

A la carte menu for tuna: Kids' dishes, regional and seasonal specialities, or how tuna diets vary in the Pacific

A young female scientist from New Caledonia is earning her master's degree at the University of Montpellier in France. She came returned to the Pacific for six months as an intern at the Oceanic Fisheries Programme (Fisheries and Ecosystem Monitoring and Analysis Section) and the Climate Change and Environmental Sustainability Division of the Pacific Community (SPC). At SPC, she was trained in studying the diet of tunas in the western and central Pacific Ocean (WCPO) in order to provide knowledge on tuna ecosystem dynamics in the face of climate change.

The Pacific Ocean is the biggest ocean on Earth. It presents a characteristic distribution of sea surface temperature with two different bodies of water (Fig. 1). To the east is the 'cold tongue', a nutrient-rich and highly saline body of water with a high primary productivity and a sea surface temperature of about 20°C. To the west is the 'warm pool', an oligotrophic and warm water body with a sea surface temperature of about 29°C. Where these two bodies of water meet, they form a convergence zone in the equatorial Pacific Ocean. In this region, there is a major climatic phenomenon called the El Niño-Southern Oscillation (ENSO), which is an alternation between a warm period named El Niño, and a cold period named La Niña. This event has effects on the convergence zone that moves eastward during an El Niño period and westward during a La Niña period. This convergence zone impacts the entire ecosystem, especially with regard to the distribution of tunas and, consequently, the productivity of commercial fisheries, which are very important in this region.

This physical environment is host to a very rich ecosystem, where each species is a link in the food web (Fig. 2). The apex predators in these waters include tunas, sharks, marlins and mammals. Micronekton (2–20-cm-long organisms) are part of these top predators' diet. Micronekton feed on the first links at the base of the food web: phytoplankton, that are the primary production of the environment, and zooplankton. Micronekton play a central role in this complex food web.

The aim of the internship was to determine whether climate change is impacting the pelagic ecosystem of the WCPO through the study of apex predators' diet. The results should, in turn, provide a more general overview of the composition of micronekton in the ecosystem, and help to understand and model its dynamics.

