Importance of reef prey in the diet of tunas and other large pelagic species in the western and central Pacific Ocean

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Recent descriptive ecology work has demonstrated that tuna and other pelagic species associated with oceanic tuna fisheries feed on reef prey, particularly around fish aggregating devices located in specific geographic areas.

Introduction

It has been demonstrated that targeting a specific fishery species affects untargeted individuals as well within an ecosystem through the interactions in the food chain's prey–predator relationships. Up until the 1980s, however, work focused on the single-species management of fisheries and did not consider the impact that capturing one species could have on other associated species.

In 1982, the United Nations Convention on the Law of the Sea introduced the ecosystem management concept, which involved managing not only target species, but also associated and dependent species in the ecosystem as a whole. Such an approach is particularly important in the western and central Pacific Ocean (WCPO), which contains the planet's largest tuna stocks. Tuna and other large pelagic species are upper-trophic-level predators (Fig. 1), and fishing effort there has very likely had a major impact on the rest of the ecosystem.

The Oceanic Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC) has been working on acquiring biological knowledge of tuna and their environment since 2001. Among the various research avenues pursued, OFP has described the diet of tuna and other large WCPO pelagic species, with a particular emphasis on the disparity between current tuna stock estimates and the amount of oceanic micronekton available in the area.

Tuna diet

Tuna diet studies have demonstrated that tuna and other large pelagic species are not selective in terms of their diet, adapting to available prey and the latter's vertical distribution in the water column. Different diets were identified based on the tuna species considered, fishing grounds, or school configuration while fishing

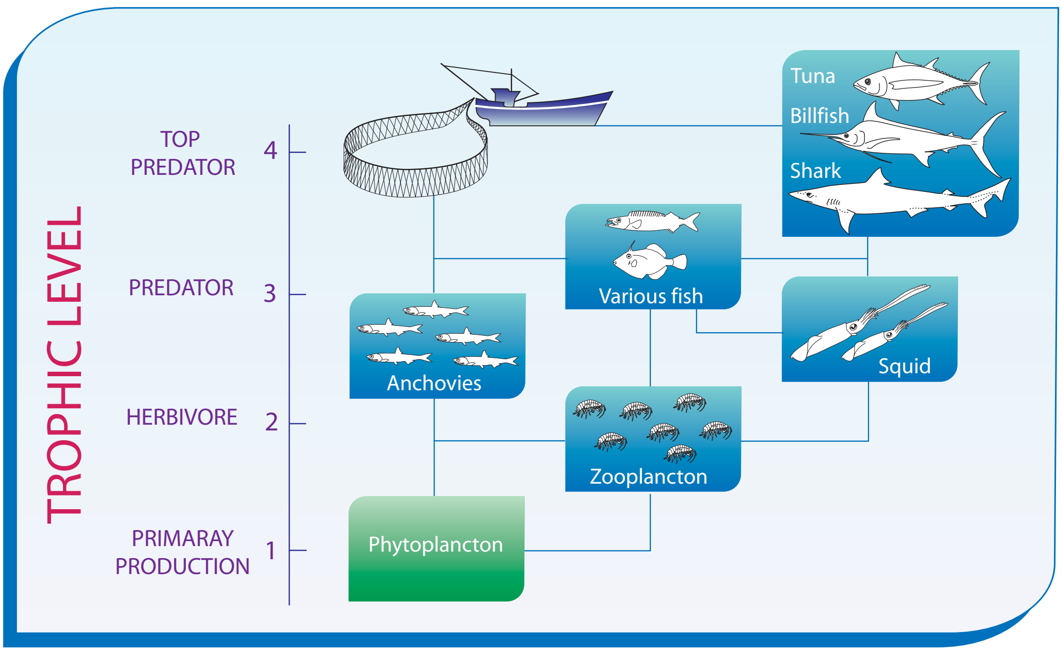

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Figure 1. The food chain and the relationship between tunas and associated species.

