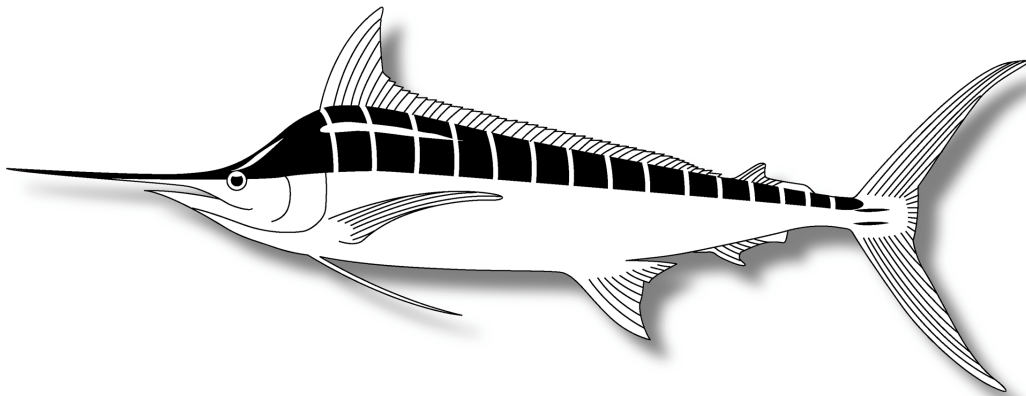


## BBRG-2



### Food web study in the tuna ecosystem of the Western and Central Pacific Ocean



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## 1. Background

More and more attention is given to the impact of fishing on ecosystems with the concern of the sustainability of the resource, biodiversity conservation and environment protection (Garcia & Newton, 1997; Gislason *et al.*, 2000). Conventional fisheries management focuses on a single species or stock and generally assumes that the productivity of that stock is a function only of its inherent population dynamics characteristics. However the inter-dependence of all ecosystem components is increasingly recognised and an ecosystem is considered as a new level of management to be taken into account according to the FAO Code of Conduct for Responsible Fishery (FAO, 1995) and the precautionary approach (FAO, 1996). Ecosystem-based management could be an important complement to single-species models that would not suffice for management of complex, exploited ecosystems especially in a long-term perspective (Christensen, 1996). Biomass values for single species will have to be constrained by the results of the ecosystem model (Pitcher, 1998).

The need for ecosystem-based management is widely recognised and accepted, but ecosystems models have not yet proved themselves as management tools (Mace, 2001). Moreover, there is still great uncertainty as to how to implement an effective ecosystem management in practice on these complex and poorly known systems (Beamish & Mahnken, 1999; WHAT, 2000, [www.what.org.uk](http://www.what.org.uk)). Several actions are recommended to begin to implement ecosystem-based management (The Reykjavik conference on Responsible Fisheries in the Marine Ecosystem, October 1-4, 2001, <http://www.refisheries2001.org/>; NMFS Ecosystem Principles Advisory Panel, 1999, <http://www.nmfs.noaa.gov/sfa/reports.html>). Among others are the identification and delineation of the ecosystems, the establishment of objectives taking into account conservation of biodiversity, protection of endangered species, precautionary approach, the establishment of sustainability indicators to assess the status of the system, the design and implementation of suitable management strategies and monitoring system.

To implement these recommendations, a good understanding of the influences that regulate species naturally in the ecosystem is required (Beamish & Mahnken, 1999). It is then of prime necessity to improve our knowledge on these complex and poorly understood aquatic ecosystems. This knowledge will allow to reduce the existing uncertainties concerning ecosystem management and hence to facilitate improved management strategies. Simultaneously with the immediate implementation of ecosystem-based management, it is hence necessary to undertake further research about food web models, diet composition and population dynamics of key species, by-catch and discards monitoring and critical habitats.

Understanding and modelling food webs are primordial in an ecosystem context as prey-predator relationships are a key factor in the ecosystem (Link, 1999). In fact, on a global scale, fish predation is roughly estimated to be 3 times the fishery production (Christensen, 1996).

