SCIENTIFIC COMMITTEE
FIFTH REGULAR SESSION

10-21 August 2009
Port Vila, Vanuatu

Progress in the study of the pelagic ecosystem trophic dynamics

WCPFC-SC5-2009/EB- IP-5

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Introduction

Within the frame of the two consecutive GEF-funded projects SAP 2000-2005 (Strategic Action Programme of the Pacific Small Island Developing States) and OFM 2005-2010 (Pacific Islands Oceanic Fisheries Management Project), the SPC Oceanic Fisheries Programme developed a pelagic ecosystem trophic dynamic study to answer one of the objectives of the GEF projects: "*to improve understanding of the transboundary oceanic fish resources and related features of the western and central Pacific warm pool large marine ecosystem*". The long term objective is to develop ecosystem approaches of fisheries management by building ecosystem models to assess fishing and environmental impacts on the whole ecosystem and evaluate management options.

The structure of the ecosystem is based on prey-predator relationships that are the most important interactions between species. Determining trophic interactions between species by examining stomach contents is the primordial step towards a better understanding and modeling of the ecosystem dynamic.

In this brief information paper are presented the progress in sample examination, issues about data analysis and some results on trophic dynamic and ecosystem modelling.

Methodology and data analysis issues

Based on new observations (stomach content) we are able to build diet matrices that become input data into ecosystem models (Ecopath). Ultimately these models will be used to simulate scenarios to evaluate the impact of new management measures on the whole ecosystem.

Since the beginning of the study, two major sources have provided stomach samples: the national observer programmes in the region, since 2001, and the PTTP Pacific Tuna Tagging Programme since 2006. In June 2009, the total number of samples collected was about 7700; 48% coming from the tagging cruises and 52% from the observer programmes.

In June 2009 about 56% of the collection had been examined, that is about 4400 samples from 72 different species (tuna, bycatch and discarded species - Annex 1). Samples are coming from different EEZ and high seas area as shown on Figure 1.

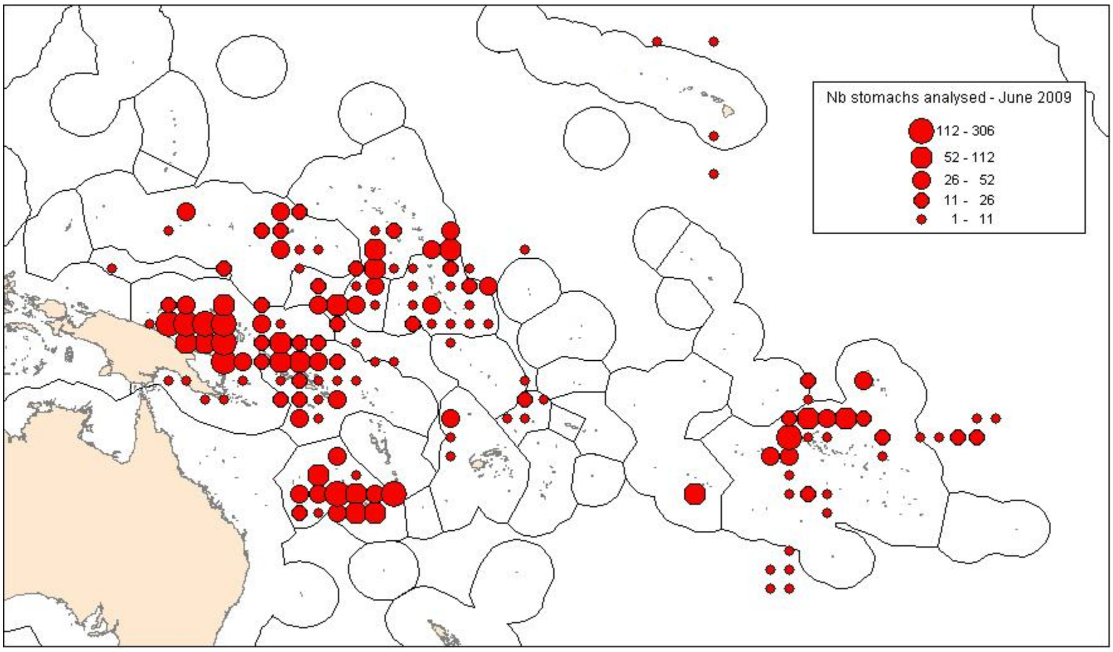

Figure 1. Spatial distribution of the number of stomach samples examined by June 2009 in the western and central Pacific Ocean.

With the increasing number of fish stomachs examined, data analysis has been started to describe the diet of all the species. Preliminary analyses revealed some issues linked to the sampling strategy and to the nature of the data collected that are impairing the representativeness of the studied fish and the finalisation of the results.