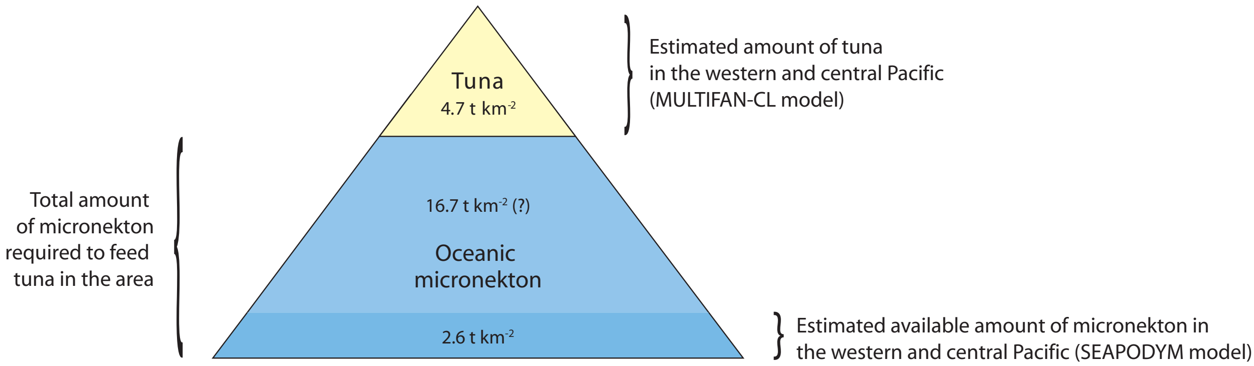

Figure 2. Diagram of the shortfall between tuna quantities and available micronekton as estimated by pelagic ecosystem models.

(e.g. schools near fish aggregating devices [FADs)], schools associated with whale sharks, and free schools). For example, a recent study showed that yellowfin tuna caught in Papua New Guinea (PNG) and French Polynesia feed mainly on crustaceans, such as mantis prawns (Stomatopoda), while those caught in New Caledonian waters mainly consume flying fish, reef fish and crab larvae (Allain 2005).

Pelagic ecosystem models now integrate these diet differences, even though there are still many problems with balancing them in terms of weight and prey numbers.

Two mathematical models were developed by SPC to study tuna population dynamics.

1. The spatial ecosystem and populations dynamics model (SEAPODYM), which integrates population dynamics and an ecosystem's spatial aspect to provide a general framework for integrating biological and ecological knowledge on tuna and other oceanic predators and their responses to fishing pressure. The model targets three tuna species found in the South Pacific: skipjack (*Katsuwomis pelamis*), bigeye (*Thunnus obesus*) and albacore (*T. alalunga*). The model matches ocean-basin-scale biological and physical fishery data by including phytoplankton-zooplankton quantities, micronekton quantities and tuna ages.
2. MULTIFAN-CL, a stock assessment modeling approach, was developed by Fournier et al. (1998), and is the main tool for assessing WCPO tuna stocks. This computer programme conducts a statistical analysis based on tuna length and age.

By integrating data from both models, plus using information acquired on diet into a third model (known as Ecopath), we were able to gain an understanding of how the WCPO ecosystem functions.

Ecopath showed that micronekton in the WCPO (as estimated by the SEAPODYM model at 2.6 t km^{-2}), was insufficient to feed the tuna in the area as estimated by the MULTIFAN-CL model (at 4.7 t km^{-2}). According to available biological data, 19.3 t km^{-2} of oceanic micronekton are required to feed such numbers of tuna. The Ecopath model, therefore, suggests a shortfall of 16.7 t km^{-2} in micronekton or other prey items (Fig. 2).

Reservations regarding estimates based on the models may partly explain the discrepancies. It has also been shown that the models do not account for two major factors: prey transfers from other areas, and reef prey (Allain et al. 2007).

The latter hypothesis was examined by OFP's Ecosystem Monitoring and Analysis Section during a master-degree attachment that focused on measuring the importance of reef prey in these upper-trophic-level pelagic fishes diet.

