrease with increasing extinction coefficient of luminance. Therefore the visibility range of bluefin tuna might be affected by turbidity in a similar manner. In addition, the behaviour of juvenile bluefin tuna in net cages was observed by a video camera. The relationship between the behaviour of juvenile bluefin tuna and water turbidity in the net cages will be discussed. How do bluefin tuna see the twines of the net-cages in the ocean? Bluefin tuna have sensitivity peak around 480 nm (blue-green colour) (Matsumoto et al., 2009). We are also investigating on how bluefin tuna see the twines using mounted 5 band-pass interference filters (420, 450, 480, 510, 540nm wavelengths) on the front of video camera. (Reference: Matsumoto et al. (2009) *Biol. Bull.* 217: 142-150).

Proteomic approach to investigate alterations, within physiological limits, in serum protein of sea bass (*Dicentrarchus labrax*)

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Introduction

The aquaculture fish production will continue to expand and the perception of aquaculture rearing systems are often associated to high stocking density in tanks. Today, consumer demand for safe and ethically defendable food products is increasing. Production systems must consider animal welfare, which depend on good husbandry practices. Previous studies analyzed the effect of stocking density on biological performance in the growth of fishes. Generally high stocking density is considered as a potential source of stress, with a negative effect. Biological indexes and blood parameters, such as plasma cortisol and glucose level can be used to measure the potential effect of stocking density on fish performance and welfare. Alterations in total serum protein (TSP) concentration are used as a broad clinical indicator of health, stress, and well being of terrestrial and aquatic organisms. TSP was also used to determine crowding stress in trout. Two studies of protein panel modification in sera by chromatography were published. One concerning brown trout injected with PBS and the other, sea bass stressed by ammonia, they permitted to precise modification indiscriminate by TSP. Genomic approach was recently used and shown that increase of stocking densities affect gene level expression in sea bass. Proteomic approaches were recently used on fish tissues by using either 2D electrophoresis and MALDI-TOF3 or SELDI-TOF4 to investigate panel and variation of type of fish tissue proteins. In this experiment, the effects of a high stocking density (100 kg m-3) were monitored on sea bass with all water parameters maintained at non limiting levels. The global results were, alteration of swimming behavior, feed intake, growth rate and respiratory activity. Blood parameter analyses do not change and no conclusive difference in TPS was found. Actually TPS level can discriminate high modifications in rearing conditions, but it cannot detect low alterations, within normal limits (welfare) like high stocking density.
In order to discriminate those situations, serum protein panels were investigated by 2 proteomic approaches: SELDI-TOF on protein lower than 20 kDa and 2D electrophoresis followed by LC-MS-MS identification on proteins from 15 kDa to 250 kDa.

Materiel and method

[3]*MALDI-TOF : matrix assisted laser desorption and ionization - time of flight*

[4] *SELDI-TOF : surface enhanced laser desorption and ionization - time of flight*

Fish sample TSP analysis

Serum used in this study comes from a previous experiment which is still published (Sammouth et al 2008) and concerned sea bass reared with stocking density at 10 kg m-3. TSP was analyzed with A Max Mat Hycel autoanalyzer expressed in mg ml-1

2D-PAGE Electrophoresis

Sera from both groups were analyzed on 18-cm pH NL gd (roughly 10-250 kDa) strips pH 3-10 .

First dimension EF

An aliquot containing 400 µg of sera proteins was mixed for 1 hour with 350 µL of rehydration buffer (8M urea, 4% w/v 3[3-cholaminopropyl diethylammonio]-1-propane sulfonate, ampholyte 1% v/v (Bio-Lyte 3/10; Bio-Rad) and just before use, DTT 20 nM , trace of bromophenol blue added. After 1 hour rehydratation, of 18-cm immobilized pH gradient strips pH 3-10 with samples, focusing was performed overnight in the Protean IEF cell.

Second dimension SDS-PAGE

Strips were in 2 ml of a equilibration solution [Tris 0.375 M, SDS 1% pH 8.8), urea (6M), SDS (1% w/v), glycerol (20% w/v), a trace of bromophenol blue, and DTT (130 mM) for 10min, followed by equilibration for 10 mn in the same buffer containing iodoacetamide (135 mM) instead of DTT.

The strips were transferred to the top of gels [acrylamide 12 %, SDS 1%, APS 0.05%, TEMED 0.03 %] and held in position with molten (0.5% w/v) agarose in running buffer [25 mM Tris pH 8.3; 192 mM glycine; 0.1% w/v SDS and trace of bromophenol blue], kept at 12°C throughout the run till migration front left the gel.

Staining

The gel is washed off gel-fixing solution (TCA 5%) for 6hr, replaced for 6 hr by staining solution [Coomassie blue G-250,0.1%w/v, ethanol 5% v/v H3PO4 8.5 %v/v]. The discoloration solution [ethanol 25%v/v,acetic acid 10% v/v] until background staining of the gel was enough clear.

Scanning and quantification of spots

Gels were scanned with Bio-rad SG 800 calibrated densitometer. Quantification of spots, production of synthetic gels and statistic comparison were performed with software ImageMaster 2D platinium v6.0 GeneBio.

Protein digestion

Proteins were digested in-gel using trypsin by described (Shevchenko et al, 1996)

LC MS-MS

Samples (1 µl) were analyzed online on a ESI quadrupole time-of-flight (Q-TOF) mass spectrometer (QSTAR Pulsar-i, Applied Biosystems, Foster City, CA) coupled with an Ultimate 3000 HPLC (Dionex, Amsterdam, Netherlands).

The Q-TOF was fitted with uncoated silica PicoTip Emitter (NewOjective, Woburn, USA) with an outlet diameter of 8 µm. Spectra were recorded using the Analyst QS 1.1 software (Applied Biosystems). Spectra were acquired with the instrument operating in the information dependent acquisition mode throughout the HPLC gradient. Every 7 s, the instrument cycled through acquisition of a full-scan spectrum (1 s) and two MS/MS spectra (3 s each). Peptides fragmentation was performed using nitrogen as collision gas (CID) on the most abundant doubly or triply charged ions detected in the initial MS scan, with a collision energy profile optimized according to peptide mass (using manufacturer parameters), and an active exclusion time of 0.60 min.

MS/MS Analysis

All MS/MS spectra were searched against the Actinopterygii entries of either SwissProt or Trembl databases (http://www.expasy.ch), or a private database by using the Mascot v 2.1 algorithm (http://www.matrixscience.com). All significant hits were manually inspected. Peptides with a good fragmentation signal that dot not led to identification were manually de novo sequenced according to classical fragmentation rules. The sequences were compared to databases using BLAST algorithm.

SELDI-TOF protein chip system

The SELDI-TOF (Ciphergen PBS II) manufacturer recommendations concern human serum. Trout, salmon and turbot were analyzed with SELDI-TOF but for sea bass serum adaptation were necessary. Two sheep Ciphergen NP20 and IMAC30 were chosen with concentration x2 and contact duration 60mn in place of 5 mn.

Results and comments

Proteinemia and choice of samples

Proteinemia means were 38.99 mg ml-1 for fish reared at 100 kg m-3 and 41.50 mg ml-1 for those reared at 10 kg m-3 with the max at 52 mg ml-1 and mini at 32 mg ml-1 (normal for this seize of sea bass). T-test show a significant difference between means (p< 005, n=30). We choose, for further investigations, the 15 closest samples from the means of each density.

2D gel comparison

Individual protein panel of 2 groups presents an important difference in number of spots. The spot number varies from 226 to 370 spots for 10 kg m-3 and from 360 to 450 for 100 kg m-3. The gel with the highest number of 10 kg m-3 is close to the smallest of 100 kg m-3.

The most representative gels were processed by Image Master Platinum software to built 2 synthetic gels with 208 spots for 10 kg m-3 and 280 for the 100 kg m-3. Specific spots labeled on the 2 synthetic gels show 17/208 specific spots for 10 kg m-3 and 99/280 specific spots for 100 kg m-3.

The number of protein increased individually in fish of 100 kg m-3 or they were fragmented. The synthetic gel confirmed this increase and permitted to confirm disappearing of 17 proteins or fragments, apparition on 99 new proteins or fragments

This comparison takes into account presence or not of spots; the specific variations in spots parameters should show more important alterations of protein panel.

Statistic analysis

Intra class analysis

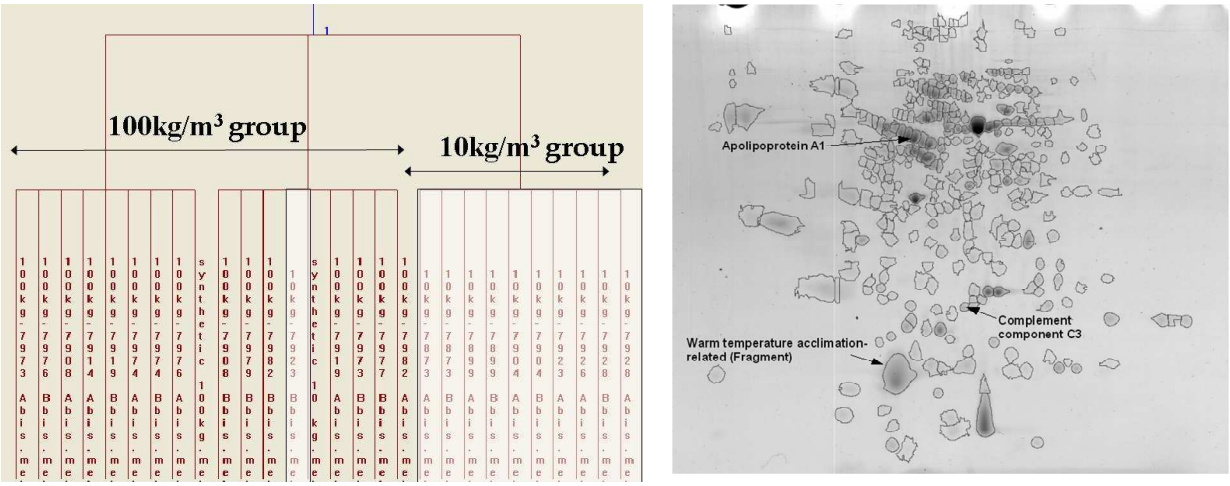
Intra class CR (% volume) shows a good homogeneity, higher in 10 kg m-3 group (0.98>C.R.>0.93 in 10 kg m-3 0.95>C.R.>0.84 in 100 kg m-3).

Analysis was done on spots volume and most of gels have a correlation with reference gel coefficient >0.9 except 3 with coefficient near 0.9 and the 10-6b which is out of its class (0.4). The references gel is a correct representation of real gels

Inter class (fig left)

Heuristic clustering performed on all gels shared them into 3 classes. One including gels from 10 kg m-3 and 2 including 100 kg m-3. Only one 10 kg m-3gel is not in the right class. Kolmogorof Smirnof test ($p<0.05$) show by an other way the protein panel difference and homogeneity.

LC-MS-MS Spot identification (right)



a) b)

Figure 1: Three classes shared by heuristic clustering (a) ; Four spots involved in inflammation identified by LC-MS-MS (b).

20 spots of interest, significantly different between 100 kg m-3and 10 kg m-3, were analyzed. 4 are spots identified are probably involved in inflammation: Inter-alpha (Globulin) inhibitorH3, C3 complement and FBP32 and the Warm temperature acclimatization related protein, (http://www.ncbi.nlm.nih.gov/protein/86610887?report=genpept). Those protein apparitions strengthen the hypothesis of stress by crowding.

SELDI TOF

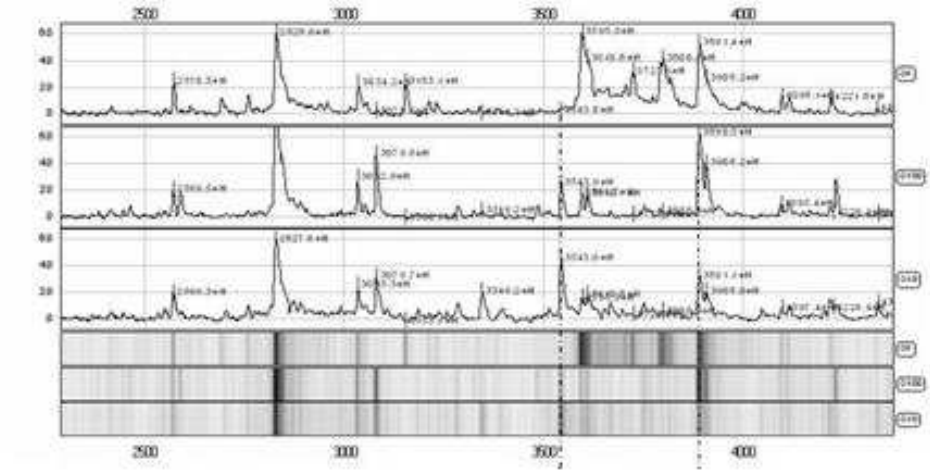


Figure 2: Discriminating picks between 10 and 100 kg m-3

Former (3543) increases in 10 kg m^{-3} and the latter (3899) increase in 100 kg m^{-3} ($P<0.05$) (spotted line).

Conclusion

2D gel electrophoresis show difference between serum proteome of sea bass reared at 100 kg m-3 and 10 m-3 stocking density in number of protein whole or fragments. 17 proteins or fragments disappeared and 99 appeared.
Four proteins probably involved in inflammation were identified at 100 kg m-3 by LC MS-MS strengthen the hypothesis of stress by crowding
SELDITOF permits to show difference in protein panel between the 100 kg m-3 and 10 kg m-3 rearing density
Proteomic analysis can discriminate modifications within normal limits in rearing conditions like high rearing density.

References

Bosworth CA 4th, Chou CW, Cole RB, Rees BB. 2005. Protein expression patterns in zebrafish skeletal muscle: initial characterization and the effects of hypoxic exposure. Proteomic, 5(5):1362-71
Coeurdacier J.L. & Dutto G., 1999. Effect of chronic exposure to ammonia on alterations of proteins and immunoglobulins in sea bass (Dicentrarchus labrax L.,1758) serum. Aquat. Living Resour., 12, 247-253..
Gopal V., Parvaty S., Blasubramaniani P.R., 1997. Effect of heavy metals on blood protein biochemistry of the fish Cyprinus carpio and its use as a bio-indicator of pollution stress. Environmental Monitoring and Assessment 48: 117–124.
El-Gohary M.S., Safinaz G. Mohamed, Khalil R.H., El-Banna S., Soliman M.K., 2005. Immunnosupressive effects of nitrofonate on Oreochromis nilotus. Egyptian journal of aquatic research 31, 448-458.
Kinoshita Y, Sato T, Nnaito H, OhashiI N, Kumazawa S,. (2007). Proteomic Studies on Protein Oxidation in Bonito (Katsuwonus pelamis) Muscle FSTR. Vol. 13, 133-138.
Riche M., 2006. Analysis of refractometry for determining total plasma protein in hybrid Striped Bass (Morone chrysops x M. saxatilis) at various salinities. Aquaculture 264, 279-284..
Sammouth S., E.R. d'Orbcastel, E. Gasset, G. Lemarie, G. Breuil, G. Marino, J.L. Coeurdacier, S. Fivelstad, J.P. Blancheton, 2008, The effect of density on sea bass (Dicentrarchus labrax) performance in a tank-based recirculating system. Aquacult. Eng. 40(2), 72-78.
Sutton R.J., Caldwell A.C., Blaze V.S., 2000. Observations of health indices used to monitor a tailwater trout fishery. North American Journal of Fisheries Management 20, 267–275.
Vazzana M., Cammarata M., Cooper E.L. and N. Parrinello N., 2002. Confinement stress in sea bass (Dicentrarchus labrax) depresses peritoneal leukocyte cytotoxicity. Aquaculture 210, 231–243.

Endangered species and fisheries in the Western Mediterranean: Which strategy to mitigate the interactions?

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Abstract

In several parts of the world, fishing affects directly or indirectly various species considered as threatened (IUCN) pertaining to groups such as the cetaceans, marine birds, sea turtles, or elasmobranches. In contrast, depredation, or marine mammals feeding on the catch or bait from commercial fishing gear occur and can affect severely some fisheries. The Western Mediterranean does not escape this rule and several endangered species are generally affected by the use of fishing gears with low selectivity. All the type of fisheries can be concerned (trawler, purse seine, pelagic surface long-liner, bottom longline…), but all are not affected or do not have the same impact on these groups. We carried out a state of the art on the interactions (depredation, bycatch) between the various fisheries of the Western Mediterranean and the major endangered marine species. We intended to identify the gaps of knowledge and raise concerns in order to initiate a global thinking on the potential strategies which could reduce the effects of the direct or indirect negative interactions. This should contribute to the development of a regional strategy to reduce impacts of fisheries on endangered species, based on the recommendations of the General Fisheries Commission for the Mediterranean (GFCM).

Introduction

In several parts of the world, fishing affects directly or indirectly various species considered as threatened (IUCN) pertaining to groups such as the cetaceans, marine birds, sea turtles, or elasmobranches. In contrast, depredation, or marine mammals feeding on the catch or bait from commercial fishing gear occur and can affect severely some fisheries. The French Western Mediterranean does not escape this rule and several endangered species are generally affected by the use of fishing gears with low selectivity (Table 1). All the type of fisheries can be concerned (trawler, purse seine, long-liner, …), but all are not affected or do not have the same impact on these species. The General Fisheries Commission for the Mediterranean (GFCM) bycatch group recommends more participation and contributions from scientists working on species of conservation concern from sub-regions of the Mediterranean [11].

State of the art

We carried out a state of the art on the interactions (depredation, bycatch) between the various fisheries of the French Western Mediterranean and the major endangered marine species

(Table 1). Traps and purse-seine are the less impacting and impacted gear. Inversely, hooks impacted largely all four groups of animals. Static nets, since diftnets are banned, catch also numerous species.

Concerning cetaceans, small delphinids are the most frequently interacting species, mainly with nets (gill and trammel nets around Corsica), but also with purse seine and trawl. Bottlenosed dolphin is the only species for which depredation is well documented, but it seems that pilot whale could depredate some static nets also.

In the Mediterranean Sea along and offshore French coasts, data on sea birds bycatch, events or rates, seem to be very scarce. A Mediterranean synthesis highlighted that in many countries, shearwaters in particular are by-caught mainly in longline fisheries [3]. Although longliner are not numerous in french waters until now, this problem may rise as this kind of fishery grows. Fishermen should by now applied already known practices in order to avoid bycatch.

Interactions of specimens of four sea turtles species with fisheries as well as strandings have been reported since several years |7].
Large elasmobranches individuals are also caught in Mediterranean Sea by the industrial and semi industrial longline fisheries, by the artisanal gillnet fisheries and the recreational fisheries [12] (Table 1).

Table 1: Interaction between threatened species and fisheries in the french mediterranean waters or in the north-western Mediterranean Sea

North-western Mediterranean Sea					FISHERIES					
					ACTIVE GEAR		PASSIVE GEAR			
GROUPS	SPECIES	LATIN NAME	IUCN STATUS		Purse seine	trawlers	static net	Hook and line	traps	illegal drift net**
			world	France or *Medit.						
CETACEANS	Sperm whale	*Physeter macrocephalus*	VU	EN*			[6]	[6]		[6]
	Fin whale	*Balaenoptera physalus*	EN	DD*			[6]	[6]		[6]
	Striped dolphin	*Stenella coeruleoalba*	LC	VU*	[6]		[6]	[6]		[2]
	Bottlenosed dolphin	*Tursiops truncatus*	LC	VU*		[1] **also D**	[4] **also D**	[6]		[6]
	Risso's dolphin	*Grampus griseus*	LC	DD*			[6]	[6]		[6]
	Pilot whale	*Globicephala melas*	DD	DD*	[6]		[6]			[6]
TURTLES	Loggerhead sea turtle	*Caretta caretta*	EN	DD*	[9]	[7]	[7]	[7]	[7]	[8]
	Green sea turtle	*Chelonia mydas*	EN	NA*	[9]		[7]	[7]	[7]	
	Leatherback turtle	*Dermochelys coriacea*	CR	DD*	[9]	[7]	[7]	[7]	[7]	
	Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	CR	NA*	[9]		[7]	[7]	[7]	
BIRDS	Cory's shearwater	*Calonectris diomedea*	LC	VU				[3] + [5]		
	Mediterranean shearwater	*Puffinus yelkouan*	NT	NT*						
	Balearic shearwater	*Puffinus mauretanicus*	NT	CR*				[3] + [5]		
	Audouin's gull	*Larus audouini*	NT	EN				[5]		
PELAGIC SHARKS / RAY	Basking shark	*Cetorhinus maximus*	VU	VU	[9]					
	Tresher shark	*Alopias vulpinus*	VU	DD	[9]	[10]	[10]	[10]		[8]
	Blue shark	*Prionace glauca*	VU	VU	[9]					[8]
	Porbeagle	*Lamna nasus*	CR	VU	[9]					[8]
	White shark	*Carcharodon carcharias*	EN	VU	[9]					
	Devil ray	*Mobula mobular*	EN	EN	[9]					[8]

LC : Least Concern
VU : Vulnerable
NT : Near Threatened
EN : Endangered
CR : Critically endangered
DD : Data deficient

no known bycatch
rare bycatch
known and studied
potential bycatch
D Depredation
[ ] References

** forbidden since its bycatch of endangered species has been clearly demonstrated

Boat using nets represent 64% of the fishing fleet, whereas those using hooks are not so numerous (Fig.1).

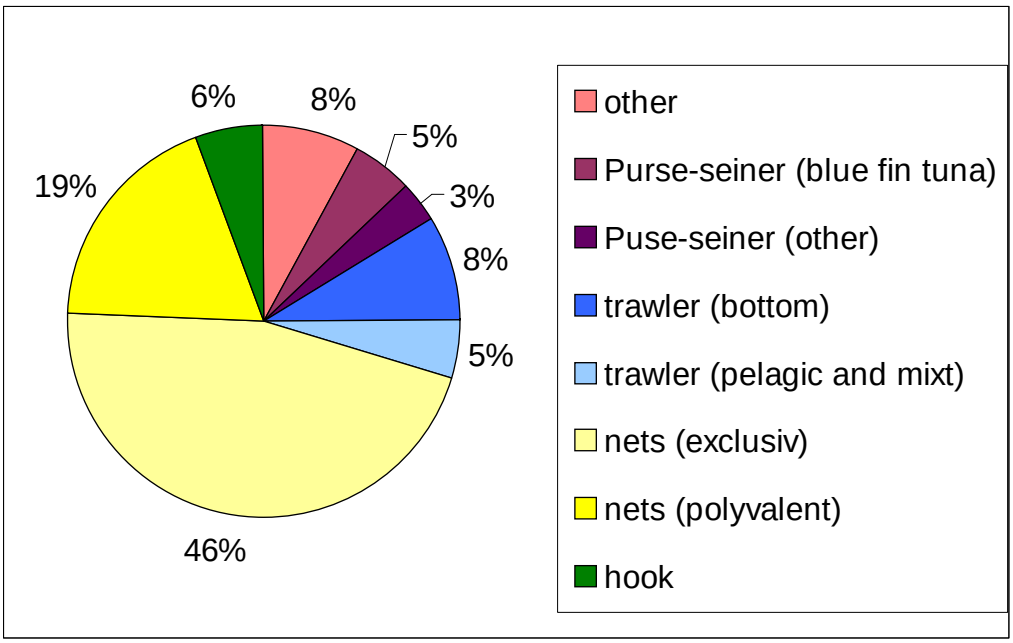

Figure 1: French Mediterranean fishing fleet by gear (2008)

Several gaps of knowledge appear clearly: the real impact of trawls, long-lines and hooks are unknown .

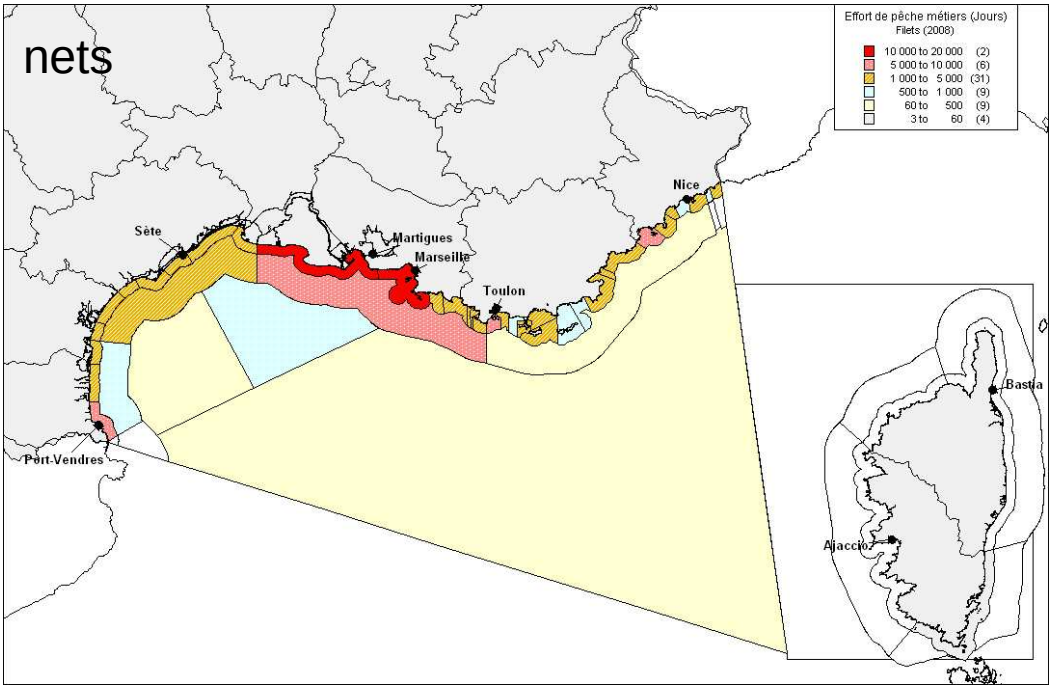

Figure 2: Fishing effort (number of days) of boats using nets in 2008

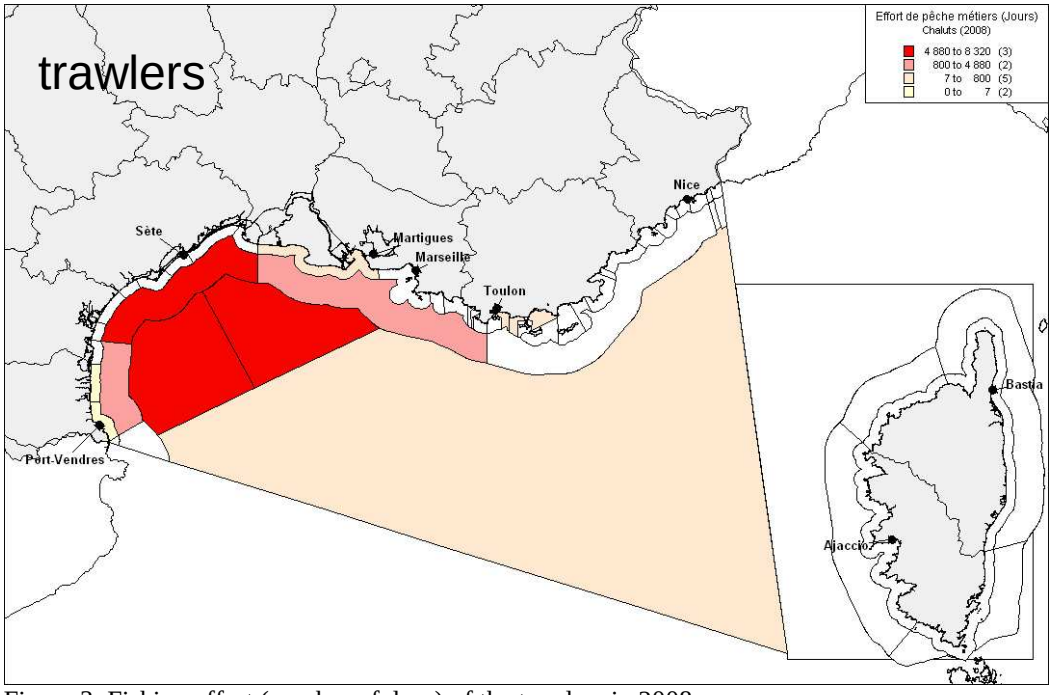

Figure 3: Fishing effort (number of days) of the trawlers in 2008

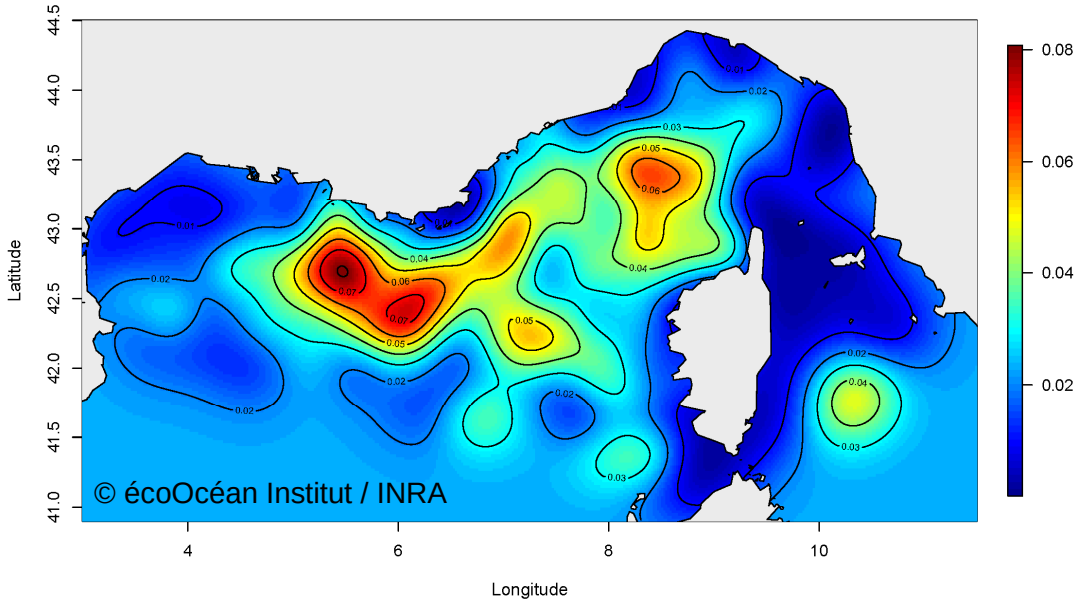

Figure 4: kriging of the sighting rate of striped dolphin (expressed in number of sighting per Km), summer 1998-2008, model based on Monestiez et al. (2006) [13].

Measures and strategies

We intended also to raise concerns in order to initiate a global thinking on the potential strategies which could reduce the effects of the direct or indirect negative interactions, based on the recommendations of the GFCM.

The most relevant recommendations of the Working Group to the SCEEM are summarized as follow [4] :

- To collaborate and promote, together with other relevant IGOs/NGOs (Table 2), coordinated studies on population dynamics of species of conservation concern, such as marine turtles, mammals, birds.
- To launch pilot projects on by-catch in specific fishery, taking into account not only technological measures for mitigation, but also the social aspects connected with that fishery (especially in artisanal ones).
- Implementation of more testing studies on promising technical and operational changes in fishing practices (e.g. circle hooks, TEDs, deep hooks, etc;)

In terms of future SCEEM work plan, Working Group recommended to follow-up on these activities :

- Drafting a protocol for data collection on by-catch of species of conservation concern, based on existing protocols (like those prepared for ACCOBAMS and MedLem);
- Evaluating existing data on by-catch, and identifying critical areas that could be object of local fishery management measures. For example, by overlapping the spatial distribution of fishing effort with nets (Fig. 2) or with trawl (Fig. 3) and the distribution of the sighting rate of striped dolphin (Fig. 4), we could be able to map the risk of bycatch and identify critical areas.

Table 2: specialist groups for the “interaction” questions in France

NAME	CREATED IN	OBJECTIVES	MEMBERS			
			National/local Administrations/agencies	Research institutes	National and local Fisheries industry	NGO networks, Rescue centers, Protected areas, aquarium éducation center
GTMF (French Marine Turtle Group)	**2008**	Reflexion on management and conservation of marine turtle in France. Exchange of informations between french stakeholders, in relationship with international actions	19	5	2	30
Groupe Requin (french technical working group on sharks)	**2008**	Provide a forum for the researchers, along delegates of the fishing industry and NGOs, to come together to share ideas, update information and report on the progress of the most recent scientific concerning the impact of the fisheries on the elasmobranches and provide perspective on where we can go in the future.	4	3	10	2

Conclusion

Among measures, the GFCM (2009) recommends that one develops and initiates a regional strategy to reduce sea turtle, marine mammal and seabird bycatch [4]. Concerning interaction like depredation by cetaceans [5], this strategy should include:

- raising knowledge (filling the gap) concerning species and impacts
- informing, educating and implying fishery industries
- implementing combined solutions and evaluating their efficiency.

We are just at the beginning of the process to better determine the importance of interactions between fisheries and non targeted threatened species. It is important to develop and initiate, from now on, a regional strategy to reduce sea turtle, marine mammal, elasmobranche and seabird bycatch as recommended by the GFCM.

References

[1] Sacchi J. and David L., 2008. Rapport National sur le suivi des interactions en Méditerranée française. International workshop on bycatch within the ACCOBAMS area ROME (FAO HQS), Italy, 17-18 September 2008, 23 pp.