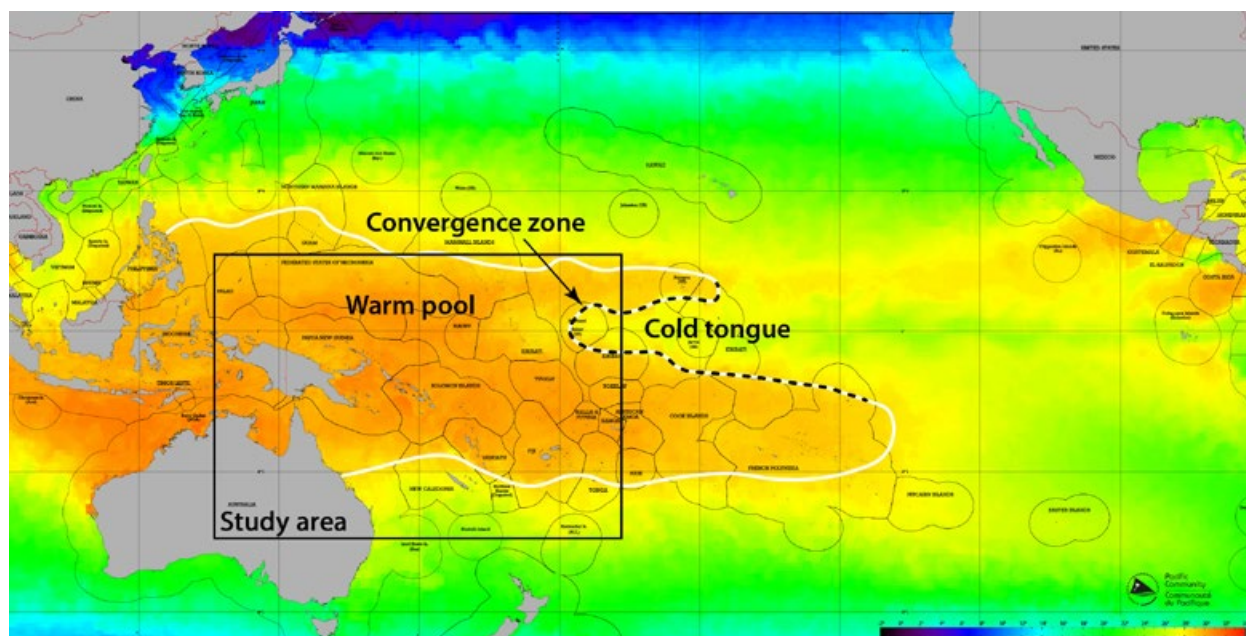


Figure 1. Average distribution of sea surface temperature (15 March 2018) and the area covered in this study. The white line is the approximated 28.5°C isotherm used to define the extent of the warm pool. Sources: SPC for the map and NOAA for the March 2018 sea surface temperature levels.¹

¹ <https://www.ospo.noaa.gov/Products/ocean/index.html>

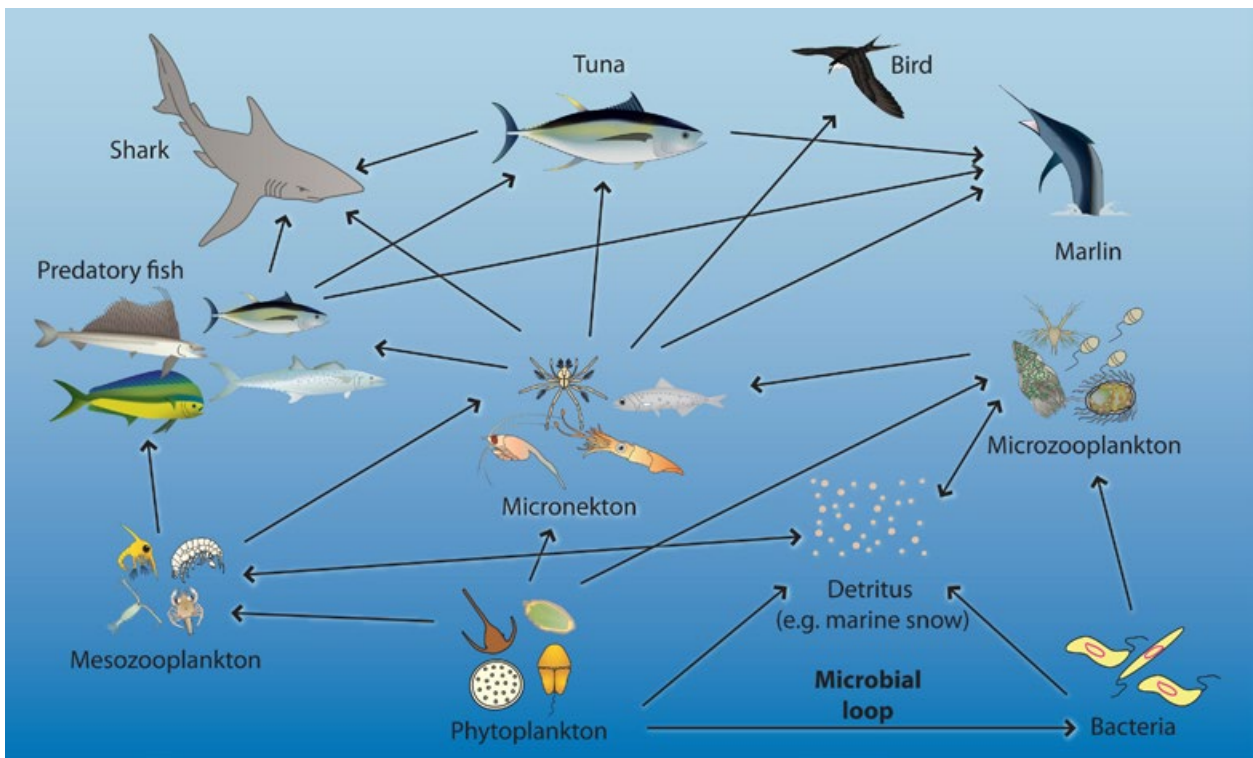


Figure 2. The pelagic ecosystem food web. (illustration: Jipé Le-Bars, SPC)

