A young scientist studies marine biodiversity of the open ocean

A few months ago, Aurore Receveur began work on her doctoral thesis, which was designed to study the biodiversity of pelagic ecosystems in the southwestern Pacific. She is carrying out her study within the Fisheries and Ecosystem Monitoring and Analysis Section of the Pacific Community's (SPC) Oceanic Fisheries Programme, and the French National Research Institute for Sustainable Development (IRD) in Noumea, New Caledonia, as part of the Biopelagos Project. This work supports SPC's commitment to encouraging young people, particularly young women, to engage in careers in science and technology. This article, written by Aurore, explains her work's background and the various avenues of research being developed.

Biopelagos Project

Pressures on pelagic ecosystems caused by human activities (e.g. resource overuse, global warming, pollution, biodiversity erosion) are rapidly increasing. They affect the composition of marine organism communities and, via trophic interactions between species, the dynamics and functioning of marine ecosystems (González Carman et al. 2016; Irigoien et al. 2014). Analysing the various biological components of such food webs would provide a better understanding of how marine communities are organised and their dynamics and, in that way, make it possible to study responses to the threats and disturbances that those ecosystems are facing.

This realisation gave rise to the Biopelagos Project, whose overall goal is to gain a better understanding of the diversity and structure of the pelagic ecosystems in New Caledonia and Wallis and Futuna. This European-Union-funded project (BEST 2.0 programme) is designed to provide decision-making support to both territories, with a view to ensuring better biodiversity and pelagic ecosystem management. The project, which began in June 2016, has been implemented through a partnership between SPC and IRD-Noumea, and is scheduled to end in June 2019. The project includes a section on acquiring new knowledge via surveys at sea, tagging marine birds, and genetics; a capacity-building component with, in particular, student training, including my thesis; and a knowledge summary and feedback component. This article explains the work to be done over the next three years as part of my thesis.

Micronekton

Micronekton are a vital part of marine ecosystems because they serve as food for top-level predators and, in that way, form the link between the physical environment and higher-level organisms in the food chain, such as tuna and seabirds (Fig. 1) (Bertrand et al. 2002). Micronekton are composed of organisms that can swim (e.g. small fish, crustaceans and molluscs) and are less than 20 cm long.

Currently, very little information exists about micronekton and their interactions with predators. So, it is vital to study the role these organisms play in open-ocean marine ecosystems so as to understand the distribution of top-level marine predators such as mammals (whales, dolphins), seabirds and tunas.