[2] David L., 2007. Synthèse des études scientifiques menées sur la thonaille méditerranéenne 2000-2005. Typologies et captures. Eco-Océan Institut. 30pp

[3] Cooper J., Baccetti N., Belda E., Borg J.J., Oro D., Papaconstantinou C. & Sanchez A., 2003 : Seabird mortality from longline fishing in the Mediterranean Sea and Macaronesian waters : a review and a way forward. SCI. MAR., 67 (suppl. 2) : 57-64.

[4] Rossi L., 2006. Rapport de l'action A2 : Qualification et quantification des interactions entre grnads dauphins et filets de pêche. Programme Life LINDA, 51 pp.

[5] Belda E. J. and Sanchez A., 2001. - Seabird mortality on longline fisheries in the western Mediterranean : factors affecting bycatch and proposed mitigating measures. Biol. Conserv., 98 : 357-363.

[6] Sacchi J., 2008 : Impact des techniques de pêche en Méditerranée. Solutions d'amélioration. Rapport CGPM/FAO. Nombre de pages?

[7] Data of the Réseau Tortues Marines de Méditerranée Française (RTMMF, French Mediterranean Network on sea Turtles. *In* Claro F., Bedel S. et Forin-Wiart M.A., 2010. Interactions entre pêcheries et tortues marines en France métropolitaine et d'Outre-mer. Rapport SPN 2010/13. MNHN-SPN, Paris, 124 pp.

[8] Banaru D., Dekeyser I., Imbert G., Laubier L., 2010. Non-target and released alive by-catches distributions observed during French driftnet fishery in the Northwestern Mediterranean Sea (2000-2003 database). Journal of Oceanography, Research and Data, vol 3 : 33-45.

[9] Fisheries Observers' data.

[10] ALOP programme (Ifremer survey).

[11] GFCM, 2009. Report of the transversal workshop on selectivity improvement and bycatch reduction.Tunis, Tunisia, 23-25 September 2009. Scientific advisory committee (SAC), 23p.

[12] Poisson, F. , Séret B., 2008. Pelagic sharks in the Atlantic and Mediterranean French fisheries: Analysis of catch statistics.SCRS/2008/134.

[13] Monestiez, P., Dubroca, L., Bonnin, E., Durbec, J.P., Guinet, C., 2006. Geostatistical modelling of spatial distribution of *Balaenoptera physalus* in the Northwestern Mediterranean Sea from sparse count data and heterogeneous observation efforts. Ecological Modelling, 193: 615-628.

Acronyms:
ACCOBAMS : Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Area
GFCM : General Fisheries Commission for the Mediterranean
MedLem : MEDiterranean Large Elasmobranchs Monitoring)
SCEEM Sub-Committee on Marine Environment and Ecosystems (SCMEE):
TEDs : Turtle Extruder device
ALOP Action Local de Préservation

Acknowledgments: The authors wish to thank the RTMMF for sharing their data.

New Designs of drifting fish aggregating devices to avoid passive catches of sea turtles and sharks

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Key words: attracting techniques, catching methods, FAD, tuna fisheries, Atlantic Ocean.

Purse seiners have always been looking for objects floating at the surface of the oceans to find and catch tropical tuna. In the last two decades, this fishing mode has been more and more important and fishers have increased the number of floating objects in the ocean by regularly deploying thousands of artificial drifting fish aggregating devices (DFADs) to increase their catch of tropical tuna. If such DFADs are suitable for fishers, the problem is that these types of DFADs are also responsible for incidental mortality of sea turtles and sharks through entanglement.

The Working Party on Ecosystems and Bycatch of the IOTC in its last meeting hold in Mombasa (12 - 14 October 2009) recommended "complete conversion to the use of ecological FADs as soon as possible and that these FADs are made of biodegradable materials" (IOTC 2009).

The main objective of this study is to design and test ecological DFADs to prevent the entanglement of sea turtles and sharks, as well as being as much as biodegradable as possible and as efficient in aggregating fish as traditional ones.

The study involves different stages until the results of the tested ecological DFADs are presented to the fishers: information about current DFADs, establishment of ecological and fisher's criteria to design ecological DFADs, testing at sea, analysis of data and report of the results.

Information about the design of current DFADs used in the three tropical oceans was obtained through 24 personal interviews with fishing masters and fleet managers (8 French and 14 Spanish).

DFAD designs in the three oceans (Atlantic, Indian and Pacific) are very similar as far as aterial of the floating structure and the netting concern. The main difference is in the netting length, being shorter in the Indian Ocean and larger (up to 55 meters) in the Pacific and Atlantic oceans.

Taking into account ecological and fishers criteria the following criteria was set to build new ecological DFADs:

- DFADs should have a submerged structure but should not have hanging panels of nets with large mesh size that can cause entanglements of animals.
- The floating structure of FADs should not be covered by several layers of nets where turtles can be trapped.
- DFADs should be made of biodegradable materials as much as possible.

Bamboo canes (as floating structure), sisal and palm leaves (in the submerged structure) were identified as the best biodegradable materials to built ecological DFADs.
A final design of the ecological DFAD, almost entirely biodegradable, taking into account those ecological and fisher's criteria, has been obtained and will be tested in the Atlantic Ocean. Two different experiments will be carried out: 1) simultaneous deployment of ecological and traditional DFADs attached together, to test turtle entanglement under the same conditions 2) deployment of 40 ecological DFADs alone to see if the ecological DFAD is efficient in aggregating fish.

Acknowledgments

This study was performed within ECOFAD project funded by ANABAC (Spanish purse seiner ship-owners association) and MADE European project, funded by the Commission of European Communities (Nº 210496).
The authors want to express their gratitude to all the persons of the Spanish tuna companies involved in the study.

References

IOTC, 2009. Report of the Fifth Session of the IOTC Working Party on Ecosystems and Bycatch. Mombasa, Kenya 12 - 14 October 2009, IOTC-2009-WPEB-R[E], 38 pp.

Estimation of fish struggle energetics using branch line movement in longline

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Introduction

Fish fatigue during the fishing process also has to been assessed to estimate survival rate of escapee or freshness of landed fish, and also should be considered from the standing point of fish welfare. To estimate fish potential kinematic energetic power, experiments in laboratory have been carried out using the water tunnel respirometer, and discussed fish swimming performance using model fish. However, there were some difficulties in the methodologies to force live wild fish to swim in the narrow tunnel or in transporting those fish from sea to laboratory. In addition, some problems would come up when reproducing fish escaping performance from fishing gear in the experimental tank. In the present study, we conducted the field experiments to assess fish kinematic performance using bottom longline in the coastal waters around Izu Peninsula Japan and around Panay Island Philippines.

Materials and methods

To estimate the energetics of restricted fish by the hook in longline the branch line movement which was accompanied with the fish struggle was recorded using motion detector (Fishing Chips;52×33×25 mm,15 g weight in water,Vsevolod Afanasyev). The minimum detecting acceleration of Fishing Chips which can detect swing number per minute in the in-line direction of branch line was previously obtained on the shaker. (36 cms^{-2}) The force to lift up a static Fishing Chip (15 g in water) with acceleration of 36 cm s^{-2} was 1,540 dyne. We hypothesized that inertia force was more dominant than drag force, since the motion of Fishing Chip within the branch line was not steady and considerably slow. The inertia force exerted on a Fishing Chip (44.0 cm^3) calculated using added mass coefficient of rectangular parallelepiped (C_M=2.2) was 3,485 dyne when moved at minimum detective acceleration of 36 cm s^{-2}. Therefore, total force required to move a Fishing Chip with countable acceleration of Fishing Chip was 4,025 dyne. As calculated for a Fishing Chip, since the distance between each branch line was 5 m, the force exerted on the 5 m long of cylindrical (C_M=1.67) mainline (7 mm in diameter) of which specific gravity was 1.3, was then 31,795 dyne. Consequently, it is required 35,820 dyne of force to move a Fishing Chip and its attachment with acceleration of 36 cm s^{-2}. Furthermore, when a Fishing Chip and its attachment of mainline were moved 2.8 cm which was the minimum detectable ampluitude of Fishing Chip, the mechanical work

to swing within the total force to move a Fishing Chip and attached mainline was then 100,297 erg (0.01 J:107 erg = 1 J).
A total of 96 experimental bottom longline operation attaching 10 to 20 Fishing Chips to the base portion of branch line was conducted using the boat (Suzaki □, 9.1 tonnage) in the coastal area around Izu Peninsula in central Japan, and the small fishing boat operated by the Filipino local fisher around Panay Island in the central Philippines. Bottom longline was set baited chopped mackerel or squid on the seabed in a depth from 30 to 50 m. Branch line movements were recorded by the Fishing Chips when the fish such as moray eel, scorpion fish, burmuda catfish, cutlassfish and red bigeye were caught. Struggle power (W) and energy (Wh) were calculated using the counted movement number and elapsed time after hooking, where the mechanical work to move Fishing Chip and its attached mainline was 0.01 J.

Results and Discussion

In the case of demersal fish species caught by bottom longline, calculated struggle power (W) using the oscillation frequency of swaying Fishing Chip and its attached mainline was decreased with the restricted duration after hooked. (Fig.1).

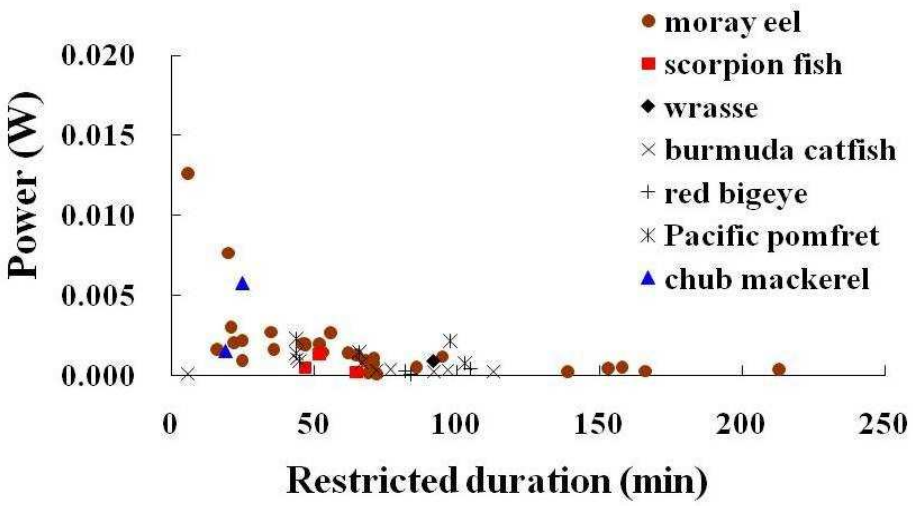

Figure1: Calculated Power (W) using the oscilation frequency of Fishing Chips against restricted duration after hooking

It is assumed that the power output of inactive demersal fish tends to be fatigable with time elapsing. Furthermore, the energy (Wh) reached a limit when the power (W) was at around 0.008 W, which was close to the value of rainbow trout obtained in the water tunnel. (0.0058 W at 0.8 $BLs^{-1}$and 0.017 W at 1.0 BLs^{-1}:Webb, 1971). (Fig.2).
It is likely there are limit in physical ability to continue execive exercise when exhibit maximun level of power. However, the value of power obtained in this study was considerably smaller than the power of yellowtail. (0.14 W at 0.8 BLs^{-1} and 0.25 W at 1.0 BLs^{-1}: Tsukamoto,1984) Although, there are still differences in the values of estimated fish potential power according to the methodologies, it may be one of the methods to evaluate fish struggle power using the longlining without experiments in laboratory.

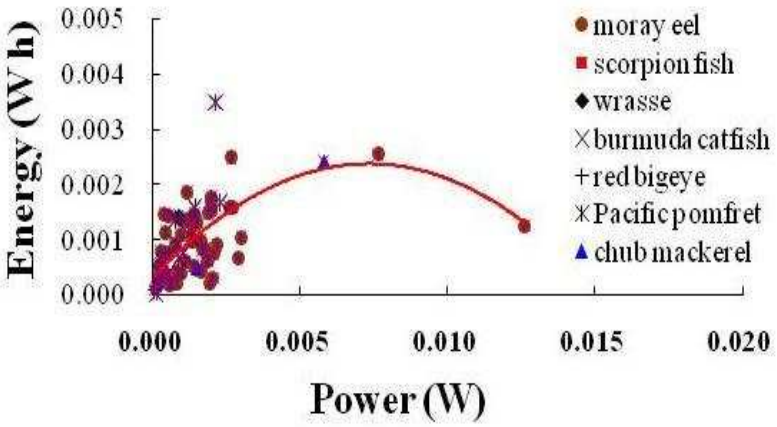

Figure 2 Relationship between exhibited gear swaying energy and power by caught fish

Further experiments, for example attaching added mass to the branch line will be required to assess struggle power of larger fish in tuna longlining.

References

Tsukamoto K.,1984, Contribution of the red and white muscles to the power output required for swimming by the yellowtail. Bull.Jap.Soc.Sci.Fish. 60, 2031-2042.

Webb P.W.,1971, The swimming energetics of trout. J.Exp.Biol. 55, 489-520.

Measuring the swimming behaviour of a cultivated pacific bluefin tuna in an aquaculture net cage

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Introduction

Many aquaculture facilities are located in calm areas, such as bays and inshore areas. The increasing development in these areas is causing severe environmental pollution, including self-contamination of existing aquaculture facilities. Therefore, it might be necessary to install aquaculture net cages offshore, where waves and currents are much greater than inshore. Under rough conditions, it is thought that the shape of the net cage changes dynamically, decreasing the living space of cultivated fish. Therefore, it is necessary to obtain behavioural data on cultivated fish in net cages. This information might help the development of net cages that place less stress on cultivated fish. However, it is difficult to examine the behaviour of cultivated fish in a net cage. An understanding of how fish swim in a net cage under rough conditions might play an important role in the improvement of offshore net cages. We measured the swimming behaviour of a cultivated Pacific bluefin tuna, Thunnus orientalis, in an aquaculture net cage using two types of micro-data logger to understand the space use of cultivated fish in the cage as its living space.

Material and methods

The study was conducted in a net cage installed offshore in Kochi prefecture, Japan. A bluefin tuna (FL 51 cm) was captured by angling in the cage and two micro-data loggers (PD3GT, Little Leonardo; DST Comp-Tilt, Star-Oddi) were attached to its body externally. The fish was released back into the net cage, which was circular in shape, measuring 30 m in diameter and 22 m deep. The PD3GT measured its swimming speed, depth, and ambient temperature at 1 Hz, and the three-axes acceleration at 32 Hz, and recorded these in flash memory on 6 and 7 March 2010. The DST Comp-Tilt measured the magnetic field strength at 1 Hz and recorded the heading estimated from the magnetic field strength in flash memory. The record of the DST Comp-Tilt was divided into four phases: dawn, day, dusk, and night. The data loggers were detached from the body by a timing device, and collected by a diver.

Results

The behaviour of the tagged fish was measured from 9:30 6 March until 17:30 7 March 2010 (Fig.1).

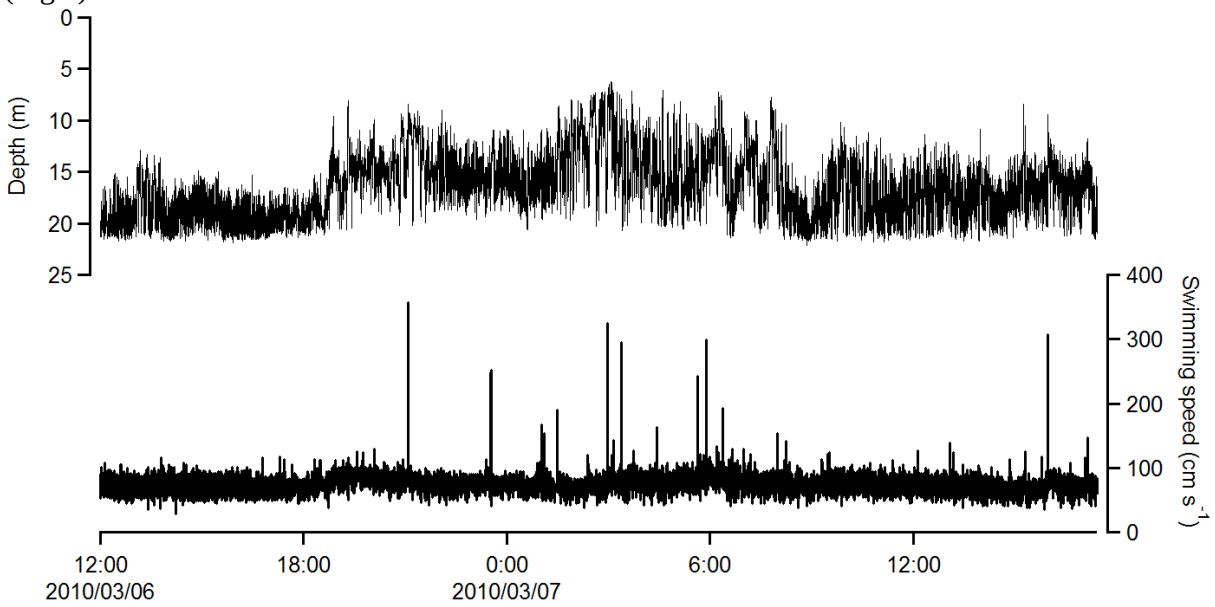

Figure 1: Time series data for the behaviour of the tagged fish showing swimming depth (top) and speed (bottom).

In the cage, the fish moved to a depth of 0–22m and at speeds of 0.7–0.8.m·s-1, with a maximum speed of 3.6 m·s-1. The spectrum analysis of the heading time series data showed that the fish circled the cage at a constant frequency at night, but swam around at an irregular frequency during the other phases (Fig. 2).

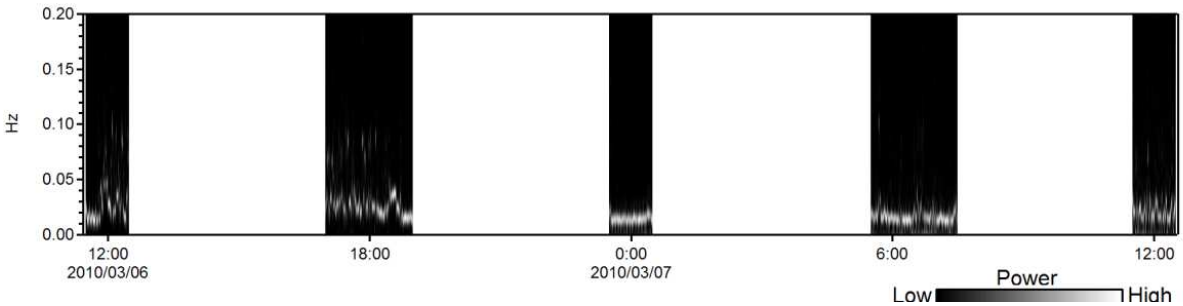

Figure. 2: The spectrum analysis of the time series data showing the heading of the orbiting fish

These records clarify how fish swim in an aquaculture net cage. The results demonstrate that behavioural measurements using data loggers are effective for understanding the behaviour of a tagged fish in a net cage. Although only one fish was analysed, this study provides useful information on the space use of cultivated fish in aquaculture net cages. Future studies must obtain sufficient data to understand the underlying generalities of tuna behaviour.

Investigation of submersible net cage movement using a model Orientation changes due to asymmetric surplus buoyancy

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Introduction

The use of submersible net cages in aquaculture has received considerable attention as aquaculture facilities have been transitioned offshore. Submersible net cages employ a system in which the depth of the cage can be controlled by adjusting the volume of air in floats attached to the sides of the cage to adjust surplus buoyancy. However, a problem currently encountered with submersible net cages is their tendency to tilt during raising and submersion, and the ultimate loss of their capability to maintain a constant orientation. In this study, we artificially induced asymmetries in the surplus buoyancy of a submersible net cage model, measured its resulting inclination.

Materials and Methods

Using an octagonal net cage model, experiments were conducted by changing the amount of weight attached to the cage frame to reproduce asymmetry in the surplus buoyancy acting on the frame. The inclination of the cage was measured at different amounts and distributions of weight up to a “critical point” that resulted in capsizing.
Fig. 1 shows a schematic drawing of the octagonal net cage frame (1/30 scale model) for this experiment. Weights were suspended from one side of the octagonal net cage model, which was floated in a water tank. The inclination of the cage was then measured as the weight being added was increased in increments. Weights were added until the net cage capsized (inclined to a vertical state). The inclination of the net was measured by gradually changing the surplus buoyancy of the entire cage frame, which was adjusted by changing the amount of water inside the floats.

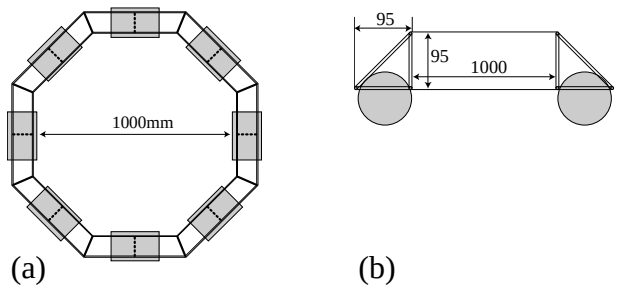

Figure 1: Schematic drawing of net cage frame ; top view (a) and side view (b) .

Results

When weight was added to one part of the cage frame, the frame inclined to a certain angle relative to the water surface, where it subsequently balanced and became motionless. When the added weight exceeded a certain limit, however, the balancing capability was lost and the cage frame capsized to a vertical state. Fig. 2 shows the relationship between the weight added and the inclination of the net cage. The horizontal axis in Fig. 2 represents a dimensionless quantity (AW/TSB) obtained by dividing the total weight added to the side of the octagonal net cage (AW) by the surplus buoyancy of the entire net cage (TSB).

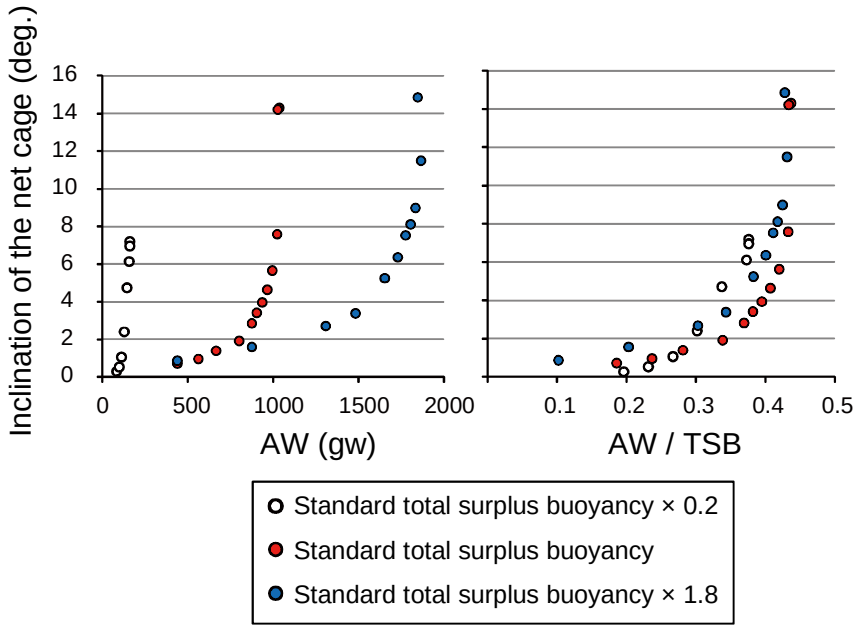

Figure 2: Relationship between the weight added (AW/TSB) and the inclination of the net cage.

The inclination of the net cage increased in proportion to AW/TSB. For any given value of AW/TSB, the inclination increased as TSB decreased. However, no clear relationship was observed between the point at which the net cage lost its balance due to the addition of weights and the surplus buoyancy of the entire net cage.

Conclusions

The attached weight at the time of capsize was termed the “critical point”, which varied with the surplus buoyancy of the entire cage frame, but was generally about 40% of the total buoyant force of the net cage.

As the floats of a submersible net cage contain both air and water, it is also necessary to consider changes in the center of gravity of the entire net cage frame due to inclination of the water inside these floats, to effectively control the orientation of the net cage.

References

K.Nagamatsu, H.Nishinokubi, K.Nasai. 1986, The Mechanical Characteristics of a Netting Store Pot. Memoirs of Faculty of Fisheries of Nagasaki University. 59, 1-10.

S.Okano, Y.Mitsunaga, W.Sakamoto, H.Kumai. 2006, Study on swimming behavior of cultured Pacific bluefin tuna using biotelemetry. Memoirs of the Faculty of Agriculture of Kinki University. 39, 79-82.

Artificial reefs as a tool to supply artisanal fishery in Réunion Island: scientific evaluation and statistic incrementation

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Introduction

Following previous projects of Artificial Reefs (ARs) in Reunion Island, throughout a coastal management, this present study fitted into a wider project to determine the functionality of two kinds of new ARs, submerged in La Possession Bay. The originality of this study was the spatial approach of the problematic, which compare natural and artificial habitats with standardized methods.

The aim of this work was to understand the links between fish community structures (twelve structural and functional components) and their habitat factors (twelve biotic and abiotic factors). These links were identified using multivariate statistic tools, such as Principal Correspondences Analysis (PCA) and Redundancy Analysis (RDA). Only the structure of ichthyologic community was studied to better understand the dependency relationships between different categories of species and their environment.

These functional dependencies brought us a better understanding of ecological integration mechanisms of new ARs in coastal areas. These results should help us to adapt management objectives to ARs specificities, in term of habitat.

Material and Methods

The studied area is located in La Possession bay, on the northwest coast of La Reunion Island (West Indian Ocean). Seven different habitats mutually exclusive were monitored during this survey:

- Three natural habitats: Outcrop Of Basalt (OOB, -40m), Pebble Bank (PEB, -5m) and Coral Bank (COB, -5m).
- Two artificial habitats ecologically mature (more than seven years old): Artificial Coastline (ARC -5m) and Artificial Reefs with Pebbles (ARP, -15m).
- Two artificial habitats ecologically immature (less than two years old): Artificial Reefs with “Hexapods” (ARH, -25m) and Artificial Reefs with “Sanwiches” (RAS, -25m) (Fig.1).

Each habitat was sampled six times (2 times x 3 stations) in 2010 April by three professional divers (Fig.2).

Figure 1: ARs with pebble (a), with sandwiches (b) and with hexapods (c)

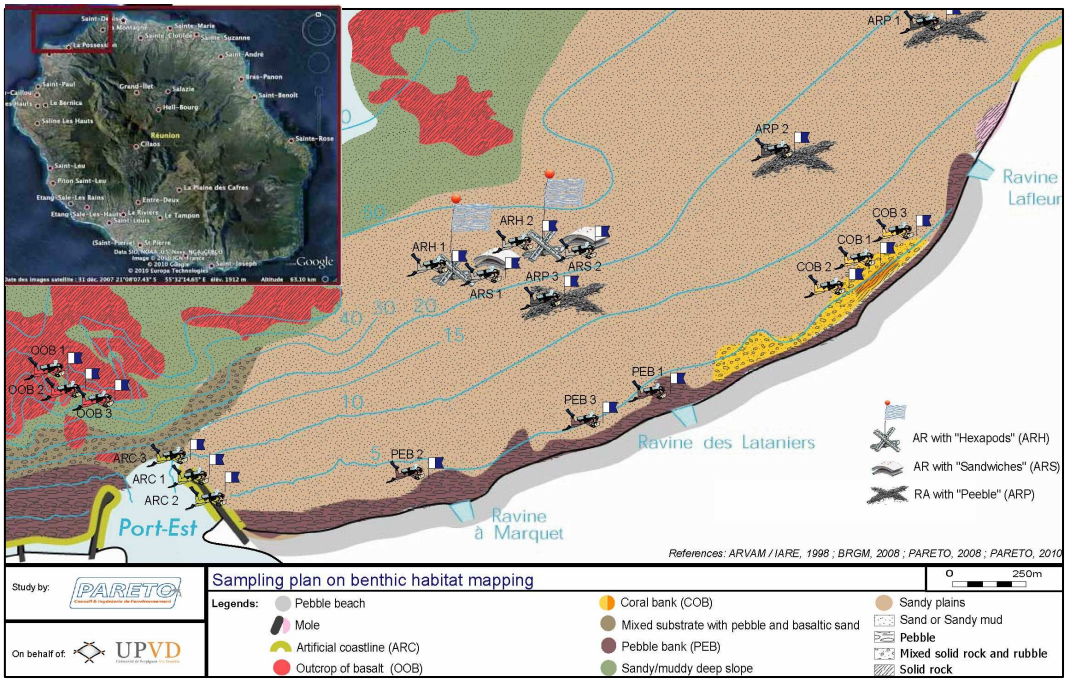

Fig. 2: Sampling plan on benthic habitats mapping

Ichthyologic fauna census (specific richness, abundance, biomass) was made by visual methods in Scuba Diving. Implemented methods were inspired by the "Underwater visual fish census survey" (Labrosse & al., 2002). All methods used were standardized using the same sampling time interval (35min) and a conversion of abundances and biomasses by 100m^2. Twelve structural and functional components were deducted from this ichthyologic sampling (Table 1).

Table 1: Structural and functional fish community components

Structural component		Functional component		
Biodiversity	**Patrimonial interest**	**Feeding**	**Maturity**	**Ecologic type**
• Biodiversity æ • Biodiversity ß	• Endemism • Rarity • Fishing interest	• Regime • Habit	• Juvenile • Adult	• Benthic • Demersal • Pelagic

A second professional diver measured biotic and abiotic environmental factors simultaneously to the ichthyologic variables. The methods were chosen to be implemented on all types of habitat. These methods were adapted from Dahl (1981), Conand & al. (1997), Hodgson & al.

(2008), Seaman (2000), Mandelbrot (1977) and Wilson & al. (2007) works. Twelve habitat factors were directly or indirectly estimated (Table 2).

Table 2: Abiotic and biotic habitat factors

Abiotic habitat factors		Biotic habitat factors	
Contextual components	**Structural dimensions**	**Sessile organisms**	**Mobil fauna**
• Origin (natural or artificial habitat) • Age (substrate stability time) • Location (depth, latitude, longitude)	• Border effect (Perimeter/Surface) • Complexity (fractal dimension, heights relative standard deviation) • Porosity (voids index)	• Algae (turf) • Coral (massive, foliaceous, encrusting) • Sciaphile organisms (sponges, ascidians) • Abiotic (sand, rock)	• Urchins (herbivorous) • Sediment fauna (above-ground and soil-dwelling)

The redundancy analysis (RDA) is a canonical version of PCA. It is a constrained ordination technique, which explores the links between various response variables (fish community structures) and explanatory variables (habitat factors) - (Chessel & al. 1987; Lebreton & al., 1991). The interpretation is done graphically, projecting the site response variables on the explanatory vectors (Chessel & al. 1987; Prodon & Lebreton, 1994).

Results

The average density of fish estimated during this survey was 109.8 fishes per 100m^2 of hard substrate. A comparison with available data on other sectors in La Reunion Island showed that this value was comparable to other non-reef habitats (105 fishes per 100 m^2 at St. Benoit – Letourneur, 1998), but was lower than data collected in the western reef of the island (150 to 1000 fishes per 100m^2).

PCA showed that biotic and abiotic variables, selected to describe sampled habitats, provided a good representation of the specificity of each habitat (Figure 3). Habitats were clearly identified and a significant proportion of spatial variability (57%), observed within study area, was characterized using selected variables. However, these variables don't seem all independent and may illustrate mechanisms of cause and effect relationship between distribution of biotic and abiotic habitat factors.

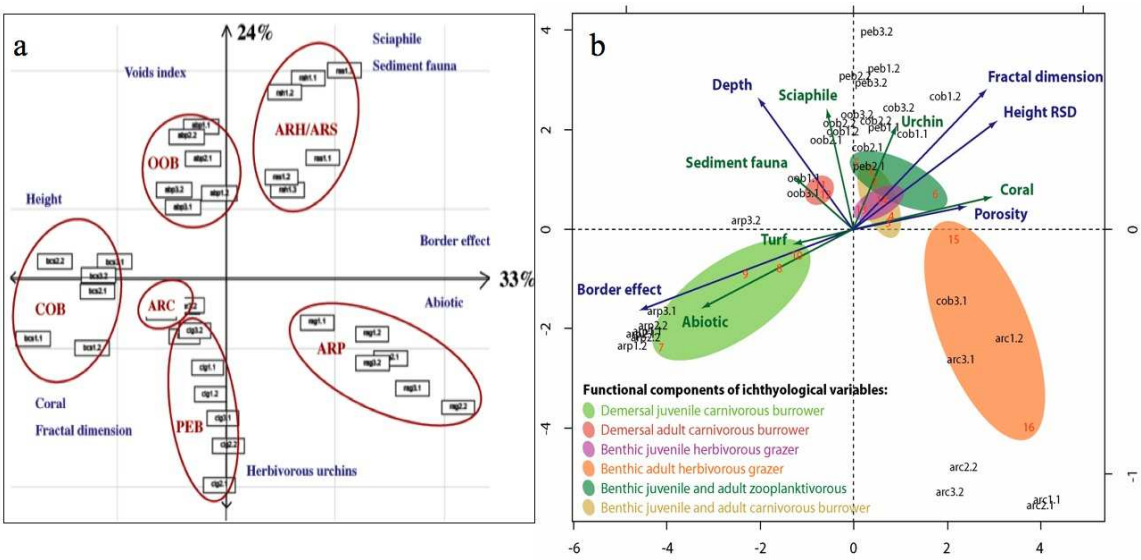

Figure 3: PCA (a) and RDA (b) analysis realized with La Possession survey data

RDA showed that all of measured variables were highly dependent on the interaction of three groups of parameters: structural complexity (fractal dimension and voids index), border effect (habitat perimeter / habitat surface) and depth. Then, they seemed to be involved, directly or indirectly, in the distribution of biotic habitat factors and fish community structures.