Sample collection is conducted on an opportunistic basis. The sampling strategy is not random in terms of area, time and sampling gear which causes problems to compile and statistically analyse the data.
Sampling is conducted over a very large area that spreads over different provinces or ecosystems as defined by Longhurst (1995) preventing aggregation of all the samples as they are representative of different ecosystems (Figure 2).

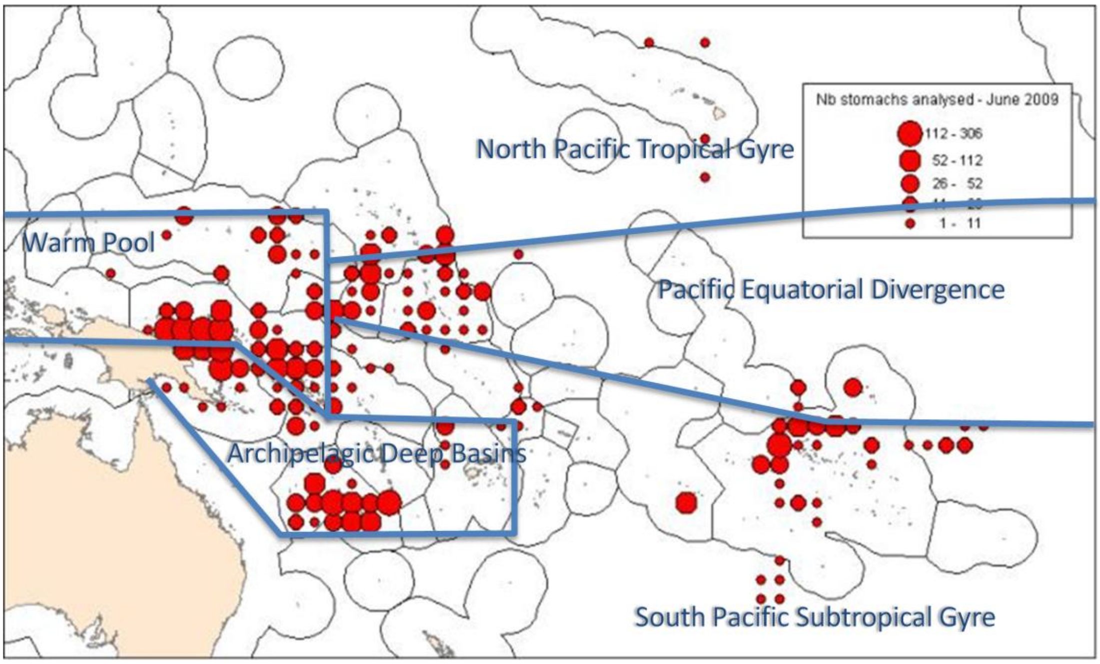

Figure 2. Distribution of stomach samples over the five biogeochemical provinces/ecosystems defined by Longhurst (1995) in the western and central Pacific Ocean.

Sampling started in 2001 and has been more or less continuous until today, but seasonnal distribution must be examined, particularly in the more temperate areas to check the existence of a potential biais towards one of the seasons that could affect the diet description.
The sampling gears used also create biaises in the results because they are sampling different fish populations or different parts of the population. Differences in the fishing gears characteristics and fishing strategy outlined, for example, that longlines catch adult fish actively looking for food, at depth, day or night while purse-seines on FAD schools catch juvenile fish at the surface early morning (Table 1). Sampling gear issues were discussed in Allain & Leroy (2006).

Table 1. General characteristics of the sampling fishing gears.

	Longline	Purse seine	
		Free school	Floating object
Setting time Hauling time	Dawn / morning Dusk / night	Dawn to dusk Dawn to dusk	Dawn Dawn
Fishing depth	50-450 m	0-200/300 m*	
Passive/active	Passive / baited	Active	
Hook / mesh size	Standard Japanese tuna hook	Mesh size about 10-25 cm	
Areas	Equatorial to temperate	Equatorial	
Main target fish	Albacore, yellowfin, bigeye	Skipjack, yellowfin	
Size of the fish	Large (mainly >80cm)	Small and large (30 to >120cm)	

* depth of the net, however the fish are caught at the surface

Stratification of the samples for data analysis appears necessary to represent corretly the diet description of the fish populations under study in the different ecosystems. Collection area and size of the fish are two factors that are primordial in terms of variability of the diet data; season could also be another important factor however it might be difficult to take it into account because of the poor repartition of the number of samples per season and year. Stratification of the samples creates however a decrease in the number of samples per strata reducing the reliability of the results.