Scientists and fisheries observers collect biological samples of tuna during SPC’s Oceanic Fisheries Programme (OFP) tagging campaigns, scientific voyages, and from commercial tuna fishing boats. They collect, in particular, tuna stomachs, which are then stored at SPC in the Pacific Marine

Specimen Tissue Bank² to later be analysed. To describe their diet (Fig. 3), we analysed 2,979 stomachs of yellowfin tuna (*Thunnus albacares*), and 1,012 stomachs of bigeye tuna (*Thunnus obesus*), which were collected between 2001 and 2018 in the study area shown in Figure 1.



Figure 3. Examples of prey animals found in the stomachs of tuna: fish, squids and shrimps. (photo: SPC)

² <http://www.spc.int/ofp/PacificSpecimenBank>

See also: http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/152/FishNews152_43_Smith.pdf

Several types of data were collected during the identification of prey, such as stage of development, stage of digestion, number of specimens and their weight. These data were entered into BIODASYS, SPC’s biological database. Scientists also found macro-plastics in tuna stomachs, which were duly recorded (Fig. 4).



Figure 4. Macro-plastic found in a tuna stomach. (photo: SPC)

According to lab work, yellowfin tuna feed on species within the epipelagic layer (0–200 m depth) such as micronekton, and mainly on the larvae of crustaceans, whereas bigeye tuna feed on species within the upper mesopelagic layer (200–500 m depth) and lower mesopelagic layer (>500 m depth), and feed mainly on fishes.

Classification trees were used to look at variations in the prey composition of the diet of yellowfin and bigeye tunas. Our objective was to try to identify which environmental factors are crucial to diet variability, and to determine if there has been a change in the diet with time between 2001 and 2018 that could be linked to climate change (Figs. 5 and 6).

This statistical method groups together predators with a similar diet and identifies which environmental characteristics best defines the groups. The results showed that the first characteristic that separated predators into two groups with distinct diets is predator length. Small and large tunas have a very distinct diet and the shift occurs at 60 cm long for bigeye tuna and 67 cm long for yellowfin tuna. Of the 1,519 yellowfin tuna examined that were smaller than 67 cm fed mainly on crustaceans, in particular, the pelagic larvae of reef species such as mantis shrimp (Stomatopoda ~30% of