The synthetic scheme of La Possession Bay ecological system (Figure 4) illustrated this interaction between the three structuring variables, biotic habitat factors and fish community structure. Habitats were placed on the diagram according to the structuring variable values. Biotic habitat factors and fish community structures were distributed according to their correlation with the three structuring variables.

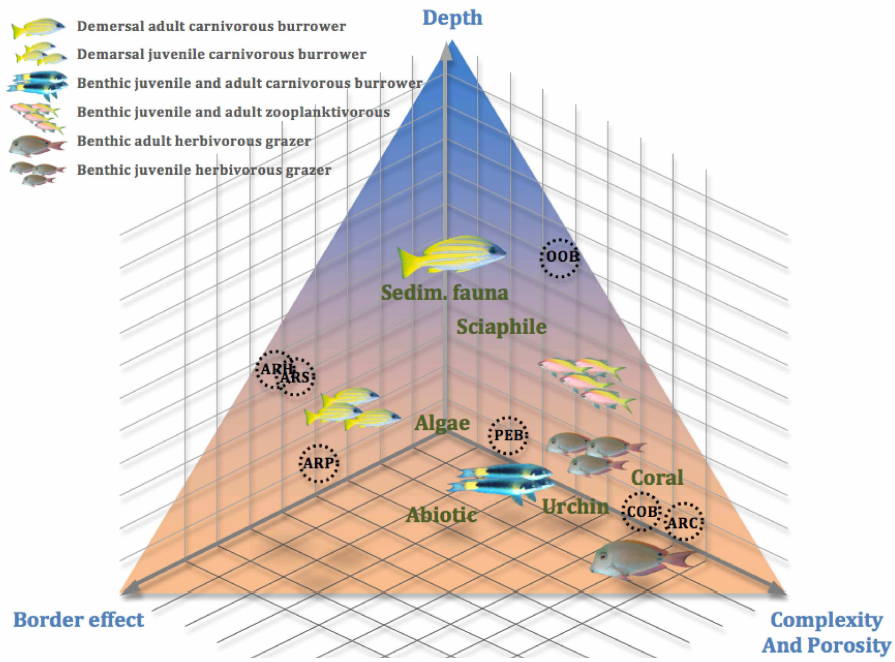

Figure 4: Synthetic scheme of ecological system in La Possession Bay

The depth axis separates littoral habitats (ARC, COB, PEB) from deep habitats (ARP, ARH, ARS, OOB). Axes "border effect" and "structural complexity and porosity" permit a finer separation of habitats identified at equivalent depths. As appropriate, coastal habitats are characterized by low border effect, structural complexity and porosity (PEB) or a medium border effect and high structural complexity and porosity (ARC, COB). Similarly, in deep habitats, ARs are distinct from OOB by their high border effect and their low structural complexity.

Distribution of biotic habitat variables showed that the coral cover rate and abundance of sea urchins were mainly influenced by high structural complexity and porosity. The rate of sciaphile organism cover and sediment macrofauna abundance increased with depth. The border effect seemed to be involved in the distribution of abiotic substrates, probably by inclusion of sandy sediment or abrasion of the outer surfaces of habitats.

Distribution of fish community structures showed that benthic species preferred habitats with high structural complexity (COB and ARC). Demersal carnivorous burrower species preferred deeper habitats with high border effect and high sediment macrofauna and sciaphile organisms abundances, as ARs for juveniles and OOB for adults.

Conclusion

This study illustrated the spatial variability of all factors measured in La Possession bay. Fish community structures, constrained by biotic and abiotic habitat factors, mainly showed an allocation strategy, based on different types of species and their ecological preferences (substrate protection, feeding habit, etc.). In Reunion Island, ARs were mainly used as support of conservation or restoration of fishery resources, to assist coastal fisheries. In this context, the targeted species were mainly demersal carnivorous burrowers (*Mulloidichthys spp*. *Lutjanus spp.*, etc.). Pattern obtained from this study suggested that this type of species is rather influenced by the border effect and abundance of food. The increase of immersion depth and surface of ARs would also encourage the establishment of more mature fishes.

References

Chessel D., Lebreton J.D., Yoccoz N. (1987) Propriétés de l'analyse canonique des correspondances ; une illustration en hydrobiologie. Revue de Statistique appliquée, 4, 55-72.

Conand C., Chabanet P., Quod J.P., Bigot L. (1997) Suivi de l'état de santé des récifs coralliens du sud-ouest de l'Océan Indien : manuel méthodologique. Programme Régional Environnement, 27p.

Dahl A.L. (1981) Coral Reef Monitoring Handbook. South Pacific Comission, Noumea, New Caledonia.

Hodgson G., Hill J., Kiene W., Maun L., Mihaly J., Liebeler J., Shuman C., Torres R. (2008) Reef check instruction manual: A guide to reef check coral reef monitoring. Reef Check Foundation, California, annual report, 21p.

Labrosse P., Kulbicki M., Ferraris J. (2002) Underwater visual fish census survey. Proper use and implementation. Secretariat of Pacific Community, Noumea, New Caledonia, 54p.

Lebreton J.D., Sabatier R., Banco G., Bacou A.M. (1991) Principal component and correspondence analysis with respect to instrumental variables: an overview of their role in studies of structure-activitiy and species environment relationship. 29p.

Letourneur Y. (1998) Composition, structures and trophic networks of the fish communities of the windward coast of Réunion Island. Réunion University. Cybium, vol. 22, n°3, pp. 267-283.

Mandelbrot B. (1977) The Fractal Geometry of Nature. Yearbook of Science and the. Future, Encylcopaedia Britannica, Inc. pp. 168-181

Prodon R., Lebreton J.D. (1994) Analyses multivariées des relations espèce-milieu : structure et interprétation écologique. Vie Milieu, 44, 69-91.

Seaman W., Jensen A.C. (2000) Purposes and practices of artificial reef evaluation. In : Artificial reef evaluation with application to natural marine habitats. W. Seaman Jr, ed. 1-19.,

Wilson S.K., Graham N.A.J., Polunin N.V.C. (2007) Appraisal of visual assessments of habitat complexity and benthic composition on coral reefs. Marine Biology, 151,1069-1076.

Investigating an avian source of shellfish microbial contaminations on the lagoon of Wild fish population around the sea-cages of the eastern Adriatic tuna farms

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Abstract

The abundance and size structure of wild fish aggregated around the sea-cages of two commercial blue-fin tuna farms were assessed and compared with control locations over a period of one year. Tuna farms were located in the Eastern Adriatic, offshore from islands Ugljan and Brač. Fish assemblages were evaluated through visual census using SCUBA bimonthly time spans, on two sites within each farm. Our data suggests that the assemblages of wild fish differ greatly between the control locations and the farms; 20 species occurred at Ugljan farm and 17 at Brač farm while only 7 were observed at both control locations. Abundance and diversity of wild fish assemblages were greater at the farms in comparison with the control locations. Most abundant families were Sparidae and Belonidae (>80% of aggregated fish). In both farms, abundance and diversity of wild fish were highest during the summer, while winter had the lowest diversity, mainly characterized by the presence of schools of *Boops boops* and *Belone belone*. Assemblages at the Ugljan farm significantly differed between the seasons, with *B. belone* being dominant during the summer and autumn, *Oblada melanura* in spring, *Sardinela pilchardus* and *Sarpa salpa* in winter. At the Brač farm, permanent dominance of *B. boops* was recorded throughout the year. We also observed that settlement have a significant role in the farm-associated fish assemblages since juveniles and advanced juveniles were common residents at both farms. The majority of species that settled at farms belonged to the sparid family. The results indicate that the aggregations of wild fish at tuna farms are persistent all through the year, but the assemblages' compositions and size structures of dominant species differ in respect to the location and seasons.

Incidental catches of thresher sharks in the Gulf of Lions (Mediterranean Sea)

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Introduction

In the Mediterranean Sea, two thresher shark species occur: the common thresher shark (*Alopias vulpinus*) and the bigeye thresher (*Alopias superciliosus*); both are coastal epipelagic sharks. These species are caught by the industrial and semi industrial trawl and longline fisheries, the artisanal gillnet fisheries and the recreational fisheries. Moreover, very little is known on their biology and ecology, and almost nothing about their population structure. Common thresher shark declined between 96 and 99.99% relative to their former abundance. According to World Conservation Union (IUCN) criteria, these species would be considered critically endangered (Ferretti et al., 2008). There are concerns about decline of their stocks in the Mediterranean Sea and ICCAT recommended (09/07) the implementation of research on thresher sharks. In France, thresher sharks are caught incidentally mainly by the trawlers targeting small pelagic fish in the Gulf of Lions and they are landed in two major harbours (Sète and Port-Vendres). Fishing industry shares the same concerns as ICCAT about the status of the thresher sharks in the Mediterranean Sea and provided some funds to carry out a small scale research programme ("Alop") in collaboration with scientists to investigate the impact of the fishing activity on their stocks.

Objectives of the "ALOP" project

The present study focus on the impact of the French trawl fishery in the Gulf of Lions on the thresher sharks (Fig. 1). The tasks of the Alop programme are (1) to monitor of the landings and to reconstruct the landing time series of thresher sharks, (2) to collect the basic biological parameters and (3) to study of the feeding ecology (isotope, fatty acids, and contaminants) of the common thresher shark. In addition, incentive and compensatory measures will be initiated to encourage fishermen to release the individuals alive at sea. We report on the preliminary results of this research programme.

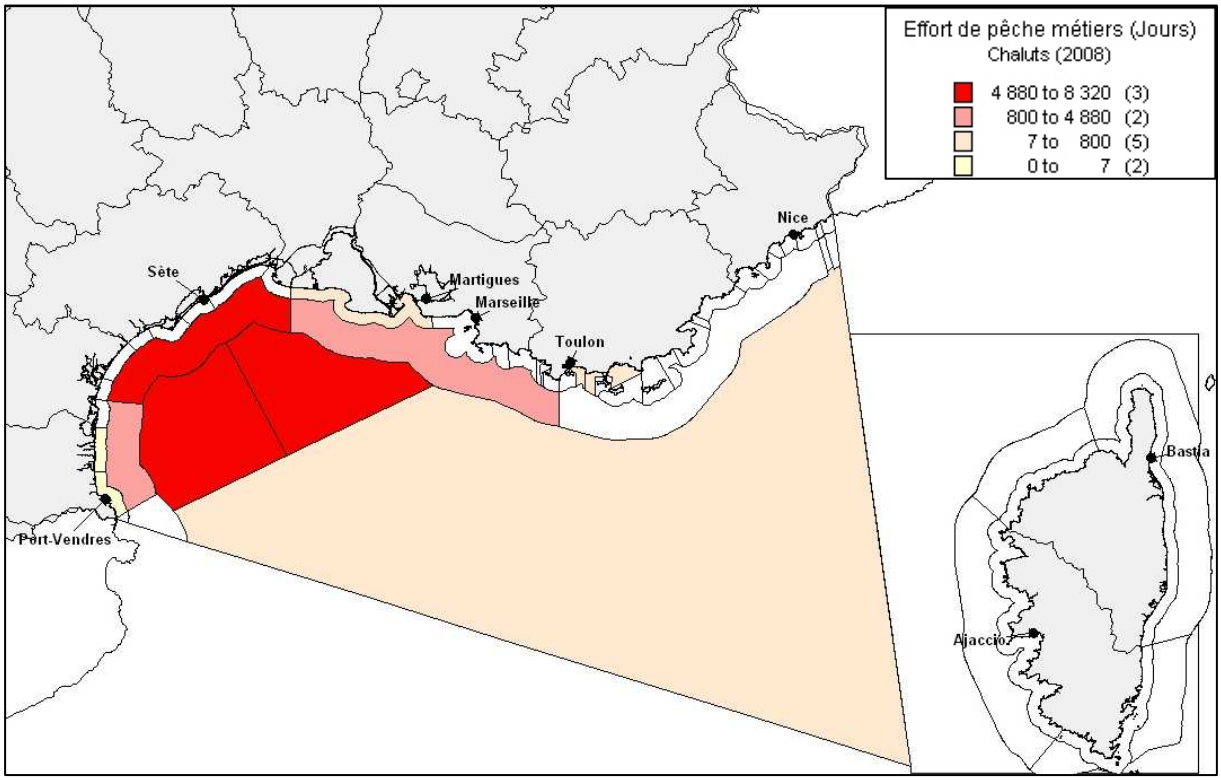

Figure 1 : Fishing effort in days of the trawlers based in the Gulf of Lions in 2009 (Number of fishing days).

To fulfill the Regional Fisheries Management Organisations (ICCAT,GFCM) catch data reporting requirements, the following tasks are undertaken:

- Collection and collation of the electronic detailed daily sale reports of the main auctions
- Update of the official catch statistics with the complementary data retrieved
- Implementation of fishers interviews and of a small scale logbook Program

This survey focus currently on Sète (Fig. 2)., which is the main harbour of the Gulf of Lions but it should be extended to other harbours in the near future.

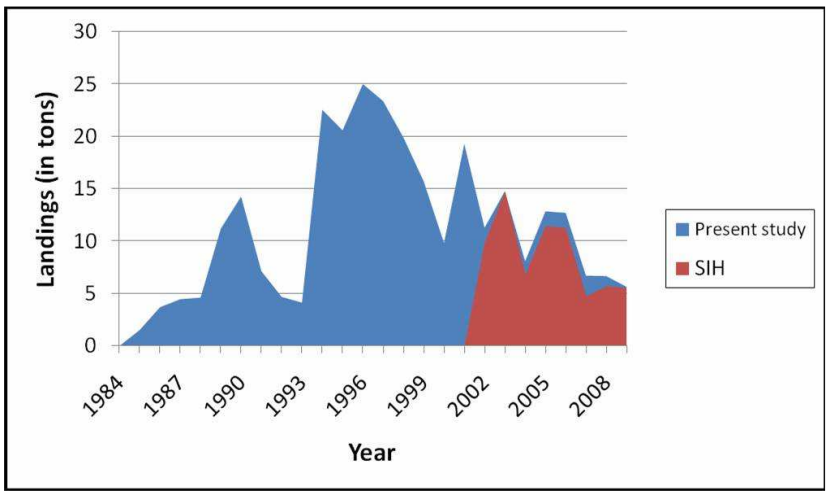

Figure 2 : Update of the landings statistics time series for thresher shark caught by the trawlers fleet in Sète from 1984 to 2009 (SIH official data).

The number of thresher sharks caught has been decreasing over the year (Fig. 3). The occurrence of small individuals (<10 kg) has been noticed suggesting nursery grounds in the

Gulf. This information must be confirmed during our samplings on the field. The thresher sharks are mainly caught in summer, especially in July, and their catch are highly associated with the catch of pelagic fish.

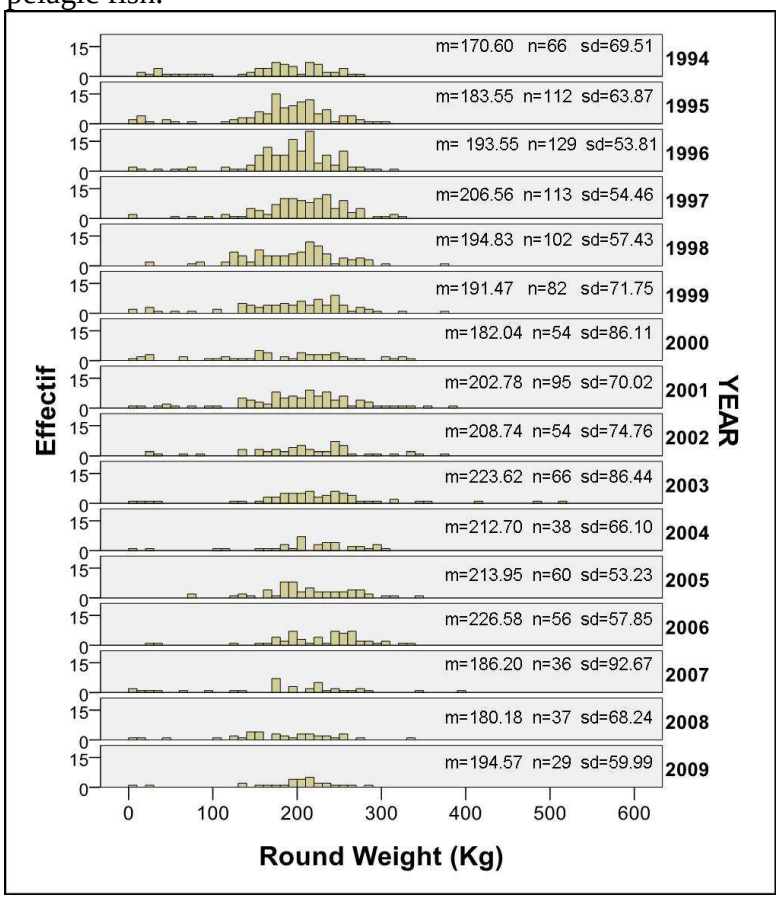

Figure 3: Size frequency distribution (10-kg classes) for thresher sharks landed between 1994 and 2009, at Sète the main auction of the French coast.

Conclusion

The local Fishing industry has serious concerns about the status of the thresher sharks. Complementary fundings have been granted by the regional council in order to finance :

- At port samplings (1) to confirm the occurrence of both species in the area, (2) to collect basic biological parameters (weight, sex, conversion factor) and (3) to collect tissues for the isotope and fatty acids Analyses.
- Incentive and compensatory measures which could encourage fishers to release thresher sharks alive
- Tagging experiments on released sharks with pop-up tags to assess their post-release mortality rate and provide information on their diel behaviour and movement patterns

In addition, Guidelines to handle and release sharks at sea will be provided to fishers in order to reduce post release mortality.

References :

Ferretti, F., Myers R. A., Serena F., and Lotze H. K.,2008. Loss of large predatory sharks from the Mediterranean Sea. Conservation Biology, 22:952-964.

Human impact on the catch composition of traditional set-net operated in the south – basin fishing ground of Lake Biwa

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Abstract

This study aims to obtain basic information on the influence of exotic species on a small set-net catch operated in the western part of the south-basin fishing ground of Lake Biwa - the largest lake in Japan with an area of 672 km^2 and a maximum depth of 103.8 m. It is also one of the oldest lakes in the world. Presently, 24 species of fish (including six endemic species), five species of shellfish, and two species of prawns are being fished commercially. The small set-net is designed to catch migratory species that tend to follow the shore of the lake. One of the features of set-net catch is that due to its passive function, it is closely related with the temporal-spatial migration pattern of aquatic organisms living near the fishing ground. To identify, the influence of exotic species on both set-net catch quality and quantity, the set-net catch data from 1991 to 2005 were evaluated. While the native species catch had been decreasing from 1993, the exotic species catch had on the other hand been increasing from 1993 to 2003. The value of catch species diversity index (δ) for 2005 is almost half the value in 1993 value. In this region, the temporal and spatial distribution pattern of the migrating species seems to have significantly changed, and for the past 15 years, there is less diversity in the catch of native migratory species.

Objective

This study aims to obtain basic information on the influence of exotic species on a small set-net catch operated in the western part of the south-basin fishing ground of Lake Biwa - the largest lake in Japan with an area of 672 km^2 and a maximum depth of 103.8 m. It is also one of the oldest lakes in the world.

Lake fisheries

Presently, 24 species of fish (including six endemic species), five species of shellfish, and two species of prawns are being fished commercially. The passive function is characteristics of the fisheries in Lake Biwa. The largest passive gear in the lake fisheries is a set-net “Eri” and the amount of catch by set-net fishery is the second largest among the major fisheries contributing about 28% to the total catch (2006). It is designed to catch migratory species that tend to follow the shore of the lake (Fig.1).

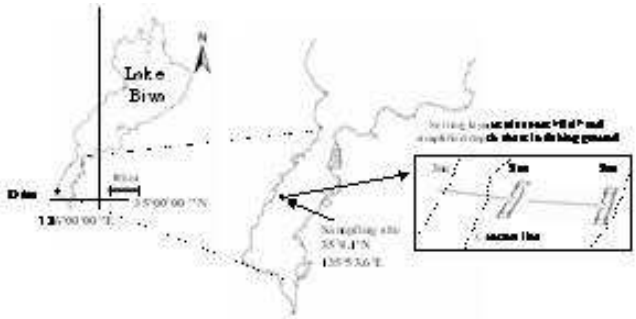

Figure 1: Sampling site

Results and Discussion

The set-net catch data from 1991 to 2005 were evaluated. While the native species catch had been decreasing from 1993, the exotic species catch had on the other hand been increasing from 1993 to 2003 (Fig. 2). The value of catch species diversity index (δ) for 2005 is almost half the value in 1993 value (Fig. 3). In this region, the temporal and spatial distribution pattern of the migrating species seems to have significantly changed, and for the past 15 years, there is less diversity in the catch of native migratory species. It is reasonable to assume that the dominant species change could indicate the possibility of a coastal ecosystem change in the western coast of south-basin fishing ground, it seems more probable that the effect of dominant species changes in the area on the apparent set-net catch reduction.

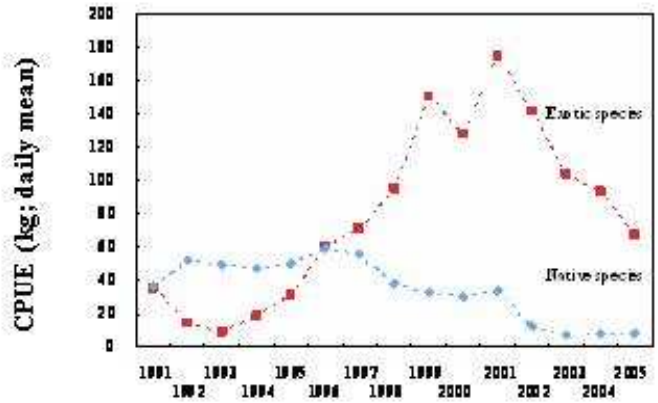

Figure 2: Daily catch variations in exotic and native species

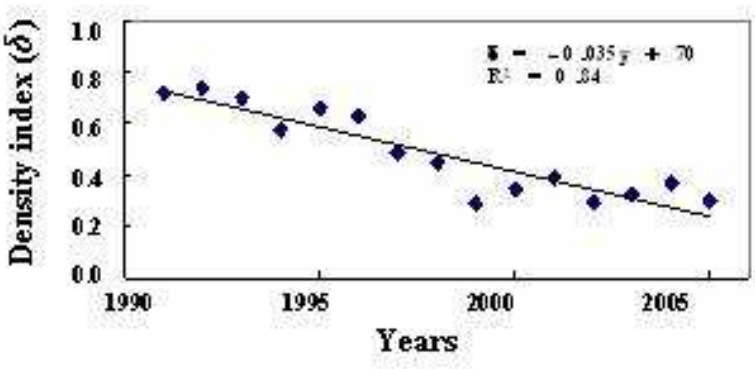

Figure 3: Yearly changes in diversity index (δ) for 15 years

Relationship between the discards and catch-diversity of the set-net fishery

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Abstract

The set-net fishery is one important coastal fishery in Japan, and in 2005, it comprised 38% (554500 tons) of the 1.465 million tons of total catch in coastal fisheries. In set-net fishery, generally many species (including non-commercial species) are caught but with only a small number for each species. The catch diversity is reflected in the biological process such as distribution or behavioural pattern of migrating species near the set-net. Generally, both the quantity of catch and its composition are closely related with each other. For effective management of coastal resources, it is necessary to clarify the relationship between the quantities and discards problem of this fishery. In Japan's coastal area, there are many commercial species have been distributing, and these species have been caught by many fishing units. Both the catch composition and the amount of catch varied depending on the season and geographical position of the fishing ground. This report provides an example of the relationship between the catch-diversity and the amount of discards using daily catch data obtained from three fishing grounds at different latitudes fishing ground, Tateyama (middle latitude), Taiji (middle latitude) and Kaimon (low latitude) during 1996, 1998, 1999, 2000 and 2001 fishing periods. Although there are differences in the fishing grounds, the results suggest that the amount of discards decreased with the increase in the landing and the diversity of catch species which is also closely related with the amount of landing.

Objective

The set-net fishery is one important coastal fishery in Japan, and in 2006, it comprised 38% (554,500 tons) of the 1.465 million tons of total catch in coastal fisheries. In set-net fishery, generally many species (including non-commercial species) are caught but with only a small number for each species. The attention is focused on the relationship between the amount of landings, species diversity, and the amount of discards.

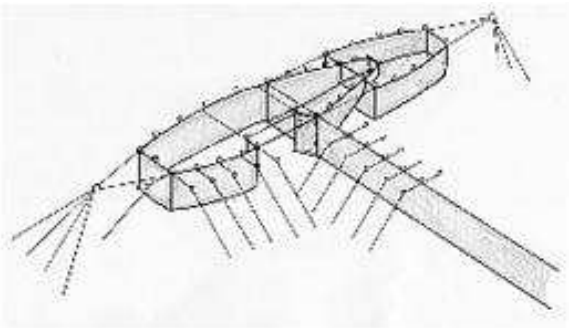

Figure 1: Schematic diagram of a set-net

Results

The amount of discards using daily catch data obtained from three fishing grounds at different latitudes fishing ground, Tateyama (middle latitude), Taiji (middle latitude) and Kaimon (low latitude) during 1996, 1998, 1999, 2000 and 2001 fishing periods (Fig. 2).

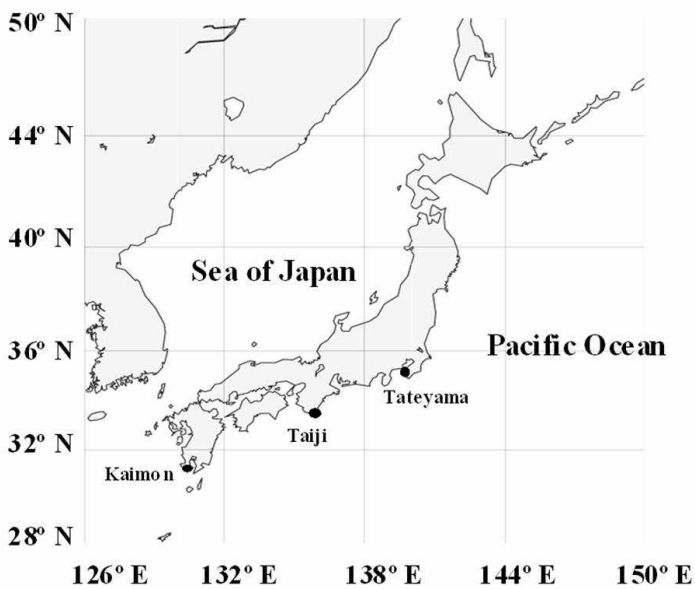

Figure 2: Sampling sites

In set-net fishery, generally many species (including non-commercial species) are caught but with only a small number for each species (Fig. 3).

Figure 3: Discarded fishes

Both the catch composition and the amount of catch varied depending on the season and geographical position of the fishing ground. The evidence indicates, however, that the decreasing trend of the value of δ indicates an increase in the amount of landing (Fig. 4).

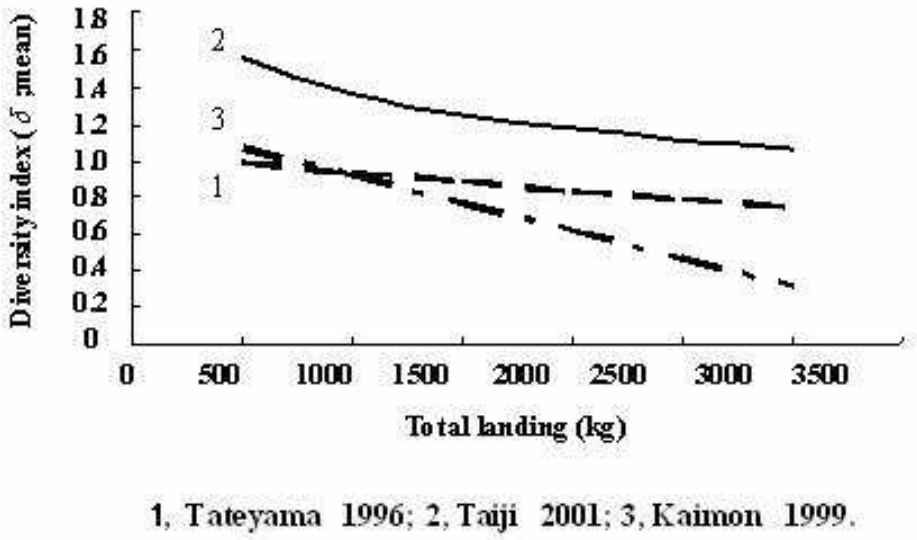

Figure 4: Relationship between δ and total landing(kg)

Discussion

It is to expect that the amount of discards will be controlled by the bio-diversity. One can estimate that the mean values of δ for each fishing ground will change according to the difference in the latitude.

How to minimize the discards from set-net fishery

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Abstract

One major fishery in the coastal area of Japan uses set-net, which employs many subtype of nets designed to reflect its regional characteristic. Both the catch composition and quantity vary depending on the season and the geographical position of the fishing ground. Consequently, we can emphasize that this has been in effect a multi-species fishery. Nonetheless, it remains necessary to provide cost-effective methods and techniques to minimize waste at this fishery. However, the evidence indicates that it is very difficult to collect useful data under actual conditions. The most serious difficulty is encountered during the selection process. Decisions about the selection are an important issue for this particular fishery because the catch is diversified depending on its passive catching function. Of course, the selection of species varies every day according to the catch diversity in each area. The methods developed in the southern area of Japan are appropriate in terms of reduction of discard mortality, making optimum use of harvests and reduction of post-harvest losses. This report provides one example of how the optimization of this operation method for multispecies fishing has been achieved for effective utilization of resources.

Objective

One major fishery in the coastal area of Japan uses set-net, which employs many subtype of nets designed to reflect its regional characteristic. This report provides one example of how the optimization of this operation method for multi-species fishing has been achieved for effective utilization of resources.

Figure 1: Sampling sites

Results

The species composition varied depending on the season (Fig. 2). In sub-system I, non-commercial species are used as feed mainly for aquaculture but some are released or consumed (Fig. 3). When considering the actual conditions in operation, the selection method in the sub-system is reasonable to get seedlings for aquaculture at low cost. This can be understood that it is one of the effective methods to reduce the post-harvest losses. In sub-system II for the processing, several processing methods are commonly provided to satisfy the requirements from the market. In this system, one can preserve the product after processing during several days in a warehouse equipped with freezer.

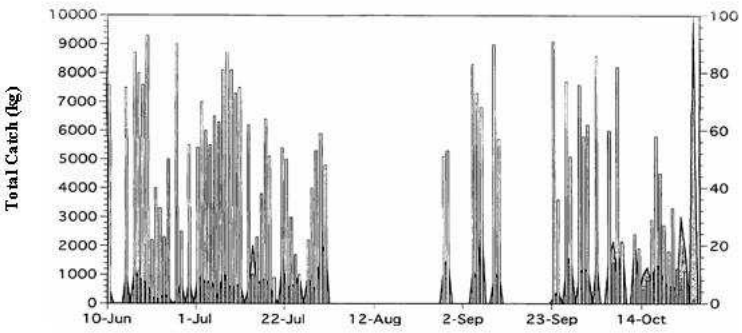

Figure 2: Daily catch variations and the ratio of non-commercial species or small commercial species in the catch.(white), the daily total catch;(grey), the ratio of non-commercial or small commercial species in the catch

Discussion

The methods developed in the southern area of Japan are appropriate in terms of reduction of discard mortality, making optimum use of harvests and reduction of post-harvest losses.

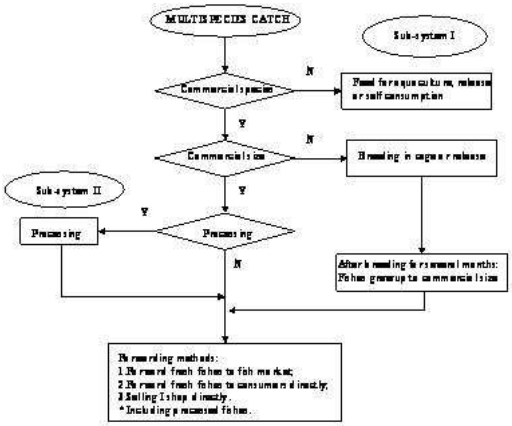

Figure 3: Flow-chart for effective multi-species utilization

Effects of currents and the induced net deformation on set-net fishery, experimental and numerical approach

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Abstract

Catch characteristics of set-nets which are classified as passive fishing gear are probably affected by hydrodynamic conditions in fishing grounds. To investigate relationship between set-net deformation and fish catch quantities, we measured depths of 5 places of a bag net bottom in the set-net and current velocity and direction around the set-net. The experiments were carried out in Toyama Bay, Japan. In addition, we estimated the net volume in several current conditions using a net geometry simulator. The current condition was different from that other side. Deformation of the bag net in southward current is larger than that in northward currents. In the numerical simulation, net volume reduction with southward current was 30% and that with northward current was 10%, in the same velocity of 0.2 m/s (or 20 cm/s). The trend of catch quantity was low in the southward current and high in the northward current. These results show that differences of the net deformation caused by variation in hydrodynamic condition affect catch quantity a great deal.

