International Workshop on
Remote-Sensing Applications to Fisheries

Marie-Hélène Forget, Dalhousie University, Canada; Michel A. Petit, Institut de Recherche pour le Développement, France; Antonio Gonzalez Ramos, Univ. de Las Palmas de Gran Canaria, Spain; Serge Andrefouet, IRD de Nouméa Ctr., New Caledonia;
Cécile Dupouy, IRD de Nouméa Ctr., New Caledonia; Aneesh Lotlikar, Indian National Ctr. for Ocean Information Services, India; John Hampton, Secretariat of the Pacific Community, New Caledonia

ABSTRACT

A workshop on fisheries was held in Noumea on November 21, 2008 to address remote-sensing applications to fisheries adapted to the particular needs and problems of Western and Central Pacific Island countries. During the workshop, presentations and discussions covered various topics related to remote sensing of coastal and open ocean waters and its applications to fisheries. Participants were introduced to remote sensing of ocean colour and its significance vis-à-vis the marine food web. Applications to fisheries included improvements of fisheries operations to increase efficiency of fishing effort, assessment of fish stocks health, growth and recruitment, and ecosystem dynamics. A project on the Societal Applications in Fisheries & Aquaculture using Remote Sensing Imagery (SAFARI) and a global Network for marine ecosystem management (ChloroGIN) were also presented. The particular issues arising in the use of remote sensing for fisheries in the tropical island regimes were reviewed and recommendations on the use of remote sensing in the context of fisheries were presented.

Remote sensing, fisheries, ecosystem-based management, ocean colour, chlorophyll concentration, sea surface temperature, altimetry

1. INTRODUCTION

For the majority of the communities living near the coastline, where about half of the world population resides, fish is an important source of protein and the fishery industry is a major source of revenues. However, world scale fisheries are facing a suite of problems which need to be addressed in order to protect this globally important resource. The population growth is highest at the margin of the continents, thus world overpopulation results in over exploitation of the resource of the oceans and the deterioration of coastal and open ocean environment. There are also concerns to maintain the marine biodiversity and the unknown impact of climate change on the marine ecosystems. Many initiatives using remotely sensed data to address some of the issues related to fisheries management have been taken place in the past decade, but no coordination of these activities was in place.

The Societal Applications in Fisheries and Aquaculture using Remotely-sensed Imagery (SAFARI) project, funded primarily by Canadian Space Agency, was created in 2007 to accelerate the assimilation of Earth Observation data in fisheries research and ecosystem-based fisheries management on a world scale and to coordinate the numerous efforts already deployed in the field. The SAFARI project is the leading project of the task AG-06-02 on Earth Observation data utilization in Fisheries and Aquaculture of the Group on Earth Observation (GEO).

The SAFARI project has brought together an international forum of leading experts to facilitate the application of rapidly-evolving satellite technology to fisheries management questions through collaboration and networking. It is currently editing a monograph on Remote Sensing Applications to Fisheries and Aquaculture, which will be published in 2009. More information on the SAFARI project can be found at the following website: www.geosafari.org.

In addition to the SAFARI project, the Chlorophyll Global Integrated Network (ChloroGIN) project was created in 2006 to facilitate the dissemination of ocean colour data and to promote validation of satellite images by increasing *in situ* measurements of chlorophyll concentration. ChloroGIN is the leading project of the Regional Network for Ecosystem subsection of GEO task EC-09-01 for Ecosystem Observation and Monitoring Network (GEO EcoNet).

The ChloroGIN project was inspired by the Antares network that provides satellite coverage over Latin America and collaboration between Antares members. There are currently three ChloroGIN nodes, namely Latin America, Africa and Asia. Ultimately, in *situ* chlorophyll measurements and other optical data would be made available to chloroGIN members within a node in addition to satellite images to facilitate ground truthing of remotely-sensed ocean-colour data. Satellite images from different sensors are available on the ChloroGIN website www.chlorogin.org.

In the current workshop, we had an overview of the physical and biological characteristics of the Western and Central Pacific as seen from space and the status of the regional fisheries will be presented along with some local initiatives on the use of remotely-sensed data to address some of the local problems in fisheries management. In a second session, examples of remote-sensing applications to fisheries managements in different regions of the globe were presented. A discussion on the relevance of these new approaches at the regional level followed.

2. WESTERN AND CENTRAL PACIFIC CONTEXT

2.1. Ocean color in the South Western Tropical Pacific

Cécile Dupouy[1,2]
1. Centre IRD de Nouméa, BP A5, 98848, Nouméa, New Caledonia;
2. LOBP, Université de la Méditerranée, 13007, Marseille cedex 09, France