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## **2. The GEF project**

In this context, the Oceanic Fisheries Programme (OFP) of SPC undertakes a GEF project (Global Environment Facility) from the United Nations Development Programme: the Strategic Action Programme for the International Waters of the Pacific Small Island Developing States. The stated objective for the Oceanic Fisheries Management component of the project is “to enable conservation and sustainable yield of ocean living resource” and one of its activities is to “improve scientific advice relating to regional tuna stocks, non-target species and the oceanic ecosystem available to support management decision-making”. In this activity, biological research on the ecosystem supporting the Western and Central Pacific Ocean (WCPO) tuna fishery is undertaken and will particularly focus on the non-target species with the assessment of the impacts of fishing on these species, through the application of biodynamic models.

The first subject addressed is the food web of the WCPO tuna ecosystem. A sampling strategy using national observer programmes will be implemented to collect samples of the components of the tuna ecosystem that are obtainable by fishing. The expected results are diet composition (from stomach content examination) and trophic level evaluation (from stable isotope analyses). Analyses of by-catch composition and assessment of their biomass will also be conducted. The whole data can be included in biodynamic models (Ecopath/Ecosim/Ecospace – Sepodym) to produce a model of the tuna ecosystem for which it will be possible to evaluate the impact of fishing and environmental changes.

## **3. Sampling strategy**

### **3.1. Area and Observer Programmes**

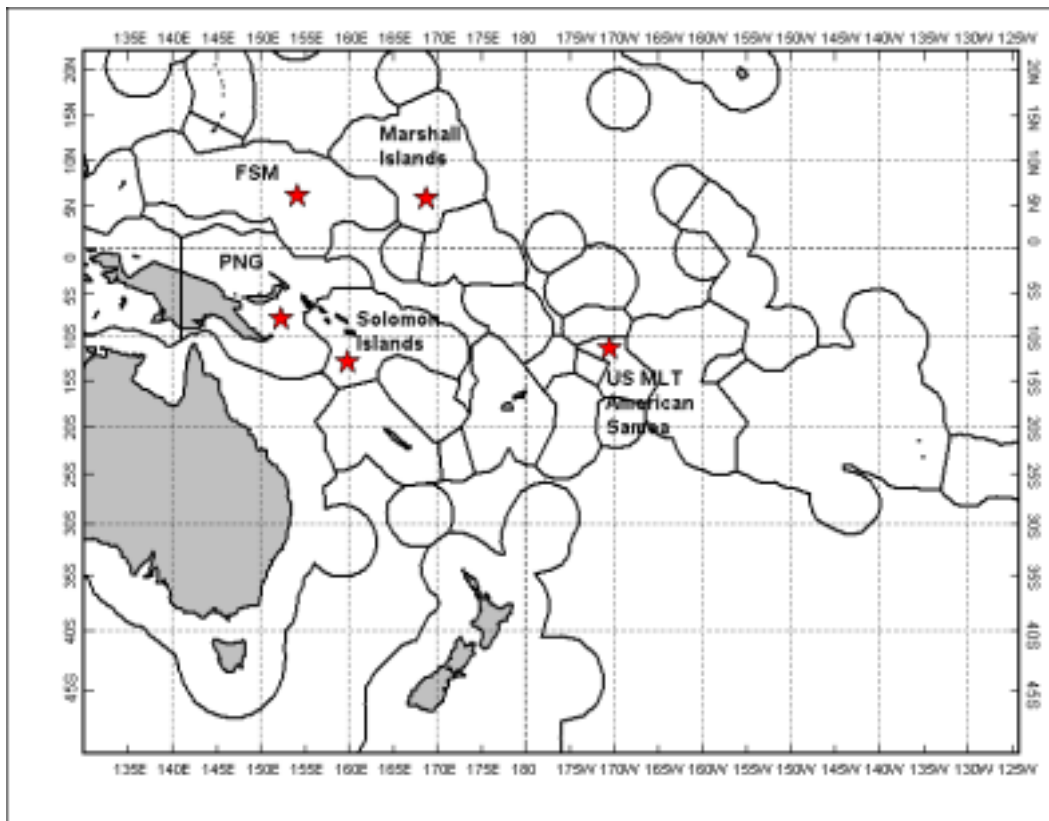
The food web study of the WCPO tuna ecosystem will be undertaken using the national observer programmes in their areas of influence from which the area of the study will depend. It is hoped that enough samples will be collected to allow a comparison between two ecosystems, one that would be in an area under the influence of high islands (Papua New Guinea, PNG) and the other in a more oceanic area without the influence of high islands (*e.g.* Marshall Islands). During the 3<sup>rd</sup> FFA Observer Coordinators Workshop held at the end of June 2001 in Pohnpei (FSM), the participants agreed in principle to contribute to the collection of samples. The observer programmes involved were: Federated States of Micronesia, Marshall Islands, PNG, Solomon Islands and the US Multilateral Treaty coordinated by the FFA (Figure 1).

