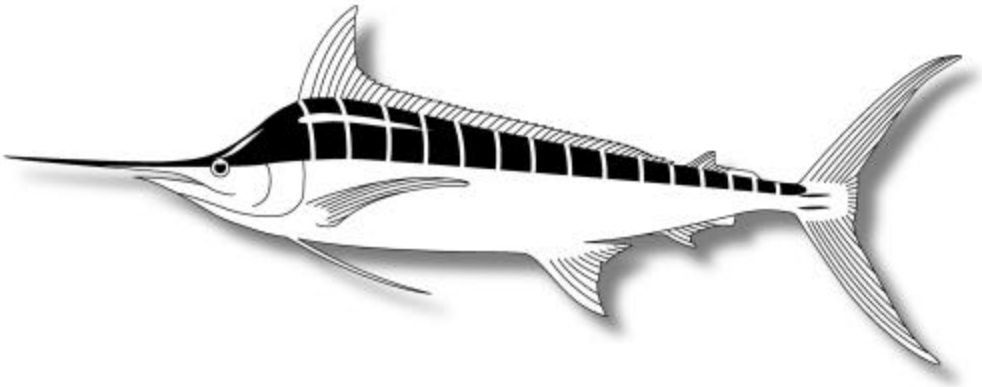
SCTB15 Working Paper

BBRG–7

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



Valerie Allain

Oceanic Fisheries Programme

Secretariat of the Pacific Community

Noumea, New Caledonia

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

Valérie ALLAIN[1]

1 Introduction

It is now widely accepted that ecosystem-based management is an important complement to single-species models, which are not sufficient to manage a complex, exploited ecosystem especially in the long-term. The need for ecosystem-based management is recognized, but ecosystem models have not so far had the opportunity to prove themselves as management tools. Moreover, there is still great uncertainty as to how to implement an effective ecosystem management. Several courses of actions are proposed, but it is also necessary to undertake further research about the complex and poorly understood aquatic ecosystems such as WCPO simultaneously.

As prey-predator relationships are a key factor in the ecosystem, understanding and modeling food webs are primordial in an ecosystem context. The study of the food web is a priority to understand the warm pool pelagic ecosystem. This study includes the implementation of a sampling programme to collect stomachs and tissue samples, the examination of the fish stomach contents, to establish the diet of different components of the ecosystem, as well as isotopic analyses of muscle and liver samples, to determine the trophic level of the fish. This information introduced into biodynamic models should allow better modeling of the tuna ecosystem, and assess the fishing impact on the ecosystem and tuna stocks.

2 Sampling

All the necessary equipment for sampling was prepared by June 2002 and a sampling request outlined to the Fourth meeting of observer co-ordinators in July 2002. Sampling is expected to be undertaken in the countries where observer programmes exist (FSM, PNG, Marshall Island, Solomon Island, New Caledonia, USMLT) or are proposed (French Polynesia). Sampling kits including a pamphlet with the sampling protocol (in English or in French), an esky with dehydrated gelice, a knife, plastic bags, waterproof labels and forms (in English or in French) will be provided to the observers. The frozen samples will be sent to SPC (New Caledonia) for analysis. Sampling will be undertaken onboard longline and purse seine vessels and will focus on top predators but other by-catch will also be taken into consideration depending on sampling opportunities.

Four sampling trips were undertaken in 2001: 3 longline trips in New Caledonia EEZ and one purse seine trip in FSM-Marshall Islands EEZ. Two longline trips have been undertaken in June-July 2002, one in New Caledonia EEZ (New Caledonian observer), and one in FSM EEZ (Micronesian observer).