Objective

This study aims to obtain basic information on the influence of the current profile concerning the capture process of a set-net by focusing on the relationship between the daily changes in the amount of the catch and current profile near a set net.

Materials and Methods

A series of observations was done in 2006 and 2007 fishing periods off Waki, off the Waki area on the west coast of Toyama Bay (N37°25' E137°05'), Japan (Fig. 1). A current meter (ALEC ELECTORONICS LTD., COMPACT-EM, accuracy ±1cm/s) was set near a chamber of set net and ground to observe the current magnitude, while direction and temperature were recorded continuously for 10 min. In addition, in order to measure the amount of change on the volume of the chamber, five micro pressure data loggers (DST –milli; Star- Oddi LTD.) were attached to the four corners and the center of the chamber's bottom. The deformation of the chamber by current was recorded through pressure change for each portion continuously for 10 min. In addition, we estimated the net volume in several current conditions using a net geometry simulator (NaLA).

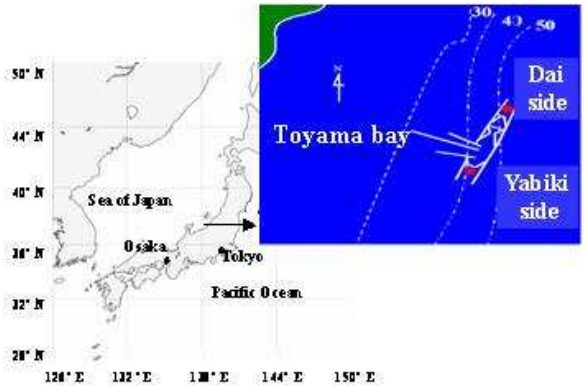

Figure 1: Sampling sites

Results and Discussion

Deformation of the chamber in southward current is larger than that in northward currents. In Figure 2, the relationship between current directions (degree), current velocity (cm/s) and chamber bottom depth are shown. All catch data were arranged through Catching index C_i (Daily catch / Mean catch during observation period). Actually, here, the C_i values were separated in two groups due to its magnitude. For the first group, C_i value is less than 10, and for the second group, C_i value is over 10. Both current directions during low current velocities in the area bring good catches. In the numerical simulation, net volume reduction with southward current was 30% and that with northward current was 10%, in the same velocity of 0.2 m/s (or 20 cm/s). The trend of catch quantity was low in the southward current and high in the northward current. These results show that differences of the net deformation caused by variation in hydrodynamic condition affect catch quantity a great deal.

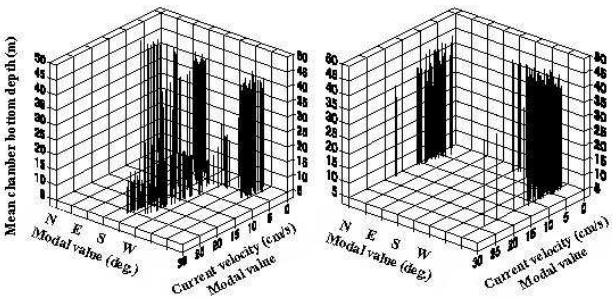

Figure 2: Relationship between chamber bottom depth and current profile. The left half shows results for catch index less than 10, and the right half shows those for over than 10.

Integration of Fisheries and Aquaculture industries into planning and management

Synthesis of scientific studies undertaken during six years on the Mediterranean "thonaille" fishery: bycatch and solutions

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Introduction

The thonaille net is considered by the European Union as a drift gillnet and is so prohibited since 2002 (Regulation 894/97). The prohibition aims at a particular artisanal French Mediterranean fishery called "thonaille" which targets the blue fin tuna (*Thunnus thynnus*) and the swordfish (*Xiphias gladius*). Practised off the Mediterranean French coasts by small boats (< 14 m), the thonaille fishery uses surface pelagic net sets at dusk and rises at dawn. This night-type fishery is ancient and seasonal, fishing during less than 24 hours. In 2002, professionals concerned mobilized as a trade-union coordination aiming at making their activity live and showing that these kinds of nets cannot be assimilated to large drift nets targeted by the UNO (A/RES/44/225). Within this framework, they requested help from the Regional Councils of Provence-Alpes-Côte d'Azur (PACA) and Languedoc-Roussillon (LR). The latter then entrusted from 2000 to 2003 to the "Centre d'Océanologie de Marseilles" (COM) a scientific expertise in order to characterize in a precise way the fishery organisation and to evaluate its impact on the main captured populations. In 2004 and 2005, the French Ministry of Ecology and Sustainable Development as well as the region PACA ordered a complementary study to the "Groupe d'Etude des Cétacés de Méditerranée" (GECEM) to estimate the impact of the thonaille fishery on striped dolphins (*Stenella coeruleoalba*).
This fishery profits at the French level from a Special Fishing Permit (PPS) defining the technical use of the thonaille with criteria in order to frame this fishery. Among them: a number of PPS limited to 100, the global use of "pingers" (device emitting high frequency acoustic signals of low power) to decrease captures of cetaceans, a net length of 1 nautical mile (1 852 m) per man, 5 men being the maximum number of men aboard (that is 9 260 m).
In March 2009, an European Decree prohibited definitively this fishery.
The following document presents the main results of the scientific studies undertaken between 2000 and 2005.

Area and method of study

Observers from the C.O.M. and the G.E.C.E.M. have collected data aboard the thonailleurs (boats) between May 2000 and October 2005 (tab.2). Data picked up from the ship's books and the monthly fishermen's official declarations have also been gathered.

Table 2: numbers of night sets carried out by scientists aboard compared to the total number of night sets done by the fishermen each year (according to David 2005 and Imbert and Al, 2005 4)

Organization	Year	total number of declared sets	scientific data		Observation effort
			Sets with observer	Control at the dock	Observed set/ declared set
COM	2000	943	69	77	7.3 %
COM	2001	834	114	24	13.7 %
COM	2002	619	102	60	16.5 %
COM	2003	630	69	41	11.0 %
GECEM*	2004	1095	23	0	2.1 %
GECEM	2005	1180	82	0	6.9 %
	Total	5301	459	202	8.6 %

* study started in the course of fishing year thus considered to be non representative.

The thonaille fishery is one of the most observed in Europe: nearly 45% of the flotilla, 2 990 km of net in 459 sets were examined. The observation effort reaches an average of 8.6% in the annual fishing effort over 5 year ½ .

Fishing Area and effort

The thonaille fishery covers a wide area in the north of the Western basin, from Port-Vendres (French-spanish frontier) to Nice (Figure 1). About a half of the sets is located within the limits of the PELAGOS Sanctuary for marine mammals. The effort is seasonal, mainly concentrated from May to September. The boats get out on average 2.5 to 7 days a month.
Capture rate and estimate of cetacean bycatch

The thonaille fishery is selective: both of the targeted species constitute more than 66% of the captured fish. Almost 85% of the captures are marketed and only 1% concern protected species. Among them, the very great majority of the animals returned at sea are alive, except the cetaceans found dead in the nets.
Of a total of 459 sets and 2,990 km of net examined in 6 years, the observers recorded 104 captures of cetaceans of 4 different species, mainly striped dolphin.
The average capture rate of the striped dolphin from 2000 to 2005 (except 2004), was: 90 dolphins from 436 sets observed = 0.206 striped dolphin/set over 5 years. We calculated using bootstrap method that on average 155 dolphins (CI 95%: 114 – 199) are bycaught every summer by the whole fleet from June to Sept.

Globally, more than half of all bycaught dolphins are year-born calves, and this usually occur from June to September with a peak in August (David 2005). Among the bycaught animals, it seems that there are slightly more females (55.8%) than males (44.2%), if one take into account sex-determined individuals only (N=52) (David 2005).

Factors influencing captures

Design features

On the 9 design features of the ship and its net that were tested, it was found that **only the** length of the net influences the captures of cetaceans. According to Gaertner *et al*, (2002), all of the ships which caught one or more dolphins in 2000 fished with a net length of ≥ 5.5 km. Moreover, according to Diéval (2003), opposing oceanic currents create an important deformation of the net which would lead to significantly more captures (p=0.0002). Annual and monthly variability

According to data collected, David (2005) does not find inter-annual variability of the captures, on the other hand there is a significant monthly variability (p=0.03), i.e. the probabilities of captures are higher in August and September and weaker in July. Spatial variability

Dolphin bycatch is rare below 5°E, and no particular area of capture was highlighted in the fishing zone. In addition, there are almost as many captures within the limits of the Sanctuary than outside. Pingers

All years confounded, the use of pingers significantly reduce (p=0.02) the number of dolphins captures, especially those of calves (David 2005). This could reduce dolphin bycatch's rate by 58% and the number of individuals captured by 64% (David 2005).

Possible solutions

In the various reports, operational solutions aiming at decreasing dolphin bycatch were highlighted by the results obtained. All fishermen should commit to applying them:

- Set the net against the current
- Keep the net tightened right and rectilinear without creating "pocket" (geometry complexes)
- Use a sufficient number of pingers to cover the net, attach them on the lower rope of the net and every 200 m at maximum

Other solutions can be introduced, having proven to be reliable in similar fisheries:

- Aerial acoustic signal (bell)
- Set the tuna fishing gear deeper under the surface
- Attract calves and juveniles towards exit gates

At the same time the precautionary approach is the most effective measure, i.e reduction of effort of fishing:

- Partial closure of the fishery in August and September in the Sanctuary
- Shorten the tuna fishing gear to < 5.5 Km
- Limit the amount of time the gear is in the water

Operational solutions can easily be implemented to reduce the number of incidental captures. It is necessary to be aware that risk zero does not exist.

Indicators, Management and Conservation Plans

Several authors used the "Potential Biological Removal" (PBR) in order to measure the impact of the fisheries on the population of striped dolphins. It is defined as "the maximum number of animals that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population". The PBR is the product of (Nmin) the minimum evaluation of population, (0.5 Rmax) half of the maximum net rate of productivity and of a factor of recovery (FR), such as

PBR = Nmin * 1/2 Rmax * FR.
The threshold of negligible impact is evaluated with 10 percent of the PBR**.**

The number of dolphins captured by the tuna fleet was estimated at 155/summer on average in the entire fishing zone, being certainly a minimum. Currently dolphin bycatch by the tuna fishery represent slightly less than 10% of the PBR (=184 individuals) if one takes into account the entire population in the north of the western basin (184 380 ind.).

Conclusion

This fishery has been one of the most studied in Europe, greatly pushed by fishermen themselves.
In fact the captures reflect the diversity of species, the abundance of the animals, the composition by age class and the sex ratio of the groups of cetaceans in the fishing zone.
Indeed the zone is often frequented by cetaceans, including an important majority of striped dolphins that favour the oceanographic conditions. The calving period for *Stenella* takes place from July to October, with a peak which would occur from end of July to August-September. These peaks correspond to those of the captures.
According to the studies carried out from 2000 to 2005, it seems that if actual mitigation measures and operational procedures aiming at decreasing cetacean bycatch are correctly and systematically applied, the impact of the accidental captures on striped dolphins should not endanger the population of the north of the Mediterranean basin.

Acknowledgments

We thanks all the benevolent observers, the fishermen and colleagues scientists who take part to this study.

Reference

Banaru D., 2004. Conditions d'environnement dans le nord du bassin occidental de la Méditerranée et abondance des grands prédateurs pélagiques. Rapport de DEA, Centre d'Océanologie de Marseille, 40p.
Contino F. 2004. Contenus stomacaux des thons rouges (*Thunnus thynnus* L., 1758) capturés par les thonailles dans le bassin provençal. Rapport de maîtrise. Centre d'Océanologie de Marseille, Université de la Méditerranée, Marseille, 26p.
Coordination des pêcheurs de l'étang de Berre et région. 2005. La pêche à la thonaille : Un enjeu pour l'avenir du secteur « petit métier » en Méditerranée. Document technique, 18p.
David L, 2004. Pêche à la thonaille et dauphin bleu et blanc quel impact ? Evaluation du nombre de *Stenella coeruleoalba* pris accidentellement lors de la pratique de la pêche à la thonaille, et caractéristiques biologiques des dauphins. Rapport intermédiaire. GECEM : 42p.
David L, 2005 Pêche à la thonaille et dauphin bleu et blanc quel impact ? Evaluation du nombre de *Stenella coeruleoalba* pris accidentellement lors de la pratique de la pêche à la thonaille, et caractéristiques biologiques des dauphins. Rapport final 2005. GECEM : 51p.
Dieval E., 2003. Relations entre la dynamique d'un filet de surface et sa sélectivité en pêche (approche préliminaire appliquée au cas de la thonaille méditerranéenne), 2003.DEA Université de la Méditerranée, Centre D'Océanologie de Marseille, 25 p.
Gaertner J_C., Imbert G., Laubier L., Massié A-L., Dekeyser I., 2002. Typologie de la flottille pratiquant la pêche à la thonaille en Méditerranée française. Aix-Marseille II, Centre D'Océanologie de Marseille. 50p.

Imbert G., Gaertner J_C. et Laubier L., 2001. Expertise scientifique de la pêche à la thonaille méditerranéenne : suivi en mer de la campagne 2000. Centre D'Océanologie de Marseille. Région PACA, commande n°3340, 90p.

Imbert G., Gaertner J_C., Cerbonne S. et Laubier L., 2002. Effets des répulsifs acoustiques sur la capture de dauphins dans la pêche à la thonaille. Centre D'Océanologie de Marseille. Région PACA, commande n°15241, 36p.

Imbert G., Bouchart O., Gaertner J.-C. et Laubier L., 2005-1. Suivi en mer de la campagne de printemps 2001 au large des côtes du Languedoc-Roussillon. *In :* Imbert G., Laubier L., Gaertner J.-C., Malan L. et Dekeyser I., 2005. Thonaille méditerranéenne. Rapport d'expertise finale (n°IV), 15 décembre 2005 : 325 pp.

Imbert G., Cerbonne S., Malan A., Dekeyser I et Laubier L., 2005-2. Effet d'un balisage acoustique sur les captures de dauphins dans les thonailles. *In :* Imbert G., Laubier L., Gaertner J.-C., Malan L. et Dekeyser I., 2005. Thonaille méditerranéenne. Rapport d'expertise finale (n°IV), 15 décembre 2005 : 325 pp.

Imbert G., Contino F., Astruc A., Laubier L. et Dekeyser I., 2005-3. Prélèvements d'échantillons cétologiques et analyses de contenus stomacaux. *In :* Imbert G., Laubier L., Gaertner J.-C., Malan L. et Dekeyser I., 2005. Thonaille méditerranéenne. Rapport d'expertise finale (n°IV), 15 décembre 2005 : 325 pp.

Imbert G., Bànaru D., Laubier L. et Dekeyser I., 2005-4. Apports de l'imagerie spatiale à l'étude de la thonaille méditerranéenne. *In :* Imbert G., Laubier L., Gaertner J.-C., Malan L. et Dekeyser I., 2005. Thonaille méditerranéenne. Rapport d'expertise finale (n°IV), 15 décembre 2005 : 325 pp.

Imbert G., Laubier L. et Dekeyser I., 2005-5. Etat descriptif de la flotte aux petits métiers armant saisonnièrement à la thonaille. *In :* Imbert G., Laubier L., Gaertner J.-C., Malan L. et Dekeyser I., 2005. Thonaille méditerranéenne. Rapport d'expertise finale (n°IV), 15 décembre 2005 : 325 pp.

Imbert G., 2005-6. Etude comparative des pêcheries utilisant des filets similaires à la thonaille. *In :* Imbert G., Laubier L., Gaertner J.-C., Malan L. et Dekeyser I., 2005. Thonaille méditerranéenne. Rapport d'expertise finale (n°IV), 15 décembre 2005 : 325 pp.

Imbert G., Laubier L., Malan A., Gaertner J.-C. et Dekeyser I., 2005-7. Compléments et exposé de synthèse finale. *In :* Imbert G., Laubier L., Gaertner J.-C., Malan L. et Dekeyser I., 2005. Thonaille méditerranéenne. Rapport d'expertise finale (n°IV), 15 décembre 2005 : 325 pp.

Imbert G., Contino F., Malan A., Astruc G. et Relini G. 2007. Interactions trophiques entre cétacés et thons rouges. Présentation au colloque « Pêche, Acoustique et Mammifères marins », 27 février 2007, CNPMEM, Paris.

Laubier L., Imbert G., Malan A., Cerbonne S. et Dekeyser I., 2007. Effet des microbalises acoustiques sur la prévention des captures de *Stenella coeruleoalba* dans les thonailles. Présentation au colloque « Pêche, Acoustique et Mammifères marins », 27 février 2007, CNPMEM, Paris.

Malan A. 2007 Principe d'une gestion durable des populations de dauphins. Présentation au colloque « Pêche, Acoustique et Mammifères marins », 27 février 2007, CNPMEM, Paris.

Monestiez P., Dubroca L., Bonnin E., Durbec J_P. and Guinet C., 2005. Geostatistical modelling of spatial distribution of *Balenoptera physalus* in the northwestern Mediterranean Sea from sparse count data and heterogeneous observation efforts. Ecological modelling : 193 (2006) 615–628

Artificial reefs as fisheries management tools in the northern Adriatic Sea

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Introduction

The setting up of artificial reefs to attract fish in the Mediterranean Sea goes back at least to around 3000 years ago. Later on, between 1800s and 1960s the rocks used as anchors for the tuna fishery nets were left on the seabed at the end of each fishing season and accumulated over time to make new rocky habitats populated by benthic fauna and fish which were exploited by local fishermen during the intervals between the fishing tuna seasons (Riggio et al. 2000). In spite of this ancient tradition, the modern concept of ARs was adopted only after the second half of 1900s. Since then, a great number of ARs have been deployed in many Mediterranean countries to date and several programs continue to this day. France, Israel, Italy, Principality of Monaco, and Spain were the first countries to construct ARs between 1970s and 1980s. In the last twenty years ARs have been also deployed in Cyprus, Greece, Malta, Tunisia, and Turkey. In most of these countries ARs have been realised for purposes of fisheries management, that means: to enhance small-scale fisheries using set gears, to reduce conflicts between different fishing activities, and to protect either coastal spawning and nursery areas or other sensitive habitats such as sea grass meadows (e.g., *Posidonia oceanica*) against illegal trawling.

2. Description of the area

A typical example of the use of ARs for fisheries enhancement and management can be found in the western side of the northern Adriatic Sea. This area is characterised by a heavy river runoff causing eutrophication and, hence, making this sea highly productive. Such feature and the occurrence of a wide continental shelf favor several fishing activities, both professional - trawling, hydraulic dredges for bivalves (e.g.. *Chamelea gallina*, *Callista chione*, *Ensis minor*), mussel (*Mytilus galloprovicialis*) harvesting on wild banks, set gears - and recreational (e.g., spearfishing, line fishing, long lines). Shellfish culture, mainly mussel culture, is also well developed. Nevertheless, most of these activities compete each other for space and resources.

Competition for space and the decline of several fish stocks have pushed the search for improved management tools, including ecosystem-based fisheries management, Marine Protected Areas and ARs. ARs are usually deployed to protect inshore nursery areas from illegal trawling inside the 3 nm from the coast, to reduce conflicts between different professional fisheries, and to improve small-scale fisheries by increasing local finfish populations, providing safe areas for set gears, and developing new populations of mussels.

Sixteen ARs have been deployed since the second half of 1970s (Figure 1).

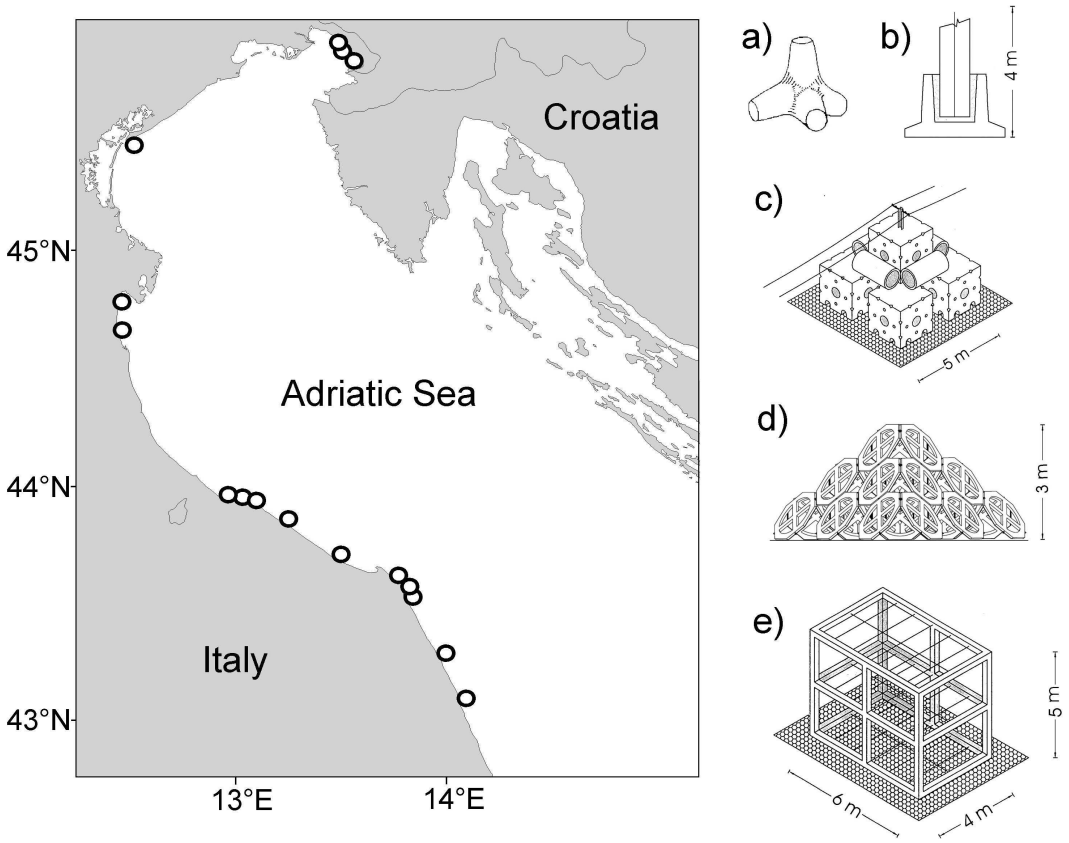

Figure 1: ARs deployed in the western side of the northern Adriatic Sea. a) and b) protection modules; c) production and protection modules; d) and e) production modules.

Most of them were realised by regional and local Authorities, some have been constructed and are directly managed by fishermen organizations, and a few small ARs have been deployed for research purposes.

Three general types of ARs can be identified on the basis of their function: protection, production and mixed. Protection and mixed reefs are usually large-scale reefs placed at about 3 nm off the coast and cover a seabed surface ranging between 0.5 and 365 km^2. The former are deployed to protect the coastal areas and other sensitive habitats against illegal trawling and are made of simple anti-trawling bodies (e.g., tetrapods, concrete cubic blocks; Figure 1). The latter are used to both impede illegal trawling and enhance fish populations, hence they can consist of either anti-trawling, mixed and production modules (Figure 1). Production reefs are medium-sized reefs placed within the 3 nm coastal area and occupy a seabed surface between 0.04 and 0.08 km^2. They are usually made of mixed or production modules with the aim of increasing fish stocks and exploitable biomass by providing shelter and food, improving local small-scale fisheries and, in eutrophic waters, developing extensive mussel culture.

Methods

Multi-year monitoring programs are usually carried out at the ARs before and after their installation. Fishing sampling using set gears and UW visual census are performed to investigate the fish assemblages associated with the artificial structures. Catch data collected inside the ARs are compared either to catches obtained at open sea control sites and to the landings of professional fishermen in order to assess the impact of the artificial substrates both on the fish community and on the yields of small-scale fisheries. Ecological and biological studies (e.g., feeding behaviour, growth rates, demography) are carried out to investigate the relationships between reef-dwelling fish and the artificial substrates. The biomass of mussels settled on artificial modules is also yearly assessed.

Results

Species richness is always higher at ARs than at the open-sea sites, considering either the experimental catches and the landings obtained by the professional fishermen on the natural soft bottom (Figure 2).

In terms of biomass, around 70% of the catches at the ARs are constituted by several species which are attracted or partially attracted by the artificial structures (e.g., *Sciaena umbra*, *Umbrina cirrosa*, *Lithognathus mormyrus*, *Dicentrarchus labrax*), whereas the catches obtained on the natural habitat mainly consists of 3 soft bottom species: sole (*Solea solea*), mantis shrimp (*Squilla mantis*), and tub gurnard (*Chelidonychtys lucernus*) (Figure 2).

Some reef-dwelling fish such as *S. umbra*, *U. cirrosa*, and *Scorpaena porcus* seem to constitute resident populations at the reefs.

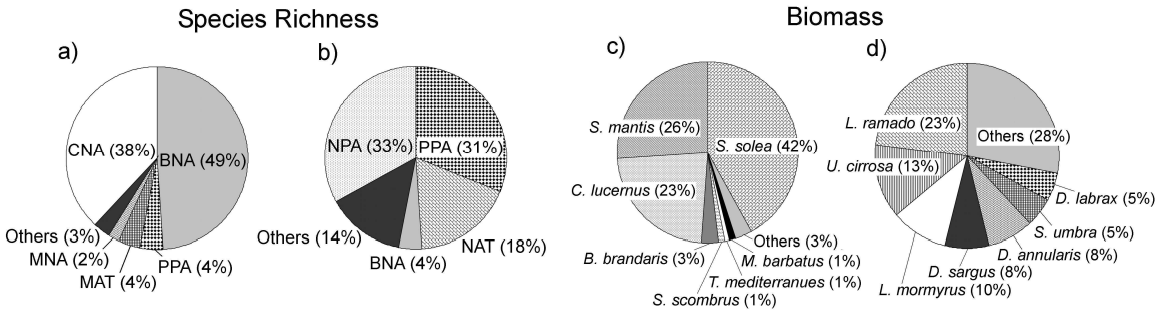

Figure 2: Composition in terms of species and biomass of the catches obtained with set nets in the natural habitat (a, c) and at ARs (b, d). CNA = crustaceans not attracted, MNA = mollusks not attracted, MAT = molluscs attracted, PPA = pelagic fish partially attracted, BNA = benthic fish not attracted, NPA = nekto-benthic fish partially attracted, NAT = nekto-benthic fish attracted. Attraction is referred to the reefness towards natural and/or artificial hard substrates.

The composition of the reef fish assemblage strongly depends on the heterogeneity of the reef. For example, pelagic fish tend to aggregate around open structures which extend along the water column, while nekto-benthic fish seem to prefer more complex structures provided with crevices and shelters.

Analysis of gut contents have demonstrated that ARs contribute to increase the biomass of some exploitable fish species by providing available food (Fabi et al., 2006). In fact, they represent the main source of food for brown meagre *S. umbra*, annular seabream *Diplodus annularis*, and striped seabream *L. mormyrus*. The affinity to the reef gradually weakens from

S. umbra to *D. annularis* to *L. mormyrus*. Brown meagre, indeed, gains its nutrition almost exclusively from the manmade structures. On the contrary, the outer natural habitat supplies a good proportion of prey items to the two sparids, especially *L. mormyrus*.
Some fish, as the black scorpionfish *S. porcus*, show an improved growth performance at ARs in respect to the natural habitat (La Mesa et al., 2010).
ARs provide new suitable surfaces for the development of filtering bivalves (i.e., *M. galloprovincialis).* The biomass of mussels settled on the manmade modules ranges from 20 to 55 kg m^{-2} per year, while on natural rocky habitat it varies from 10 to 40 kg m^{-2} per year (Bombace et al., 1994). This contributes to increase and diversify the income of small-scale fishermen who shift, during summer, from set gears to mussel harvesting on the artificial substrates.

Conclusions

The deployment of ARs along the Italian coast of the northern Adriatic Sea actually represents an additional tool for fisheries management. They contribute, indeed, to: a) mitigate conflicts for space between small-scale fisheries using set gears, hydraulic dredges and illegal trawling inside the 3 nm from the coast; b) widen the pool of species exploited by the small-scale fisheries and, hence, increasing fishers' income; and c) shift an amount of fishing effort from overexploited resources (e.g., *S. solea*) to valuable species (finfish and mussels) that are rare in the muddy bottoms where the artisanal fisheries usually operate. Consequently, small-scale fishermen ask for more ARs, but there is also a need of a better management of these areas. In fact, as most ARs are constructed by public Authorities in public waters, they are usually either completely closed to each type of fishing, both commercial and recreational, or open to all potential users and not subjected to any type of fishing restriction. However, in the former case the fishery ban is scarcely respected because of poor controls by the maritime authorities. Both situations may lead to overexploitation and rapid depletion of the reef resources as well as to conflicts within and between user groups.

References

Bombace G., Fabi G., Fiorentini L., Spagnolo A., 1997, Assessment of the ichthyofauna of an artificial reef through visual census and trammel net: comparison between the two sampling techniques. In: Hawkins L.E., Hutchinson S. with Jensen A.C., Sheader M., Williams J.A. (Eds.) The Responses of Marine Organisms to their Environments - Proceedings of the 30th European Marine Biological Symposium, Southampton, University of Southampton, pp. 291-305.
Bombace G., Fabi G., Fiorentini L., Speranza S., 1994, Analysis of the efficacy of artificial reefs located in five different areas of the Adriatic Sea. Bull. Mar. Sci. 55(2-3), 559-580.
Fabi G., Manoukian S., Spagnolo A., 2006, Feeding behaviour of three common fishes at an artificial reef in the northern Adriatic sea. Bull. Mar. Sci. 78(1), 39-56.
La Mesa M., Scarcella G., Grati F., Fabi G., 2010, Age and growth of the black scorpionfish, *Scorpaena porcus* (Pisces, Scorpaenidae) from artificial structures and natural reef in the Adriatic Sea. Sci. Mar. 74(4), 677-685.
Riggio S., Badalamenti F., D'Anna G., 2000, Artificial reefs in Sicily: an overview. In: Jensen A.C., Collins K. J., Lockwood A.P.M. (Eds.) Artificial Reefs in European Seas, Dordrecht, Kluwer Academic Publishers, pp. 66–74.

A Fisheries restricted area in the Gulfs of Lions (France)

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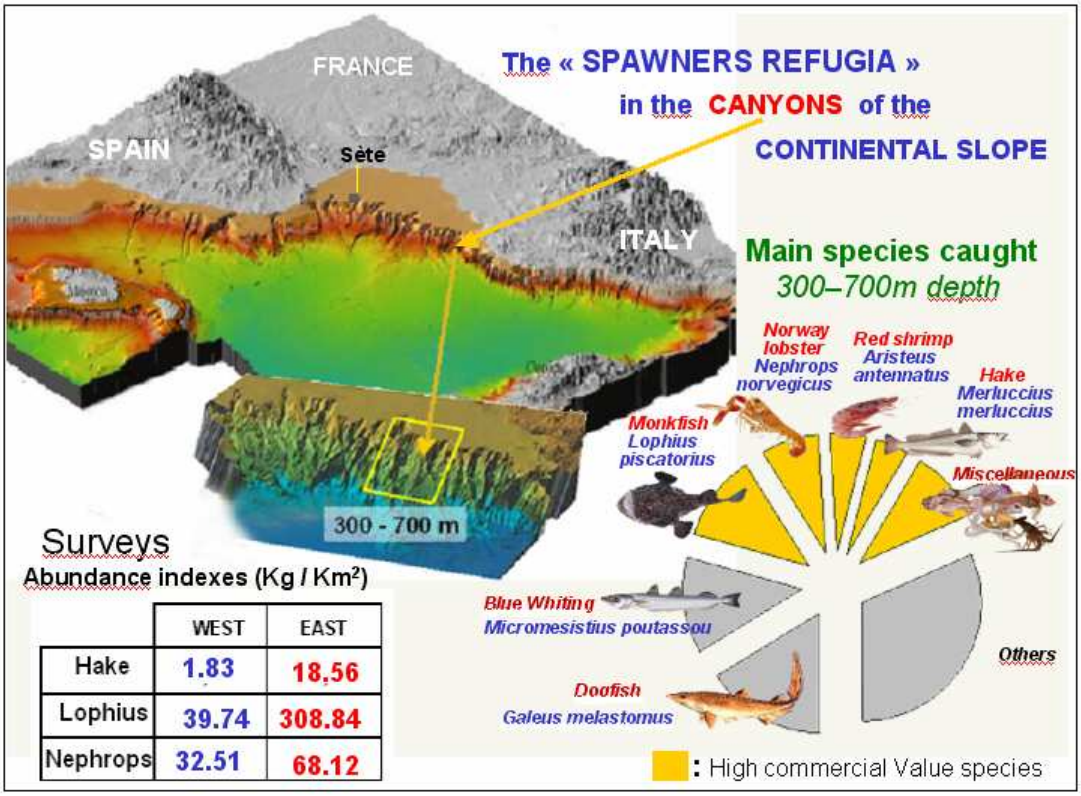
In the NW Mediterranean area, part of the fishing fleets of northern Catalonia (Spain,) and Languedoc-Roussillon (France) exploit the fishing resources of the Gulf of Lions. This is a relatively well known shared fishery, with its main target species being hake (*Merluccius merluccius*), which is exploited using trawls, longlines and gillnets. The fleets operating in the area or in neighboring areas are based in French and Spanish ports. Around 220 boats are involved in the fishery :111 French bottom trawlers, 67 French gillnetters, 27 Spanish bottom trawlers and 15 Spanish long-liners.