### **3.2. Fleets**

According to the fishing activity and number of observers, both longline and purse seine fleets will be sampled, and pole-and-line fleet may be taken into consideration in the future sampling design.

### **3.3. Sampling**

Tuna and by-catches species will be sampled. The sampling will focus on top predators but other by-catch will also be taken into consideration according to sampling opportunities. Sampling will be undertaken during observer trips. Data will be obtained on reported by-catch quantities, and stomachs and muscles samples will be collected, labelled and stored (frozen).



**Figure 1. Observer programmes involved in the food web sampling of the WCPO tuna ecosystem.**

## **4. Analysis**

Among common methods for reconstructing food webs (Link, 1999), two are particularly relevant to this study: diet analysis and stable isotopes analysis.

### **4.1. Diet**

Diet analysis consists in determining what has been eaten by a predator by examining its stomach content. It will allow qualifying the linkages of a food web and also quantifying the magnitude and rate of energy and mass exchange. Stomach contents of both tuna and by-catch species will be analysed at SPC. Prey (including otoliths and squid beaks) will be identified to the lowest taxonomic level possible, numbered, measured and weighted for quantitative analysis.

Laboratory equipment was purchased for this aspect of the study (stereomicroscope, scales, etc.).

### **4.2. Stable isotope**

Stable isotope analysis is based on the conservation of elements during nutrition: isotopic distributions of a predator are highly related to isotopic distributions of its preys. Some elements are subject to fractionation between their light and heavy isotopes during the feeding process. This is the case of nitrogen ( $\delta^{15}\text{N} = ^{15}\text{N}/^{14}\text{N}$ ) and carbon ( $\delta^{13}\text{C} = ^{13}\text{C}/^{12}\text{C}$ ) that show a significant enrichment of their heavy isotopes ( $^{15}\text{N}$  and  $^{13}\text{C}$ ) between the preys and the predators. This enrichment in the body tissue as you

move up the food chain (increasing trophic level) will allow reconstructing trophic level position of the different components of the ecosystem: a top predator will have higher isotopic ratios than animals feeding on primary production. See, among others McConnaughey & McRoy, 1979; DeNiro & Epstein, 1981; Minagawa & Wada, 1984; Hesslein *et al.*, 1991; Cabana & Rasmussen, 1994. Isotope ratios are measured by mass spectrometry. Analyses will be done by another laboratory and several laboratories have been contacted.

### **4.3. Biodynamic multispecies models**

A number of tools have been developed to analyse multispecies interactions, but no consensus exists on using a single methodology (Walters *et al.*, 1997; Christensen & Pauly, 1997). Different approaches have been developed:

Among them, the multispecies virtual population analysis (MSVPA) is a direct extension of the single species VPA. This multispecies age-structured population models utilises extensive time series of catch-at-age data which is not available in the case of the WCPO tuna ecosystem (Magnússon, 1995).

Hence, considerable interest has focused in the use of mass-balance models, another approach relatively simple and less demanding. One of these models, Ecopath with Ecosim model (EwE, [www.ecopath.org](http://www.ecopath.org)), is now widely used as a tool for analysis of exploited aquatic ecosystems (Christensen & Pauly, 1993; Walters *et al.*, 1997; Pauly *et al.*, 2000; Christensen & Walters, 2000). Ecopath is an ecosystem trophic mass-balance analysis that can be used to examine the relative importance of the groups and calculate the flows required to support predation demands. Ecosim is a dynamic modelling capability that provides a tool to explore hypothesised changes in production by means of dynamic simulations. The model requires the following information:

- identification of the components of the food web (including functional groups and trophic ontogeny),
- predator-prey links (proportions of preys in the diet),
- predator consumption rates (Q) or energy requirements,
- biomass estimates (B),
- production rates estimates (P),
- removals from the system (landings, discards, immigration, emigration).