Ocean color in the South Western Tropical Pacific (SWTP) ocean is used to initialize models aiming at determining the distribution of tuna forage. Upper layer ocean color, which is measured by the satellite sensors, is governed by its content of dissolved and particulate material. The main optical quantities are the algal pigments (measured as chlorophyll-a concentration), the particulate material (measured as Total Suspended Material, TSM) and the dissolved organic material (measured as yellow substance, CDOM). In oligotrophic marine environment such as the SWTP, the average chlorophyll a of the first 20 meters is the main parameter governing ocean colour. The SWTP region is considered as an N-limiting oligotrophic area characterized by permanent deep thermocline and nutricline. However, the analysis of SeaWiFS chlorophyll concentration in the area between 5°S-25°S and 150°E-170°W shows a strong seasonal chlorophyll cycle, with large blooms that has been attributed to nitrogen-fixing cyanobacteria as *Trichodesmium* (Dupouy et al., 1988, 1990, 1992, 2000, 2004; 2008; Moutin et al., 2005). An Empirical Orthogonal Function (EOF) analysis helped in decomposing the SeaWifs series of chlorophyll in two modes corresponding for mode 1 to the classical annual winter chlorophyll enrichment in response to the seasonal cooling and for mode 2 to summer enrichments related to diazotroph cyanobacteria localized in the archipelagos of Vanuatu and New Caledonia or Fiji. This last hypothesis is reinforced by our *in situ* observations during the DIAPALIS cruises and a ship of opportunity program that, even if *Trichodesmium* is present all year long in the region, its biomass peaks only during the warm season. The inter-annual variability of *Trichodesmium* summer blooms (high abundance in 1998 and 2003) may be related to a variation in macronutrients (most likely iron) inputs by dust winds or changes in the general circulation patterns. Determining the source and the fate of the winter and summer blooms would be useful to understand the phytoplankton dynamic in order to model tuna forage distribution in the South Western Tropical Pacific Ocean (Fig. 2.1).

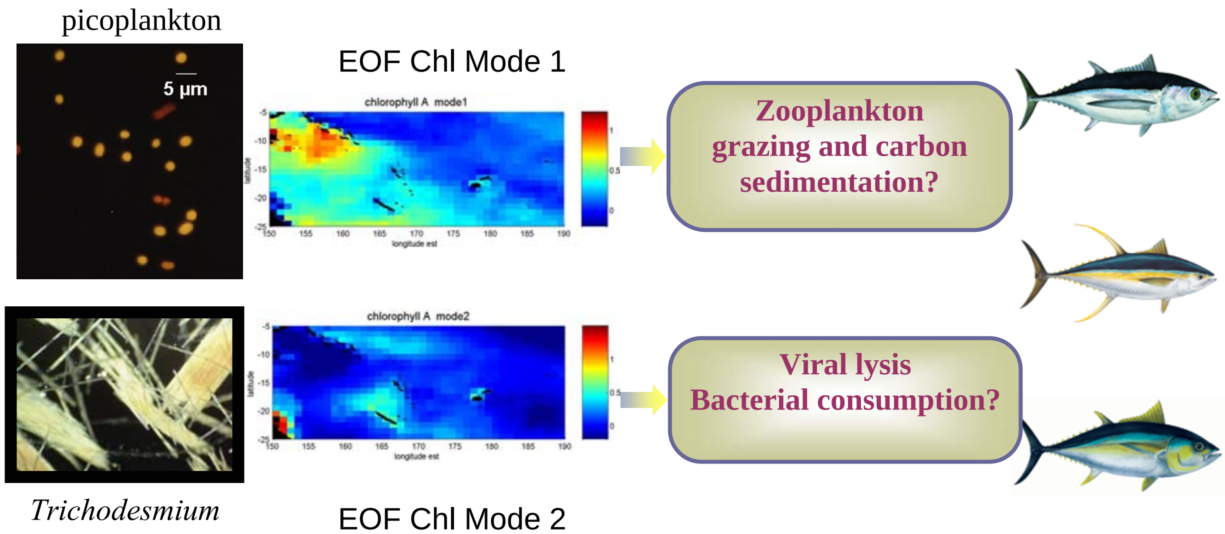

Figure 2.1: Possible fate of the winter and summer blooms as determined by Empirical Orthogonal Function (EOF) is critical to model tuna forage distribution in the South Western Tropical Pacific Ocean

2.2. Tuna Fisheries in the Western and Central Pacific: Modelling the Impact of Environmental Variation

John Hampton[1], Karine Briand[1], Patrick Lehodey[2]
1. SPC Oceanic Fisheries Programme, Nouméa
2. CLS, Direction Océanographie Spatiale, Toulouse

The tuna fishery represents a major part of the fishing industry in the Western and Central Pacific Ocean. Total catch has increased spectacularly over the history of the fishery and reaches now 2.4 million tonnes, representing over 60 % of the world tuna production. Most of catches are occuring by purse seine. Oceanographic factors (e.g. water temperatures, currents, productivity, etc) and climate dynamics have major influences on tuna population dynamics and fisheries at different spatio-temporal scales. The largest proportion of the tuna catch in the Pacific Ocean is made within the warm pool area, located in the western equatorial region. Climatic episodes such as El Niño Southern Oscillation (ENSO) influenced the eastern extension of the warm pool and strongly affect the distribution and abundance of tuna stocks. The purse seine fishery responds to the movements of tuna with eastwards displacement during El Nino and westwards contraction during La Nina. There is an obvious impact of this phenomenon for the Pacific Island Nations through variations in quantity of tuna catches in their Exclusive Economics Zones, and consequently on their economical revenue, according to the ENSO situation. Environment variability has also a profound impact on tuna stocks in terms of growth, mortality and recruitment. The Spatial Ecosystem And Population Dynamic Model (SEAPODYM) was developed at SPC to explore the underlying mechanisms by which environmental variability affect the pelagic ecosystem and tuna population (Figure 2.2, left panel). It uses both environmental data and a mid trophic sub-model (forage) to predict the spatial distributions of different tuna species based on the dynamic tuna sub-model structured by age classes (larvae, juveniles, young and adults). Fishing data such as catches and effort as well as length frequency are used as observations in the parameter optimization procedure to enhance the predictions of the model. In the recent context of climate change, SEAPODYM is a useful tool to integrate the ecosystem approach to regional fisheries management (Figure 2.2, right panel).