Importance of reef prey in the diet of upper-trophic-level predators

Several studies have shown that reef prey was present in tuna diets (e.g. Bertrand et al. 2002; Jacquemet et al. 2011), but no qualitative or quantitative studies have yet been undertaken. It was, therefore, difficult to estimate how important reef prey was in the diet of tuna and large pelagic fish.

Our study consisted of carrying out a quantitative taxonomic analysis of the stomach content of 4,357 predators sampled during commercial fishing campaigns conducted in the exclusive economic zones (EEZs) of the WCPO. The results focused on the proportion of reef prey estimated in terms of weight, and excluded other prey. Major fluctuations in reef prey proportions were observed in the diet.

In order to attempt an explanation, various factors were examined such as space-time variability, fishing gear type, school configuration during fishing, reef/lagoon distances and surface area, and some predator biological characteristics such as weight, length, habitat and species.

Despite major variability in the results based on the tested factors, the results demonstrated that:

1. reef prey accounted for an average of 16.3% of predators' diet (Fig. 3), with figures fluctuating from one month to another, and remaining low in December–January and June–July;

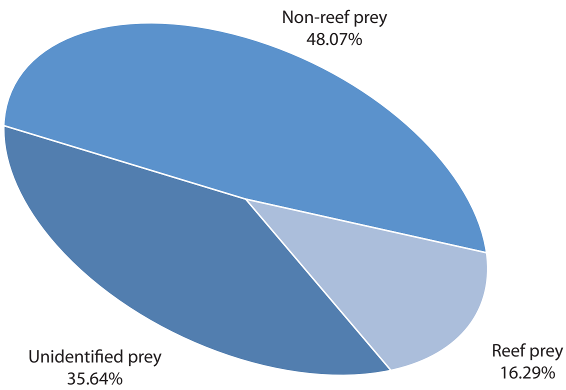

Figure 3. Illustration of reef, non-reef and unidentified prey weight proportions as analysed in the sampled stomach content

2. in the area examined, predators captured in PNG's EEZ showed higher rates of reef prey in their stomach content (Fig. 4);

3. a higher rate of reef prey were noted in predators that were captured using surface gear, such as seine nets or pole and line, used mainly in PNG and Federated States of Micronesia than in predators captured using deep-sea longlines in French Polynesia's EEZ farther to the east of the area under consideration;

4. predators caught using surface gear near anchored FADs in PNG's EEZ had higher amounts of reef prey in their diet than those caught near free-floating and drifting FADs or in free schools;

5. the proportion of reef prey in the diet of tuna and large pelagic species fell as the prey moved away from coasts, reefs or lagoons (Fig. 5); and

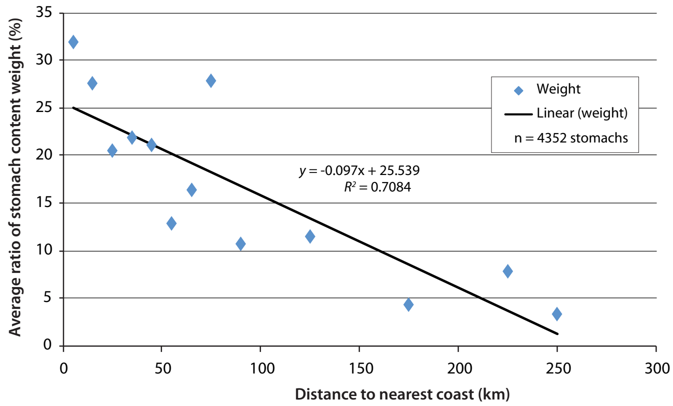

Figure 5. Correlation between reef prey weight in the stomach of predators and the distance from the nearest coast.