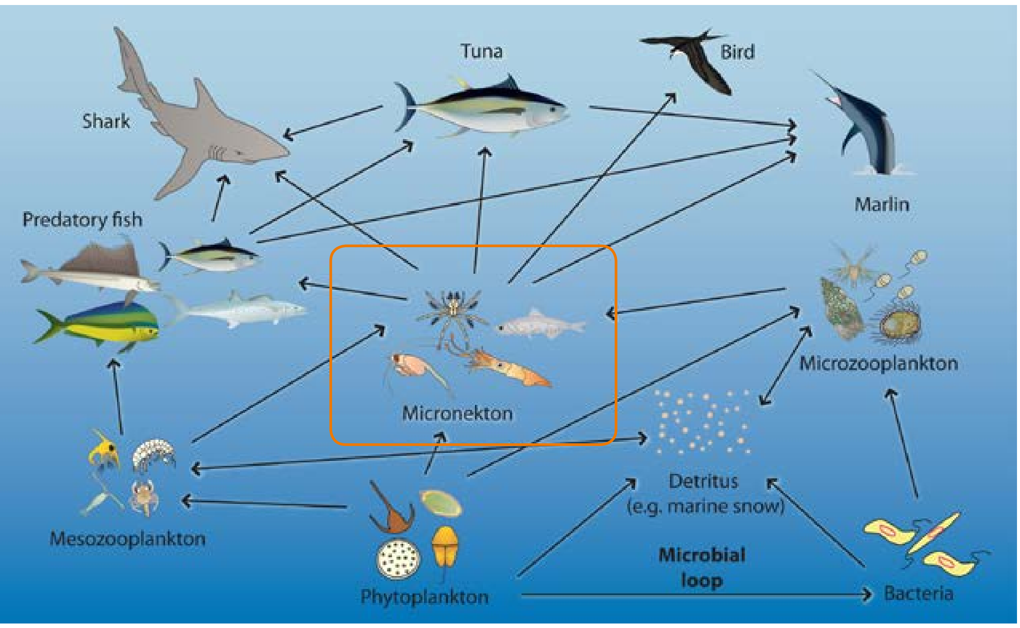

Figure 1. Diagram of the pelagic ecosystem with the micronekton compartment in the orange box (illustration: Jipé LeBars, SPC).

Given the key role this trophic group plays in the food chain, it is necessary to increase our knowledge about it, first by better describing micronekton distribution and diversity. The second part of this study will focus on the link between micronekton distribution and that of top-level predators (e.g. tuna, seabirds and whales). The final part will be spent producing decision-making tools to assist governments; for example, biodiversity maps that could help identify zones where priority should be given to management and protection efforts.

Compiling existing data on pelagic ecosystems

Since 2011, IRD and SPC have been conducting surveys at sea in New Caledonia's exclusive economic zone (EEZ) in order to study micronekton. These surveys have already been reported on in previous issues of the *SPC Fisheries Newsletter* (Allain 2011; Allain and Menkes 2015; Allain and Vourey 2017), but presently, no overall examination of all the surveys has been done. So, my first job will be to compare all of the data gathered since 2011.

The survey routes and periods were selected to optimise grid-wise searches of the EEZ and to cover the various seasons (hot and cool) (Fig. 2). In 2018, a survey at sea will also be carried out in Wallis and Futuna. All of these surveys will be conducted onboard the F/V Alis, IRD's research vessel (Fig. 2 – top), and will collect a wide range of data on micronekton and local oceanographic conditions.

1. Micronekton diversity and distribution

Because this trophic level is still poorly known, the goal is to characterise both micronekton distribution and its diversity. In order to study micronekton diversity, organisms need to be sampled using a pelagic trawl (Fig. 3 – left). The net is positioned at a certain depth in the water column and dragged behind the ship for about 30 minutes. The net is then brought back onboard and the specimens caught are collected and identified (Fig. 3 – right). Figure 3 shows a diverse range of organisms brought up by a trawl net.

An echo sounder is used to characterise micronekton distribution. The echo sounder is located under the ship's hull and sends sound waves into the water column (Fig. 4). Those waves reflect all objects whose density differs from the water's (e.g. living organisms or the seafloor). Through the time needed for the wave to come back to the boat and the reflected acoustic intensity, the position of the

Survey	Year	Season	Colour
Nectalis 1	2011	winter	
Nectalis 2	2011	summer	
Nectalis 3	2014	winter	
ESSCHA	2015	winter	
Nectalis 4	2015	winter	
Nectalis 5	2016	summer	
Puffalis 1	2017	summer	