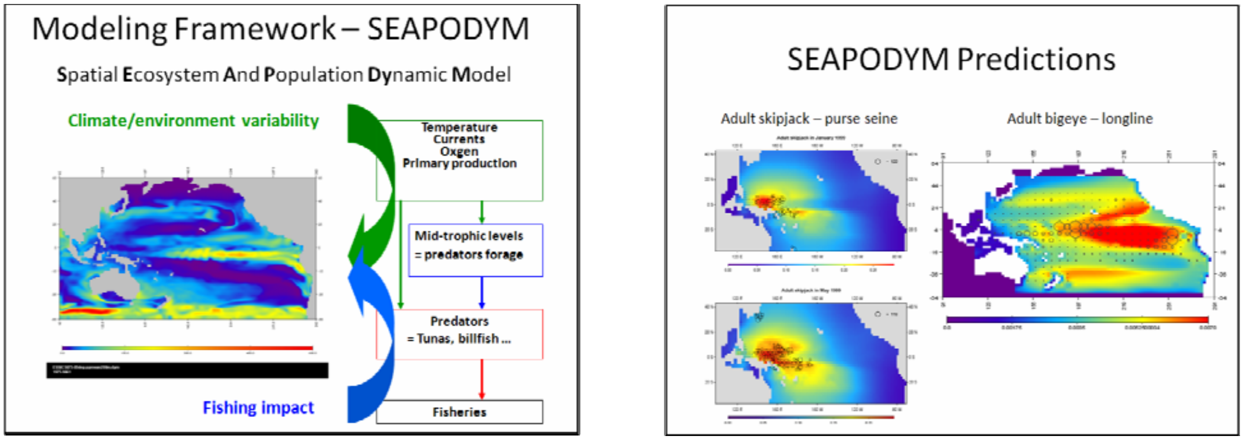

Figure 2.2 (left panel) inputs and output to fish distribution model-the Spatial Ecosystem And Population Dynamic Model (SEAPODYM) and (right panel) SEAPODYM prediction examples for the skipjack and bigeye and comparison with catch numbers.

2.3. High resolution habitat mapping for fishery assessment in coral reefs

Serge Andréfouet[1]

1. Centre IRD de Nouméa, BP A5, 98848, Nouméa, New Caledonia

To support fishery assessment in tropical coral reefs and lagoons, remote sensing is currently used to provide better estimates of critical habitat extents, stocks, forecasts for food sustainability, and management decisions overall. Habitat maps have been provided at different geographic scales (regional to local, i.e. the size of fishery grounds or few 100s of km2), and at different thematic resolution. The thematic resolution is itself a function of the geographic scale, the sensors used in input, the availability of ground truth data, and the targeted fishery.

The recent growing number of applications has enhanced our understanding of the potential of high resolution mapping using commercial sensors such as Quickbird and IKONOS, and Landsat as well for reef fishery assessment. There are now methods available to combine remote sensing, habitat mapping and field assessment to estimate stocks more rigorously and accurately than before, and achieve spatially explicit management schemes. Two practical examples are provided for New Caledonia (sea cucumber fisheries) and French Polynesia (giant clam fisheries). These examples represent well two local-scale applications and emphasize the interface between local population, scientists and managers.

3. REMOTE SENSING APPLICATIONS TO FISHERIES

3.1. Ecosystem variability and fisheries: assessment by remote sensing

Trevor Platt[1], Shubha Sathyendranath[2] and Marie-Hélène Forget[3]

1. Bedford Institute of Oceanography, Dartmouth, Canada,
2. Plymouth Marine Laboratory, Plymouth, United-Kingdom,
3. Dalhousie University, Halifax, Canada,

In the context of stewardship of the oceans, it has been globally recognised that management should have an ecosystem basis and that ecosystem integrity should not be compromised. To quantify the ecosystem integrity, a suite of ecosystem indicators has been developed as an aid to ecosystem-based management of the fisheries. The ecosystem indicators are objective metrics for the pelagic ecosystem that can be applied serially, in operational mode, to detect changes that may occur in response to environmental perturbations. Ideally, these indicators should have the following characteristics: (1) represent a well-understood and widely-accepted ecosystem property, (2) be quantifiable unambiguously in standard units, (3) be measurable rapidly at low incremental cost, (4) have a repeat frequency compatible with intrinsic time scale of properties under study, (5) be measurable at a variety of scales and (6) present the possibility to create long (multi-decadal) time series. Luckily, remotely-sensed indicators fulfil these requirements. In fact, they meet requirements of speed, resolution, repeat frequency and cost-effectiveness, the autotrophic biomass is an important ecosystem property and primary production fields can also be generated, sea-surface temperature and chlorophyll concentration are obtainable at same resolution (Figure 3.1), time series can be constructed and the seasonal dynamics can be quantified objectively, and finally, remote sensing allows interannual comparisons.