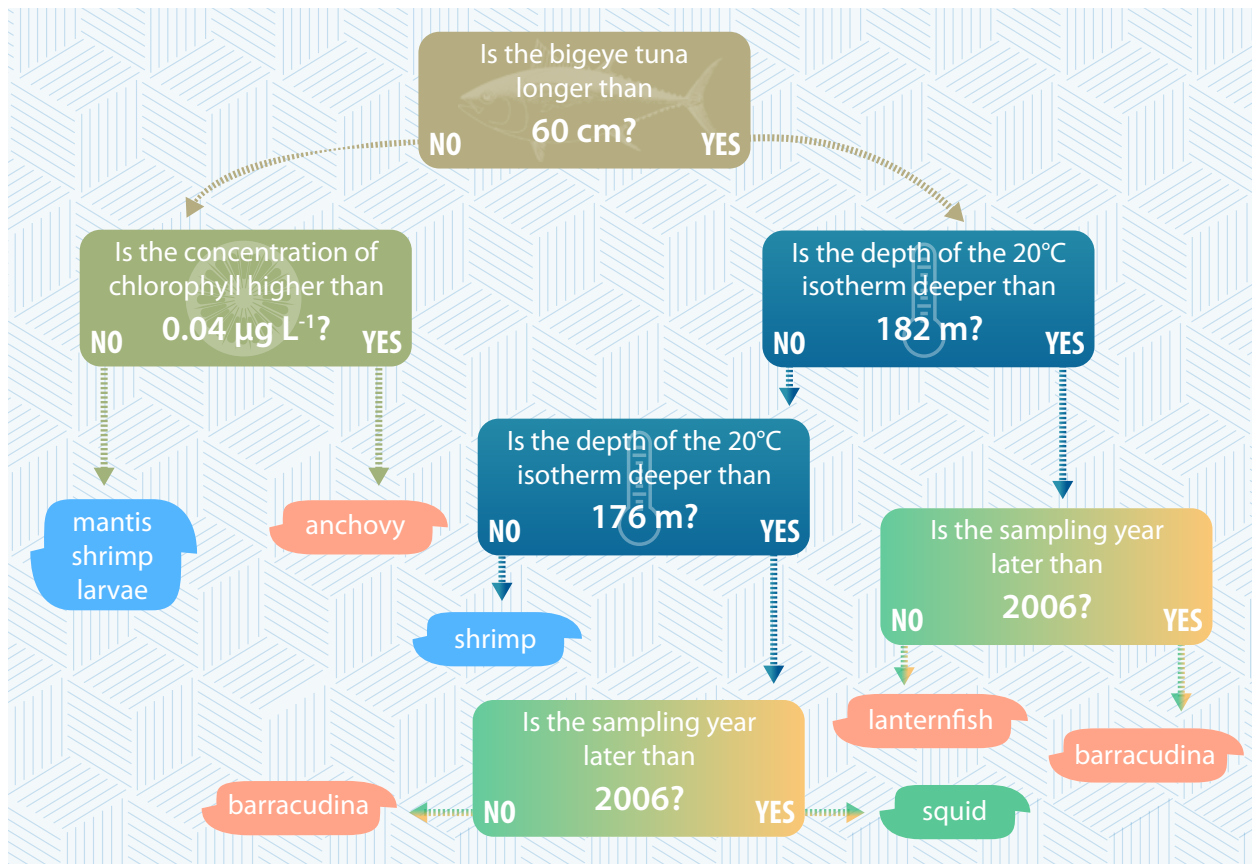


Figure 5. Representation of the classification tree ordering the bigeye tuna predators according to their diet, and identifying the basic environmental factors that influence the classification.