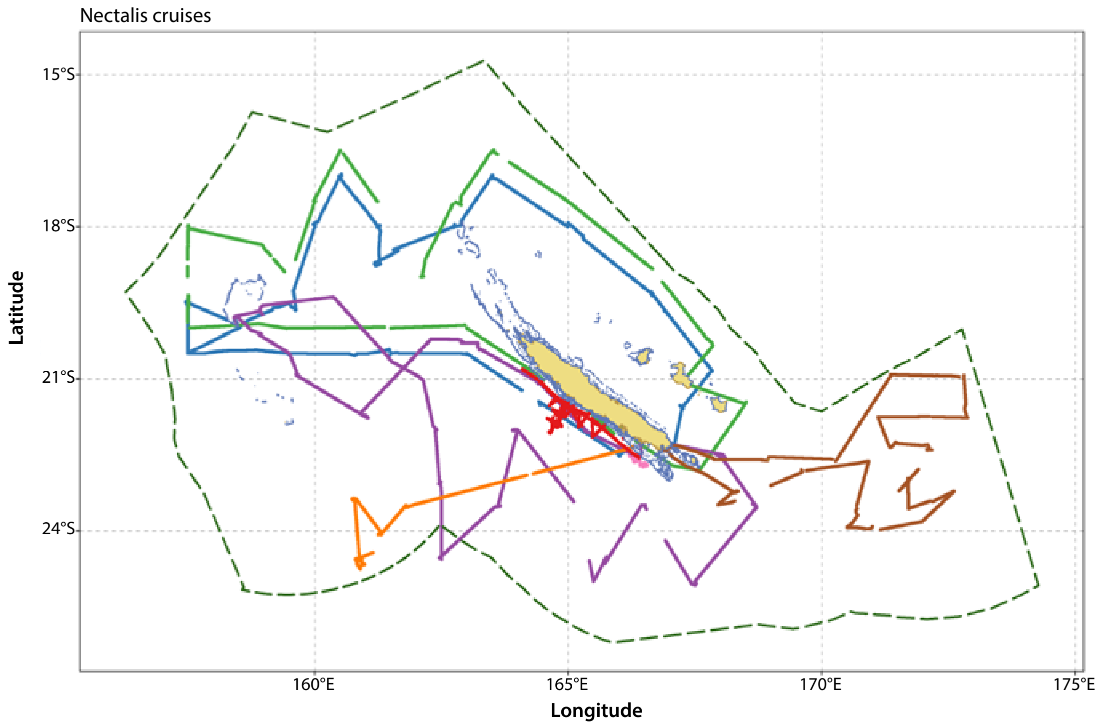

Figure 2. Sampling campaigns with, on the top left, a summary chart; on the top right a photo of RV *Alis*, IRD's research vessel; and below a map of the routes within New Caledonia's exclusive economic zone.

Figure 3. Micronekton sampling with, at left, the pelagic trawl used on the RV *Alis* and, at right, a micronekton sample with deep-sea fish, shrimp and a squid (images: Valérie Allain, SPC).

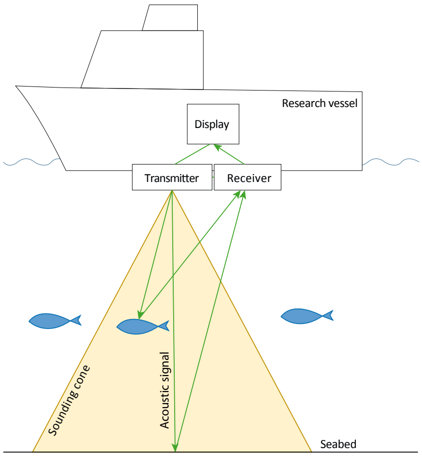

Figure 4. Illustration of an echo sounder and its search cone in the water column (illustration: Aurore Receveur, SPC).

object detected in the water column can be determined and its volume estimated. By choosing the frequency sent out by the echo sounder, it is possible to target organisms that correspond to micronekton. The data are shown on the echogram, which displays the intensity of the objects detected by sound, based on depth and time (Fig. 5). The echogram shows higher acoustic intensity at the surface (0–100 m) at night, and higher acoustic intensity deeper down (500–700 m) during the day. During the day–night transitions, the layers of high acoustic intensity move vertically in the water column. These vertical day–night migrations have been reported and described in the literature. One of the objectives of my thesis is to study the vertical migrations more in-depth, by calculating, for example, the speed of ascent or descent of these migrations, and characterising the layers in comparison to the data from the trawl net.