In the Pacific Ocean, Ecopath with Ecosim model was applied to tuna ecosystems in the eastern tropical Pacific Ocean to explore the effects of El-Niño-Southern-Oscillation (ENSO) and greenhouse warming (Olson *et al.*, 2001), and in the central north Pacific to evaluate the relative importance or keystone predator role for each of a suite of top predators of this food web (Kitchell *et al.*, 1999). In our study of the ecosystem(s) of the western and central Pacific we expect to explore the impact of environmental changes (ENSO) as well as fishery exploitation variations.

Data gathered and obtained from this food web study will also be included in the SEPODYM model developed at the OFP-SPC (Lehodey *et al.*, 1998; Bertignac *et al.*, 1998). The model is a 2D coupled physical-biological interaction model at the scale of ocean basin, combining a forage (prey) production model with an age structured population model of targeted (tuna predator) species. See P. Lehodey paper, SCTB14 Working Paper SKJ-2, and SEPODYM web page: [http://www.spc.int/OceanFish/Html/TEB/Env/sepodym\\_intro.htm](http://www.spc.int/OceanFish/Html/TEB/Env/sepodym_intro.htm).

## 5. First data

### 5.1. Samples collected

Since the beginning of 2001, samples were collected during three trips at sea. Two trips were conducted on a New Caledonian longline in New Caledonia EEZ (January-February and March), and the third trip was done onboard a Korean purse seiner in the Marshall Islands EEZ (May). Observer data were reported for each trip, *i.e.* species caught (target and by-catch, including discards), quantities, measurements, fate. According to the fate of the fish and to the time available, some fish were sampled (stomach and muscle) for further analysis. Twenty-four species were sampled (Table 1) and 375 stomachs were examined (only the non-empty ones were collected for diet analysis) as well as 273 muscle samples for isotope analysis. Three species of tuna were sampled (yellowfin, bigeye, skipjack), five billfish (swordfish, black, blue and striped marlin, sailfish), three sharks (shortfin mako, blue, silky) and 13 other fish (Table 1).

Species	Longline		Purse seine		Total	
	Stomach sample	Muscle sample	Stomach sample	Muscle sample	Stomach sample	Muscle sample
Yellowfin	39	32	19	14	58	46
Bigeye	41	23	8	8	49	31
Skipjack	2	2	182	122	184	124
Swordfish	4	4			4	4
Black marlin	1				1	
Striped marlin	1				1	
Blue marlin			5	5	5	5
Indo-Pacific sailfish	1		1	1	2	1
Dolphinfish	13	8			13	8
Opah	9	7			9	7
Escolar	3	3			3	3
Black mackerel	2	2			2	2
Wahoo	4	4	1	1	5	5
Snake mackerel	1	1			1	1
Longnouted lancetfish	11	10			11	10
Dealfish	1	1			1	1
Great barracuda	2	2			2	2
Triggerfish			3	3	3	3
Rainbow runner			3	3	3	3
Pelagic sting ray	1	1			1	1
Manta ray			3	3	3	3
Shortfinned mako shark	2	1			2	1
Blue shark	11	11			11	11
Silky shark			1	1	1	1
Total	149	112	226	161	375	273

**Table 1. Number of stomach and muscle samples collected from species on two longline trips and one purse seine trip in 2001.**

## **5.2. Sampling protocols**

According to the fishing procedures observed onboard, a sampling protocol for stomach and muscle collection has been established for longline and purse seine vessels. This protocol is presented in a pamphlet that will be distributed to the observers from the national programmes. It explains how to collect the samples and which data are to be recorded. The draft is under revision, publication and distribution are expected before the end of this year.

## **5.3. Shipping difficulties**

An important problem that slows down the implementation of the sampling strategy is the shipping of samples. Stomach and muscle samples are frozen onboard during the observer trip. When returned to a harbour, the samples will be stored in freezers that belong to the different fishery services involved in the sampling or that will be provided to them. The main problem is to ship these frozen samples from the different countries to New Caledonia. Considering the large distances to cover and the lack of direct flights most of the shipping companies do not want to transport these items because they can't assure the arrival of the samples in good condition, *i.e.* still frozen. At the moment the samples collected in May during the purse seine trip in the Marshall Islands EEZ are still stored in a freezer in Pohnpei (FSM). Different options are under consideration to implement a routine procedure to ship the samples. As soon as this problem is resolved, the sampling strategy will be implemented and the observers will start to collect samples.

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