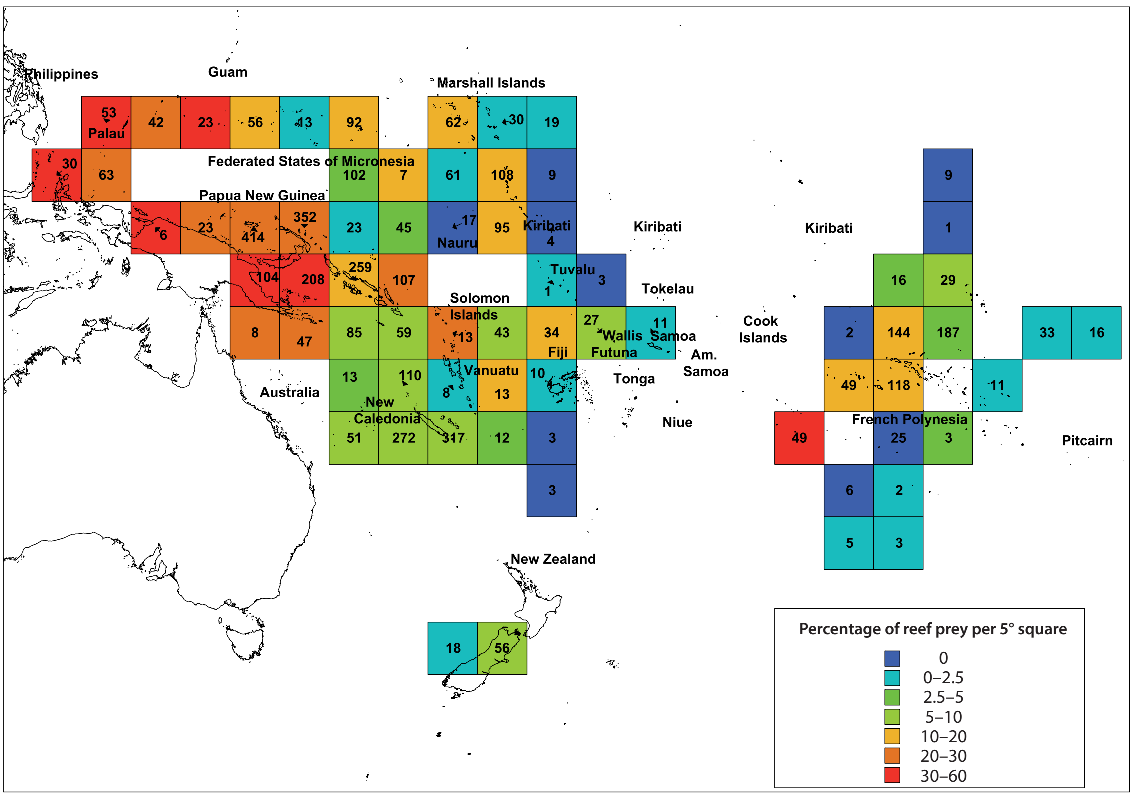

Figure 4. Spatial distribution of reef prey weights in the stomach of predators by five-degree squares of latitude and longitude with the number of predators captured in each square.

6. small predators living mainly in surface waters, particularly yellowfin (*Thunnus albacares*) and skipjack (*Katsuwomis pelamis*) had higher rates of reef prey in their stomachs than larger predators, such as bigeye (*T. obesus*), which tended to feed in deeper waters.

Reef prey could be classified into three categories (Fig. 6):

- fish, mainly triggerfish (Balistidae) and surgeonfish (Acanthuridae) (Fig. 7).
- crustaceans, mainly mantis shrimps (Stomatopoda) (Fig. 8)
- molluscs (Fig. 9).

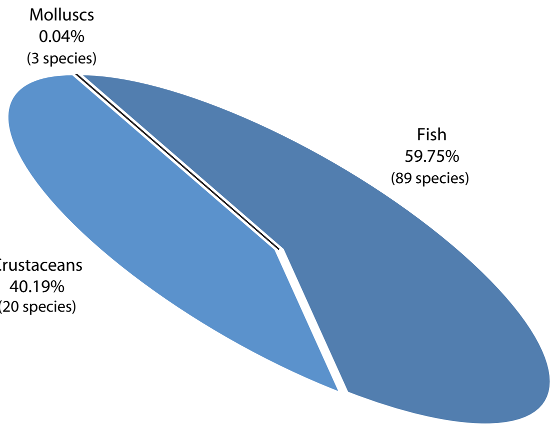

Figure 6. Distribution by major categories of reef prey identified in sampled predator stomachs.