[1] valeriea@spc.int

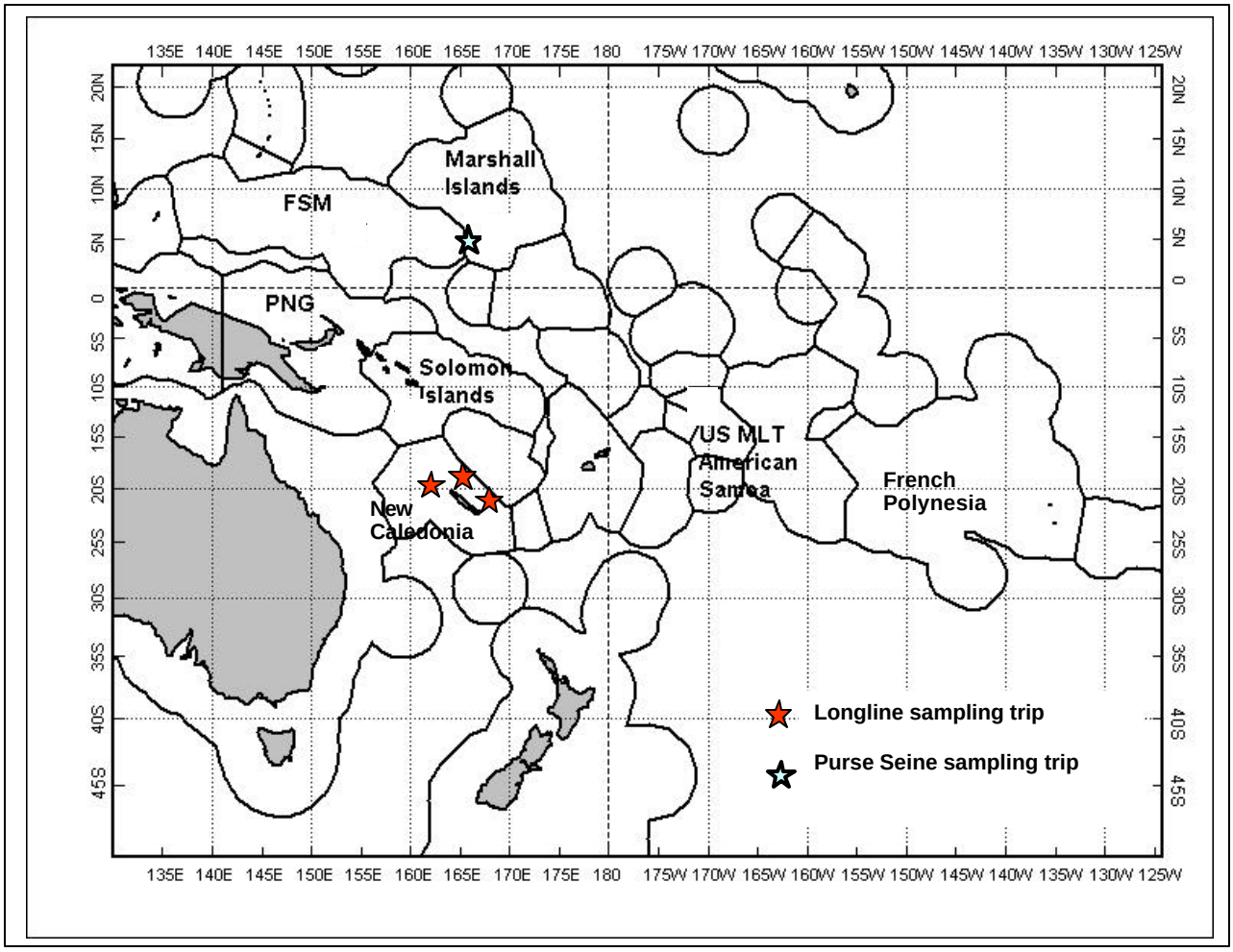


Figure 1. Observer programmes involved in the food web sampling of the WCPO tuna ecosystem and sampling trips completed.

3 Diet analysis

Diet analysis will establish the linkages within the food web and also quantify the magnitude and rate of energy and mass exchange.

During the 4 sampling trips, 391 stomachs were examined, of these 46% were empty. It appears that the percentage of empty stomachs is higher for fish caught with the purse seine (211 stomachs examined, 77% empty stomachs) rather than for fish caught on the longline (180 stomachs examined, 10% of empty stomachs). This is easily explained by the fact that fish caught on the longline are always in an active feeding phase, while schooling fish caught with the purse seine are not necessarily in a feeding phase.

	Longline		Purse seine		Total	
Species	Stomachs examined	% of empty stomachs	Stomachs examined	% of empty stomachs	Stomachs examined	% of empty stomachs
Yellowfin tuna YFT	42	2%	19	79%	61	26%
Bigeye tuna BET	43	2%	8	87%	51	16%
Skipjack tuna SKJ	2	0%	167	77%	169	76%
Swordfish SWO	4	25%			4	25%
Black marlin BLM	1	0%			1	0%
Striped marlin MLS	1	0%			1	0%
Blue marlin BLZ	1	0%	5	80%	6	67%
Indo-Pacific sailfish SFA	1	0%	1	100%	2	50%
Dolphinfish DOL	18	0%			18	0%
Opah LAG	9	0%			9	0%
Escolar LEC	3	33%			3	33%
Black mackerel F38	2	0%			2	0%
Wahoo WAH	6	0%	1	100%	7	14%
Snake mackerel GES	1	0%			1	0%
Longnouted lancetfish ALX	24	21%			24	21%
Dealfish DSM	1	0%			1	0%
Barracuda BAR	2	0%			2	0%
Great barracuda GBA	2	0%			2	0%
Triggerfish TRI			3	100%	3	100%
Rainbow runner			3	67%	3	67%
Pelagic sting ray PLS	1	0%			1	0%
Manta ray			3	0%	3	0%
Shortfinned mako shark SMA	3	33%			3	33%
Hammerhead shark SPM	1	0%			1	0%
Blue shark BLS	11	64%			11	64%
Silky shark FAL			1	100%	1	100%
Unidentified shark	1	100%			1	100%
Total	180	10%	211	77%	391	46%