Both fleets are subject to the rules of the EC Common Fisheries Policy, concretely to the management framework established by Council Regulation No 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea.

Assessments of the hake stock have been carried out by the French and Spanish scientists since 1993 and have been regularly presented to the GFCM sessions of stock assessment. These studies point to heavy growth overexploitation and likely recruitment overexploitation. The remaining spawning fraction of the hake stock appears to be limited to the most inaccessible areas on the continental slope of the Gulf of Lions, where it is lightly exploited. Its preservation from full commercial exploitation is considered vital for avoiding the intensification of recruitment overexploitation and the associated collapse of the fishery.

From several decades the scientists working on the North Western Mediterranean Fisheries noted that the recruitment sustaining that fishery appears to be more or less constant for some of the most important Mediterranean fisheries. They built an hypothesis based on the spawners refugia paradigm, meaning that a relatively untouched spawning stock providing good recruitments to the fisheries of juveniles must exist somewhere, otherwise they cannot explain the situation of “sustainable overfishing” on juveniles. Such an hypothesis has been confermed by several French and Spanish scientific cruises realized in the gulf of Lions during the last ten years. The presence of large mature individuals of several species of fishes and crustaceans has been particularly observed in a zone situated in the eastern part of the gulf and bounded by lines joining the following geographic coordinates: 42°40'N, 4°20' E; 42°40'N, 5°00' E; 43°00'N, 4°20' E and 43°00'N, 5°00' E, including three submarine canyons This zone is extended 598 NM^2 and its depth range is 100 to 700m (see figure below).

In this zone, a total of 88 fish species has been recorded, of which 12 are priority species for the GFCM. Up to 17 species account for 90% of the biomass caught. 12 species are of commercial importance and 6 of high economic importance: *Lophius piscatorius*, *Nephrops norvegicus*, *Aristeus antennatus*, *Merluccius merluccius*, *Trigla lyra* and *Lepidorhombus boscii*.



	WEST	EAST
Hake	1.83	18.56
Lophius	39.74	308.84
Nephrops	32.51	68.12

Figure 1: Characteristics of the fisheries restricted area

These observations, joint to the bottom characteristics and the hydrographic conditions of the zone, strongly suggest that this area is one of such refugia of paramount importance in the North Western Mediterranean fisheries supplying recruits to the nearby fishery. Extending longevity and prolonging the reproductive phase can be viewed as a natural safeguard against subsequent recruitment failure. In fact large females are much more fecund because the number of eggs increases exponentially with length in most species, their eggs also tend to be larger, thus giving a greater chance of survival to larvae. Furthermore reaching old ages is usually a sign of overall individual fitness and thus these mega-spawners are reservoirs and distributors of desirable genes.Moreover in the case of no effort control, an exacerbation of fishing pressure is expected in the area, particularly by larger fishing vessels from ports from the Gulf of Lions, in quest of higher fishing yields in the most inaccessible areas of the continental slope. From several decades the fishing effort is heavier on the western part of the gulf (i.e. near the boundary between France and Spain) due to the fact that the Spanish regulation do not allow its boats to stay at sea more than 2 consecutive days, which is not a sufficient time to reach the eastern part of the gulf, fish there and come back. In fact the western part of the gulf is particularly overexploited as shown by the data of the trawl surveys which indicate that the abundance indexes of many commercial species are much lower in the west than in the east (Fig;1). Fishermen were recently asking for being allowed to be more time at sea in order to reach this zone. If this situation occurred it would lead to a destruction

of the last relevant spawning aggregations of hake, Norway lobster and other important fish species in the Gulf and soon the continental slope would be transformed into an overexploited zone, similar to the slope closer to harbors where the results of the trawl surveys show abundance indexes .

This is why the establishment of a fisheries Restricted Area has been proposed to the General Fisheries Commission for the Mediterranean which mandate is to manage fisheries in the international waters ; in fact this area is located in international waters, outside of the Spanish Fishing Protected Area and inside the French "Zone de Protection Ecologique". A part of the FRA corresponds to a depth beyond 1000 m, for which from 2005 a GFCM recommendation prohibit the use of towed dredges and trawling.

The FRA has been created officially in March 2009 and it has been adopted in conformity with the GFCM Agreement that the fishing effort for demersal stocks of vessels using towed nets, bottom and mid-water longlines, bottom-set nets shall not exceed the level of fishing effort applied in 2008 in the area (Fig.1).

Members and cooperating non-Members of GFCM shall communicate to the GFCM secretariat the list of vessels that have used towed nets, bottom and midwater longlines, bottom-set nets in the area together with the number of fishing days exerted by each vessel in the year 2008 and number of fishing days exerted in the fishery restricted area. They also shall indicate the legal conditions, as in force at 31 December 2008, as for the maximum time of daily fishing activity, the maximum number of days a vessel can stay at sea as well as the compulsory timing between the exit and return to the registered port of their fishing vessels.

These data will allow establishing a register of the fishing vessels authorized to fish in the area which ensure that the vessels not having records of fishing in the area prior 31 December 2008 are not authorized to start fishing therein.

Members and cooperating non-Members of GFCM shall ensure that fishing vessels operating in the area respect their obligation as in force at 31 December 2008 as for the maximum time of daily fishing activity, the maximum number of days a vessel can stay at sea as well as the legally compulsory timing to exit and return to the registered port. They also shall call the attention of the appropriate national and international authorities in order to protect this area from the impact of any other human activity jeopardizing the conservation of the features that characterize this particular habitat as an area of spawners' aggregation.

The boundaries of the area and conditions to fish therein may change on the basis of SAC advice when additional information will be available.

In order to increase the protection of spawning aggregations on the continental shelf edge and slope the GFCM Scientific Advisory Committee is requested to continue its work by extending the scope of advice to the entire canyons system in the French and Spanish northwestern mediterranean coast. In order to reach this goal the next steps will be to carry out an analysis of the available information on distribution of spawning aggregations and nurseries areas of the main demersal stocks on the shelf edge and continental slope and to evaluate the biological effects and the possible socio-economic effects of a fishing effort displacement as a consequence of the establishment of one or more fishery restricted areas in the canyons system. Finally the SAC Intend to establish a multi-annual work programme for the extension of its advice to other canyons in the Mediterranean.

References

Aldebert, Y., L. Recasens & J. Lleonart.- 1993. Analysis of gear interactions in a hake fishery: The case of the Gulf of Lions (NW Mediterranean). *Sci. Mar.*, 57(2-3):207-217.

Caddy, J.F. 1990. Options for the regulation of Mediterranean demersal fisheries. *Natural Resource Modeling*, 4: 427–475.

GFCM.- 2009. Report of the thirty-third session of the General Fisheries Commission for the Mediterranean, Tunis, 23–27 march 2009: appendix G, recommendation gfcm/33/2009/1 on the establishment of a fisheries restricted area in the gulf of lions to protect spawning aggregations and deep sea sensitive habitats

Massutí, E., F. Ordinas, N. González, A. Pérez, B. Guijarro, U. Fernández de Arcaya, V. Rubio y G. Pomar.- 2008. Informe del seguimiento científico de la acción Piloto RAI/AP-26/2007: pesca experimental con arte de arrastre de fondo en el Golfo de León (Mediterráneo noroccidental). 112 pp

Olivar, MP; Quilez, G; Emelianov, M (2003) Spatial and temporal distribution and abundance of European hake, *Merluccius merluccius*, eggs and larvae in the Catalan coast (NW Mediterranean). Fisheries Research, 60(2-3): 321-331.

Recasens, L., Lombarte, A., Morales-Nin, B., Torres, G.J.- 1998. Spatiotemporal variation in the population structure of the European hake in the NW Mediterranean. *J. Fish. Biol*. 53, 387-401.

Recasens, L, P. Belcari and V. Chiericoni (2008) Spawning pattern and batch fecundity of the European hake (*Merluccius merluccius* (L.)) in the western Mediterranean. *Scientia Marina*, 72(3).

Appendix

Recommendation gfcm/33/2009/1 on the establishment of a fisheries restricted area in the Gulf of Lions to protect spawning aggregations and deep sea sensitive habitats

The General Fisheries Commission for the Mediterranean (GFCM), *RECALLING* that the objective of the Agreement establishing the General Fisheries Commission for the Mediterranean is to promote the development, conservation, rational management and best utilization of living marine resources;

RECALLING Recommendation GFCM/29/2005/1 on the management of certain fisheries exploiting demersal and deepwater species and, notably, Article 1 therein;

CONSIDERING that the Scientific Advisory Committee (SAC) assesses that several stocks are overexploited, some with a high risk of collapse, and that sustainable management requires that measures aimed at limiting the capture of juveniles are implemented;

REAFFIRMING its commitment to further improving the gear selectivity of demersal trawl fisheries beyond what can be achieved by a minimum 40 mm square mesh size with a view to ensure better protection of juveniles of several species as well as to reduce discarding practices in a multispecies context;

CONSIDERING that selectivity of some fishing gears cannot go beyond certain level in

Mediterranean mixed fisheries and that, in addition to the overall control and limitation of the fishing effort and fleet capacity, it is fundamental to limit the fishing effort in areas in which adults of important stocks aggregate in order to allow these stocks to deliver the necessary recruitment, thus allowing for their sustainable exploitation;

NOTING that the SAC advises to ban the use of towed and fixed gears and longlines for demersal resources in an area on the continental shelf and slope of the Eastern Gulf of Lions;

CONSIDERING that more scientific information is needed with a view to understand the relevance of other adjacent areas on the continental shelf and slope for the protection of spawners and sensitive habitats as well as to better known the level and spatial distribution of the fishing effort exerted

PENDING the delivery of this additional information by the SAC.

***ADOPTS* in conformity with the provision of paragraph 1 (b) and (h) of Article III and Article V of GFCM Agreement that:**

1. The fishing effort for demersal stocks of vessels using towed nets, bottom and mid-water longlines, bottom-set nets shall not exceed the level of fishing effort applied in 2008 in the fisheries restricted area of the eastern Gulf of Lions as bounded by lines joining the following geographic coordinates:

42°40'N, 4°20' E;
42°40'N, 5°00' E;
43°00'N, 4°20' E;
43°00'N, 5°00' E;

2. Members and cooperating non-Members of GFCM shall communicate to the GFCM Executive Secretary not later than June 2009 the list of vessels that have used towed nets, bottom and midwater longlines, bottom-set nets in the area referred to in paragraph 1 in the year 2008.

3. The list shall contain the following information for each vessel:
_ Name of vessel
_ Register number
_ GFCM unique identifier (country ISO 3-alpha code + 9 digits, e.g.xxx000000001)
_ Previous name (if any)
_ Previous flag (if any)
_ Previous details of deletion from other registries (if any)
_ International radio call sign **(**if any)
_ Type of vessel, length overall and gross tonnage (GT) and/or gross registered tonnage (GRT)
_ Name and address of owner(s) and operator(s)
_ Main gear(s) used to fish in the fishery restricted area
_ Seasonal period authorized for fishing in the fishery restricted area
_ Number of fishing days exerted by each vessel in the year 2008 and number of fishing days exerted in the fishery restricted area

4. Members and cooperating non-Members of GFCM shall establish a register of the fishing vessels authorized to fish in the area which ensure that the vessels not having records of fishing in the area prior 31 December 2008 are not authorized to start fishing therein.

5. Members and cooperating non-Members of GFCM shall communicate to the GFCM Executive Secretary not later than September 2009 the legal conditions, as in force at 31 December 2008, as for the maximum time of daily fishing activity, the maximum number of days a vessel can stay at sea as well as the compulsory timing between the exit and return to the registered port of their fishing vessels.

6. Members and cooperating non-Members of GFCM shall ensure that fishing vessels operating in the area respect their obligation as in force at 31 December 2008 as for the maximum time of daily fishing activity, the maximum number of days a vessel can stay at sea as well as the legally compulsory timing to exit and return to the registered port.

7. For the fisheries restricted area referred to in paragraph 1 , Members and Cooperating non-Members of GFCM shall call the attention of the appropriate national and international authorities in order to protect this area from the impact of any other human activity jeopardizing the conservation of the features that characterize this particular habitat as an area of spawners' aggregation.

8. Boundaries of the area and conditions to fish therein as referred to in previous paragraphs may change on the basis of SAC advice.

Actions of the French purse-seine industry to reduce its footprint on the tropical pelagic ecosystem

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Abstract

Purse-seiners often use FADs to catch skipjack tuna in tropical oceans. However, some incidental mortality of turtles and sharks can be associated with the use of FADs. Therefore, in order to contribute to the preservation of these species, French boat owners have lunched en 2010 two programs to reduce, if not eliminate such incidental mortalities. On one side, FADs are being modified to deter any entanglement of turtles or sharks, and, on the other side, crewmen are trained to techniques that allow releasing sharks alive without injuries. This communication shows the progress realized up to now and the perspective of the French tuna boat-owners in this development of good practices.

Moored Fishing Aggregating Devices exploitation by Small-Scale Fleet in the Caribbean: Review and Outlook after 20 years

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Abstract

Since the 1990s, moored Fishing Aggregating Devices (FADs) have had a sharp success in the Lesser Antilles and beyond, because they make it possible for small no decked fishing units to reach, at low costs, offshore resources which they could do only seasonally or resources normally accessible by large scale vessels only. After 20 years of experience, the objective of the paper is to carry out an assessment of the impact of FADs on the basis of two case studies; the Guadeloupe and Martinique island fisheries in which two type of management approach have been implemented. Considering the primary objectives of FADs setting, the re-allocation of effort from overexploited coral reefs fisheries to offshore pelagic species and the reduction of seasonality in pelagic fishing yields, the paper analyses their achievement. A set of indicators were established to describe fleet structure, economic returns especially gross margin per metier and effort allocation all over the year. The difference in fishing patterns between the two case studies is tested to explain the gap in FADs density between the two islands. The consequences in terms of network FADs management (collective or private) including investment and maintenance cost around the islands are finally discussed by taking into account FADs interactions and interactions between vessels around FADs.

Ecological Footprint and Life Cycle Assessment of Antarctic Krill Fishery Products

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Reliance on meal and oil inputs from reduction fisheries is a major contributor to the ecological footprint, resource depletion, energy use and greenhouse gas emissions associated with aquaculture systems for many farmed species. The fishery for Antarctic krill has the potential to grow substantially to help feed the growing demand of aquaculture for meal and oil products. Currently, only 150,000 tonnes of krill are extracted from the Southern Ocean annually, far below the maximum harvest deemed to be ecologically sustainable by the Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR), and representing only a small fraction of the global meal and oil industry. However, new technologies, coupled with rapidly growing demand, may result in expansion of this fishery over the coming years.

Here we evaluate the environmental performance of an Antarctic krill fishery using two biophysical accounting frameworks: Ecological Footprint Analysis (EF) and Life Cycle Assessment (LCA). EF is a measure of the bioproductive land and sea area required to sustain products, services and activities. The EF of krill products was measured to show the area of marine ecosystem support required to sustain appropriation of net primary productivity, and this was compared to several other important fisheries for meal and oil globally. LCA is a standardized methodology used to quantify the contributions of products and services to a suite of globally important environmental issues, such as global warming and energy use. LCA was used here to measure the total contributions of krill products to several regional and global impact categories, identify areas of the product life cycle which contribute most heavily to impacts, and make recommendations to effectively decrease the environmental burden of krill products.

Results of the EF indicate that krill meal and oil have a relatively low marine footprint in comparison to fisheries targeting higher trophic level species (fig. 1). EF results contain a significant amount of uncertainty, largely attributed to uncertainty and natural variability regarding ecological processes and trophic levels. While the EF results may not provide absolute measures of biophysical limitations to harvesting, they are useful in making relative comparisons of different species.

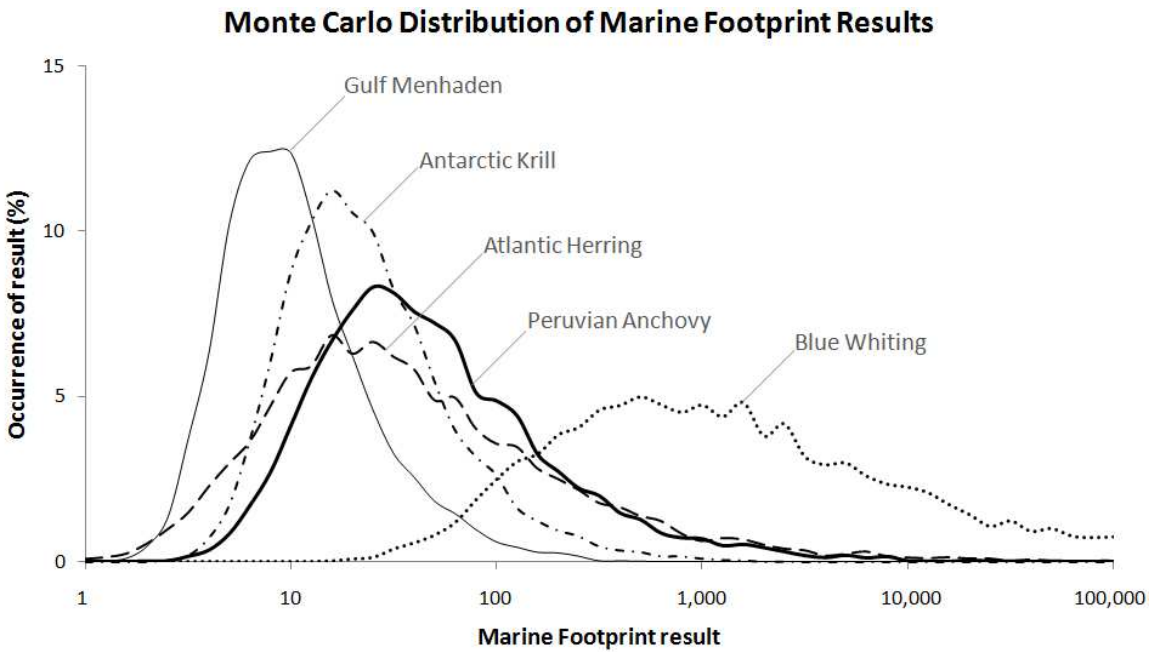

Figure 1. Marine footprint results for five reduction fisheries with uncertainty distributions

LCA results identify the fishing stage as the primary contributor to most impact categories for meal and oil products. This is concurrent with other recent fisheries LCAs. Energy use, and related greenhouse gas emissions, in the krill fishery studied is higher than that in other reduction fisheries. This is as a result of the distance that must be travelled by the fishing vessel in order to reach the fishing grounds two to three thousand kilometers southeast of the port in Montevideo. This distance between port and fishing grounds necessitates the use of two vessels, one fishing vessel and one transport and re-supply vessel.

These two methodologies provide measurements of different elements of sustainability, and demonstrate the existence of trade-offs between different environmental impacts. The relative weight given to each is dependent on human values placed upon different environmental issues. Many environmental concerns associated with fisheries are not successfully captured by these tools (e.g. stock status, habitat destruction and alterations, etc.), and so other frameworks such as the Marine Stewardship Council must be used in conjunction with these measurements if we are to achieve a holistic view of the sustainability of seafood products.

Mediterranean marine ecosystems: an economic valuation

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Abstract

Blue Plan (UNEP/MAP), whose mission is to advise stakeholders for sustainable development in the Mediterranean region, has been entrusted to assess the economic value of benefits provided by Mediterranean marine ecosystems. The objectives are to enhance awareness of these benefits to society and offer policy makers a common metric for better management. This study proposes a first exploration at the scale of the 22 Mediterranean countries of the economic value of the benefits to society provided yearly by marine ecosystems. Methodology is inspired from the System for Environmental and Economic Accounting of the United Nations and valuation is restricted to sustainable and direct benefits (e.g. fishing excluding over fishing and seafood processing). Calculation of benefits is based on proxy values for the reference year 2005 using available ecosystem characteristics and national or regional level data extracted from various public databases. At regional level, the aggregate value stands at over 26 billion Euros for 2005, which corresponds by comparison to 120% of Tunisia's GNP. In terms of value per unit area, the surface covered by the Mediterranean Sea, i.e. 2.5 million km², would thus contribute to an annual benefit of over 10 000 €/km².

Le Plan Bleu (PNUE/PAM), dont la mission est de conseiller les décideurs pour un développement soutenable de la Méditerranée, s'est engagé à évaluer la valeur des bénéfices fournis par les écosystèmes marins méditerranéens. Les objectifs sont d'accroitre la prise de conscience sur ces bénéfices pour la société et de fournir aux décideurs politiques une métrique commune pour une meilleure gestion. Cette étude propose une première estimation à l'échelle des 22 pays riverains de la Méditerranée de la valeur économique des bénéfices pour la société fournis annuellement par les écosystèmes marins. La méthode utilisée est inspirée du Système de Comptabilité Economique et Environnementale des Nations Unies et se limite aux bénéfices soutenables et directs (par ex. la pêche hors sur pêche et secteur aval des produits de la mer). Le calcul des bénéfices fait appel à des proxys pour l'année de référence 2005 en utilisant les informations disponibles concernant des caractéristiques des écosystèmes et des statistiques nationales et régionales extraites de diverses bases de données publiques. Au niveau régional, la valeur agrégée se monte à plus de 26 milliards d'Euros pour 2005, ce qui est comparable à 120% du PNB de la Tunisie. En terme de valeur par unité de surface, celle couverte par la Mer Méditerranée, soit 2.5 millions de km², contribuerait à un bénéfice annuel de plus de 10 000 €/km².

Key words: Ecosystem services, economic valuation, Mediterranean Sea, Services écosystémiques, évaluation économique, Mer Méditerranée.

*

Introduction

The Mediterranean Sea is recognised as an international biodiversity hotspot, yet increasingly compromised by human activities, specially coastal development, marine habitat destruction, chemical pollution, eutrophication, introduction of invasive species, over fishing... Blue Plan (UNEP/MAP), whose mission is to advise stakeholders for sustainable development in the 22 Mediterranean countries, has been entrusted to assess the economic value of the sustainable benefits provided by Mediterranean marine ecosystems. The objectives are to enhance awareness of these benefits to society and offer policy makers a common metric for better management [1].

Materiel and methods

Benefits provided by ecosystems to people are obtained from ecological services (see Table 1), following a widely accepted classification adapted from [2]. The economic valuation method used is inspired from SEEA [3] and is restricted to sustainable and direct benefits (e.g. fishing excluding over fishing and seafood processing). Estimation of benefits is based on computable substitutes, or proxy values computed for the reference year 2005 using available ecosystem characteristics and national or regional level data extracted from various public databases (Fishstat, Labor-stat, UNdata, AQUASTAT, Eurostat…) such as fish catches, value added (VA), labour force.. Various value transfer methods had been used when necessary. All details and calculations are available in [4].

Table 1: List of the benefits assessed by this study

Category	Ecosystem services	Benefits assessed
Provisioning services	Provision of food resources	Resource rent of fisheries & aquaculture sectors
Cultural services	Amenities	Resource rent of tourism, hotels & restaurants and real estate in coastal areas
	Support of recreational activities	
Regulating services	Climate regulation	Value of man-made CO_2 sequestration
	Mitigation of natural hazards	Value of protection against coastal erosion through *Posidonia* meadows
	Waste treatment	Recycling of waste water by marine ecosystems

In short, the resource rent of fisheries and aquaculture was estimated on the sector VA, overfishing and other non sustainable practices being expressed by an overall coefficient valued to 80% of the sum of the both sectors derived from [5]. Resource rent for tourism, hotels, restaurants and real estate was evaluated at 5% of their VA in coastal areas through a multiple regression analysis of the coastal attractive effect computed on. Benefits relating to the provision of amenities and recreational supports were evaluated using a statistical assessment focused on the “coastal effect” benefiting hotel and restaurant activities in coastal as compared to other areas, using coastline length as the explanatory variable. The coefficient which emerged from the statistical analysis of four European countries for which NUTS 3 Eurostat data was available (5%) was applied to all the countries in the region. For lack of

data allowing the same kind of assessment of the coastal effect on real estate and tourism, the same coefficient was applied to household accommodation expenditure and to the estimated VA in tourism in coastal areas of each country. Erosion protection was appraised on the basis of the avoided coastal protection expenditure for approximately 1000 km of coast length, this figure being derived from available data on coastal erosion, protections in place and presence of *Posidonia* meadows. Benefits relating to climate regulation were assessed using an estimate of anthropogenic CO_2 volume absorbed by the marine environment based on recent scientific work [6], and then valued at the price per tonne of CO_2 in force under the European Emission Trading Scheme in 2005, the year of reference for the study. Benefits relating to erosion mitigation were assessed on the basis of the length of coastline where Posidonia meadows are present and which is threatened by erosion. The benefits were calculated as the avoided cost of replacement by defensive infrastructure and action. Benefits relating to waste treatment - a particularly crucial case in terms of sustainability of the service- were valued using a tutelary fee per unit of volume of domestic water consumed, the revenue of which is used to maintain a sustainable situation considering the present environmental standards. This reference value, deducted from a real French situation considered as sustainable, was transferred to all the riparian countries.

Results

At regional level, the aggregate value stands at over 26 billion Euros for 2005, which comparatively speaking corresponds to 120% of Tunisia's Gross National Product (GNP). In terms of the area covered by the Mediterranean Sea, i.e. 2.5 million km², the Mediterranean large marine ecosystem would thus contribute to an annual benefit of over 10.000 €/km². The distribution of the value by type of benefit (Fig. 1) shows that 68% thereof stems from the provision of amenities and recreational supports (some 18 billion Euros).

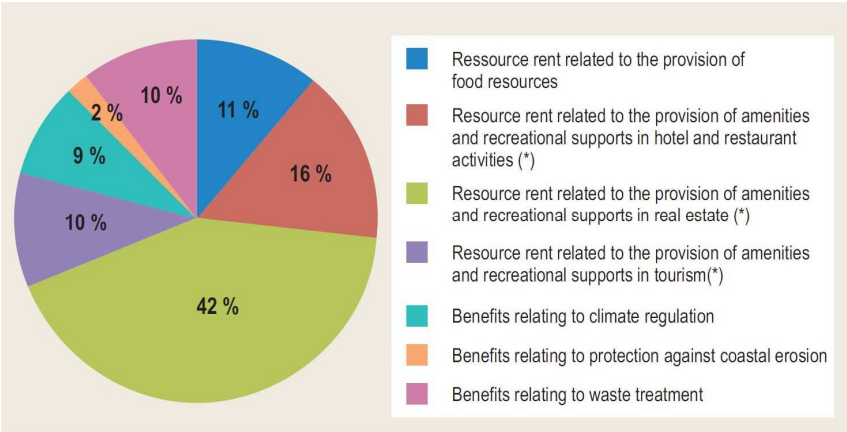

Figure . 8: Distribution of value by type of benefit

These benefits are related to three sectors: hotels and restaurants, real estate and tourism. Total international tourist spending in the Mediterranean, about one third of worldwide tourist spending, amounts to 108.5 billion Euros [7]. The value of benefits arising from the provision of amenities and recreational supports thus amounts to about 17% of international tourist spending in the Mediterranean. The distribution of the value of benefits relating to the provision of food resources can be presented by ecosystem type (Fig. 2 &3).

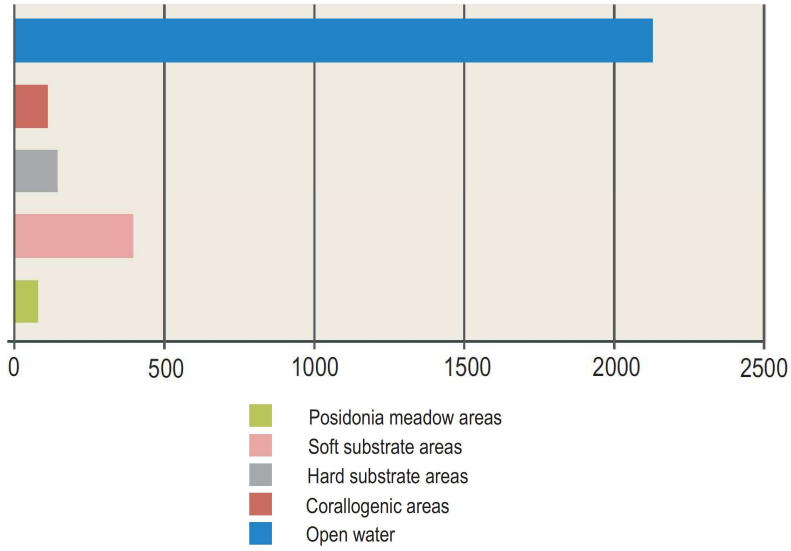

Figure 9: Value of benefits relating to food provisioning by type of ecosystem (in millions €)

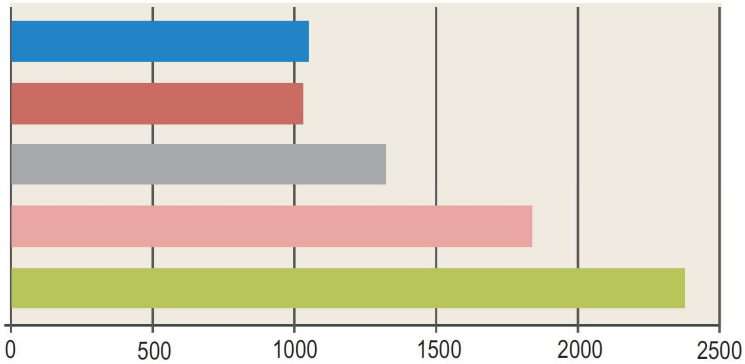

Figure 10: Value of benefits per unit area covered by each type of ecosystem (in €/km²)

The high seas appear to contribute to the production of over 70% of the value of benefits relating to fisheries in proportion to the volume of catches they represent, whereas Posidonia meadows and rocky sea-beds provide the best fishing productivity in terms of catches per unit area.

Discussion and conclusion:

The choices and constraints which guided this analysis, whether concerning the application of a sustainability criterion for assessing benefits or the lack of data resulting in certain benefits being neglected, have given rise to what is most probably an underestimated initial assessment of the annual value of all sustainable benefits resulting from marine ecosystems. Nevertheless, and despite the further work which will be required particularly in order to correct the shortcomings relating to specific data, it is clear that the sustainable benefits resulting from the Mediterranean marine ecosystems are of considerable economic value.

References:

1. CIESM, 2008. Economic valuation of natural coastal and marine ecosystems, n°37 in CIESM Workshop Monographs [F.Briand, Ed].
2. Beaumont, N.J., et al., 2007. Identification, definition and quantification of goods and services provided by marine biodiversity: Implications for the ecosystem approach, Marine Pollution Bulletin, 54, 253–265.
3. United Nations, 2003. Handbook of National Accounting: Integrated Environmental and Economic Accounting.
4. Mangos A., Bassino J.-P. & Sauzade D. (2010). The Economic Value of Sustainable Benefits rendered by the Mediterranean Marine Ecosystems. Plan Bleu. Valbonne. (Les cahiers du Plan Bleu, n° 8) http://www.planbleu.org/publications/Cahier8_marin_EN.pdf
5. CGPM, 2008, General Fisheries Commission for the Mediterranean, report of the eleventh session of the Scientific Advisory Committee, Marrakech, Morocco, December 2008.
6. Huertas, I.E., 2009, Anthropogenic and natural CO2 exchange through the Strait of Gibraltar, Biogeosciences Discuss., 6, 1021–1067.
7. Plan Bleu, (2005). Dossier on tourism and sustainable development in the Mediterranean. MAP Technical report, 159 :1- 92.

Comparative reflections on the management pronciples of artificial reefs: Japan,-France-Senegal

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Key words: artificial reefs – Management principles - comparative analysis - characterization - protection of the marine environment - governance of areas - regulation of fishing - sea users

Introduction

The analysis is focused primarily on the principles of management of artificial reefs (AR) retained by the States (post immersion). By artificial reefs, we consider here solid structures immersed directly and arranged on the seabed, without anchorage in the basement. Note however that many models exist around the world, targeting different types of species of fish (pelagic or demersal), shellfish, crustaceans and algae. Some fish aggregating devices (FADs) have fastening systems at the bottom, connected by a floating surface and whose components may "navigate" in the water column. Others may drift over large underwater areas, while not having any form of anchor or ground contact. Conventional international law determines a minimum regulatory framework for the conservation of water and seabed, including the immersion of artificial reefs (pollution control) and assessment of risks inherent in such operations.

ARs are generally located in coastal areas and their installation/management is the primary responsibility of States. However, the legal regimes applicable to artificial reefs are numerous, conditioned by management principles and practices (access, use, protection) of the marine environment (public space not subject to private ownership). Various procedures of concessions and authorizations are used to define and determine the settlement areas and the conditions for awarding/exploitation for their managers and users. Without going into the regulatory and administrative complexity, we simply retain the principles that characterize these different forms of approach and "governance" as compared with three-State models: Japan, France and Senegal.