In total, 109 different reef species were identified.

Several hypotheses can be advanced to explain the results.

1. The observed seasonal minima can be explained by seasonal larval production in reef spawning environments and pelagic larval lifespans prior to recruitment.
2. Geographic areas where predators had higher rates of reef prey in their diets were natural sources of larval production. The farther the larvae moved from areas with reefs, lagoons and coasts, the more dispersed they became and the less they appeared in predator diets.
3. PNG-anchored FADs aggregated larvae by acting as reef substitutes (Kingsford and Choat 1989) to which larvae recruited, guided by FAD sound emissions (Mann et al. 2007).
4. Small predators prefer smaller prey, particularly reef fish larvae, although proportions varied in terms of the predator under consideration. Such variability could also be explained by opportunistic feeding.

By linking information on space-time factors and biological characteristics of predators tested for reef prey

Figure 7. Acanthuridae (top) and Balistidae (bottom) larvae found in the stomachs of a predator caught in Federated States of Micronesia and Solomon Islands, respectively. (Photos: Dominique Ponton, IRD).

Figure 8. Stomatopoda larva found in the stomach of a predator caught in Solomon Islands (Photo: SPC).

Figure 9: Octopus defilippi *larva found in the stomach of a predator caught in New Caledonia (Photo: SPC).*

variability rates, the results showed that small predators around FADs that were anchored less than 80 km from coasts, particularly in PNG's EEZ, had maximum reef prey rates of 62.3% in their stomachs.

Conclusion

The study conducted in the WCPO revealed a number of general trends and showed that despite sampling biases, such as spatial coverage restricted to EEZs, the proportion of reef prey in the diets of tuna and other upper-trophic-level pelagic species was quite significant in some circumstances, particularly when school configuration during fishing and the geographic area were considered.

More in-depth and finer-scale analyses, however, particularly a cross analysis between geographic areas and seasons in areas for which a large number of samples are available, could better explain the space-time distribution of reef prey and the diet preferences of some predators. Similarly, better knowledge of ocean phenomena such as currents, could provide more accurate explanations for larval dispersion and explain why larvae are encountered in tuna diets at distances of hundreds of kilometres.

The ultimate aim of this work would be to integrate the "reef prey" variable into future pelagic ecosystem models, in order to better estimate actual oceanic micronekton quantities required to feed the numbers of tuna present in the area, as estimated by mathematical models.

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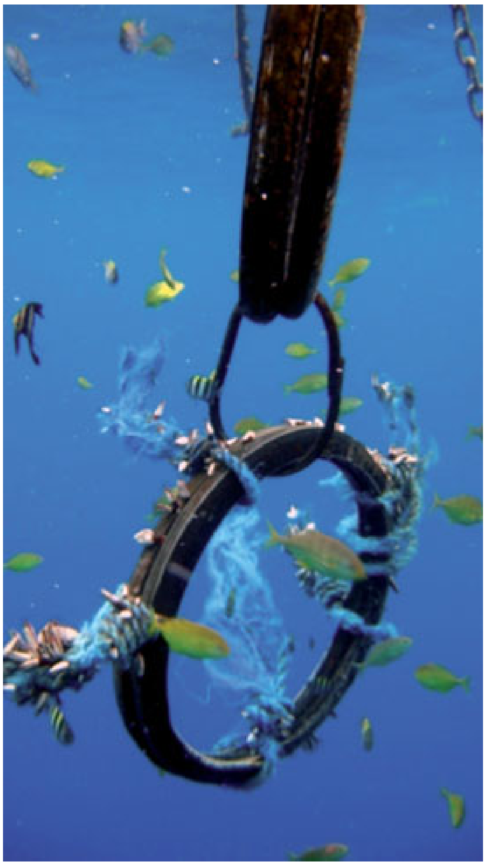

Reef fish juveniles around a FAD anchored in Papua New Guinea waters.