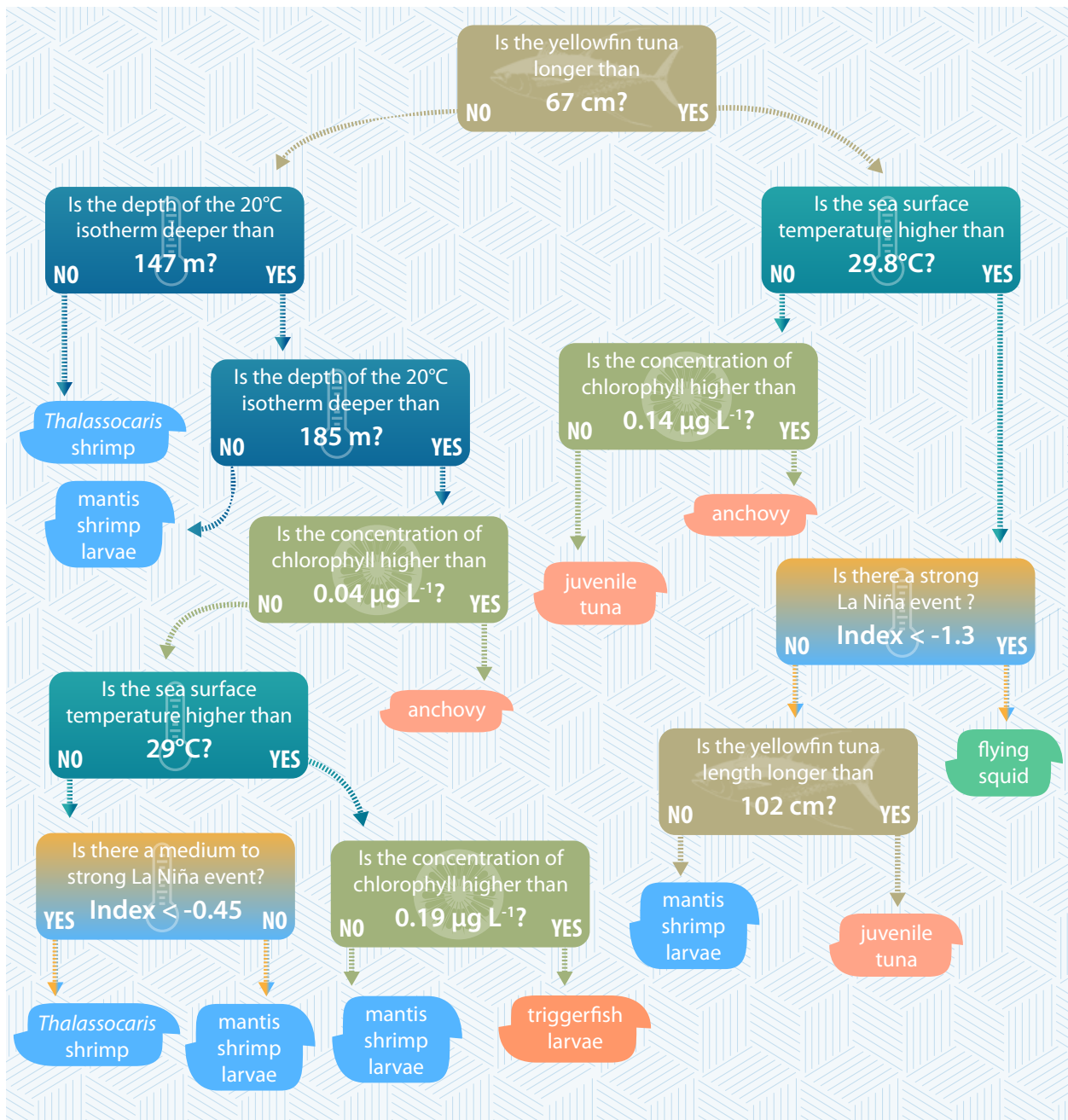


Figure 6. Representation of the classification tree ordering the yellowfin tuna predators according to their diet and identifying the basic environmental factors influencing the classification.

the diet in weight) and crab (*Brachyuran megalopa* ~15%), but also on small 1–2 cm long *Thalassocaris* shrimps (~10%) (Fig.7). Yellowfin tuna also feed on triggerfish larvae (Balistidae ~10%), oceanic anchovies (Engraulidae ~5%) and flying squids (Ommastrephidae ~5%). Of the 627 yellowfin tuna that were larger than 67 cm, all had fed on a wider diversity of prey, with a preference for fish, particularly juvenile tunas (Scombridae ~10%), triggerfish larvae (~10%), oceanic anchovies (~10%), flying squids (~10%), mantis shrimp (~5%) and crab (~5%) larvae (Fig. 7). The 70 bigeye tuna examined that were smaller than 60 cm demonstrate the same appetite as small yellowfin tuna for crustaceans, feeding primarily on mantis shrimp larvae (~35%),

Thalassocaris shrimp (~15%), shrimp (~5%) and 1–2 cm long *Phrosina* crustaceans (~5%) (Fig. 7). They had also fed also on oceanic anchovies (~10%) and small flying squids (~10%). The 384 bigeye tuna larger than 60 cm had a more diverse diet than the small bigeye and fed preferentially on deepsea fish such as barracudina (Paralepididae ~20%), lanternfish (Myctophidae ~10%), pomfrets (Bramidae ~5%) and lancetfish (Alepisauridae ~5%) (Fig. 7). They had also consumed shrimp (~10%) and flying squids (~5%).