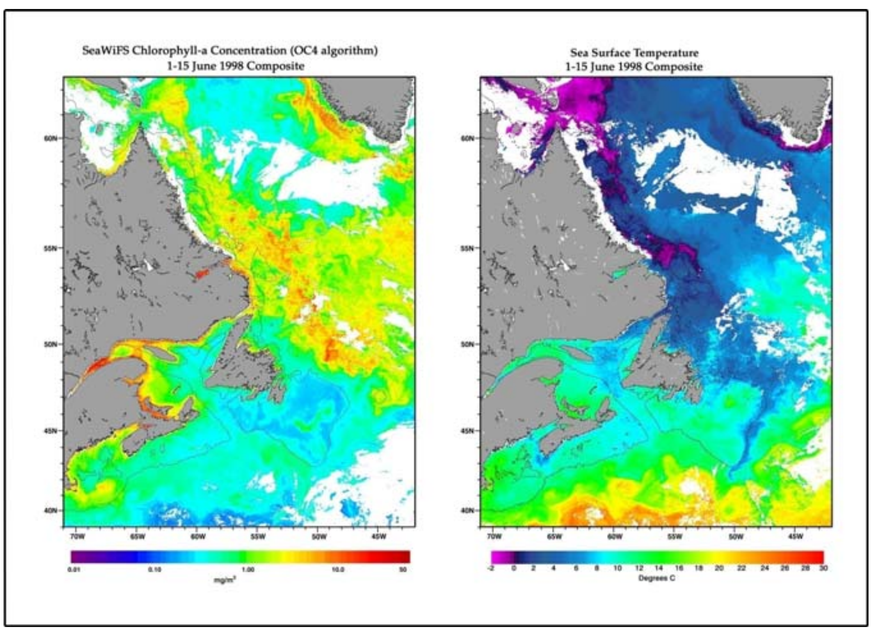

Figure 3.1: Remotely-sensed data of the Northwest Atlantic for the period of 1-15 June 1998 (left panel) SeaWiFS chlorophyll-a concentration and (right panel) AVHRR sea-surface temperature.

Ecological indicators available at an operational level are listed in Table 3.1 (Platt and Sathyendranath, 2008).

Table 3.1: Ecological indicators determined by remote sensing of ocean colour, their label and dimensions.

Indicator	Label	Dimensions
Initiation of spring bloom	b_i	[T]
Amplitude of spring bloom	b_a	[ML^{-3}]
Timing of spring maximum	b_t	[T]
Duration of spring bloom	b_d	[T]
Total production in spring bloom	b_p	[ML^{-2}]
Annual phytoplankton production	P_Y	[ML^{-2}]
Initial slope of light-saturation curve	α^B	[L^2]
Assimilation number	P^B_m	[T^{-1}]
Particulate organic carbon	C_T	[ML^{-3}]
Phytoplankton carbon	C_p	[ML^{-3}]
Carbon-to-chlorophyll ratio	χ	dimensionless
Phytoplankton growth rate	μ	[T^{-1}]
Generalised phytoplankton loss rate	L	[ML^{-3}T^{-1}]
Integrated phytoplankton loss	L_T	[ML^{-3}]
Spatial variance in biomass field	σ_B^2	[M^{2}L^{-6}]
Spatial variance in production field	σ_P^2	[M^{2}L^{-4}]
Phytoplankton functional types	NA	NA
Delineation of biogeochemical provinces	NA	NA

These indicators can be used in the context of ecosystem-based management of fisheries by relating them to fish recruitment, survival or distribution. For example, it has been shown that the Cushing match-mismatch hypothesis was applicable to the Northwest Atlantic haddock, where a relationship was found between the survival index of the larvae and the timing of the spring blooms, i.e. early blooms resulted in greater survival index (Platt et al., 2003). Such hypotheses could not have been tested without the advent of remote-sensing of ocean colourI it is the only tool that can collect data at the relevant scales of time and space.

In conclusion, remotely-sensed data are useful for construction of time series, but care in quality control is required. Time series provide a cost-effective basis for development of ecological indicators, when averaged at appropriate time and space scales. Even with only two remotely-sensed variables (chlorophyll and temperature), a rich set of ecological indicators can be derived. Models can be interrogated to estimate the magnitude of ecosystem indicators, which can then be validated by remote sensing measurements. The 10-year series in chlorophyll-a concentration has already yielded some interesting results, and we should strive to maintain continuity of reliable ocean-colour data stream.

3.2. Estimation of primary production from remotely-sensed data - application to fisheries management in the Caribbean

Marie-Hélène Forget[1], Trevor Platt[2], Shubha Sathyendranath[3] and Paul Fanning[4]

4. Dalhousie University, Halifax, Canada,
5. Bedford Institute of Oceanography, Dartmouth, Canada,
6. Plymouth Marine Laboratory, Plymouth, United-Kingdom,
7. Food & Agricultural Organisation, Sub-regional Office for the Caribbean, Bridgetown, Barbados

Primary production is at the basis of the food web, and precise and accurate estimates of this process are essential in the context of ecosystem based management of the fisheries when using mass-balanced models such as EcoPath with Ecosim. Chlorophyll concentration (a proxy for phytoplankton biomass) is an environmental variable that can be remotely sensed from ocean colour on a high temporal and spatial resolution. From these measurements made on synoptic fields, and using *in situ* measurements of chlorophyll-a profile and photosynthetic parameters, one can estimate primary production. Although good models exist for under water light field and photosynthetic response to irradiance, one important remaining problem in computation of primary production is the choice of the method of assignment of the *in situ* parameters on a pixel-by-pixel basis. Different approaches are proposed in the literature, namely the assignment on a regional basis, the use of relationships with environmental factors (temperature, chlorophyll, mixed-layer depth, etc.) or a new method called the Nearest Neighbour approach. In this study, we present the basis of the estimation of primary production, and assess the different approaches for assignment of the photosynthetic parameters.

