DIET OF FOUR TUNA SPECIES OF THE WESTERN AND CENTRAL PACIFIC OCEAN

Valérie Allain
Oceanic Fisheries Programme
SPC, Noumea
New Caledonia

Introduction

Assessing the impact of fisheries and environmental variability on an ecosystem — in order to develop ecosystem approaches to fisheries management — requires a good comprehension of the elements of this system. Fish predation induces mortality in the ecosystem that is often higher than fishery mortality, and determining trophic interactions between species is a major step towards a better understanding and modelling of dynamics of this ecosystem.

A large sampling programme, involving the collection of samples and determining the diet of top predators, has been implemented in the western and central Pacific Ocean in order to develop a better understanding of the pelagic ecosystem. Based on stomach content data, this paper (presented during the first regular session of the Scientific Committee of the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean; see article on p. 2) discusses the diet of four tuna species of the warm pool area, where most tropical tuna fishing occurs. The classification of prey according to their vertical distribution and migration provides information on tuna behaviour.

Prey from the stomach of a tuna: fish, squid and shrimp

Methods

Sampling programme, sampling protocol

Stomach samples are collected from target fish (tunas) and bycatch species by observers from the different national observer programmes in the area. Since the beginning of the programme in January 2001, 81 sampling trips have been made: 54 on longline boats, 17 on purse-seine vessels, and 10 on other boats. Sampling trips were organised as follows: French Polynesia (20), New Caledonia (13), Federated States of Micronesia (2), Papua New Guinea (6), Solomon Islands (12), the FSM Arrangement programme (10), Marshall Islands (1), SPC (2), Wallis and Futuna(1), ships of opportunity (12), Cook Islands (2).

Stomach examination

Prey were sorted by species or group, and identified at the lowest taxonomic level. A digestion state was attributed, from 1 (fresh) to 4 (bones), the development state determined when possible (larvae, juvenile, adult), and prey were counted, weighed and measured. Forage species prey were classified according to their depth distribution and vertical behaviour (from epipelagic to mesopelagic and bathypelagic, with night-surface migrating components) and to the degree of association with reefs (data compiled from literature).

Sample characteristics

This study presents only data from samples collected in the warm pool: 173 yellowfin (YFT), 119 bigeye (BET), 300 skipjack (SKJ), and 12 albacore tuna (ALB). Most of the fish collected were caught by purse seine but a significant proportion of the YFT and BET were caught by longline, as well as all the ALB. Mean length of the fish examined are: YFT and BET, about 77 cm, SKJ 54 cm and ALB 94 cm. Fish smaller than 80 cm were generally caught by purse seine and larger fish by longline.

Nearly all the SKJ and ALB examined were considered to be adults, while all BET were juveniles, as were more than two thirds of the YFT.