Co-management between state andf professional fishermen: the case of Japan

Background and historical approach to integrated management of AR

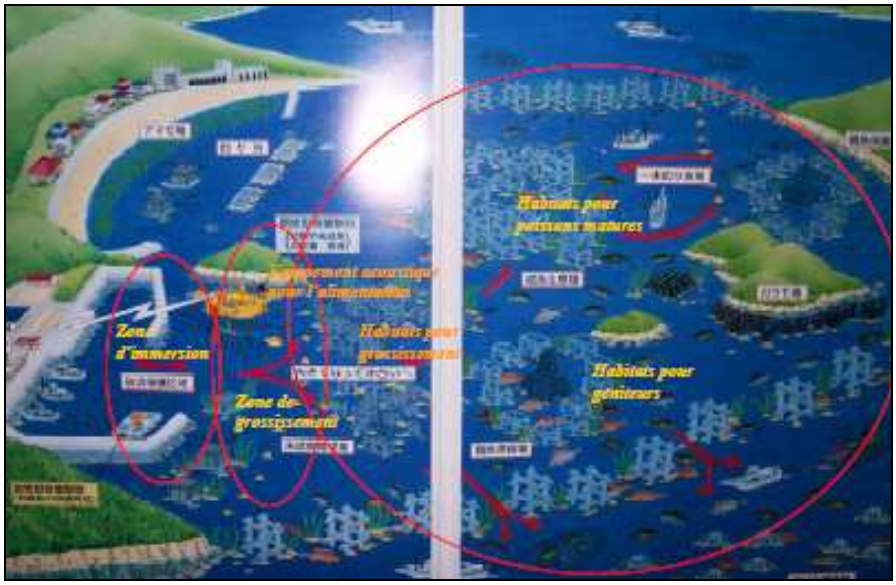
- Current environment: world leader for AR immersions (volume> 20 million m3 = 12% of the continental shelf), experience (since 17th century), databases, monitoring, evaluation of results.
- Background of Japanese coastal fisheries (3 miles): **1)** very old organization (national value, length/fish products) and complex (state, cooperative, fishermen), **2)** importance of coastal fishing communities (management skills and self regulation), **3)** grant of exclusive

use and exploitation of fish stocks to fishermen (collectively) in a near vision of rent (tenant farming counterpart to the "feeding" of the population by fishermen).

- AR enrolls in this mode of operation and overall integrated Japanese coastal fisheries.

A balanced co-management, highly decentralized

- integrated and balanced system: **1)** the State regulates (national quotas), finances, directs public policies (fisheries, aquaculture, “mariculture” with AR), **2)** fishers manage their land fish ("owners " collective resource for monopoly access / use), **3)** are individual fishing rights (license), but attached to the community structures of cooperatives (circumscribed rights and territorial strong identification) and the condition of exercising the rights are derived directly from the fishermen (with controls and sanctions).
- Central role of cooperatives (membership required to obtain a license): scientific monitoring, finance, insurance, purchasing, product development, representation and advocacy group.
- Managing AR = National Plan of resource restoration and daily management decentralized (see above) with diverse tools (quotas, spatial management, seasonal fallow, partial ...)



Schematic of pilot Ranching, Okayama, Japan *(modified from Henocque, 2010, p. 16).*

Central public management: the French example

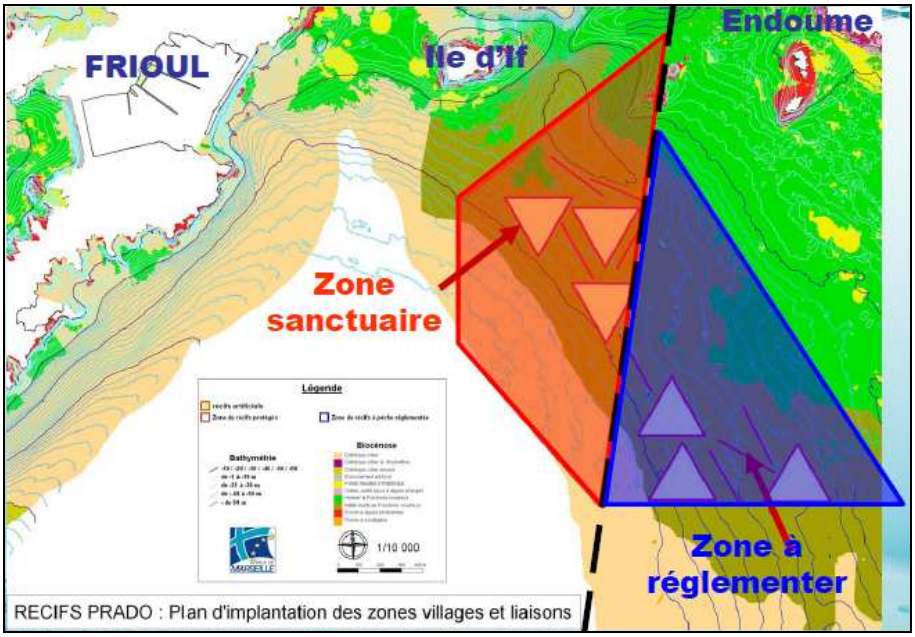
The centralized State tradition and responsibility at sea

- Authority of the State at sea: central administrations (often scattered) and general powers of prefects (local State’s representative in “department”, “region”, at sea or “maritime”). Example of Frioul: 6 State administrations involved in a single project!
- Maritime Public Domaine (“DPM” in French): **1)** protection very strong (inalienability & imprescriptibly), not subject to private appropriation; **2)** ability to access / use based on concessions precarious, temporary and revocable; **3)** AR without specific legal regime, dependent mechanisms of “CUDPM” (concessions for the use of “DPM” outside ports) under a decree of 2004.

- Preliminary phases highly participatory and broad consultations: project design, site selection, financing, public inquiry, impact studies, immersion.

The recurrent problems of local ownership and organizations

- Concessionaire (dealership) Authorities (usually local) devoid of all regulatory or enforcement powers regarding to AR sites. Including the implementation and monitoring of State decisions at sea.
- RA affected compulsorily for public use, inability to use restrictive for the benefit of certain groups (professional fishermen…others), problems of conflict and specific guidance in the management and the objectives of AR (almost all ARs are immersed without specific management plans), need for lengthy negotiations and sometimes sterile among all actors (state, manager, users) to achieve an operating environment (no predetermined solution to the post disposal of AR).



Site layout and zoning of Prado AR, Marseille, France (modified from J.C.LARDIC, L'opération Prado, un projet exemplaire de la gestion du littoral marseillais, PPT, Sète, 2008)

Privatized management for recreational purposes : the example of Senegal

Initiative and opportunistic categorical outcome of sport fishing

- 1990s to today: over 150 immersions of RA off-shore of the Senegalese coast.
- Characteristics of immersion operations : **1)** boats reformed (cleared) from industrial fisheries (trawlers ...) and sink off, **2)** heavy and hazardous operations (explosives) performed the Senegalese Federation of Sport Fishing (autonomy and cost) without effective coordination, support, or State Control (prior approval and GPS coordinates of disposal sites), **3)** individual initiative group of sporting fishermen, marked by strong opposition, sometimes conflicts, with commercial fishermen (artisanal) as to access and information related to AR.
-

The "return" of the State to promote the reform of fisheries policy

- Japanese Cooperation 2000s made the 1st AR sites (12 pilot sites in progress) set up for small scale fisheries: interesting results, but cost issues (installation and monitoring) and non compliance management by fishermen (lack of ownership and exploitation "heritage").
- Location of fishing crisis in Senegal: **1)** rethink to access modes and global structuring of the whole sector (reform of the Fisheries Code), **2)** objective of "territorialization" of fishermen communities (including halting nomadic fisheries) using the AR as a tool for setting the fishermen, and **3)** fix the general problem of enforcement and regulation (registration of pirogues, compliance devices, sizes, fishing ...) as a prerequisite for the development of a territorial policy.
- Formalize the legal regime of AR reflecting on new models of concessions, representation of fishing communities, distribution management skills ...

Immersion opérations off-shore of the Senegalese coast *(modified from T.DIOUF, Fédération Sénégalaise de Pêche Sportive, PPT, Dakar, octobre 2008*

References

- Y. Asada et al. , 1983, *L'aménagement des pêches au Japon*. FAO Doc. Tech. Pêches, (238), 35p.
- B. Cazalet, S. Pioch, 2010, « La gestion des récifs/habitats artificiels au Japon : un modèle décentralisé de concessions territoriales », Actes du *Colloque International sur la gestion des récifs artificiels pour l'aménagement des pêches et la conservation des ressources marines,* pp. 147-153.
- B. Cazalet, 2009 « La situation juridique incertaine des récifs artificiels français », Annuaire du Droit de la Mer, Tome XIII, pp.239-259.
- F. Féral, 2010, « Politique d'aménagement et cadre juridique général des récifs et des concessions », Actes du *Colloque International sur la gestion des récifs artificiels pour l'aménagement des pêches et la conservation des ressources marines,* pp. 143-146.
- Y. Henocque, *Le Japon maritime contemporain, éléments de stratégie pour une collaboration élargie*, Nature & Société, DP2S, IFREMER, janvier 2010, 38 p.
- L. Mbaye et al. (Ed.), 2010, La gestion des récifs artificiels pour l'aménagement des pêches et la conservation des ressources marines, Actes du Colloque International, Dakar, 11-14 2008, (FSPS Coll.), Sénégal, 212 p. et annexes.
- M. Quimbert, 2005, « Les récifs artificiels : autorisation d'immersion, régime d'occupation du domaine public et cadre d'exploitation en droit français », Revue juridique de l'environnement, pp. 121-129.

- M. Taquet, 2004, *Le comportement agrégatif de la dorade coryphène (Coryphaena hippurus) autour des objets flottants*, Thèse de Doctorat de l'Université de Paris 6, Océanologie biologique, Editions Ifremer, 168 p.
- R. Townsend et al. (Ed.), 2008, *Case studies in fisheries self-governance*, FAO Fisheries Technical Paper, No. 504, Rome, FAO, 451 p.

The "Groupe tortues marines France" (G.T.M.F: Marine Turtle Group France), an initiative for increasing effectiveness of the management and conservation of marine turtles in France .

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Abstract :

Among the seven species of marine turtles, six occur in the French territorial waters and coasts, mainly in France's 13 oversea's collectivities, which offer suitable habitat for breeding, foraging and resting. Since marine turtles are endangered species and several French nesting sites are recognized of world importance, the patrimonial responsibility of France is high. France has therefore made decisions in the field of i) legal protection of marine turtles: enacting a specific decree, ratifying and signing the relevant international conventions for the protection of species and habitats - ii) conservation or restoration (initiating 3 action plans in Guadeloupe, Martinique and French Guiana; participating in regional programmes …). Since the pioneer monitoring and artificial incubation activities of Fretey, Lescure and coll. in French Guyana in the 70s', numerous conservation and research programmes have been developed throughout the national territory and serious experience has been acquired. However, considering the dispersion of French departments and collectivities, and the various technological and knowledge levels regarding the marine turtle population biology, conservation status and threats in French areas, it has been stressed that a tool for coordination of actions and exchange of experience between the different actors would significantly increase the effectiveness of initiatives and allow a global vision of the knowledge gaps and needs for marine turtle management and conservation. In 2008, French Ministry in charge of Environment set up the "Groupe Tortues Marines France" (GTMF). It includes more than 150 members, working in governmental and non governmental organizations, scientific institutions, and sighting networks. We here present the conservation problematics and activities on marine turtles in France, and the GTMF's objectives and actions, with particular emphasis on the by-catch working group results.

Introduction

Among the seven species of marine turtles, six occur in the French territorial waters and coasts, mainly in France's 13 oversea's collectivities, which offer suitable habitat for breeding, foraging and resting. Since marine turtles are endangered species and several French nesting sites are recognized of world importance, the patrimonial responsibility of France is high. France has therefore made decisions in the field of

i) legal protection of marine turtles: enacting a specific decree (1) protecting

marine turtle and their habitat , ratifying and signing the relevant international conventions for the protection of species and habitats (Bonn, Berne, Carthagena _SPAW)

ii) conservation or restoration (initiating 3 action plans in Guadeloupe, Martinique and French Guiana; participating in regional programmes …). Since the pioneer monitoring and artificial incubation activities of Fretey, Lescure and coll. in French Guyana in the 70s', numerous conservation and research programmes have been developed throughout the national territory and serious experience has been acquired. However, considering the dispersion of French departments and collectivities, and the various technological and knowledge levels regarding the marine turtle population biology, conservation status and threats in French areas, it has been stressed that a tool for coordination of actions and exchange of experience between the different actors would significantly increase the effectiveness of initiatives and allow a global vision of the knowledge gaps and needs for marine turtle management and conservation.

Results:

In 2008, French Ministry in charge of Environment set up the "Groupe Tortues Marines France" (GTMF). It includes more than 150 members, working in governmental and non governmental organizations, scientific institutions, and sighting networks.
Exchanges of information and experience are performed through a mailing list (gtmf@mnhn.fr) meetings and visioconferences. The first colloquium on marine turtles in France was held in Paris from the 20th to the 22th of January 2010. 100 participants from mainland and overseas collectivities were invited to present a synthetis of the past and present actions (2) in order to identify gaps in research and conservation actions for marine turtles.

Figure 1: map of french oversea's collectivities (after www.outre-mer.gouv.fr)

3 working groups (WG) have been created in order to work on priority topics for the conservation of sea turtles in France: i) the "legislation and training WG" which works on harmonizing stranding network training and circulating procedure amongst officers, ii) "education and communication WG" which share tools through the blog "autour des tortues marines", iii) "bycatch WG" which objective is to contribute to mitigate the effects on sea turtles of their interactions with fishery activities, and enlarge the work initiated in french Guyana on TTED with shrimp fisheries (3).
Expertise activities (2 contracts and 8 expertises in 2008-2010) were performed as part of an increasing collaboration with french Ministries in charge of the environment and fisheries.

Among them, a synthetis on interactions between fisheries and sea turtles on the French territory (4) was performed by SPN-MNHN in collaboration with the GTMF bycatch WG.

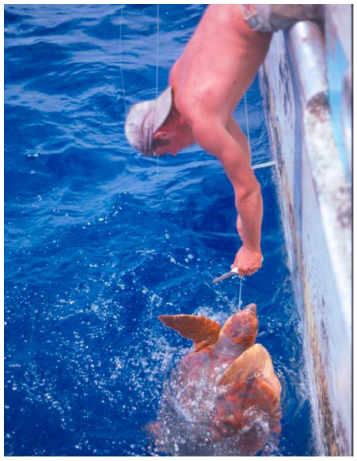

Figure 2: bycatch of a loggerhead by longline (photo Ifremer/Programme Palangre Réunion).

Conclusions and perspective

The 2008-2010 period showed that GTMF is a good tool for increasing effectiveness of the management and the conservation of marine turtles in France (mainland and in overseas territories) with a good level of participation and interactivity and an overall national representativity. The bycatch topic is one of the priorities of the GTMF. The publication of the synthetis on interactions between sea turtles ands fisheries on the French territory is the first step on the way to definition of practical actions to be initiated in 2011 for increasing mitigation actions.

References

(1) Arrêté du 14 octobre 2005 fixant la liste des tortues marines protégées sur le territoire national et les modalités de leur protection. Journal Officiel du 06/12/***2005.***

(2) Colloque "Tortues Marines en France métropolitaine et d'outre-mer". MNHN Paris, 20-22 Janvier 2010. *Bulletin de la Société herpétologique de France.* N° double spécial en prep.

(3) Kelle, L. and M. Nalovic, 2009. Coastal fisheries and interactions with marine turtles in French Guiana, Proceedings of the Technical Workshop on Mitigating Sea Turtle Bycatch in Coastal Net Fisheries, Honolulu, Hawaii, 24.

(4) Claro F., Bedel S. et Forin-Wiart M.A., 2010. Interactions entre pêcheries et tortues marines en France métropolitaine et d'Outre-mer. Rapport SPN 2010/13. MNHN-SPN, Paris, 124 pp.

Acronyms

SPN- MNHN: Service du Patrimoine Naturel du Muséum National d'Histoire Naturelle (www.mnhn.fr/spn)

TTED : Turtle and Trash Exclusion Devices

Indeterminacy of waters "Under the jurisdiction" in the Mediterranean : Issues of maritime delimitation in semi-enclosed sea

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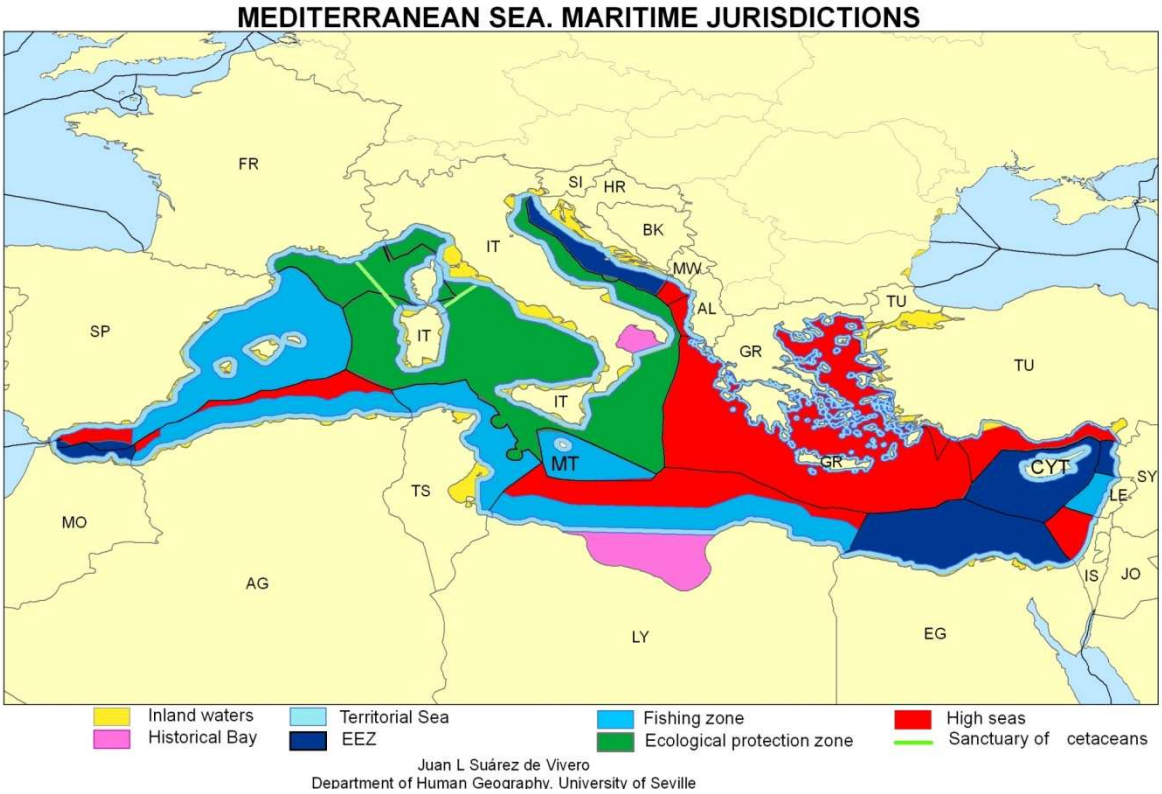
Key words: maritime delimitation - Mediterranean - International Law - Law of the Sea - Exclusive Economic Zone - semi-enclosed sea - coastal states - spatial governance - Fisheries – Marine Environment Protection

Introduction

Geostrategic enclave surrounded by three continents, *Mare Medi Terra*, whose etymology means literally "sea in the middle of land", built its maritime history on conflicting and bloody inclinations, relations and episodes. The thirst for political domination, the stakes for controls of ports, trading, shipping and sea lanes have strongly conditioned the relationship between the great imperial powers and their areas of influence. In the modern era, international law governs state relations now allayed, strengthened by the instruments of cooperation on the use, access, exploitation and protection of the common regional sea.

However, the spatial configuration of the Mediterranean maintains a recurring problem of delimitation of the waters "under the jurisdiction." Defined in international law of the sea, these are the waters beyond the limits of the territorial sea (12 nautical miles), better known as the Exclusive Economic Zones (EEZ). In accordance with Articles 55 and following of the United Nations Convention on the Law of the Sea (UNCLOS) signed at Montego Bay in Jamaica in 1982 and came into force in 1994, the maximum width of the EEZ can not exceed 200 nautical miles or 370 km. Without a full and complete sovereignty over this area, the coastal State exercises its jurisdiction, benefits from rights and obligations extended, called sovereign, primarily in economic terms. The principle of adjacency, sometimes called the "coastal privilege" (Apollis, 1980), bases the claim for extension, formalized through unilateral declarations. This historical process of recognition of EEZ under international law marked a phase of standardization and expansion of the right of coastal states to sea, also considering as dominant phenomenon of the "contemporary revolution of international law of the sea" (Apollis, 1980). This extension builds on the content of the rights granted to states, mainly in fisheries and exploitation of the riches of the soil and subsoil, and more recently for reasons of protection/conservation and sustainable use of environment and marine resources. In this legal context favorable to maritime "nationalism", the Mediterranean would almost act as an exception. Its cramped *de facto* prohibits the establishment of EEZs with a maximum width of 200 nautical miles. Beyond the territorial seas, it is always the high seas regime that

prevails. The situation remains largely undetermined, heterogeneous, despite several unilateral States initiatives, but remains relative on the enforceability against neighboring countries and international law. The Mediterranean offers a complex legal landscape, burdened by its international status of semi-enclosed sea (art. 122 UNCLOS). Through the dialectic of law and territory, marine spatial claims of Mediterranean states seem inclined by a new impetus. Since the 2000s, and in support of international environmental law, the need to protect ecosystems and marine biodiversity appear as a legitimate ground for consolidation of state powers in continuity of territorial waters.



Status of maritime jurisdiction in the Mediterranean (although some inaccuracies persist in this mapping representation, it clearly illustrates the multiplicity of situations and States claims).

A semi-enclosed sea: Major constraint to unilateral delimitation

A few binding but self-limiting international status

- Article 122 & 123 UNCLOS: a principle of cooperation in specialized fields of management of biological resources, preservation of the marine environment and scientific research.
- "Diplomatic" dimension of the governance of a semi-enclosed sea: consensual approach of fact and law.
- Art.74 UNCLOS on the delimitation process "of the exclusive economic zone between States with opposite or adjacent coasts" by agreement, treaty, thus excluding any individual and exclusive action.
-

. *Scope and limits of Mediterranean governance: the example of fisheries*

- 80% of Mediterranean waters are under a regime of high seas (56% worldwide - Sumaila et al., 2007). The International Legal Regime of the high governs by the ultimate survival of the customary principle of Mare Liberum (Grotius in 1608). Freedom on the high seas (art. 87 UNCLOS), including fisheries, but framed in the goal of mutual respect for state interests, equitable and sustainable exploitation of stocks (MSY) and conservation of biological resources.
- General Fisheries Commission for the Mediterranean (GFCM) (regional cooperation in managing fisheries resources): Advisory institution (reports, recommendations and resolutions) without any legally binding, but having a normative scope that we could qualify as "indirect".
- International law principle of pacta sunt servanda: Treaties must be performed in good faith by the States, without raising breaches of reasons based on provisions of national (internal) law. Legal problems of applicability (enforcement) in areas of high seas or in fuzzy areas “under the jurisdiction", where governments are responsible only for their own nationals, without any capacity for preventive action or repressive towards foreign fleets or ship-owners.
- The GFCM: explicit illustration of a low-normative Mediterranean policy, emphasizing soft law, consultation and consensus.

The heterogeneity and legal fragility of territorial claims

Status and legal significance

- Heterogeneity of the claims and declarations of coastal States: multiplication of spaces "under the jurisdiction" beyond the territorial waters with the terminology, aims and methods of various calculations.
- List commented: Exclusive Economic Zone, Fishing Protection Area, Exclusive Fishing Zone, Ecological Protection Area…

Conflicts and legal disputes

- Disputes/objections from neighboring States about these unilateral statements: loading maritime borders and methods used (baselines, equidistance ...).
- Several cases of litigation (international law) for the delimitation of territorial waters and continental shelves. Another obstacle for States to focus now on the EEZ with Problems of interpretation and difficulties in establishing boundaries in accordance with art. 174 UNCLOS.
- At present International law does not provide alternative form to the EEZs and recognizes no right to establish new categories of legal areas "under the jurisdiction" by other statutes or specific names (Significant legal uncertainty as to the true scope of these boundaries and their enforceability in international law of the sea).

The environmental protection, the new etendard of coastal state’s hold over sea spaces

The conservationist impulse and its legal consequences

- The phenomenon of Marine Protected Areas (MPAs): International and Regional Law in hard development especially since the 2000s (general overview and many examples).
- Tendency to expand MPAs "seaward" (off-shore) : deep sea, canyons, mammals, highly migratory fish, EBM ...

- Media power, political and financial international lobby groups, favoring a network approach, with significant national and local relay. Proposals for many large protections with studies and scientific arguments (biodiversity, habitats, corridors, species ...).
- Rapid assessment of the situation of MPAs, including "large MPAS" and incentives to off-shore: regional actions (Barcelona Convention, GFCM ...) and national actions (eg the French strategy).

Subsidiarity and responsibility benefit of the states

- Virtues and Limits of Regional Governance: Problems of implementation of joint and consensual decisions: means, controls and monitoring, fiscal and legal powers of police powers at sea (fisheries, environment, pollution ...). Multiple instances with FAO GFCM, the implementation of the Barcelona Convention and its various protocols. International law exists only through the States and their common will.
- An environmentalist discourse sometimes unrealistic and alarmist or constrained by the willingness of States, by national contexts and economic issues clearly superior.
- The legitimacy of extending the right (hold) of coastal states? Idea of the most appropriate level of decision/management or "governance" for a semi-enclosed regional sea. Integrating the concepts of effective protective action in connection with the special responsibility of coastal states (a consequence of the principle of "coastal privilege").
- Willingness of States to develop protected areas beyond the territorial waters: examples of MPAs in place or planned beyond territorial waters.

Conclusion

Reflections have been conducted on the subject discussed in this article, especially for fisheries management, but mainly in terms of theoretical scientific research, without creating the conditions for its political ownership and legal translation. Several ideas were put forward, which can be summarized into two directions: **1)** On the basis of an international treaty, design and develop the conditions for a "meta-decision" to solve the technical problems related to water and geographical in court (delineation criteria, methods of calculation of the widths of EEZ, fair and balanced distribution of space ...). This process aimed to match the requirements of general international law to local Mediterranean. In this first configuration, this approach remains a classic inter-state cooperation with the main objective (and temporary) would be the final settlement of boundary issues navy. In this case, we can imagine the gradual “erosion” of high-seas to its disappearance altogether. **2)** Submit a *sui generis* status for the Mediterranean. On this last point, some authors suggest the recognition of a "patrimonial sea", a synonym of common interest rather than exclusive, with the establishment of a supranational institution (condominium) responsible for water resources and management (much more integrated system). In the second, setting the EEZ would no longer be an imperative of governance, since it would be a sharing of powers between the states (12 miles zone) and an autonomous and competent regional organization (high seas)...

References

- A. Abdulla et al., 2008, *Status of Marine protected Areas in the Mediterranean Sea*, UICN, Malaga and WWF, France, 152 p.

- G. Andreone, 2000, « Le régime juridique de pêche en Méditerranée et le développement soutenable : quelques réflexions », In *The Euro-Mediterranean Co-operation for Sustainable Developement*, pp. 86-100.
- G. Apollis, *L'emprise maritime de l'Etat côtier*, Pedone, 1980, 293 p.
- S. Beslier, 2008, La responsabilité de l'Etat du pavillon : cas des navires de pêche, Annuaire du droit de la mer, Tome XIII, pp. 11-22.
- E. Doussis, 2001, « La protection du milieu marin en mer Egée », Annuaire du droit de la mer, Tome VI, Pedone, pp. 9-43.
- V.L. Guitierrez Castillo, 2008, « Le système espagnol des lignes de base », Annuaire du droit de la mer, Tome XIII, pp. 123-142.
- S. Ihraï, 2008, « Les lignes de base marocaines », Annuaire du droit de la mer, Tome XIII, pp. 111-122.
- S. Pannatier, 1997, « Problèmes actuels de la pêche en haute mer », Revue Générale de Droit International Public (RGDIP), 1997-2, pp. 421-445.
- G.R. Russ, D.C. Zeller, 2003, "From *Mare Liberum* to *Mare Reservarum*", Marine Policy Volume 27, Issue 1, January 2003, Pages 75-78.
- T. Scovazzi, 2001, « Les zones côtières en Méditerranée : évolution et confusion », Annuaire du droit de la mer, Tome VI, Pedone, pp 95-108.
- H. Slim, 2008, « Vers une meilleure gouvernance de la Méditerranée occidentale au-delà des eaux territoriales », Annuaire du droit de la mer, Tome XIII, pp. 451-461.
- M. Voelckel, 2001, « Comment vit la zone économique exclusive ? », Annuaire du droit de la mer, Tome VI, Pedone, pp 109-134.

Overfishing: the Atlantic Bluefin tuna case

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Abstract

During the 2000s, Atlantic bluefin tuna crisis has crystallized most of the problems of many fisheries: severe overcapacity, open access in international waters, geographical expansion of the fisheries, high market value and deficient governance at both the international and national levels. A long lasting and heavy pressure from various parties has however changed the situation in 2008 and last the last stock assessment displayed obvious signs of stock rebuilding. The presentation will track the main steps of this highly mediated crisis, identify the main causes and will finally confront the main management options that are nowadays implemented or contemplated.

Atlantic bluefin tuna general traits

Atlantic bluefin tuna (ABFT) inhabit the pelagic ecosystem of the entire North Atlantic and its adjacent seas, primarily the Mediterranean Sea (Figure 1). Among the tuna, ABFT has the widest geographical distribution and is the only large pelagic fish living permanently in temperate Atlantic waters (Fromentin and Powers 2005). Archival tagging and tracking information confirmed that BFT can sustain cold (down to 3°C) as well as warm (up to 30°C) temperatures, while maintaining stable internal body temperature (Block et al. 2005). The spatial distribution and movement of ABFT have been traditionally hypothesized to be controlled by preferential ranges and gradients of temperature, similar to other tuna species, but recent works appear to converge toward the opinion that juvenile and adult BFT frequent and aggregate along ocean fronts. ABFT is also known to be a high migratory species displaying a homing behaviour (Rooker et al. 2008), i.e. ABFT migrate to spawn in specific and well defined areas where it was born (Figure 1).

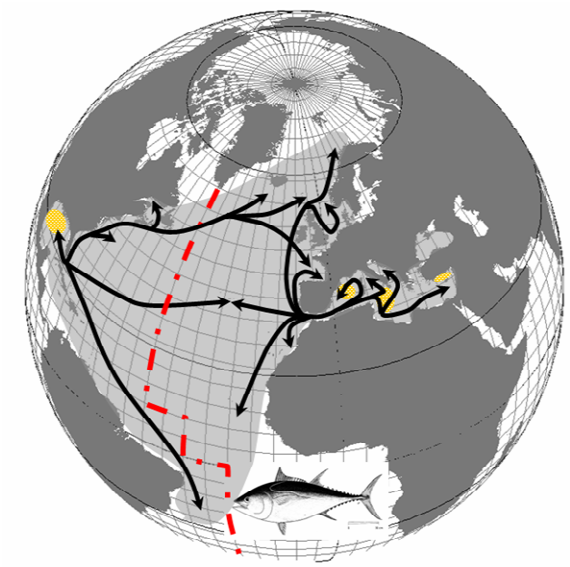

Figure 1. Spatial distribution (gray shading) and main migration routes (black arrows) of Atlantic bluefin tuna. The vertical dashed line depicts the stock delimitation between the two current ICCAT management units. The main spawning grounds currently assumed in the literature are depicted by dotted yellow areas (from Fromentin and Powers 2005).

Little is known about feeding migrations within the Mediterranean and the North Atlantic, but results from electronic tagging indicated that migration and movement patterns of BFT vary considerably between individuals, years and areas (Sibert et al. 2006). The appearance and disappearance of past fisheries also suggest that important changes in the spatial dynamics of BFT may be environmentally driven. However, the key scientific uncertainty about this species remains its population structure. ICCAT (International Commission for the Conservation of Atlantic Tuna) currently manages ABFT as two stocks with the boundary between the two spatial units being the 45°W meridian (Figure 1), but recent analyses lead some scientists to postulate that ABFT may be seen as a metapopulation (Fromentin and Powers 2005), i.e. a collection of discrete local populations, occupying distinct and patchy suitable habitats and displaying their own dynamics.

Fisheries History

Archaeological excavations have shown that fishing on ABFT has occurred in the Mediterranean since the 7th millennium BC. About a hundred fisheries sites (along with salting plants) were established by the Phoenicians, then by the Romans around the Western Mediterranean Sea. At that time, fishermen primarily used hand lines and several varieties of seines, particularly beach seines. ABFT exploitation remains active in the Middle-Age and beach seines were progressively replaced by traps since the 16th century. Traps and beach seines were used throughout the Mediterranean and Gibraltar strait and were the first industrial fisheries in this area, catching between 7,000 and 30,000 tonnes per year, with a mean range of about 15,000 tonnes per year. The trap catches largely fluctuated and displayed a dominant 100-120 years periodic cycle that would be due to variations in ABFT abundance of entering the Mediterranean each year for spawning in response to modifications in oceanographic conditions (Ravier and Fromentin 2001).

Until the 19th century, ABFT fishing primarily occurred in the Mediterranean Sea and the Ibero-Moroccan embayment, but exploitation progressively expanded. A hand line fishery targeting juveniles ABFT and North Atlantic albacore arose in the Bay of Biscay during the mid-19th century. ABFT was also occasionally caught in the North Sea, Norwegian Sea and Kattegat since the 1920s by hook and line and, later, by purse seine. These Nordic fleets grew rapidly such that their yields exceeded that of the traditional trap fisheries during the 1950s

(up to 16,000 tonnes/year, Figure 2). These catches were mainly composed of large ABFT migrating North in summer to feed on pelagic fish, such as herring and sprat (Tiews 1978). The late 1960s and early 1970s were a transitory period for both the Atlantic and Mediterranean BFT fisheries. The landings were lower than in the previous decades because of the sudden decreasing activity of the traps and Nordic fleets in the East Atlantic and a reduction in purse seine catches of juveniles in the West Atlantic (Fromentin 2009). Also during that period, purse seine and long-line fleets progressively replaced the traditional fisheries of the Mediterranean and East Atlantic.