An oceanographic survey was conducted in Caribbean waters in April and May 2006 to assess the marine ecosystem. According to analyses of pigment and absorption data, phytoplankton community was determined to be dominated by pico- and nano-phytoplankton, particularly at the deep chlorophyll maximum. From cluster analysis on remotely-sensed data, three dynamic provinces were defined for the region. A five-year time-series of sea-surface temperature and chlorophyll concentration provided information on the annual cycle of the bio-physical processes and the phytoplankton response to ENSO events. To implement the computation of primary production on a synoptic scale, parameters characterising the biomass profiles and photosynthesis-irradiance relationships were assigned using four different protocols: two regional approaches, a regression with surface chlorophyll and the Nearest-Neighbour Method, the last of which has the advantage of assigning parameters on a pixel-by-pixel basis. Monthly images of primary production were computed over an annual cycle using MODIS chlorophyll-a concentration and the Nearest-Neighbour Method emerged as the method of choice for parameter assignment (Figure 3.2). Finally, carbon-to-chlorophyll ratios were assessed to compute the production-to-carbon ratio for phytoplankton, a key input to Ecopath models.

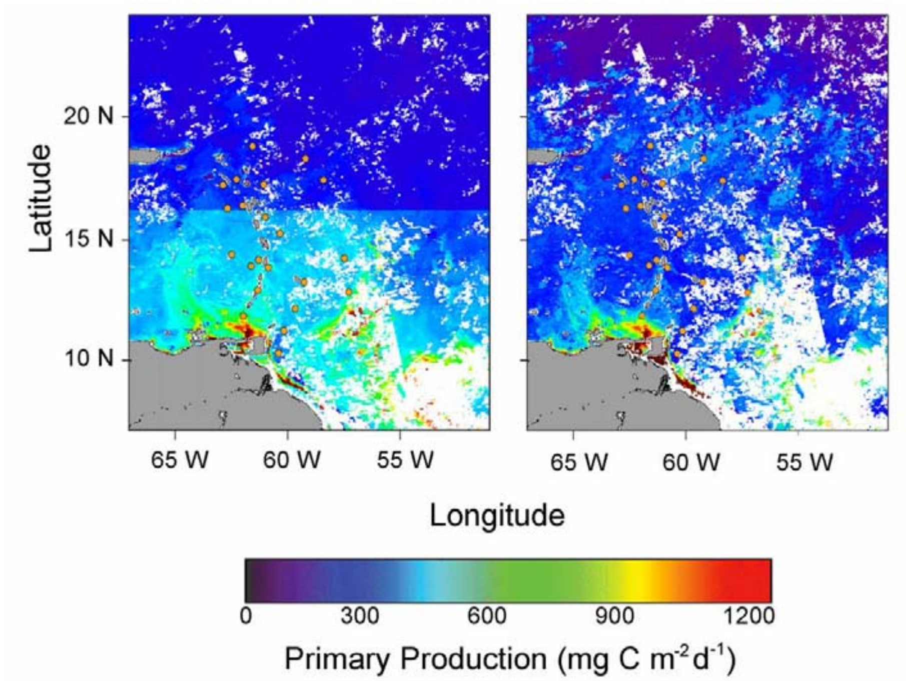

Figure 3.2: Water column primary production of the LAPE Caribbean waters in May 2006 estimated using parameter assignment (left panel) based on a regional approach and (right panel) using the Nearest Neighbour Method.

Future work should make advantages of the provided indices (dynamic provinces, chlorophyll annual cycle, chlorophyll and SST inter-annual variability, production-to-carbon ratio, etc.) and relate them to ecosystem characteristics such as fish species, recruitment and spawning to ensure a sustainable exploitation of this resource in the Caribbean waters. Management of fisheries could take into account the spatial and temporal variability of the phytoplankton biomass and use the boundaries of the dynamic provinces in future evaluation of fish quotas and fishing areas.

3.3. SEASAP Canarias: Artisanal pelagic Fisheries management assisted by satellite

Antonio Gonzalez Ramos[1], Josep Coca[1], Alex Redondo[1], Michel Petit[2]

1. SeaSNET Canarias, Dpto. de Biología (Universidad de Las Palmas de Gran Canaria). Facultad de Ciencias del Mar. Campus Universitario de Tafira, 35017 Las Palmas de GC, Canarias, España.
2. SeaSNET Montpellier. Institut de Recheche pour le Développement (IRD). Maison de la Télédétection, 500 Rue JF Breton, 34093 Montpellier CEDEX 05, Francia.

SEASNET (Survey of the Environment Assisted by Satellite) runs a pool of satellite receiving and remote sensing processing stations (L band). They are located in three centres of IRD-Reunion (Indian Ocean), IRD-Nouméa (SW Pacific), IRD-Cayenne (W Atlantic) and, in the framework of a strong cooperation, in the Polinesian Fishing Service (Central Pacific) and at the University of Las Palmas de Gran Canaria (NE Atlantic).