Other difficulties appeared when starting analysing the data. Major ones are the number of empty stomachs, the percentage of unidentified preys and the taxonomic level at which the preys are identified. For example, more than 80% of the stomachs of fish collected by the purse seine fishery under FADs are empty, requiring a very high number of samples to obtain some information on the diet (see also Annex 1). In the case of skipjack, in the purse-seine fishery, up to 85% of the preys are unidentied inducing a large uncertainty on the diet description. Another difficulty when compiling or comparing data is the fact that preys can be identified at different taxonomic level from group (fish, crustaceans…) to species. A taxonomic level has then to be chosen according to the type of information that needs to be highlighted.

Despite these difficulties several analyses have been conducted. In the following paragraph is presented an abstract of the results of a Pacific-wide pelagic ecosystem comparison.

Results on the pelagic ecosystem trophic structure in the equatorial Pacific.

The OFP, in collaboration with University of Hawaii, IATTC and CICIMAR Mexico have recently completed an analysis comparing the trophic structure of the pelagic ecosystems in the equatorial Pacific. The aim of this project was to try and explain how the high production of tuna in the west (84% of Pacific tuna) is sustained by the low primary productivity in this area (325 $mgC.m^{-2}.d^{-1}$ – Pennington *et al.* 2006) while in the eastern Pacific where there is a lower tuna production (16%) the primary production is much higher (642 $mgC.m^{-2}.d^{-1}$).

A large sampling prorgramme was implemented in the whole equatorial Pacific. Stomach content examination demonstrated that yellowfin, bigeye and skipjack collected from purse-seiners had similar percentages of empty stomachs along the equator; however when containing some food, fullness of the stomachs was 2 to 4 times higher in the western Pacific than in the eastern Pacific.

The western Pacific tuna were characterized by a fish dominated diet while tuna in the eastern Pacific were eating squids in high proportion. Specific preys were found in the eastern and western parts of the equatorial Pacific such as mantis shrimps Stomatopoda, anchovies, juveniles of reef-associated fish (surgeonfish, butterflyfish) in the west and the swimming crab *Callinectes sp.* and 14 squid species, particularly the jumbo squid *Dosidicus gigas* in the east. If some preys were found both in the western and eastern Pacific, the proportions varied: many different species of flying fish were eaten in large proportion in the east as well as a variety of Scombridae (tuna and mackerel family) while in the west only skipjack were eaten from this fish family and little flying fish were consummed.

Using this diet information compiled into diet matrices and incorporated into food-web models, spatial heterogeneity was identified in the structure of the Pacific ecosystems. In the eastern Pacific there was a large influence of squids and bullet/frigate tuna *Auxis spp*., while in the western Pacific skipjack had a key role in the ecosystem. Moreover in the western Pacific building the model showed a disagreement in the data: the forage biomass estimates from the SEAPODYM model could not sustain the tuna biomass estimates of the stock assessment models (MULTIFAN-CL). One possible explanation could be an underestimation of forage biomass. In this regard, the importance of reef and island associated preys in the western Pacific, which is scattered by islands and atolls, should be explored in addition to the possible advection of forage from the eastern Pacific.

Data analyses in progress and future directions.

More analyses are in progress such as the study of the sampling gear effect on the diet description or the impact of FADs on the trophic status using diet information, isotope and fatmeter data. In Septembre 2009 in Sète, France, a CLIOTOP workshop will gather experts from the 3 oceans to conduct inter-ocean comparisons of oceanic food webs.

New analyses should start in the close future: an updated diet matrix will be produced to develop a new Ecopath model in Septembre-Decembre 2009; a 2-year project on micronekton importance for the tuna ecosystem in New Caledonia has been submitted and will provide new data in 2010 and 2011 if funded; the importance of reef-fish in the pelagic predators diet should also be explored.

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Annex 1. Number of stomachs examined, including number of non-empty stomachs, for the 72 species collected by June 2009.