The difference in food composition and prey diversity between small and large tunas is explained by the fact that they do not occupy the same vertical habitats: large tuna are

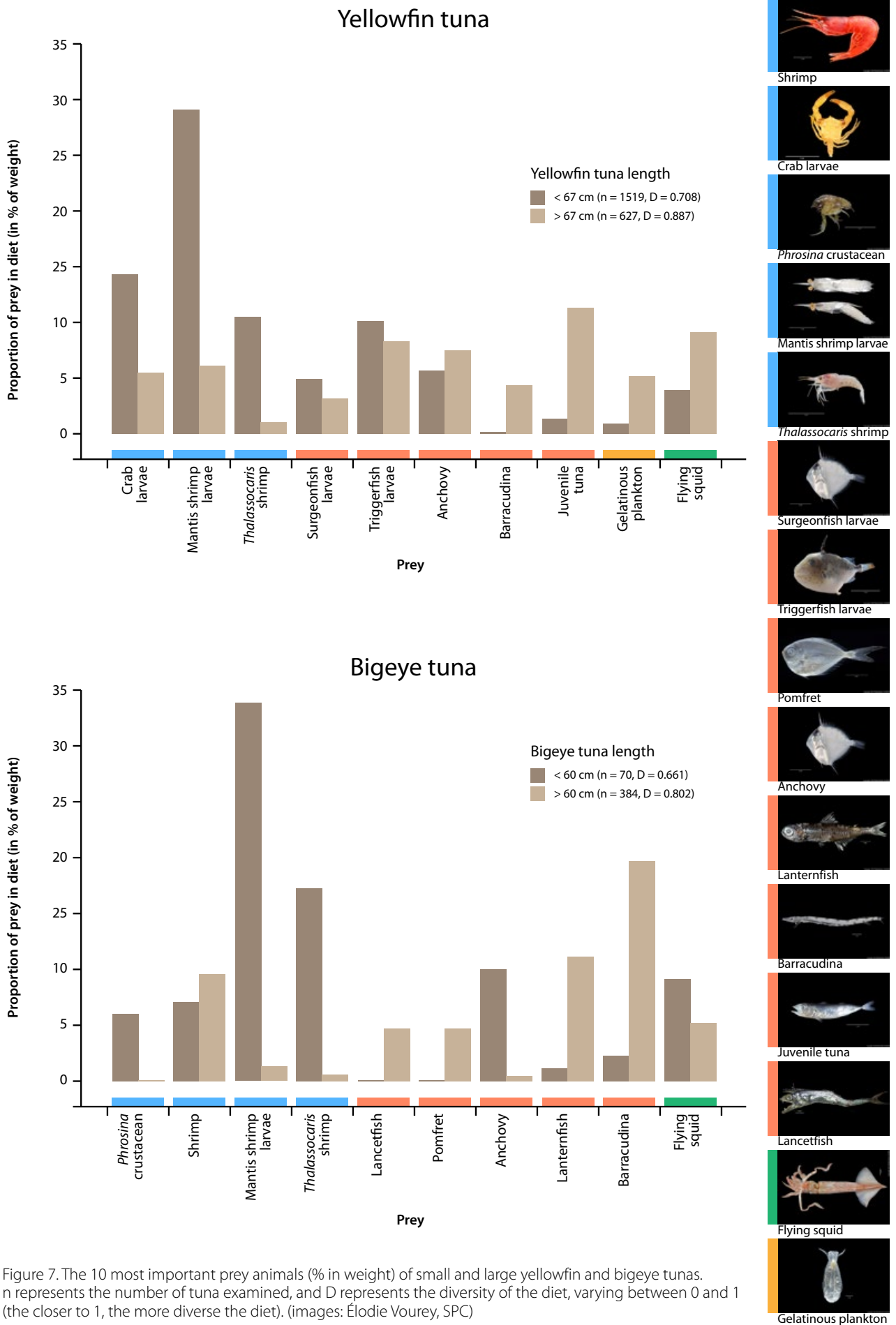


Figure 7. The 10 most important prey animals (% in weight) of small and large yellowfin and bigeye tunas. n represents the number of tuna examined, and D represents the diversity of the diet, varying between 0 and 1 (the closer to 1, the more diverse the diet). (images: Élodie Vourey, SPC)

able to access deeper and larger prey while small tuna are limited to surface waters.