SEASNET collects, processes and achieves satellite-derived data sets coming from different radiometric sensors and radars platforms (*AVHRR/NOAA, MODIS/Terra-Aqua, SeAWiFS/OV-2, TOPEX, JASON, GEOSAT F1, ENVISAT and NSCAT*). Data sets are used to define the seasonal variations of the ecosystem observed in the NE Atlantic and W Mediterranean, in the SW Indian Ocean and in the SW Pacific. By addressing fishing activities and applied ocean research simultaneously, SEASNET contributes to the scope of a strong international concern: the rational and sustainable management of the marine living resources.

SEASNET also participates in international and national research projects on physical and biological changes observed in the oceans since 1985 as a result of global warming and CO_2 increment (Project SeAWiFS/Geoeye, GMES/ESA, GODAE/NASA, ARGOS/CLS). The main objective of these projects is to assess the impact of the bio-physical changes on the living resources dynamic.

3.4. Satellite-based operational fishery service of India

M. Nagaraja Kumar[1], Aneesh A. Lotliker[1], T. Srinivasa Kumar[1], Shailesh R. Nayak[2]

1. Indian National Centre for Ocean Information Services (INCOIS) “Ocean Valley”, P. B. No. 21, IDA Jeedimetla P.O., Hyderbad 500 055, India
2. Ministry of Earth Sciences (MoES) Mahasagar Bhawan, Block-12, C.G.O. Complex, Lodhi Road, New Delhi-110003

About 7 million people living along the Indian coastline, spanning more than 8100 km, are dependent on fishing for their livelihood. Locating and catching fish is, however, becoming more challenging as fish stocks dwindle and move further offshore, thus increasing the search time, cost and effort. A reliable and timely forecast on the potential zones of fish aggregation will benefit the fishing community to reduce the time and effort spent in searching the fishing grounds, thus improving their socio-economic status. The concerted efforts of scientists from Earth Sciences, space and fishery science in collaboration with the coastal states have resulted in a unique service of Potential Fishing Zone (PFZ) advisories at Indian National Centre for Ocean Information Services (INCOIS), India.

In the recent past, the PFZ advisories were initiated using the traditional techniques considering Sea Surface Temperature (SST) as a proxy. Later, the ocean colour products, such as chlorophyll concentration, were introduced in the identification of potential fishing grounds. Recently, the component of wind is also added along with chlorophyll and SST to provide more reliable short term PFZ advisories.

These multilingual PFZ advisories are being disseminated during the non-ban and non-monsoon period to the entire fishermen community situated all over the entire coast of India and Islands under 12 sectors. To improve the coverage, advances in Information and Communication Technology have been adapted. INCOIS has designed and installed Electronic Display Boards (EDB) at major fishing harbours which have made significant impact in the delivery chain. PFZ advisories were found more beneficial to artisanal, motorised and small mechanised sector fishermen engaged in pelagic fishing activities such as ring seining, gill netting etc., thereby reducing the searching time which in turn results in saving valuable fuel oil and human efforts. A validation experiment conducted along the west coast of India reported a reduction in search time of about 60-70% for oil sardine shoals in ring seining with 30-40% reduction reported for mackerel, anchovy, tuna and carangid shoals in ring seining operations.

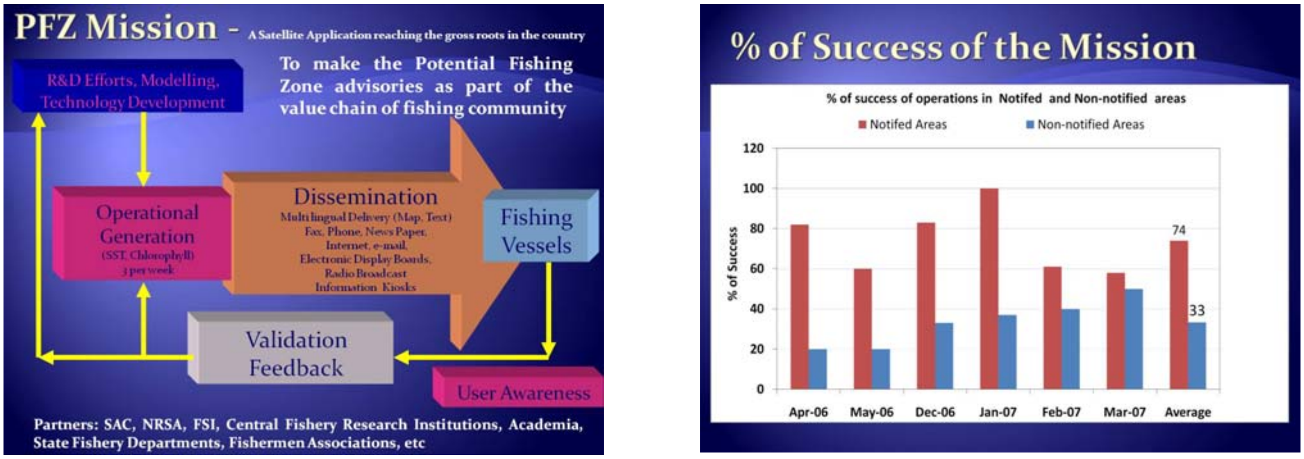

Figure 3.3 (left panel) Description of the Potential Fishing Zone (PFZ) mission and (right panel) validation of the PFZ mission.

3.5. Space technology and maritime intelligence/decision centre and environmental information system for fishery harvesting and management: a thought based on last decade projects conducted in Indian and Pacific oceans.