***Alepisaurus ferox* (lancetfish):** 24 specimens (16.4-150 cm), caught on a longline, were examined and among them 5 were empty. *Alepisaurus* stomach content is characterized by the fact that prey items are nearly always intact, so it is probable that they are digested in the intestine rather than in the stomach. This allows for a higher identification rate of the preys compared to other fish where preys are highly digested and their identification difficult. The most frequent preys were molluscs (in 95% of the stomachs), fish (84%) and crustacea (63%); where present they accounted for 55.3% of the total prey weight for the fish, 48.2% for the mollusc and 7.4% for the crustacea. The most frequent items found in the stomachs were Heteropoda molluscs (68%), Phronimidae crustaceans, *Alepisaurus* juveniles, Octopodidae (37%) and Onychoteuthis squid (31%). This species preys on a wide variety of fish: from pelagic juveniles of coral reef fish (Balistidae, Acanthuridae, Monacanthidae), to epipelagic fish (Alepisauridae, Gempylidae, Bramidae), and meso - bathypelagic fish (Sternoptychidae, Chiasmodontidae, Anoplogasteridae).

***Coryphaena hippurus* (dolphinfish):** 18 specimens (100-126 cm), caught on a longline, were examined, none were empty. In general digestion process was

advanced and did not allow the identification of most of the preys found. Preys were exclusively fish (present in 100% of the stomachs), except in 2 specimens (11%) where molluscs were found, respective percentages of fish and mollusc in weight were 73.4% and 26.6% for one fish, and 93.7% and 6.3% for the second fish. The most frequent identified items was Tetraodontidae fish (55%) easily recognized even when almost digested by their jaws modified to form a beak. Preys caught by this species are almost exclusively epipelagic such as Exocoetidae, Molidae, pelagic juveniles of Diodontidae, *Alepisaurus*.

***Lampris guttatus* (opah):** 9 specimens (93-117 cm), caught on a longline, were examined, none were empty. In general digestion process was advanced and did not allow the identification of many of the preys found. Fish were observed in 66% of the stomachs, molluscs in 55% and crustacea in 22%. When present in the stomach, fish represented in weight 70.3%, mollusc 41.7% and crustacea 11.5%. A lot of cephalopod beaks (up to 26) not taken into account in the weight were observed in 8 of the 9 fish examined. The most frequent preys were Sternoptychidae (44%), Myctophidae and Enoploteuthidae squid (33%). Most of the preys identified are mesopelagic such as Sternoptychidae, Myctophidae, Chiasmodontidae.

***Thunnus albacares* (yellowfin):** 61 fish were examined (16 empty), 19 were caught with the purse seine (15 empty; 49-158 cm) and 42 with the longline (1 empty; 110-149 cm). Prey fish were observed in 91% of the stomachs, crustacea in 62% and molluscs in 60%. When present in the stomachs, they represented respectively in weight 78.7%, 9.2% and 26.3%. The most frequent items are small crustacea: Phronimidae 40%, megalopa stages of crustacea 20%, shimps 17%, Heteropoda mollusc are found with a frequency of 31%, and bigger preys are also frequent: Alepisaurus 22%, Scombridae 15%, Sternoptichidae 15% and squids 44%. YFT consumes a wide variety of preys, from small pelagic crustacea to pelagic, meso and bathy pelagic fish (including juveniles of coral reef fish) and squids.

***Thunnus obesus* (bigeye):** 51 fish were examined (8 empty), 8 from a purse seine (7 empty; 54-92 cm) and 43 from a longline (1 empty; 84-125 cm). Fish were present in 95% of the stomachs, mollusc in 74% and crustacea in 32%. When observed, fish represented a weight of 72.3%, mollusc 38.6% and crustacea 5.6%. The most frequent items were Myctophidae 67%, Alepisaurus 51%, Sternoptychidae 39% and shrimps 23%. Few pelagic species are found, bigeye preys mostly on meso or bathypelagic preys.