Moreover, the statistical analysis indicates that specimens are grouped together (meaning they have a similar diet), according to the depth of the 20°C isotherm. The 20°C isotherm is a line on a map connecting all of the locations and depths where the sea temperature is at 20°C. This value is used as a proxy for the thermocline, which is the depth where surface waters that are mixed and have the same temperature are separated from deeper waters where the temperature decreases with depth. Exchanges between waters above and below the thermocline are very limited and tend to create two separate habitats. Our results indicate that when the depth of the 20°C isotherm, or thermocline, is deep (>180 m depth), tuna, in particular bigeye, have access to deeper prey items and their diet looks different from tuna that live in waters where the thermocline is closer to the surface. A shallow thermocline limits the vertical habitat of the tunas that only access surface preys, while a deep thermocline allows tunas to expand their feeding range to deeper habitats.

Our primary goal for this study was to investigate whether there was a change in the diet of tunas over time that could be linked to climate change. However, no particular year emerged as a major factor contributing to diet variability. For example, the main prey of bigeye tuna in the equatorial zone was squids (Teuthida) between 2001 and 2006, but changed to barracudina after 2006. We believe that this result may be linked to ENSO, the major climatic phenomenon in the region. The analysis of the yellowfin tuna diet also indicates an impact of ENSO; the main prey of large yellowfin tuna is the flying squid during La Niña periods, but changes to mantis shrimp larvae and juvenile tunas outside this period.

Other environmental factors that can influence the diet of tunas are sea surface temperature and the concentration of chlorophyll-*a*, which indicates the level of phytoplankton, the first component at the bottom of the food web that allows the development of the whole ecosystem.

Our study covers a vast area of ocean with diverse ecosystems, where environmental conditions vary considerably. Tuna in this environment face very diverse climatic conditions and will opportunistically feed on whatever prey is available to them. Their diet varies a great deal and there are many external factors that influence this variability. The system is complex, and it is difficult to interpret complex phenomenon in a simplistic way. Moreover, even if we were lucky to access a fantastic dataset of tuna diet content, we

realised that collecting samples opportunistically does not always allow detailed analyses to be conducted. Filling the gap of knowledge we have on tuna prey (also called micronekton) would also help to interpret changes in tuna diet and determine if tuna diet changes because of changes in the available food within the low and mid-trophic levels of ecosystems, or if tuna diets change due to modifications of tuna behaviour.

The results presented here only relate to a portion of the data collected: there are still many stomach samples in the Marine Specimen Tissue Bank waiting to be examined, and biological sampling by fisheries observer programmes in the region continues. To try to determine when climate change will impact the tuna ecosystem to the point that it shifts³ would require a better sampling design to limit the biases in the analyses (e.g. samples collected from the same place every year). Obtaining fisheries independent data of tuna prey (micronekton) to describe which species are available to predators is also crucial to help understand changes in the ecosystem. Using acoustical data to determine the quantities of micronekton and their spatial distribution, and nets to collect samples of micronekton to determine their diversity and understand their biology, contributes to filling the gap in knowledge on micronekton and better understanding the relationships between tunas and their environment. The BIOPELAGOS⁴ project (BEST 2.0 programme funded by the European Union) – implemented jointly by SPC and the French Institute for Research and Development (IRD) – contributes to fill the gap of knowledge on micronekton with acoustic and net sampling during scientific campaigns in New Caledonia and Wallis and Futuna, and results of those voyages will be available in 2019 at the end of the project.

Finally, besides climate change, it would also be important to study human-caused pressures, particularly the impact of plastics on marine communities, as the examination of tuna stomachs showed that these affect pelagic species.

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³ In ecology, regime shifts are large, abrupt, persistent changes in the structure and function of a system (source: Wikipedia).

⁴ See : <http://purl.org/spc/digilib/doc/oo5pn> and <http://purl.org/spc/digilib/doc/j6i4i>;