Michel Petit[1], Michel Slepoukha[1], Laurent Demagistri[1], Morgan Mangeas[2], Christina Corbane[1], Antonio G. Ramos[3]

1. IRD, unit ESPACE, Montpellier (France),
2. IRD, unit ESPACE, Nouméa (New-Caledonia)
3. Universitad Las Palmas Gran Canaria (Espagne)

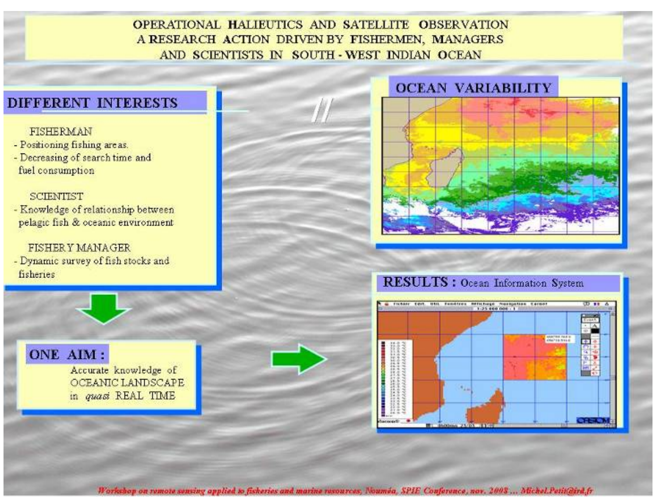

Figure 3.4: Schematic analysis of pelagic tropical fishing system

Half of the world's populations live less than 100 km from the sea and more than 300 million live on fishery activity. Toward 2020, the "seas" production must increase to 20 millions tons (FAO Source) which are beyond the aquaculture industry means. So, in spite of a bad image (recurrent macroscopic deficit, stocks apparent collapse, by catch, etc.), fishing catches must increase but in the framework of a sustainable management. In particular, for pelagic resource, spread out over large oceanic area, this management must be done at oceanic basin scale, including industrial and island local fishing companies. For these last communities that live and work with the ocean on a daily basis, understanding the landscape of the ocean is a necessity. For their livelihood, forecasts of ocean dynamics are just as vital as forecasts of the weather. Fishermen require regular information on the position of frontal areas, eddies and currents, their intensity their direction, their characteristics and evolution. They also need valuable information on fish distribution. For a sustainable development of local fishery, public managers need the same type of information to understand and support restrictive decision (quota, moratorium, fishing zone, protected area, etc.,) (Figure 3.4).

At the same time, this information is useful and necessary for scientists to model fish behaviour in its oceanic environment and to evaluate the probable resource distribution in space and time (figure 3.5). In IOC (Indian Ocean Commission) countries, several research and development programs have been developed over the last decade to elaborate an Environmental Information System (EIS) dedicated to pelagic fishing activity. This paper tries here to give a synopsis of these programs with the intent to come out with generic results and recommendations, *i.e.*:

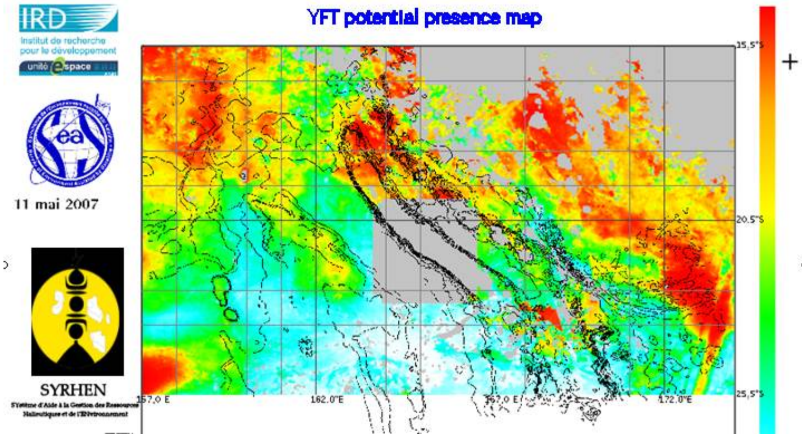

Figure 3.5: Modelled probability of Yellow fin tuna weekly distribution as function of environmental parameters. (source SYRHEN project).

(1) First, it is necessary to increase dramatically knowledge (i) on recruitment system and stock structure, (ii) on the relation between the resource and its environment;

(2) A perennial EIS, validated by scientist for fishermen but managed by public communities must be operational;

(3) A Near Real Time (NRT) data base update and flow must be operational for (i) catch and biological resources data and (ii) for oceanic environment parameters (obtained from remote sensing and modelling) at the same spatial and temporal scales;

(4) A participative approach and discussion between fishing professional, public manager and scientist must be intensified;

(5) Side fishing countries associations must be organized against illegal fishing and for negotiation with non side fishing countries.

4. RECOMMENDATIONS

A list of recommendations specific for the Western and Central Pacific has been elaborated during the workshop. Although these recommendations are specific to this region, they could be considered as the basis for global applications of remote-sensing data for sustainable fisheres managements. It was in fact discussed during the workshop that the SAFARI project should disseminate these recommendations at the internationnal level through task AG-06-02 of the Group on Earth Observation.

- Improvements of chlorophyll retrieval in coastal water surrounding the South Western Pacific islands by eliminating the contamination of the signal by optical components and more importantly from bottom reflection on shallow reefs and white sand bottom.