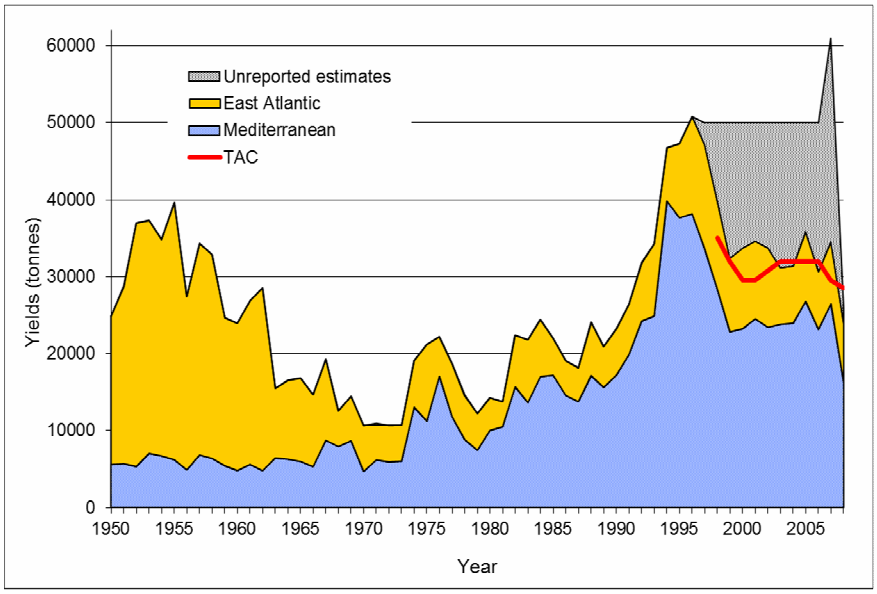

Figure 2. Reported catch for the East Atlantic and Mediterranean from Task I data from 1950 to 2009 split by main geographic areas together with unreported catch estimated by the Committee (using from fishing capacity and mean catch rates over the last decade) and TAC levels since 1998.

The overexploitation during the last decades

The development of the Japanese sushi-sashimi market during the 1980s was the most remarkable event of the recent decades, as it made BFT exploitation much more profitable than before (Fromentin and Powers 2005). ABFT was indeed a resource of rather low value until that time which was mostly canned. With the sushi-sashimi market, ABFT became expensive and exquisite seafood being in great demand. This new situation had serious implications on ABFT fisheries. First, there was a sharp increase in the efficiency and capacity of the established fisheries from the 1980s until the mid-2000s, especially in purse seiners, which led to a sharp increase in the catch (Figure 2) and to a severe overcapacity (i.e. a fishing capacity that largely exceeds the natural productivity of the stock). Second, the fishing areas economically available for exploitation expanded in both the North Atlantic and Mediterranean, so that ABFT is now exploited over its whole spatial distribution for the first time in its long millennial fisheries history. Third, there was a spectacular development of farming and fattening in the late 1990s. ABFT is further a natural wild resource that is shared by many countries (at least 20 countries and about 50 different fleets). This is probably another key difficulty for ABFT management, as the different contracting parties have often conflicting interests. All these problems made that the management regulations aiming at limiting or decreasing exploitation levels were poorly implemented and even more rarely controlled (leading, among other things, to severe underreported catch during the last decade,

see Figure 2). In conclusion, ABFT recent fisheries shared most of the problems that have been identified in well-established overexploited stocks: severe overcapacity, open access in international waters, geographical expansion of the fisheries, high market value and deficient governance at both the international and national levels.

Recent changes

This situation has become so critical that the ICCAT scientific committee raised the possibility of stock and fisheries collapse if the fishing mortality patterns were not rapidly reversed (ICCAT 2007). A long lasting and heavy pressure from various parties (including NGOs) has progressively changed the situation between 2006 and 2009, leading to the ABFT rebuilding plan and a real effort in the enforcement and the control (at sea, cages, ports, markets) of the management regulations (mostly since 2008) and a plan of fishing capacity reduction. The scientific diagnosis is still impaired by large uncertainties (especially due to uncertainties in catch and effort data from the mid-1990s until 2007), but the last stock assessment displayed obvious signs of stock rebuilding. The complete rebuilding of this heavily fished stock will probably take a decade and will necessitate strong management regulations during all that period, including a rather low quota that should not exceed 13,500 tonnes in the coming years (ICCAT 2011).

If the current ICCAT rebuilding plan for ABFT seems to be rather efficient if it is strictly applied, there is still a great need for research and data collection to decrease current levels of uncertainties in the scientific diagnosis and to improve our understanding of ABFT key biological processes, especially its spatial dynamics and habitat preferences, its population structure and its reproductive biology and early life history.

References

Block, B. A., S. L. H. Teo, A. Walli, A. Boustany, M. J. Stokesbury, C. J. Farwell, K. C. Weng, H. Dewar, and T. D. Williams. 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature **434**:1121-1127.

Fromentin, J.-M. 2009. Lessons from the past: investigating historical data from bluefin tuna fisheries. Fish and Fisheries **10**:197-216.

Fromentin, J.-M. and J. E. Powers. 2005. Atlantic bluefin tuna: population dynamics, ecology, fisheries and management. Fish and Fisheries **6**:281-306.

ICCAT. 2007. Report of the 2006 Atlantic Bluefin Tuna Stock Assessment Session. Collective Volume of Scientific Papers ICCAT **60(3)**:652-880.

ICCAT. 2011. Report of the 2010 Atlantic Bluefin Tuna Stock Assessment Session. Collective Volume of Scientific Papers ICCAT **In press**.

Ravier, C. and J.-M. Fromentin. 2001. Long-term fluctuations in the Eastern Atlantic and Mediterranean bluefin tuna population. ICES Journal of Marine Science **58**:1299-1317.

Rooker, J. R., D. H. Secor, G. DeMetrio, R. Schloesser, B. A. Block, and J. D. Neilson. 2008. Natal Homing and Connectivity in Atlantic Bluefin Tuna Populations. Science **322**:742-744.

Sibert, J. R., M. E. Lutcavage, A. Nielsen, R. W. Brill, and S. G. Wilson. 2006. Interannual variation in large-scale movement of Atlantic bluefin tuna (*Thunnus thynnus*) determined from pop-up satellite archival tags. Canadian Journal of Fisheries and Aquatic Science **63**:2154-2166.

Tiews, K. 1978. On the disappearance of bluefin tuna in the North Sea and its ecological implications for herring and mackerel. Rapport et Procès-verbaux des Réunions du Conseil international de l'Exploration de la Mer **172**:301-309.

Governance system

What makes the difference between the ecosystem approach to fisheriesand integrated coastal zone management in the Mediterranean: it's the economy, stupid!

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The 7th Protocol in the framework of the Barcelona Convention, the Protocol on Integrated Coastal Zone Management (ICZM), signed in Madrid in January 2008, provides an ambitious regional context under which countries can better manage their coastal zones, as well as deal with the emerging coastal challenges, such as climate change. Its importance lies in the mutual recognition of the severe pressure of development around the Mediterranean coasts and the urgent need for coordinated action and governance. It represents the regional framework within which local ICZM projects should evolve in the future. However, the question remains as to how to assess their real progress towards more sustainable forms of development.

Many descriptions exist of the *process* by which ICZM programmes are constructed and evolve. A widely used framework was developed by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP, 1996)[5]. The GESAMP cycle (Fig. 1) begins with an analysis of problems and opportunities (Step 1). It then proceeds to the formulation of a course of action (Step 2). Next is a stage when stakeholders, managers, and political leaders commit to new behaviours and allocate the resources by which the necessary actions will be implemented (Step 3). This involves formalization of a commitment to a set of policies and a plan of action and the allocation of the necessary authority and funds to carry it forward through implementation of these policies and actions (Step 4). Evaluation of successes and failures; learning and a re-examination of how the issues themselves have changed complete the management cycle (Step 5).

[5] GESAMP (1996): The contributions of Science to Integrated Coastal Management. Reports and studies No.61. Food and Agriculture Organization of the United Nations, Rome.

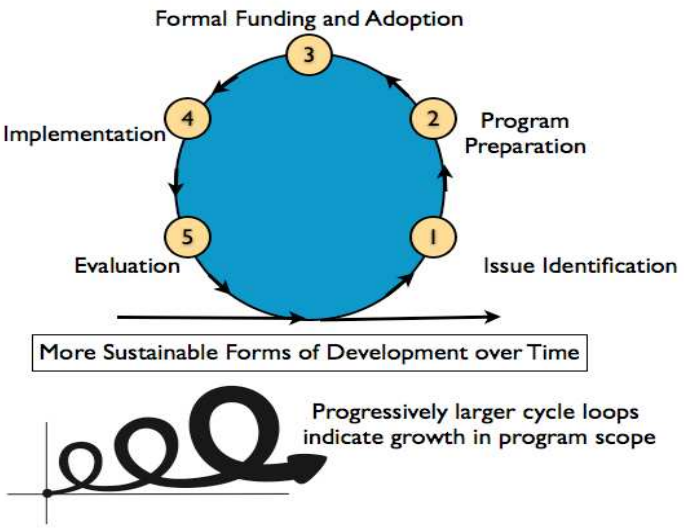

Figure 1 – Fragments of unconnected processes within the management cycle *(adapted from GESAMP, 1996)*

The reality of many coastal management programmes of all varieties is that we often see only fragments of unconnected processes. In particular, there may be a major gap between repeated efforts at issue analysis and planning (Steps 1 through 3) and the implementation of a plan of action (Step 4). Moreover, subsequent initiatives often do not build strategically on a careful assessment of what can be learned from earlier attempts to address the same or similar issues (Step 5). Experience demonstrates that in complex coastal systems well-designed and well-executed processes may not produce the desired outcomes. This is the challenge for the future of ICZM in the Mediterranean, i.e., to build on existing activities to provide an "enabling framework" to facilitate the embedding of ICZM processes across the whole Mediterranean, i.e., to take ICZM beyond the constraints of the short-term project cycle.

Moreover, the perception of ICZM as an environmental management activity is stubbornly persistent. 'Mainstreaming' the management of the coast is shorthand for extracting ICZM from its narrow perception as primarily an environmental management activity. Simply, we need to work harder to embed ICZM into other areas of policy including: fisheries, transport, health, poverty reduction, etc. This is much discussed but there is little in the way of practical advice on how to do it. In economic terms, on the macro scale, we can now relate ICZM to the standard economic measure of GDP (with reservations over accuracy), a powerful tool as GDP growth overall is slowing or even falling across the Mediterranean.

There is a case for arguing that ICZM needs to be prepared to take risks to achieve a higher prize. By being generally 'risk-averse' with relatively limited ambitions, ICZM has failed to grasp the imagination of politicians in particular and the community in general. This is often a simple case of language used; ICZM (including the term 'ICZM' itself) is expressed in technocratic and complex language. A process of "demystification" is needed, stating the seriousness of the problems and the challenges faced by the coast in simple clear terms. In relation to the lack of clarity is the lack of a clear vision for the coast. The coastal problems may be well enumerated and articulated, yet surprisingly there is no clear, simple vision of what the sustainable Mediterranean coast might look like. This lack of vision at the regional

scale has generally been replicated at the local level. A simple, practical vision of what constitutes a '"sustainable coast", comparable to the clear objectives of examples such as the European Horizon 2020 and the Millennium Development Goals, is urgently required.

Creating the enabling framework for ICZM is essentially a top-down activity and should be a priority for international funding organisations. The building of regional and national capacity, the legal and institutional frameworks offers the best and most cost-effective opportunity to match the level of future ICZM activity to the scale of the problem facing the Mediterranean. The lessons from the previous programmes are that local pilot projects are not in themselves an adequate panacea for the scale of the future challenges. The success of recent attempts to run this national capacity building *in parallel* with local action has had only limited success. A more concerted and focussed effort is therefore required if future challenges are to be met. The plethora of initiatives such as Horizon 2020, the EU Marine Strategy and other issues such as climate change, combined with the lack of coordination between programmes and agencies, pose the risk that efforts to promote a holistic approach could become diluted.

The signing of the ICZM Protocol in the Mediterranean in 2008 as an international legal document was a major achievement. It symbolises the mutual recognition of the severity of coastal problems around the Mediterranean, the relevance of ICZM as a discipline, and of the need for concerted action to tackle them. However, the signing of the Protocol is only the first stage in a lengthy and very demanding process of implementation.
In order to become part of national law the ICZM Protocol must be ratified and adopted into national legislation of the signatory states. This is in itself a complex undertaking and there are a number of potential problems including:

- the ICZM Protocol cuts across strong departmental and sectoral responsibilities, and challenges vested interests through, for example, the creation of setback zones;
- ratification and implementation requires the development of a common understanding of ICZM across all sectors and levels of government and the political structures, along with the harmonisation of the text with the national languages;
- the technical and governance capacity of the states to implement the ICZM Protocol also varies considerably. Unlike the implementation of an EU Directive to Member States, no sanctions exist to penalise states for non-compliance;
- financial and other resources required to implement the Protocol;
- as a platform on which to base a concerted attack on the problems facing the Mediterranean coast the Protocol is unparalleled. The Protocol lifts ICZM from a narrow sectoral issue to one of national importance and focus.

The maturity and the related issue of capacity, of governance systems can play a significant and determining role in the long-term sustainability of coastal management. Whereas European states possess sophisticated governance mechanisms, developed administrative cultures, long established databases and technical resources to map and measure sustainability, many southern states may still be attempting to consolidate new local governmental structures with limited resources. Local administrations in these states may still lack democratic legitimacy, technical resources such as databases and sophisticated mapping facilities. Too often however, coastal management is based on a "northern" model,

concentrating on technical issues without regard to the maturity and capacity of local systems to deal with them.
Spatial planning is seen as a key tool in moderating competing developmental demands. In the Mediterranean region spatial planning systems have been poorly developed, however it is likely that they will steadily improve in the coming years, with stronger mandatory requirements specific to each of the land and marine environments. ICZM has an important role to play in this process, in particular in moderating between marine and terrestrial uses and interactions. ICZM practitioners will need to be able to work closely with, and use spatial planning as a tool, and be familiar with use of the Strategic Environmental Assessment (SEA) and other spatial planning tools.

Embracing this wider agenda will require an influx of ICZM practitioners with new and unfamiliar skills. Current ICZM practitioners and their supporting organisations in the Mediterranean are predominantly from an environmental and scientific background. This is mirrored in the audiences at conferences, workshops and training courses. A wider skills base and constituency will be required in the future including for example; community development, economics, and climate change.

This realignment will have to take into consideration recent challenges to the current ICZM dogma which leads to the expectation of simple solutions to most of the complex and increasingly global problems facing the world's coastal zones. Tackling those in a more comprehensive way in a rapidly changing world necessitates new thinking like "adaptive management" (Mee, 2005) to keep ICZM as a key concept for adaptation.

Adaptive management of complex social and ecological systems is viewed as an experiment where the outcomes are not entirely predictable. Measurable long term system goals are set by the stakeholders on the basis of the available historical, traditional, scientific knowledge and by simulations of how the system may respond to social and economic drivers and pressures in the future under different management scenarios. This is the agreed 'Vision' so clearly lacking from many existing ICZM programmes. Then the stakeholders agree on the first practical measures that can be taken towards achieving these goals and on how their achievement will be monitored. This first step works as an experiment from which lessons can be learned to plan the next step towards the long-term goals.

References

GESAMP (1996): The contributions of Science to Integrated Coastal Management. Reports and studies No.61. Food and Agriculture Organization of the United Nations, Rome.
Mee L.D. (2005). Assessment and monitoring requirement for the adaptive management of Europe's regional seas. In: Vermaat J.,Bouwer L., Turner K., Salomons W., Editors. *Managing European Coasts.* Springler-Verlag, Berlin, pp. 227-237

Seedling Production of the Pacific bluefin tuna

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The Study of seedling Production has been conducted at the Fisheries Laboratory of Kinki University since l970 when the rearing of natural larvae started in order to farm the adult fish for seedling production (Table 1). This study ran up against various obstacles as the continual death of all reared fries. The collision which occurs in between the fry and adult stages should be in particular solved to be able to accomplish the seed production of the bluefin tuna (Fig.1). The accumulation of experience in rearing□investigation of the causes of collision death (Fig.2) and the installation of the large-sized preserve enabled us for the first time in 1995□to produce bluefin tuna seeds. With 17,307 fries at 37−44 days obtained after hatching and of 4.5−4.8 cm in total length□it could consider that the perfect aquaculture of bluefin tuna was realized after 32-years of research (Fig.3,4). The importance of bluefin tuna in the food consumption in Japan has led Japan to import this species from around the world. But face to the decline of bluefin tuna resources in the Atlantic Ocean Japanese scientists have the responsibility of developing seedling production technologies for stocking and farming and conveying this technology around the world. However there are still many problems remaining to its industrialization. The mass-production of bluefin tuna seeds includes developing technologies for reducing the early-stage death and cannibalism among the fries and to find a solution for feed supply related problems. The development of artificial compound feed is particularly essential In addition the development of the technology for collecting eggs in controllable conditions in a water tank is also vital for constant collecting of fish eggs (Table 2).

Table 1: 37 years of tuna rearing history

1970(0)	Tuna aquaculture study start
1974(4)	Culturing from wild seedling
1979(9)	Wild fish natural spawning, hatching, and larval and juvenile rearing
1982(12)	Record of seedling rearing was 57 DPH, TL 98 mm
1983-1993	**No-spawning□Rearing experiments were not conducted**
1994(24)	1,872 reared juvenile transferred to sea farm;246 DPH, TL 42.8 cm,1,327 g
1995(25)	Production of seedling for aquaculture
1997(27)	17 (hatched on 1995) and 35 tails (hatched on 1996) survived
2002(32)	Reared broodstocks (‘95 and‘96) spawned: Success in closing life cycle
2004(34)	Closing life cycle adult tuna sold
2007(37)	Birth of 3rd generation, Selling closing life cycle juvenile tuna

Table 2. The problem for the industrialization of the seedling production

1) Spawning : Instability
2) Depletion of larva stage:
    a) Adhesion of larvae to the water surface (1-4day post hatch)
    b) Dies by sinking in the bottom (3-7day post hatch)
3) Depletion by cannibalism (10-30 day post hatch)
4) Depletion by the collision (35-60 day post hatch / 5□25 cm TL)
5) Development of formula feed

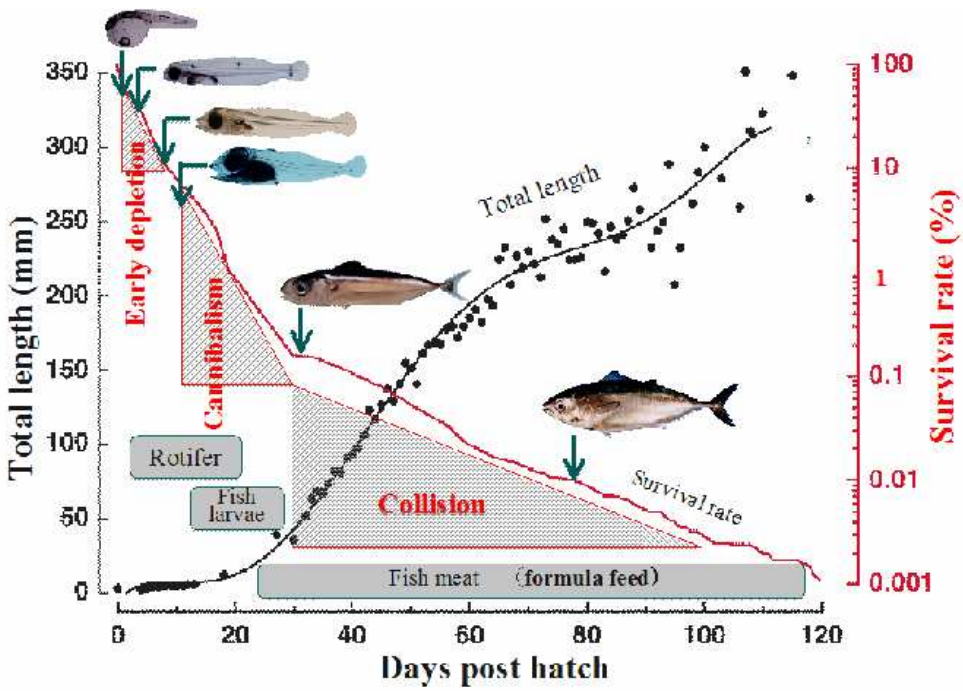

Fig. 1 The main period of death in PBT seedling production (Growth, survival and diet, Φ 7m tank, 1995).

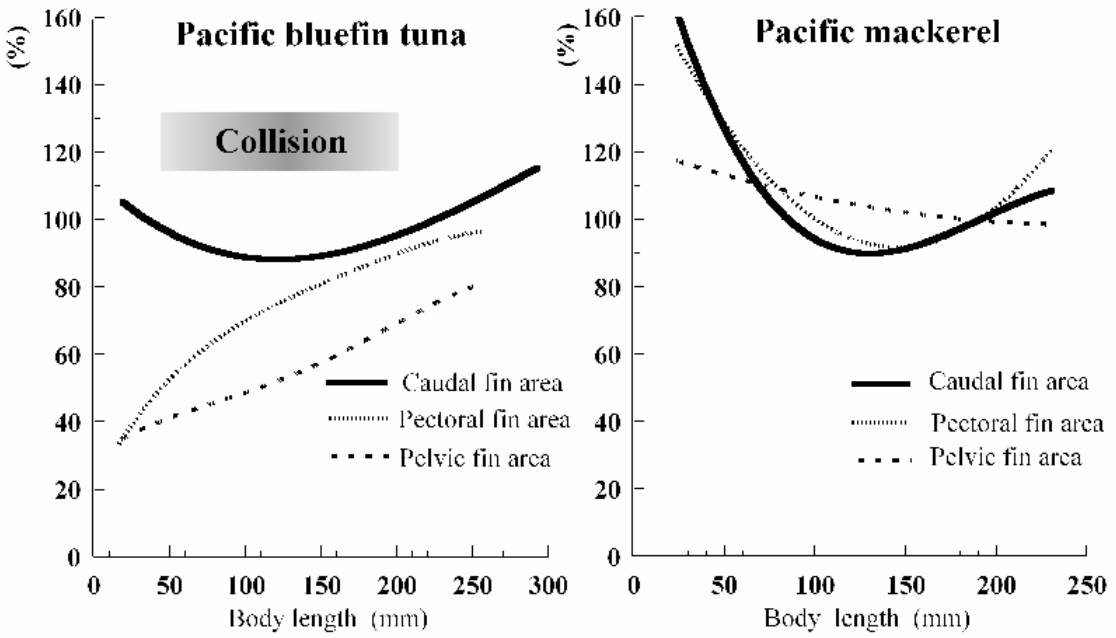

Fig.2 Change of fin area with growth of the Pacific bluefin tuna and the Pacific mackerel. Fin areas are expressed by indices relative to the areas of the adult fish. Indices of the adult fish are 100%.

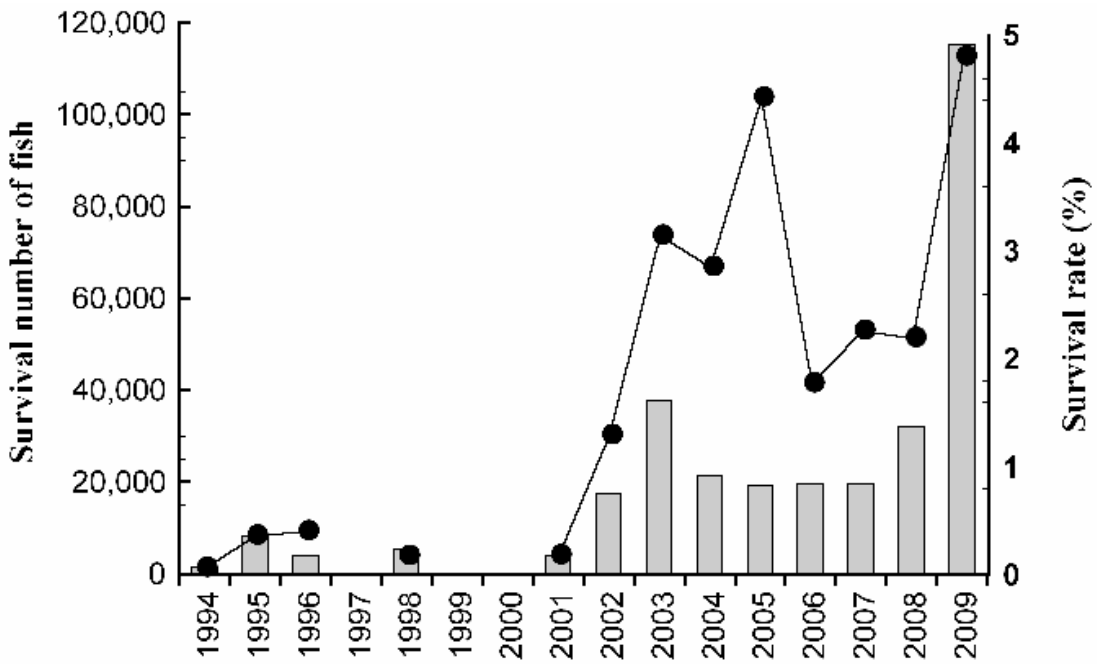

Fig.3 The seedling production of PBT (5-7 cm.TL; 30 dph /Ohshima branch). Squares indicate the number of fish. Circles indicate the survival rate. The number of the total fish which all branches produced in 2009 : 196,422

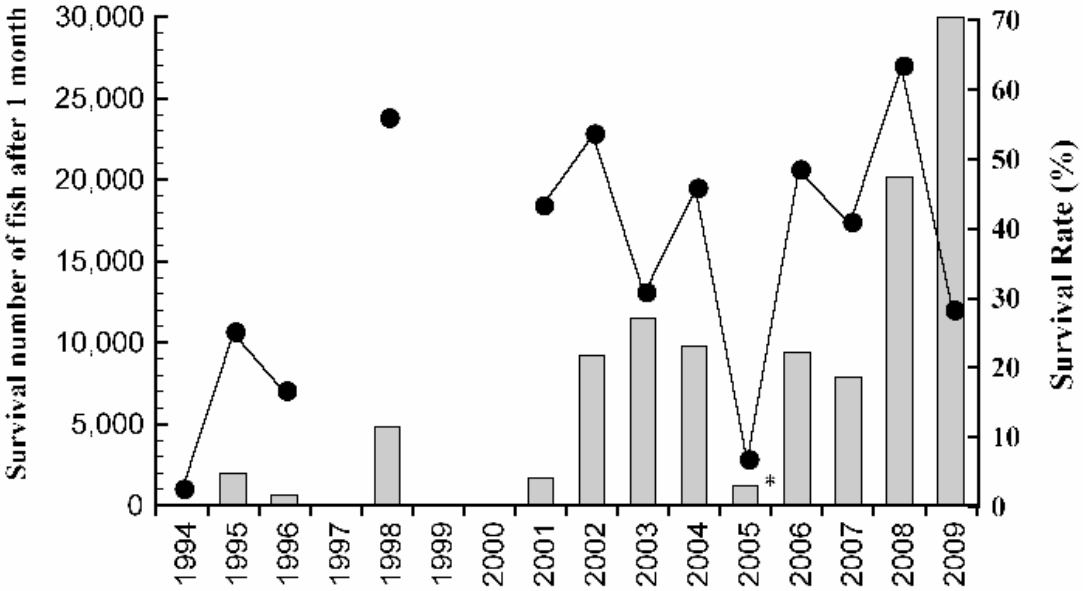

Fig. 4 Intervening culture result (from 5-6 cm TL to 20 cm TL) of the PBT in netcage (Ohshima branch).
Squares indicate the number of fish. Circles indicate the survival rate.
*The damage by the *iridovirus* infectious disease.

Marine eco-engineering construction: ICZM opportunity for biodiversity enhancement

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Abstract

The pressure for seashore use is steadily increasing, not only in developed countries but everywhere in the world. It affects inevitably the marine continental shelf down to the isobath -200 m. In this coastal space, new activities appear, such as renewable energies, recreational activities, aquaculture, in addition to traditional ones as navigation or fishing. This evolution raises new sources of conflicts which require the involvement of State in order to manage several stakeholders and lobbies.

Currently, this space presents a huge potential of development for two reasons. The first one is related to the three dimensions of this space, so the whole water column can be valorized notably to increase the fishing productivity, like in Japan. The second reason is the opportunity for innovative synergies between multiple superposed uses (a fourth dimension), socio-technical and ecological, such as a pipe-line with concrete weights specially designed to enhance marine life or the settlement of complementary structures close to the foundations of wind turbines in order to maximize positive effects on the ecosystem.

This new vision in "4D" for the equipment and the management of this large coastal area gives the possibility to reduce risks of conflicts as different uses of the sea would not necessarily exclude one another. Until now, limited applications are available because of the lack of a common ecosystem based approach among the different stakeholders and little experience in the co-construction of projects. This "green" concept implies an increasing complexity and resilience of the ecosystem on the long term if underwater infrastructures are also designed to integrate adapted habitats to protect or stimulate marine life.

Key words : Integrated coastal zone management, marine continental shelf management, ecological engineering, off-shore wind farm, aquaculture, artificial habitat, eco-designed construction.

Introduction

The « area » of the coastal sea is defined here as the space limited by the marine continental shelf, *i.e.* the volume of the sea, from the coastline to the isobath -200 m. This coastal space is huge: 27 million sq km, which represents 7% of the surface of the oceans, but it represents

only 0,3 % of the oceans volume. The offshore extension of this area is highly variable according to countries and regions. France has the second exclusive economic zone at sea (11 million sq km) with large areas of this kind of shelf. In this regard, it is worth trying to valorize this area in which progress can be made in terms of scientific knowledge and management. This multi-use space is actually fragile although highly exploited and damaged.
Most trends impacting the sea are more and more critical in terms of general quality of the seawater but also when considering the sustainability of living resources (Pauly *et al*, 1998; Zeller and Pauly, 2005; Kavanagh, 2007, Cury et Miserey, 2008). Could the increasing pressure on this area be properly managed in order to secure the productivity of marine ecosystems and sustain an eco-designed infrastructure development which could be more integrated to the ecosystem?

The coastal zone : an endangered ecosystem

Half of the world population is concentrated on a 50 km strip along the coastline with a density five times higher than the rest of inhabited lands (Crossett *et al*, 2004). Among the 20 largest cities of the world, 16 are close to the sea (DATAR, 2004). This concentration of mankind should increase as estimations indicate that 75% of the population should live at less than 50 km from the sea by 2050 (Gaudin, 1990, Saunier *et al*, 2007). The needs for water, food, energy and a lot of vital items will increase; related waste and pollution will probably affect all marine ecosystems (Gnesotto et Grévy, 2006).
As an example, in the Mediterranean, along the 46 000 km of coast, about 136 million people are recorded (The Blue Plan/ le Plan Bleu, 2005). The Blue Plan expects 50 million more people in 2025. In addition, tourism represents huge flows of population : about 170 million tourists in 2007 (25 % of the World tourism). They should be 312 million visitors by 2025.
The degradation of coastal marine ecosytems is known : sewage from industry and towns, organic muds, radionuclides, oil and coal waste, all the products and by-products of human activity finally reach the sea where several of them are integrated into the food chain (Bœuf, 2006). Of course, the impacts are higher in closed seas such as the Mediterranean (Blondel *et al*, 2010).
Regarding fisheries, FAO reports that more than 2/3 of the species are in a situation of full exploitation or over-exploitation (FAO, 2007) with a steady decline for 50 years of the global trophic index which integrates 200 species in the food web (Pauly and Watson, 2005). If this rate is maintained, most of the targeted species for fishing will disappear before 2050 (Worm *et al*, 2006; Worm *et al*, 2009). Some fishing techniques, like trawling, are known to destroy habitats and related fauna in areas where spawning grounds and nurseries are recorded (Cury et Morand, 2003). A great number of states and international organizations start anyway to pay more attention to fragile marine areas such as mangroves or coral reefs, as shown at the World summit of Johannesburg (2002) which recommended "To promote the integrated management of coasts and oceans at the national and international level, to develop networks of marine protected areas". But how could we preserve, maintain or develop coastal ecosystem? By fighting again the four main factors of marine ecosystem perturbation: pollution (which include climate change), overfishing, habitat destruction and invasive species (Cury et Morand, 2003; Jackson *et al*. 2001). Three of these threats concern political decisions through management and educational actions. Concerning habitat destruction some solutions were tested in various countries to restore coastal sea-ground with artificial habitat.