Scientific name	English name	FAO code	Nb of stomachs	Non-empty stomachs nb	Scientific name	English name	FAO code	Nb of stomachs	Non-empty stomachs nb
Katsuwonus pelamis	SKIPJACK	SKJ	1161	535	*Gnathanodon speciosus*	GOLDEN TREVALLY	GLT	6	4
Thunnus albacares	YELLOWFIN	YFT	1108	837	*Aluterus monoceros*	FILEFISH	ALM	5	1
Thunnus obesus	BIGEYE	BET	483	352	*Gempylidae*	SNAKE MACKERELS & ESCOLARS	GEP	5	1
Thunnus alalunga	ALBACORE	ALB	285	274	*Platax teira*	LONGFIN BATFISH	BAO	4	1
Elagatis bipinnulata	RAINBOW RUNNER	RRU	185	113	*Canthidermis maculatus*	OCEAN TRIGGERFISH (SPOTTED)	CNT	3	3
Acanthocybium solandri	WAHOO	WAH	159	131	*Isurus paucus*	LONG FINNED MAKO SHARK	LMA	3	3
Coryphaena hippurus	MAHI MAHI / DOLPHINFISH	DOL	148	123	*Mobula japanica*	MANTA RAY	RMJ	3	3
Alepisaurus ferox	LONGSNOUTED LANCETFISH	ALX	113	95	Mobulidae	MANTA RAYS (UNIDENTIFIED)	MAN	3	
Lampris guttatus	MOONFISH / OPAH	LAG	63	59	*Caranx sexfasciatus*	BIGEYE TREVALLY	CXS	2	1
Xiphias gladius	SWORDFISH	SWO	50	40	*Carcharhinus albimarginatus*	SILVER-TIP SHARK	ALS	2	2
Makaira mazara	BLUE MARLIN	BUM	46	38	Chiasmodontidae	CHIASMODONTIDAE	CHM	2	2
Sphyraena barracuda	GREAT BARRACUDA	GBA	42	33	*Galeocerdo cuvier*	TIGER SHARK	TIG	2	1
Prionace glauca	BLUE SHARK	BSH	40	14	*Promethichthys prometheus*	ROUDI ESCOLAR	PRP	2	1
Balistidae	OCEANIC TRIGGERFISH	TRI	38	29	*Abudefduf saxatilis*	SARGENT MAJOR	ABU	1	
Carcharhinus falciformis	SILKY SHARK	FAL	36	22	*Alepisaurus brevirostris*	SHORTSNOUTED LANCETFISH	ALO	1	1
Tetrapturus angustirostris	SHORT-BILLED SPEARFISH	SSP	32	30	*Alepisaurus spp.*	LANCETFISHES	ALI	1	
Euthynnus affinis	KAWAKAWA	KAW	30	14	*Alopias superciliosus*	BIGEYE THRESHER SHARK	BTH	1	
Tetrapturus audax	STRIPED MARLIN	MLS	30	30	*Alopias vulpinus*	THRESHER SHARK (VULPINAS)	ALV	1	
Auxis thazard	FRIGATE TUNA	FRI	26	4	*Assurger anzac*	RAZORBACK SCABBARDFISH	ASZ	1	1
Dasyatis violacea	PELAGIC STING-RAY	PLS	24	21	*Brama brama*	ATLANTIC POMFRET / BREAM	POA	1	1
Lepidocybium flavobrunneum	ESCOLAR	LEC	24	8	*Carcharhinus leucas*	BULL SHARK	CCE	1	1
	UNSPECIFIED	UNS	21	19	*Desmodema polystictum*	DEALFISH	DSM	1	1
Istiophorus platypterus	SAILFISH (INDO-PACIFIC)	SFA	18	16	Elasmobranchii	SHARKS (UNIDENTIFIED)	SHK	1	
Decapturus macarellus	MACKEREL SCAD / SABA	MSD	17	4	*Kyphosus cinerascens*	DRUMMER (BLUE CHUB)	KYC	1	
Isurus oxyrhinchus	SHORT FINNED MAKO SHARK	SMA	16	9	*Lobotes surinamensis*	TRIPLE-TAIL	LOB	1	1
Gempylus serpens	SNAKE MACKEREL	GES	15	3	*Lophotus capellei*	CRESTFISH/UNICORNFISH	LOP	1	1
Sphyraena spp.	BARRACUDAS (UNIDENTIFIED)	BAR	13	6	*Magnisudis sp.*	BARRACUDINA	MUG	1	1
Scombrolabrax heterolepis	BLACK MACKEREL	SXH	12	5	*Omosudis lowei*	OMOSUDID	OMW	1	1
Melichthys niger	BLACK TRIGGERFISH	MEN	11	2	*Platax spp*	BATFISHES	BAT	1	1
Ruvettus pretiosus	OILFISH	OIL	11	4	*Pseudocarcharias kamoharai*	CROCODILE SHARK	PSK	1	
Taractichthys steindachneri	SICKLE POMFRET	TST	10	3	*Rexea solandri*	GEMFISH	GEM	1	
Auxis rochei	BULLET TUNA	BLT	9		Scopelarchidae	PERLEYES NEI	PEY	1	1
Bramidae	POMFRETS & OCEAN BREAMS	BRZ	9	7	*Sphyraena genie*	BLACKFIN BARRACUDA	BAB	1	1
Carcharhinus longimanus	OCEANIC WHITE-TIP SHARK	OCS	7	2	*Sphyrna lewini*	SCALLOPED HAMMERHEAD	SPL	1	1
Makaira indica	BLACK MARLIN	BLM	7	7	*Sphyrna spp.*	HAMMERHEAD SHARKS	SPN	1	1
Taractichthys longipinnis	BIG-SCALED POMFRET	TAL	7	4	Tetraodontidae	PUFFERS (FAMILY)	PUX	1	1