- Increase scientific collaboration between remote sensing and fisheries experts to identify the information that is needed and missing for regional fisheries management. The use of ecological indicators should be assessed for local ecosystem-based fisheries management.

- Increase remote sensing data availability and make it user-friendly for integration in fisheries models, such as local Tuna models. The creation of a new ChloroGIN centre for western and central Pacific should be considered and the addition of sea-surface temperature, cloud and other remotely-sensed products should be added to the portal.

- Refine the spatial resolution of the available data to adapt to regional scale fisheries research and management.

- Intensify collaboration of fishing professionals, managers and scientists.

- Remote sensing as a help to fisheries harvesting should be strictly use to reduce fishing efforts rather than increase fishing catches. There should be a strong management operation in place to control such operations with, for example, an access to remote-sensing products conditional to feedback from fishermen for management processes. Thus, remote sensing products should be managed by public managers, validated by scientists and available to local fishermen.

- There should be an increase in measurements of *in situ* data for validation of the satellite data in the South Western Pacific region.

ANNEXE A: AGENDA OF THE WORKSHOP

Workshop on Remote-Sensing Applications to Fisheries
Secretariat of the Pacific Community, Noumea, New Caledonia

Friday, November 21, 2008	
	Session 1: Western and Central Pacific Context (Chair: M.-H. Forget)
8:30am to 8:40am	Marie-Hélène Forget - Introductory Remarks
8:40am to 9:10am	Cécile Dupouy – Ocean color in the South Western Tropical Pacific
9:10am to 9:30am	John Hampton – Tuna Fisheries in the Western and Central Pacific: Modelling the Impact of Environmental Variation
9:30am to 10:00am	Serge Andréfouet - High resolution habitat mapping for fishery assessment in coral reefs
10:00am to 10:30am	Break
	Session 2: Remote sensing applications to fisheries (Chair: A. Ramos)
10:30am to 11:00am	Trevor Platt, Shubha Sathyendranath and Marie-Hélène Forget - Ecosystem variability and fisheries: assessment by remote sensing
11:00am to 11:30am	Marie-Hélène Forget, Trevor Platt, Shubha Sathyendranath and Paul Fanning – Estimation of primary production from remotely-sensed data - application to fisheries management in the Caribbean
11:30am to 12:00am	Antonio Gonzalez Ramos, Josep Coca, Alex Redondo, Michel Petit - SeASAP Canarias: Artisanal pelagic Fisheries management assisted by satellite
12:00pm to 1:30pm	Lunch
	Session 3: Remote sensing applications to fisheries, continued (Chair: M. Petit)
1:30pm to 2:00pm	Aneesh Lotlikar - Satellite-based operational fishery service of India
2:00pm to 2:30pm	Michel Petit, Michel Slepoukha, Laurent Demagistri, Antonio Gonzalez Ramos – Space technology and maritime intelligence/decision centre and environmental information system for fishery harvesting and management: a thought based on last decade projects mainly conducted in Indian and Pacific oceans.
2:30pm to 3:00pm	Break
	Session 4: General discussion
3:00pm to 5:00pm	Antonio Ramos, Moderator - Remote sensing and fisheries management
5:00 pm to 5:30 pm	Marie-Hélène Forget - workshop synthesis and recommendations

ANNEXE B: LIST OF PARTICIPANTS TO THE WORKSHOP

1. Marie-Helene Forget, Dalhousie University, Canada
2. Antonio G. Ramos, University of Las Palmos, Spain
3. Michel Petit, IRD Montpellier, France
4. Robert Frouin, Scripps Institution of Oceanography, UCSD, USA
5. Frederic Guillard, Government/DTSI, New Caledonia
6. Talia McCallum, MPA design, Halifax, Canada
7. Hiroshi Murakami, EORC, JAXA, Japan
8. Simon Hoyle, SPC, New Caledonia
9. Don Bromhead, OFP-SPC, New Caledonia
10. Peter Williams, SPC, New Caledonia
11. Nick Davis, SPC, New Caledonia
12. Medhy Palfray, SPC, New Caledonia
13. Upendra N. Singh, NASA Langley Ros Centre, USA
14. Morgan Mangeas, IRD, New Caledonia
15. Telmo Morato, SPC, Noumea, New Caledonia
16. Peter Fearns, Curtin University of Technology, Perth, Western Australia
17. Being Yeeting, Coastal Fisheries Program, CPS, Noumea, New Caledonia
18. Franck Magron, Coastal Fisheries Program, SPC, Noumea, New Caledonia
19. Isabelle Jollit, UR Coreus, IRD Noumea, New Caledonia
20. Nadia Chagnaud, IRD Noumea, New Caledonia
21. Aude Chenet, SPC, Noumea, New Caledonia
22. Pablo Chavance, Adecal, Zonico Program, New Caledonia
23. Stuart Phinn, University of Queensland, Brisbane, Australia
24. Chris Roelfseiya, University of Queensland, Brisbane, Australia
25. Cecile Dupouy, Camelia, IRD, Noumea, New Caledonia
26. John Hampton, Oceanic Fisheries Programme, SPC, Noumea, New Caledonia
27. Serge Andrefouet, IRD Noumea, New Caledonia
28. Aneesh Lotlikar, Indian National Ctr. for Ocean Information Services (INCOIS), India