Results and discussion

Diet description

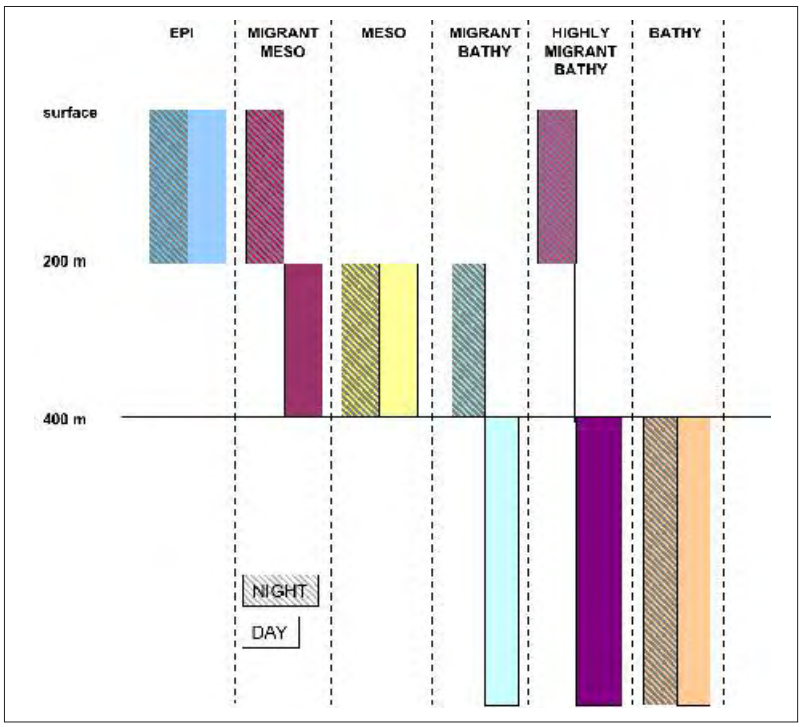
Prey groups

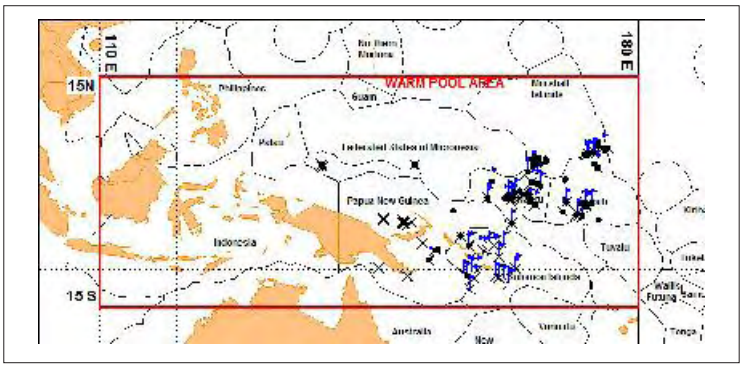
The most important prey groups (see graph below) found in the stomachs (measured by weight) were identical for all four tuna species: fish (64–88%), molluscs (6–25%) and crustaceans (0.2–9%). The most piscivorous species was SKJ, while ALB presented the lowest proportion of fish and the highest of molluscs. YFT had the highest crustacean content.

SKJ is a true piscivore while YFT and ALB have a more diversified diet, including crustaceans and molluscs; BET has an intermediate diet composed mainly of fish and molluscs.

Prey items

BET: Not taking into account the undefined items, the most important prey group in terms of





Top: Vertical distribution and migration of forage species Bottom: Locations of the tuna sampled for the study in the warm pool. BET (flag), SKJ (circle), YFT (cross)

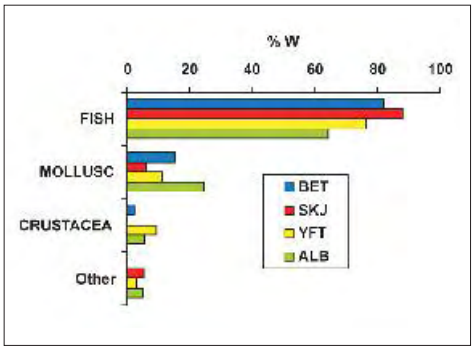
weight is the mesopelagic class (36%), particularly Paralepididae (barracudinas; 22.3%), Sternoptychidae (hatchetfish; 7%) and the squid *Moroteuthis* sp. (2%). The second prey group is the deep bathypelagic, including a Paralepididae (*Magnisudis indica*; 10%) but also Diretmidae, Scopelarchidae and Chiasmodontidae (3%, 2% and 1%). Epipelagic prey and surface migrating prey represent 5, 5 and 7% of the diet with SKJ specimens (2%), the squid *Stenoteuthis oualaniensis* (3%) and Myctophidae (4%).