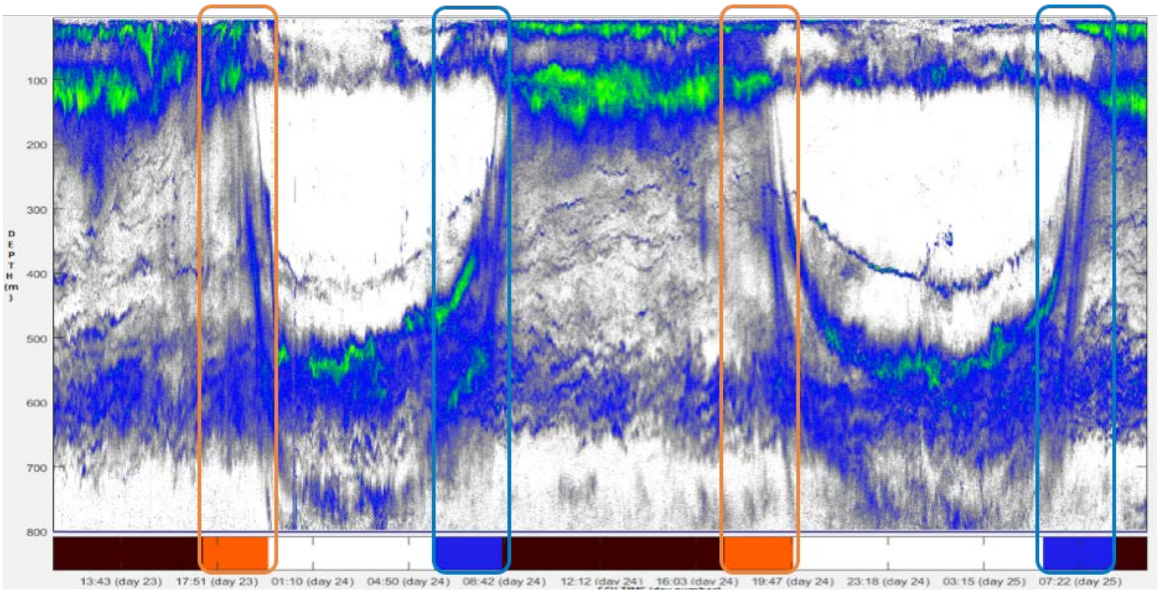

Figure 5. Two days of acoustic recordings called an echogram. On this echogram, the horizontal axis stands for time and the vertical one for depth from the surface (top) to 800 metres (bottom). The colours on the echogram show the acoustic intensity: green for very high acoustic intensity, blue for medium acoustic intensity and white for very low acoustic intensity. And the colour bar underneath the echogram shows the time of day: black for night, orange for sunrise, white for day and blue for sunset. Transition phases are encircled by their respective colours (image: Aurore Receveur, SPC).

After looking at the vertical distribution of the micronekton, I will look at its horizontal distribution. To do that, I will average the acoustic intensity over the water column and look at how that average is distributed over the EEZ (Fig. 6 – top). It is possible to extrapolate that figure over a regular grid to gain an understanding of micronekton distribution throughout the EEZ (Fig. 6 – bottom). Initial observations have already clearly shown a north–south difference with, on average, more micronekton in the south. It will be interesting to see if there are micronekton concentrations around seamounts (Morato et al. 2010) or if distribution changes according to season. In order to be able to more accurately predict distribution in the EEZ, it will have to be studied in relation to environmental factors.

2. Physical oceanography

The surveys' second objective is to link acoustical information to oceanographic data. The main interest of establishing a relationship between micronekton and its physical environment is to be able to extrapolate micronekton distribution in those zones for which we only have data on the environment. If we could correlate mikronekton abundance to environmental factors, then we should be able to predict mikronekton abundance using oceanographic data that is available via models or satellite imagery. During the surveys at sea, oceanographic data are collected via probes on a rosette – a device used for water sampling in deep water (Fig. 7). The rosette also collects water at different depths when it descends into the water column in order to describe water chemistry and phytoplankton. Those data provide information on the vertical oceanographic structure, such as temperature, salinity, oxygen levels or fluorescence profile. By comparing those physical oceanographic profiles to the vertical profiles for micronekton, it will be possible to learn which environmental variables control the vertical distribution of micronekton. We also have access to model and satellite data, which have the advantage of covering the entire zone evenly and so, will be useful for extrapolation.

3. Top-level predators

The third section of the project will involve joint analysis of prey distribution together with the distribution of top-level predators that come to feed on those prey. The ultimate goal is to quantify the degree to which food availability affects the distribution of three groups of predators: tunas, whales and seabirds. The information available for each group differs.