***Katsuwonus pelamis* (skipjack):** 167 fish, caught with a purse seine, were examined (41-79 cm; 128 empty). All the preys were highly digested and very few items could be identified, but similar items were recognized in different stomachs. All the stomachs contained fish, and 23% had some molluscs. When present, fish represented 95% of the weight and mollusc 21%. Two fish items are found regularly, they could not be identified, but one found in 87% of the stomachs is a small pelagic fish (5 cm max), probably an Engraulidae, the other one found in 23% of the stomachs is a bigger fish (10-12 cm) and could be juveniles of Scombridae. Despite the poor quality of data collected, it seems that this species only consumes pelagic preys.

Diets of the species examined reflect their depth range and confirm the fact that these pelagic predators are very opportunistic in their choice of preys. The small

amount of fish examined at this moment does not allow to give accurate data on predators diet. With the implementation of the sampling programmes and the gathering of more samples from the whole of the WCPO, the data quality will be improved. It is expected to compare the diets of fish caught adjacent and remote from landmasses, and the diets of fish caught around FADs and in free schools.

4 Isotope analysis

Stable isotope analysis is based on the conservation of elements during nutrition. The enrichment in heavy isotopes (^{15}N and ^{13}C) in the body tissue as you move up the food chain (increasing trophic level) will allow us to reconstruct the trophic level position of the different components of the ecosystem: a top predator will have higher isotopic ratios than animals feeding on primary production.

During the four trips done in 2001, 294 muscle samples were collected from 3 species of tuna (skipjack, yellowfin, and bigeye) and 20 by-catch species (billfish, shark, ray and others) for isotope analysis of nitrogen ($d^{15}N=^{15}N/^{14}N$) and carbon ($d^{13}C=^{13}C/^{12}C$).

In future sampling collection the liver should also be sampled to complete muscle analysis. While muscle isotope analyses determines the trophic level of the fish, the sampling of liver will allow conducting comparative studies on the isotopic composition of this rapid turn-over tissue with muscle isotopic composition that is a slow turn-over tissue. This comparison should allow us to determine if the different tissues from the fish are in isotopic equilibrium ie the fish did not change its food habits for a long time. If there is no equilibrium a diet shift could be inferred that could be related to the movement of the fish from one area to another. Zooplankton and Particulate Organic Matter (POM) samples will be collected to measure their isotope content. An agreement was found with Brian Popp who is in charge of the Stable Isotope Biogeochemical Laboratory at the University of Hawaii to conduct isotope mass spectrometer analysis.

5 Biodynamic model

We will include data of diet and isotope analysis into the biodynamic modeling tool *Ecopath with Ecosim (EwE)* to represent the trophic flows between the ecosystem components. *Ecopath* provides a framework for the construction of mass-balance models of ecosystems based on estimates of how abundant the resources are (biomasses), the productivity or mortality rates of the resources, how they interact (diet compositions and food consumption rates), and how efficiently the resources are utilized in the ecosystem. Given the description of the ecosystem in *Ecopath* , *Ecosim* provides a tool to explore hypothesized changes in production by means of dynamic simulations. *Ecopath* will help us translate the diet and stable-isotope data into estimates of trophic level for the system components. This will allow us to do a better job of defining the trophic structure of the systems.

A first simple model has been undertaken but several problems were noted with the estimation of biomass, production and consumption. As the problems are solved, the complexity of the model will be increased.

6 PFRP project

Contacts were established with scientists from the Pacific Ocean to collaborate on a wide study of the "Trophic structure and tuna movements in the pelagic ecosystem of the equatorial Pacific".

Recent modeling (Lehodey, 2001) suggests that tuna productivity in the western and central Pacific Ocean is tied to upwelling along the equator in the central and eastern Pacific. The study proposed tests this hypothesis by combining diet analysis, stable isotopic compositions, food-web modeling, and stable isotope markers to trace tuna movements and trophic-level variation in the equatorial Pacific (western, central and eastern). The hypothesis predicts that tunas that reside near equatorial upwelling fronts feed at relatively low trophic levels. Opposite trends are expected in equatorial regions with little upwelling, such as the warm pool of the western Pacific, where tunas are expected to feed at higher trophic levels and move extensively, searching for less-abundant prey. Results of this study should help define ecosystem linkages leading to tuna production and the effect of climate variability on the systems. This information is important for both fisheries production and ecosystem modeling of the equatorial Pacific Ocean.

Collaborators involved in this study are Robert Olson (IATTC, La Jolla, USA), Felipe Galvan (CICIMAR, La Paz, Mexico), Brian Popp (University of Hawaii, Honolulu, Hawaii) and Brian Fry (Institute of Pacific Islands Forestry, Honolulu, Hawaii). The project was approved for funding by PFRP (Pelagic Fisheries Research Program of the University of Hawaii) in 2002, and funding should start in early 2003 for three years. This strong collaboration should allow an improved understanding of the ecosystem of the equatorial Pacific Ocean.