Coastal habitat enhancement: knowledge about artificial habitat development

Artificial reefs have been placed in the marine environment since at least 1655, which is apparently the date of the first recorded deployment (Mottet, 1985; Simard, 1995). However, it is likely that these habitats providing function was recognized by fishermen long before this date. Currently, artificial reefs are used worldwide for diverse functions: primarily to enhance fishing and recreational diving, but also to prevent trawling, provide beach protection, mitigate marine construction… (Chii, 1990. Seaman and Sprague, 1991, Thanner *et al.*, 2006). For many years artificial reefs were constructed out of "materials of opportunity," i.e., used tires, old cars, construction rubble, derelict ships, and similar waste structures (Seaman and Sprague, 1991). However, it became obvious that all artificial reefs were not equal relative to habitat function and, as a result, there has been considerable research examining specific attributes of artificial habitat (AH) relative to functionality..It is useful to keep in mind this experience about habitat creation, through artificial reef development to design marine construction project. The goal of the following projects is not just to minimize damage but also to initiate a proactive approach to incorporate positive ecosystem benefits into the construction design from the onset. This so-called marine eco-engineering construction tries to mix biological with engineering knowledge for technical, economical and ecological benefits.

Eco-engineering construction approach

Eco-designed (marine eco-engineering construction) projects are in development or in process. A "green marina" with the harbor designed to attract and concentrate juvenile fishes by providing them safe and effective refuge (Pastor 2008) is in development, as are docks of a new material designed to enhance bio-filtration of harbor water to help to partly reduce pollution and organic matter sedimentation (S. Pioch, unpublished data). Attempts to create heterogeneity of habitat inside dikes will provide an increase in biodiversity associated with those structures (Moschella et al, 2005). Four projects of eco-designed pipe-line are developed; one sited in Mayotte (French island in the Indian Ocean) was completed in March 2010. The idea was to combine habitat with the need of weights to maintain the pipe on the sea-ground. 206 eco-weights were designed and built to create habitat for spiny lobster juveniles, groupers and coral reef fishes community. A specific treatment was also applied on the surface of the concrete to enhance the rugosity and help the soft, and after hard coral colonization. First monitoring observation showed important amount of fishes (mostly juveniles) in and around the "eco-weights". In the meantime the old pipe (still not destroyed) was not colonized by fishes, although it had been installed more than 20 years ago. Ecological weight habitats have been developed and deployed with this concept in September 2009 in the Mediterranean city of Agde (France). These structures are planned to mimic the natural hard bottom landscape by combining effective habitats designed for each targeted species. The concrete has a special composition to enhance colonization, and the integration of the structures in the seascape had been taken into consideration. The ecological assessment of these structures has just begun, but first results are positive and link the targeted species and designed habitat (S. Pioch, unpublished data). This application received the first price from French ministry of ecology (MEDDTL) and environmental agency (ADEME) in 2010 for its positive biodiversity impact ("Prix enterprise et envrionnement" 2010). The pole and foundation material of a wind farm may work as an "artificial reef" (AR) which uses the phenomena of species attraction for hard substratum. It results from a strong aggregation of

fishes and biota around devices (Wilhelmsson et al. 2006). However, this attractive effect could have an adverse effect and threaten the target species in the long term (Petersen et Torleif, 2005; Inger et al, 2009; Bulleri, 2010). As fishes are concentrated around windmills, with no habitat as shelter or refuge to find a protection, they might be harvested (easy target for gillnet) or killed by climatic hazards (especially juveniles concentrate around hard substratum close to the surface (Pastor, 2007). An enhancement of the structure associated with the submerged portions of offshore windmills has been proposed (Langhamer et al, 2009, Michler et al 2009; Stenberg et al, 2010). Artificial habitat could increase diversity along the poles from the sea surface (for post-larvae and juveniles) to the bottom (for adults). The eco-design of the pole consist in add artificial habitat (ecological functions of protection, breeding and spawning and feeding). These devices could also attract recreational activities (diving, fisheries). The artificial reefs could also reduce the erosion factor at the feet of the poles foundation by disturbing current and reducing sediment transport speed.

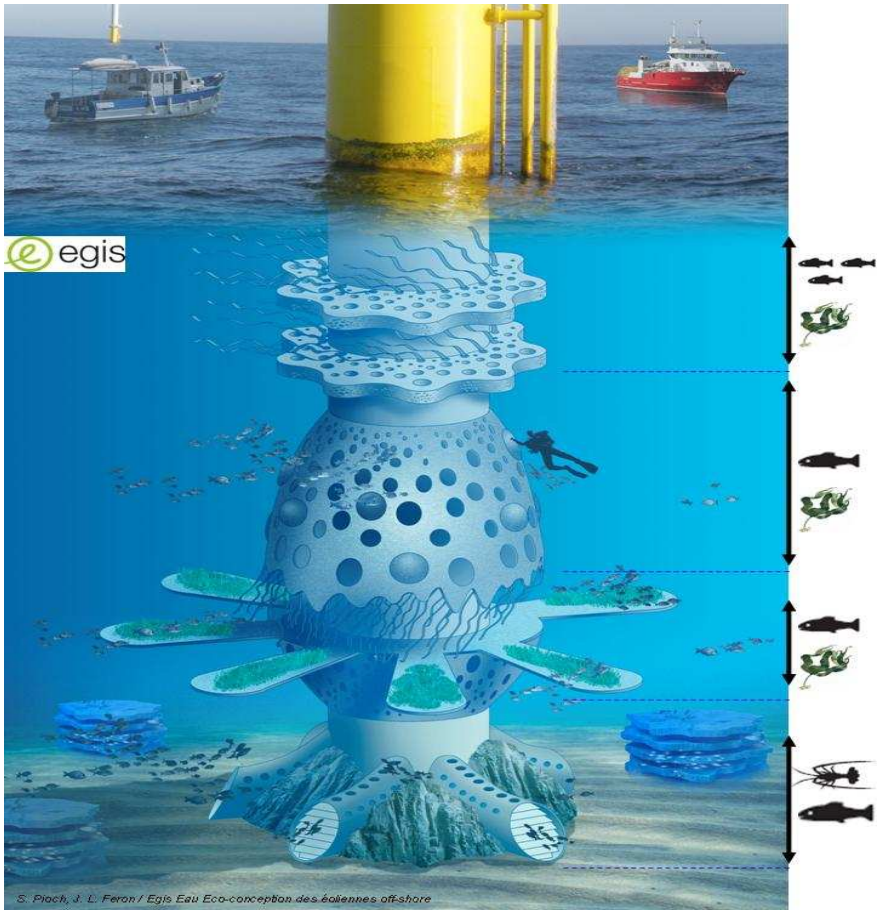

Figure. 1: Eco-designed off-shore foundation to create artificial reef (Pioch and Feron, Egis Eau Co.)

5. Conclusion

The « blue revolution », a new way of the management of the coastal sea has not occurred yet. *Homo sapiens* remains, for several aspects of his behavior, an individualistic predator “with a brain of a primate and the will of a god” (Gaudin, 1990). The challenge is to humanize the coastal sea in the same way human societies try to do on the ground, learning slowly how to

integrate the rules of sustainability and equity for next generations (Gunderson and Holling, 2002, Commission européenne, 2006; Jamieson, 2005; Yanagi, 2007). Actually, on the continental shelf, the current situation is dramatically changing under the pressure of numerous human uses, notably for aquaculture and fisheries sector, and specially in Asia (FAO/NACA, 2001). Guidelines and general recommendations are available as numerous studies had been achieved and published on this global issue (Gesamp, 2001; Katavic, 2005, Efaro, 2006, IUCN, 2007; Soto *et al*, 2008; Lacroix and Simard, 2010). Inasmuch as multiple tools have become available for the past 20 years, notably for ecosystem diagnosis, modeling, impact assessment, decision makers have new ways and indicators to better understand the weight of stakes and the consequences of their choice in various scenarios (Schwartz, 1991 ; Van der Heyden, 1996 ; Rotmans, 1998 ; Cornish, 2004 ; Mermet, 2005 ; Hénocque et Billé, 2005; Dale *et al*, 2007). This new approach emphasizes the interest of more complex infrastructures at sea and, subsequently, expects a higher resilience of ecosystems on the long term since these devices had been designed to stimulate or protect marine life. Two disciplines could support this trend in the conception of marine devices: ecological engineering and sociology of innovation (Callon *et al*, 2001; Maruyama *et al*, 2007; Pahl-Wostl, 2008). This evolution could be enhanced by initiatives about regional seas management such as the Mediterranean or the Baltic sea. The existing ambitious programs of offshore wind farms could be an opportunity for a concerted action at an international level.

Acknowledgement*:* the authors thank E. Claverie, R. Spieler and C. Soudais for support in final fine-tuning of the text.

References

Arena, P.T., Jordan, L.K.B., and R.E. Spieler, 2007. Fish assemblages on sunken-vessels and natural reefs in southeast Florida, U.S.A. Hydrobiologia, 580, 157-171.

Bailly D., 1989. "Pêche et aquaculture au Japon". Nantes, Ifremer. 24 p.

Baine M., 2001. "Artificial reefs: a review of their design, application, management and performance." Ocean and Coastal Management 44: pp 241-259.

Baron, R.M., Jordan, L.K.B. and R.E. Spieler, 2004. Characterization of the marine fish assemblage associated with the nearshore hardbottom of Broward County Florida, USA. Estuarine, Coastal and Shelf Science, 60, 431-443.

Bigot, L., 2008. Projet de pose d'une conduite d'eau potable entre Petite et Grande Terre (Ile de Mayotte). Expertise biologique complémentaire et recommandations environnementales. Rapport Equilibre pour EGIS Eau. 20 p.

Blondel J, J. Aronson, J.Y. Bodiou et G. Bœuf, 2010 : The Mediterranean region : biological diversity in space and time. Oxford university press; 376 p.

Bœuf G., 2006 : Quel avenir pour la biodiversité ? In « Un monde meilleur pour tous : projet réaliste ou rêve insensé ? » Colloque européen 2006 ; Collège de France sous la dir. de J.P. Changeux et J. Reisse. p. 47-87

Bohnsack, J.A.,, Harper, D.E., McClellan, D.B. and M. Hulsbeck, 1994. Effects of reef size on colonization and assemblage structure of fishes at artificial reefs off S-E Florida, USA. Bull. of Marine Science, 55, 796-823.

Bombace G., Fabi G., Fiorentini L., Speranza S., 1994; Analysis of the efficacy of artificial reefs located in five different areas of the Adriatic sea. Bulletin of Marine Science, 55 (2-3): 559-580

Bortone, S. A. (2006). "A perspective of artifcial reef research, the past, the present and the future." Bulletin of marine science 78(1): 1-8.

Bulleri F, Chapman M.G , 2010: The introduction of coastal infrastructure as a driver of change in marine environments. Journal of applied ecology Vol. 47 . Issue: 1. Pp.26-35

Charbonnel E., Francour P., Harmelin J.G., 1997. Finfish population assessment techniques on artificial reefs: a review in the European Union. European Artificial Reef Research, A.C. Jensen edit. Proceedings of the first EARRN conference, Ancona, Italy : 261-275.

Commission européenne, 2006 : Livre vert: vers une politique maritime de l'Union; une vision européenne des océans et des mers. Bruxelles COM 2006.

Crossett, K.M., Culliton, T.J., Wiley, P.C. and T.R. Goodspeed, 2004. Population Trends along the coastal United States. NOAA National Ocean Service. Retrieved May 23, 2010, from www.oceanservice.noaa.gov/programs/mb/pdfs/coastal_pop_trends_complete.pdf

Cury P. et Y. Miserey, 2008 : Une mer sans poissons. Ed. Calmann-Lévy Paris. 283 p.

Cury P., S. Morand, 2003. "Biodiversité marine et changements globaux : une dynamique d'interactions où l'humain est partie prenante". Biodiversité, science et gouvernement, Adpf: 50-77.

Datar, www.datar.gouv.fr/IMG/Fichiers/archives/DatarRLittoral.pdf).

Délégation à l'Aménagement du Territoire et à l'Action Régionale, 2004. Construire ensemble un développement équilibré du littoral La Documentation Française, Paris 2004 ; 156p

Denis J., Y. Henocque, M. Antona, J. Barbière, P. Barusseau, L. Brigand, G. David, C. Grognon-Logerot, B. Kalaora, M. Lointier, 2001 : Des outils et des hommes pour une gestion intégrée des zones côtières. Guide méthodologique. Vol. II, Paris. Manuels et guides de la COI / UNESCO, N°42, 64 p.

Devillers, P., Clerc, L., Buisson, C., Pioch, S. and J.C. Souche, 2009. Faisabilité technique d'un béton à base de déchets de coquillages - XXVII AUGC, Saint Malo 3-5 June 2009, 12p.

D'Itri, F. M. (1985). Artificial reefs, Marine and freshwater applications. Chelsea, MI (USA), Lewis publishers, inc.

FAO, 2007: Sustainable growth and expansion of aquaculture: an ecosystem approach. In FAO state of the World fisheries and aquaculture Sofia 2006. p 76-83.

FWC, www.USFWC.org

Gaudin T. (Coord.), 1990 : 2100 récit du prochain siècle. Etude Ministère de la Recherche. Ed. Payot, Paris. 689 p.

Gnesotto N. et G. Grevi (Coord.), 2006 : The new global puzzle : what world for the EU in 2025? Institute for Security studies 2006. 250 p.

Grove, R.S., Yuge, J.E. and C.J. Sonu, 1983. Artificial reef technology a strategy for active impact mitigation. Proceedings Oceans, 2, 951-956.

Hénocque Y. and R. Billé, 2005 : Gestion intégrée du littoral. Comm. Colloque Prospective du littoral pour les générations futures. Min. de l'écologie (MEDD). Mars 2005. Paris. 14 p.

Ito, Y, 2007). Japanese marine-ranching with artificial reef (unpublished data). JIFIC. Tokyo.

IUCN, 2007: Aquaculture and environment in Mediterranean aquaculture. Guide for the sustainable development of Mediterranean aquaculture. 110 p. (26 experts)

Kakimoto, H., M. Ohgai, et al. (1995). International conference on ecological system enhancement technology for aquatic environments, Tokyo, Japan.

Koike, Y. (2001). "Artficial reef for lobster in Tateyama station, Banda." Japan Society for Fisheries Science 61: 17p.

Kuroki T. 1952. "The shape of a reef and its function as a habitat for fish." Japan Fisheries Magazines 18(1).

La Recherche, 2009 : Dossier spécial : La mer. Numéro 36.

Lacroix D. et F. Simard, 2010: Integrating coastal zone dialogue : can initial networking of partners reduce conflicts in marine coastal areas? Unpublish. Pres. ICES annual science conference. Nantes, France. 20-24 Sept. 12 p.

Monteiro, C. and M. Santos (2000). Portuguese artificial reefs. Artificial reefs in European seas. A.C Jensen et al. (Eeds), Kluwer academics pub.: 249-261.

Nakamura M. 1985: Evolution of artificial fishing reefs concepts in Japan. Bulletin of Marine Science 37 : 271-278.

Ogawa, Y., S. Takeuchi, et al. 1977. "An estimate of the optimal size of artificial reef." Bull. Jap. Soc. Fish. Oceanog.

Pastor, J., 2008. Role of artificial coastal reefs in the connectivity of populations. The case of the white seabream (*Diplodus sargus*, L, 1758) in north-western Mediterranean. PhD dissertation, Univ. de Perpignan, 180 pp.

Pauly D. and R. Watson, 2005 : Background and interpretation of the Marine Trophic Index as a measure of biodiversity. Philosophical transactions of the Royal Society. N° 360; p. 415-423

Pioch, S. 2007b : Le marine ranching au Japon, la gestion proactive des ressources avec les récifs artificiels et le repeuplement. Ifremer - Université Montpellier 3 - Egis Eau. 133 p.

Pioch, S. 2008. Les « habitats artificiels » : élément de stratégie pour une gestion intégrée des zones côtières? Essai de méthodologie d'aménagement en récifs artificiels adaptés à la pêche artisanale côtière. Ph.D. thesis, Paul Valéry University, Montpellier – Tokyo University of Marine Science and Technology, Tokyo. [In French.]

Santos, M. N., C. C. Monteiro 2007. "A fourteen-year overview of the fish assemblages and yield of the two oldest Algarve artificial reefs (southern Portugal)." Hydrobiologia 580 (1): p. 225-231.

Saunier C., M. Duval et P. Laffitte, 2007. "L'apport de la science et de la technologie au développement durable. La biodiversité : l'autre choc ? l'autre chance ?" Paris, OPECST, Assemblée nationale. 192 p.

Seaman W, 2000 : Artificial reefs evaluation with application to natural marine habitats. CRC Press. 246 p.

Simard F., 1996: Socio-economic aspects of artificial reefs in Japan. Proc. of the 1st EARRN Conference 26-30 mars 1996, Ancona, Italy. p. 233-240

Spieler R., Gilliam, D., and R., Sherman, 2001. Artificial substrate and coral reef restoration: What do we need to know to know what we need. *Bulletin of Marine Science,* 69(2), 1013-1030.

colour. *Biofouling.* 22(5-6), 425-9.

Wickel, J., Bigot, L. and A. Jamon, 2010. Suivi environnemental du milieu marin – Sealine, Mayotte. Rapport d'expertise N°2, Groupement Equilibre Co. et Lagonia Co., 22p.

Wolsink M., 2005: Wind power implementation: The nature of public attitudes: Equity and fairness instead of backyard motives. Elsevier Ed. Renewable and Sustainable Energy Reviews 11 (2007) 1188–1207

Worm, B., E. B. Barbier, N. Beaumont, J. E. Duffy, C. Folke, B. S. Halpern, J. B. C. Jackson, H. K. Lotze, F. Micheli, S. R. Palumbi, E. Sala, K. A. Selkoe, J. J. Stachowicz, R. Watson, 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314: p. 787-790.

Worm, Boris, Ray Hilborn, Julia K Baum, Trevor A Branch, Jeremy S Collie, Christopher Costello, Michael J Fogarty, et al. 2009. Rebuilding global fisheries. Science (New York, N.Y.) 325, no. 5940 (Juillet 31): 578-585. doi:10.1126/science.1173146.

Governance system

Fisheries Data Integration for Ecosystem Approach to Fisheries

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The overexploitation of natural resources has been underlined by sustainable development principles. The goals of scientific studies, previously focused on target resources management have thus evolved to include new kinds of management strategies more respectuous of all elements interacting in the affected ecosystem. The EAF concept (Ecosystem Approach to Fisheries) represents this evolution in the fisheries domain:
This approach strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. In the EAF concept, the sharing of IR (Informational Resources: knowledge, information and data) produced by the different stakeholders is crucial to improve the management of marine ecosystems. Indeed, exploited resources are often distributed widely accross the globe's surface. Each stakeholder, according to his area of study and the elements and interactions he is working on, brings a part of the IR required to make common decisions about the global issue of management. Nevertheless, collecting and aggregating sufficient IR to enable analyses at a relevant spato-temporal scale remains a difficult task. To reach this goal would require the ability to locate and make the IR accessible and understandable to everybody, when (i) they are currently collected and managed in heterogeneous ways (syntactic and semantic interoperability issues) by stakeholders distributed in different countries, and (ii) free IR access is still rare. These systems have thus to comply with shared methods to manage same kinds of IR.
For over 50 years, IRD has been contributing to the understanding of marine ecosystem dynamics and to set up EAF by research on different objects (some ecosystems, elements and interactions). In particular, CRHMT studies the dynamics of tropical fisheries (artisanal or industrial) in West Africa, the Indian and Pacific Ocean, to assess their impacts on ecosystems.
These species are often wide-ranging and their spatial distributions overlap the study areas of different institutions. Collaborations with stakeholders from the entire range are thus required, to gather all the data currently distributed into different systems.
At IRD, research leads to collection of thousands of raw data observations, which have been managed, treated and analyzed into heterogenous systems focusing on different scientific goals (databases, information systems, knowledge bases...). Even at the local scale of CRHMT, the management of information and knowledge (indicators, references, Web sites...) produced by different projects remains difficult.

Our goal is to fill the lack of meta-information systems by setting up new kinds of applications, which aim to handle IR managed locally (into heterogeneous management systems) and serve them to client applications through standardized formats and protocols.

In the long term, our application aims to facilitate IR sharing (by describing, searching, formalizing, giving access and representing them in a standardized way) with external systems by implementing the following reference recommandations:

- description of all kinds of IR by using the metadata elements of Dublin Core (ISO 15836) : pictures, videos...
- management of spatial information by using OGC standards (normalized by ISO) : formats of metadata (ISO 19115/39, SensorML), data (GML, KML, O&M...) and related protocols (Web Services CSW, WMS, WFS...),
- management of data on biodiversity by using the work of GBIF and TDWG : formats of metadata (NCD, ABCD...), data and access services (GBIF wrapper),
- use of RDF, OWL, SPARQL languages recommended by W3C to facilitate (meta)data and knowledge sharing on the Web for both human and software agents (e.g. FOAF to describe social networks, SKOS for thesaurii...).
- Currently, some biodiversity projects already use these technologies to manage their own IR.

So far we set up a knowledge base architecture based on standards for informatics, spatial information and biodiversity. The current prototype is the first step for a long term project. In the future, we aim to go further by:

a better matching between our ontology and external ones,

adding more content (by using local sources),improving querying abilities for searching (SPARQL),

serve spatial information to external clients with other standardized formats (GML and O&M or NetCDF for multidimensional gridded data) and protocols (WMS/WFS/WCS/SOS),

converting OWL ontologies into SKOS thesaurii usable by other applications (like metadata editor),

adding other metadata schemas than DCMI or ISO 19139 (ABCD, NCD, SensorML...),

serving metadata to external CSW clients.

A numerical atlas of the Channel marine resources: The Charm Project

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Abstract

The Channel Habitat Atlas for Marine Resource Management (CHARM) is a trans-border collaboration project between France and United Kingdom. It has become, since 2003, a growing network of scientists geared on investing in science through joint collaboration, communication and knowledge management. The initial objective of the project is to provide an atlas for the Eastern English Channel that will serve as significant support to stockholders and policy-makers towards sustainable exploitation and management of this ecosystem. The project started as a pilot program collecting information and "translating" these into comprehensive and integrated knowledge. The two published version of the CHARM atlas which focused on the Dover Strait and Eastern English Channel, respectively, feature a combination of map-based information and inventories on environment, living resources, exploitation and sensitive areas. Integrated studies were conducted in the second volume through construction of food web (ECOPATH) and systematic conservation planning (MARXAN) models. The project is actually in its third phase (2009-2012) which aside from providing map-based inventories of information covering the whole English Channel is geared towards a better understanding of this complex environment an ecosystem-based approach covering more aspects on integrated modeling such as trophic network dynamics, climate change effects, habitat map classification, economics and systematic conservation planning.

The English Channel is facing major challenges due to human actions that are causing unprecedented impacts on ecosystem health (Vaz, Carpentier and Coppin, 2007). This is a crisis that needs to be apprehended as it threatens the collapse of its living resources and the benefits to human society offered by this ecosystem.

The CHARM project aims to awaken consciousness and emphasize a commitment of a cross-section of international experts on the Channel to focus on how to better sustain and

conserve this fragile ecosystem. It focuses on habitats which is an important factor especially in explaining the occurrence and distribution of living resources that lives in it. Studying habitats can also provide information about modifications in abundance of biological resources and identify the factors that can lead to these changes.

In 2003, French and English researchers from eight institutes were gathered to collaborate in establishing an initial protocol for collecting environmental and biological data along the Dover Strait (Carpentier, Vaz, Martin et al., 2005). During the second phase (2006-2008), scientific efforts were geared on exhaustive data collection and map-based representation of environmental, social and biological information of the eastern English Channel (Fig 1). Initial attempts were also done to describe and determine ecosystem state as well as defining better management and conservation options in order to slow down the system's degradation process (Carpentier, 2009). Scientific experts assembled were devoted in developing synthesized data focused on specific issues and actions to achieve a better comprehension of system health and pin down current threats while outlining the consequences related to identified challenges and gaps while providing an opportunity for the popularization of information and approaches developed within the context of the project. Critical needs that were identified and covered by the project to date include: (1) provide information on biology and ecology of aquatic living resources, (2) establish ecological links and functioning, (3) comprehension of fisheries dynamics, (4) synthesis and distribution of available data (5) fishers' perception of marine environment and their socio-economic context (6) enhance comprehension and facilitate implementation of regulation in and between states and (7) knowledge on ecosystem management and conservation.

In order to produce a comprehensive atlas, there is a need to provide a census of marine life. This means that it was necessary to identify the existing species, where they occur and what is their habitat. Information on environment (physical and hydrobiological features), living resources (fish and benthic organisms), fisheries and exploitations and existing regulations were collected for the first and second phases of the project were based on existing historical and newly collected data (Fig. 2). A summary of collected information are enumerated below. These along with data integration modeling techniques (habitat, food web and systematic conservation models) used in the atlas (Carpentier, 2009) can be found in the atlas and can be downloaded in this URL site : http://www.ifremer.fr/charm.

The success of scientific initiatives launched in the project since its conception is the increasing scientific recognition reflected by the on-going growth, in terms of collaborations and scientific productions, of the Charm Consortium. It provided an opportunity of bridging the gap between scientists, managers, stockholders, policy-makers, fishermen and the grand public, creating a social-learning institution among different sectors that are concerned with marine management. The atlas has become a significant reference material of knowledge on the eastern English Channel and its living resources.

Acknowledgements

CHARM, with a total project financement of 5 825 462 €, is a project selected within the scope of the INTERREG IVA France (Channel) – England cross-border Eurepean Cooperation Programme, co-financed by the European Regional Development Fund (ERDF). The authors would like to acknowledge the organizers for their invitation to the French-Japanese symposium organized by the Kinki University and IFREMER. The authors would also thank the rest of the Charm Consortium Network collaborators whose work contributions were cited in this paper.

Refrences

Carpentier A., Martin C., Vaz S. (Eds.) 2009, Atlas des habitats des Ressources Marines de la Manche Orientale. Boulogne-sur-Mer, IFREMER.

Carpentier A., S. Vaz, et al., 2005, Eastern Channel Habitat Atlas for Marine Resource Management (CHARM), Atlas des Habitats des Ressources Marines de la Manche Orientale,, IFREMER, pp. 225 pp.

Martin C., A. Carpentier, et al., 2009, The channel habitat atlas for marine resource management (CHARM): an aid for planning and decision-making in an area under strong antropogenic pressure. Aquat. Living Resour. 22, 499-508.

Vaz S., A. Carpentier, et al., 2007, Eastern English Channel fish assemblages measuring the structuring effect of habitats on distinct sub-communities. ICES J. Mar. Sci. 64.

Monitoring Mediterranean fish stocks and fisheries management measures

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The Agreement for the establishment of the General Fisheries Commission for the Mediterranean (GFCM), under the provisions of Article XIV of the FAO constitution, was approved by the FAO Conference in 1949 and entered into force in 1952. Amendments to this Agreement were approved in 1963, 1976 and 1997. The latter amendments were related to the change in name of GFCM previously "General Fisheries Council for the Mediterranean" and to new obligations for the Contracting Parties including their contributions to an autonomous budget for the functioning of the Commission. These new obligations came into force on 29 April 2004.

Convention area: Mediterranean, Black Sea and connecting waters. Consisting of 23 Member countries along with the European Union, the GFCM's objectives are to promote the development, conservation, rational management and best utilization of living marine resources, as well as the sustainable development of aquaculture in the Mediterranean, Black Sea and connecting waters. Membership is open to both Mediterranean coastal states and regional economic organizations as well as to United Nations member states whose vessels engage in fishing in Mediterranean waters.

Membership : Albania, Algeria, Bulgaria, Croatia, Cyprus, Egypt, European Community, France, Greece, Israel, Italy, Japan, Lebanon, Libya, Malta, Monaco, Morocco, Romania, Spain, Syria, Tunisia, Turkey, Yugoslavia.

Main functions: to keep under review the state of the resources, to formulate and recommend appropriate measures for the conservation and rational management; to keep under review economic and social aspects of the fishing industry, to encourage, recommend, coordinate and undertake research and development activities, including cooperative projects in the area of fisheries in the protection of living marine resources: to assemble, publish or disseminate information regarding exploitable living marine resources and fisheries and to promote programmes for marine and brackish water aquaculture and coastal fisheries enhancement.
The Commission is the principal organ and the main decision-making body. In addition to the Commission itself, the GFCM is composed of a number of subsidiary bodies: Committee on Aquaculture, Scientific Advisory committee and ad-hoc technical panels to advise the SAC in the review of the state of the resources and thus in the formulation of management measures for consideration by the Commission.

GFCM is composed of the following subsidiary bodies (Fig. 1):

- Committee on Aquaculture (CAQ): established in 1995.
- Scientific Advisory Committee (SAC): established in October 1997. The SAC includes four Sub-Committees on:
  - Stock Assessment (SCSA)
  - Economics and Social Sciences (SCESS)
  - Marine Environment and Ecosystems (SCMEE)
  - Statistics and Information (SCSI)
- Compliance Committee (COC) : established in January 2007
- Ad-hoc technical panels: to advise the SAC in the review of the state of resources and thus in the formulation of management measures for consideration by the Commission.

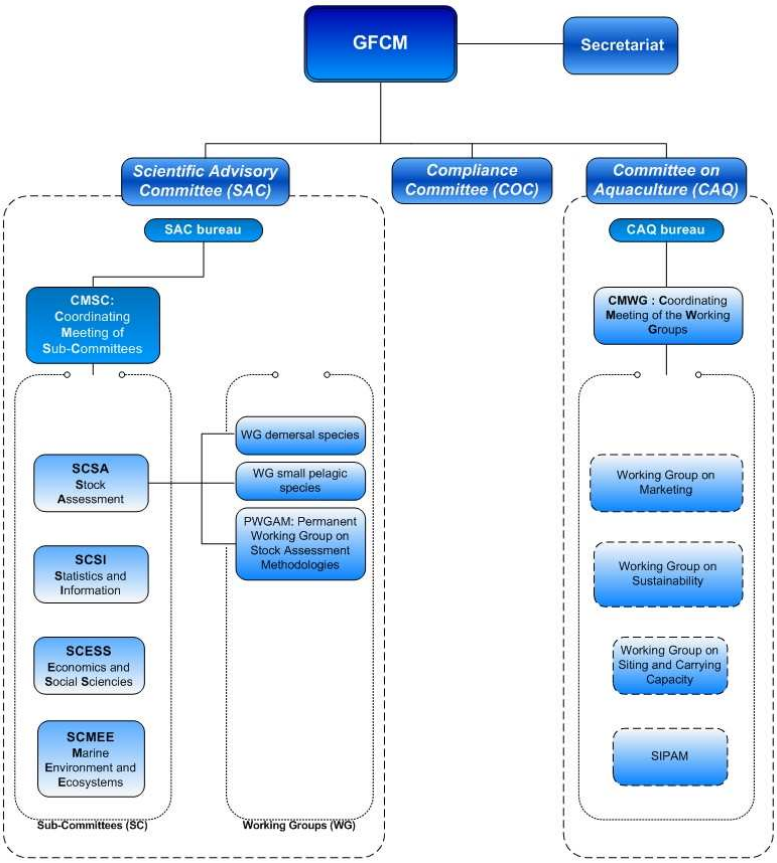

Figure 1: Flow chart of the the General Fisheries Commission for the Mediterranean (GFCM)

The Scientific Advisory Committee (SAC) provide independent advice on the technical and scientific bases for decisions concerning fisheries conservation and management, including biological, social and economic aspects, in particular: assess information provided by Members and relevant fisheries organizations or programmes on catches, fishing efforts, and other data relevant to the conservation and management of fisheries; formulate advice to the Commission on the conservation and management of fisheries; identify cooperative research programmes and coordinate their implementation; undertake such other functions or responsibilities as may be conferred by the Commission.

SAC operates through five subsidiary bodies:

- Coordination Meeting of the Sub-Committees (CMSC)
- Sub-Committee on Stock Assessment (SCSA)
- Sub-Committee on Marine Environment and Ecosystems (SCMEE)
- Sub-Committee on Statistics and Information (SCSI)
- Sub-Committee on Economic and Social Sciences (SCESS)

The Committee on Aquaculture (CAQ) monitor trends and promote the sustainable development and responsible management of marine and brackish water aquaculture in the region, and provide independent advice on the technical, socio-economic, legal and environmental bases for common standards, norms and guidelines and decisions for consideration by the Commission.

The Compliance Committee (CoC) review compliance with conservation and management measures adopted by the Commission and make such recommendations to the Commission as may be necessary to ensure their effectiveness; review the implementation of measures of monitoring, control, surveillance, and enforcement adopted by the Commission as may be necessary to ensure their effectiveness; define, develop and make recommendations to the Commission concerning the phased development and implementation of the GFCM Control and Inspection scheme; monitor, review and analyze information pertaining to the activities of Non-Contracting Parties and their vessels which undermine the objectives of the Agreement including, in particular, IUU fishing, and recommend actions to be taken by the Commission to discourage such activities; perform such other tasks as directed by the Commission.

The Commission normally holds its Regular Session on an annual basis and convenes special sessions, as appropriate, at the request or with the approval of the majority of the Members. It seeks to promote the conservation and rational management of living marine resources through, inter alia, drawing up binding measures related to the regulation of fishing methods, fishing gear and minimum landing sizes, together with the establishment of open and closed fishing seasons and areas. It also strives to implement a fishing effort control regime by Operational Units through the regulation of catch and fishing effort and their allocation among Members. Sessions of the Commission are attended by delegates, their alternates, experts and advisers. Each Member has the right to one vote except in the case of a Regional Economic Integration Organization (REIO) which is entitled to the number of votes equal to the number of its Member States which are also Members of the Commission. Competence and voting power over specific Session issues are indicated by REIOs prior to the Session; REIOs cannot exercise their votes when their Member States exercise theirs and vice versa.