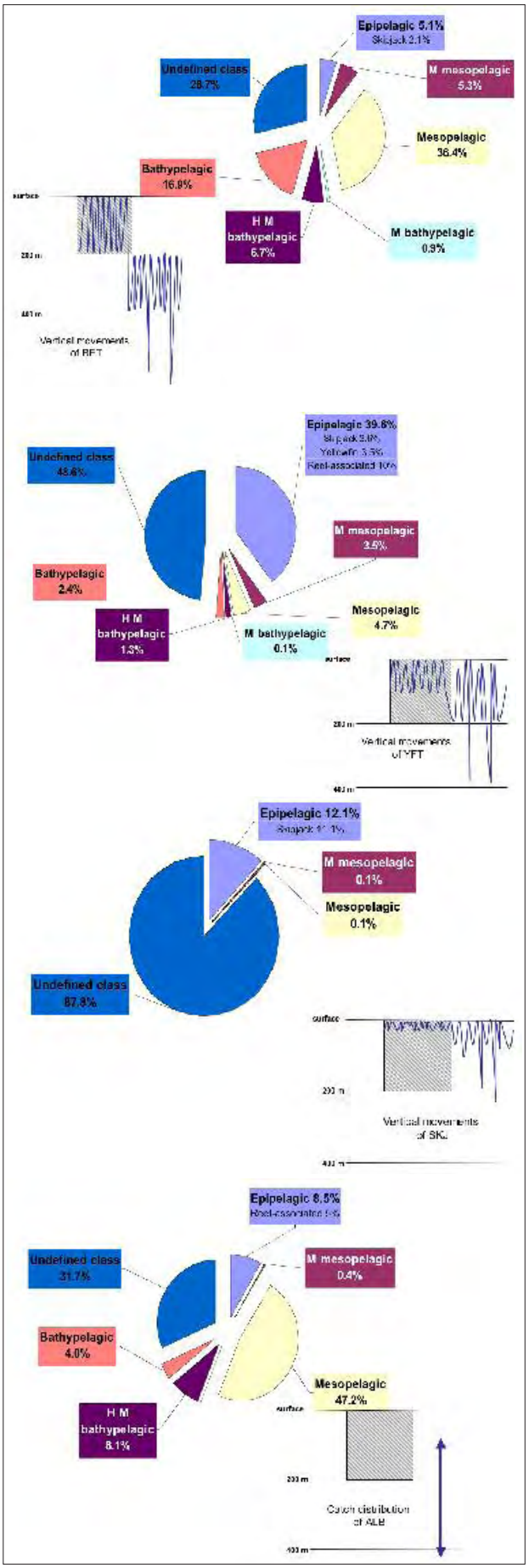
This diet composition is in agreement with the vertical behaviour of BET, as determined through electronic tagging: at night they stay between the surface and 250 m, while during the day they dive to depths of 200–500 m, and on rare occasions as deep as 900 m (Allain et al. 2005; Musyl et al. 2003). This suggests that this species eats during the day and at night at all depths. This is in agreement with its eye characteristics, which makes BET an efficient visual hunter even in dim light (Fritsches and Warrant 2001).

YFT: A large portion of the YFT diet is composed of epipelagic prey (40%), particularly *Elagatis bipinnulatus* (rainbow runner; 7%), Exocoetidae (flying fish; 4%), SKJ (4%), YFT (3%), juvenile reef fish, including Acanthuridae (surgeon fish; 2%), Balistidae (trigger fish; 3%), Tetraodontidae (puffer fish; 2%) and small crustacea (megalopa, Amphipoda, Stomatopoda, and Phronima). The reef-associated prey species represent 10% (by weight) of the YFT diet. YFT also consumes deeper prey species: mesopelagics (5%) including Paralepididae (3%), bathypelagic species (Chiasmodontidae; 2%), and migrant deep prey (the squid *Stenoteuthis oualaniensis*; 2%) and Myctophidae (lanternfishes; 1%).

It is interesting to note the presence of juvenile tuna in the YFT diet, demonstrating predation pressure on SKJ (4%) and cannibalism (3%). It also appears that YFT can have an important impact on the mortality of juvenile reef-associated fish; this predation is opportunistic and depends on the area and the presence of islands (Allain 2004). The predominantly epipelagic diet is in agreement with what is known regarding the vertical distribution of YFT, which stays between the surface and 200 m (both during the day and at night), and dives to 500 m depths on rare occasions (Dagorn et al. 2001).

SKJ: Because of the large portion of highly digested and unrecognizable prey, for which the vertical class could not be





defined, less than 13% of the prey (by weight) could be classified; a total of 12% of prey were epipelagic. The most important prey is SKJ (11%), with other prey collectively representing less than 1% (these include Bramidae, Acanthuridae, Pomacanthidae, and Stomatopoda). Deeper prey species accounted for less than 0.1%.

On the basis of the prey items identified, SKJ is exclusively an epipelagic predator and shows significant cannibalism. It will be important to try to improve the percentage of identified prey to validate this high rate of cannibalism. Genetic techniques coupled with examination of hard parts is a promising technique in identifying highly digested prey (Smith et al. 2005) and could be applied to the case of SKJ to obtain a more accurate estimate of cannibalism. SKJ is an epipelagic predator that stays between the surface and 100 m during the day and night, diving on rare occasions to depths of up to 250 m (Ogura 2003); the fact that no deep prey that migrate to the surface at night were found in their stomach contents suggests SKJ feed exclusively during the day. This is in agreement with the fact that all SKJ caught early in the morning around FADs have empty stomachs; however, the hypothesis of exclusively daytime feeding needs to be confirmed by analysis of an increased percentage of identified preys. In addition, the effect on FADs on SKJ feeding strategy needs to be clarified (Musyl et al. 2003)

ALB: The most important prey group in the ALB diet consists of the mesopelagics (47%), particularly Paralepidae (25%), the squid *Ancistrocheirus lesueuri* (9%), the squid *Moroteuthis* sp. (7%) and the fish *Scombrolabrax heterolepis* (black mackerel; 3%). Epipelagics and surface migrating bathypelagics both represent 8%, including the cephalopoda Sepiida (1%), small crustacea (megalopa 1% and Stomatopoda 1%), Acanthuridae (1%) and Myctophidae (8%). Reef-associated prey species represent 5% of the ALB diet. ALB also consumes deep bathypelagic

Prey items for the four different species of tuna; from top to bottom: BET, YFT, SKJ, and ALB

prey (4%) such as Chiasmodontidae (3%) and *Sternoptyx* sp. (hatchet fish 1%).

The ALB diet is similar to that of BET, but ALB do not appear to dive as deep, relying more on mesopelagic and epipelagic prey (including reef-associated species), or surface migrating prey. Deep prey species (bathypelagics) are less important for ALB than they are for BET (4% and 17%, respectively). Few data are available on the vertical movements of ALB, but diet data are in agreement with depth distribution inferred from catch data.

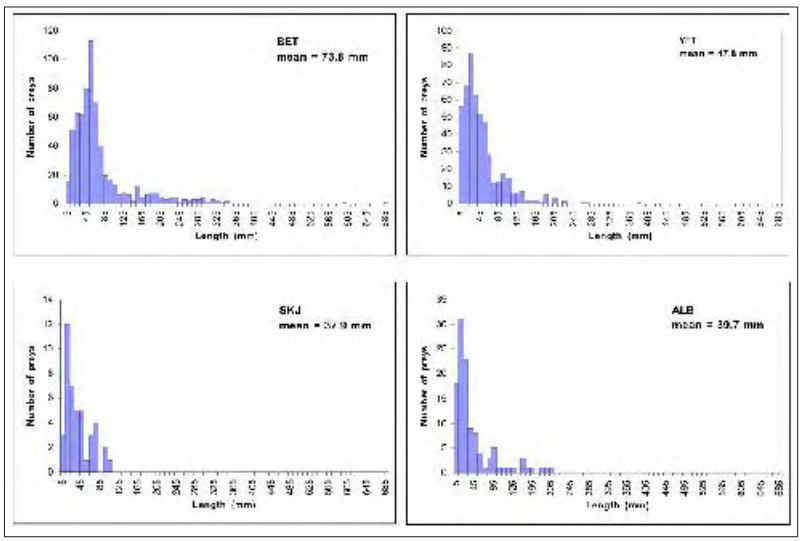
Prey size distribution

BET ingests prey between 0 and 690 mm, with most in the 50–60 mm length class. Other tuna species eat smaller prey: SKJ, prey length ranged from 0–109 mm, with most in the 10–20 mm class; YFT, 0–387 mm and 20–30 mm; ALB, 2–203 mm and 10–20 mm.

Conclusion

Examination of tuna stomach contents provides important information on feeding strategies. It appears that to balance its high metabolism SKJ eats more and digests faster than the other tuna species. Due to their vertical distribution and behaviour, the four tuna species have access to different depth strata, and this is noticeable in the composition of their diet. SKJ, which stays closer to the surface, eats only epipelagic prey (mainly fish), with a very high cannibalism rate, and shows a low diversity in prey. YFT eats also mainly surface preys but also deep water organisms. BET and ALB have a high percentage of deep preys in their diet. While the diets of these pairs of species (SKJ and YFT, and ALB and BET) show similarities, there are differences in the size of the prey consumed. The diet of the four tuna species shows relatively low overlap.

Diet studies provide information on basic biology and behaviour of the fish, but are also an important part of the parameterization of ecosystem models such as Ecopath/Ecosim (Allain 2005). Information such as prey diversity, prey size, and diet composition can be used in conjunction with other ecosystem indicators to detect changes in the ecosystem (Kirby et al. 2005).



Length-frequency distribution of the prey consumed by the different predators

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