For tuna, I will use catch-per-unit-effort data as an abundance index. Onboard observer data will also be used for the bycatch diversity aspect. In those zones where fisheries data are limited, such as Wallis and Futuna's EEZ, I will use the SEAPODYM model (Lehodey et al. 2008; Receveur et al. 2016), which makes it possible to predict tuna abundance in a given zone based on the environment.

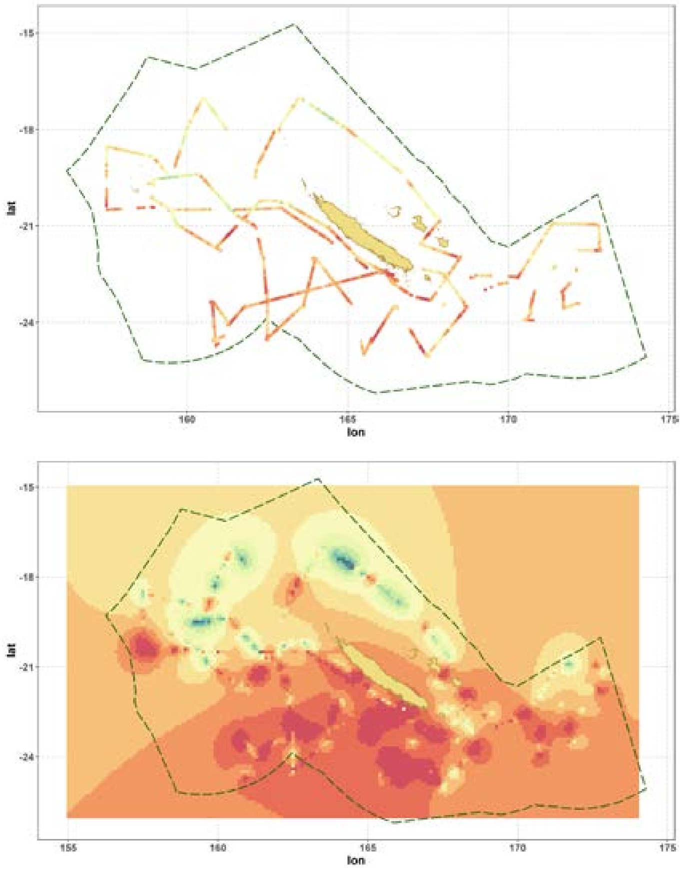

Figure 6. Average acoustic intensity of micronekton in the water column along the routes of all the surveys in New Caledonia's EEZ (top) and extrapolation over a regular grid for the EEZ as a whole (bottom). Blue shows low quantities of micronekton and red high quantities.

Figure 7. The rosette used on the RV *Alis* for water sampling (image: Florian de Boissieu, IRD).

For whales, in 2014 the French Marine Protected Areas Agency (now called the French Biodiversity Agency) funded a flyover of the two EEZs (Fig. 8) in order to do a marine mammal census (Laran et al. 2016) conducted by the PELAGIS Observatory, under the umbrella of the French National Center for Scientific Research (CNRS) and the University of La Rochelle. That campaign (REMMOA) led to the production of maps showing relative abundance in both EEZs (Fig. 9) that I will use.

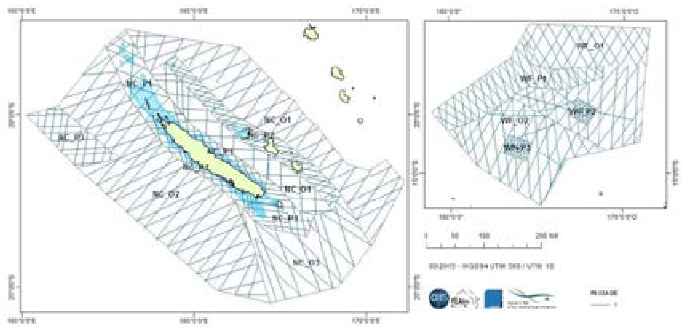

Figure 8. Sampling plan of the flyover for the REMMOA expedition (2014) in New Caledonia (left) and Wallis and Futuna (right) for observing whales, large pelagic organisms and seabirds (figure reproduced from Laran et al. 2016).

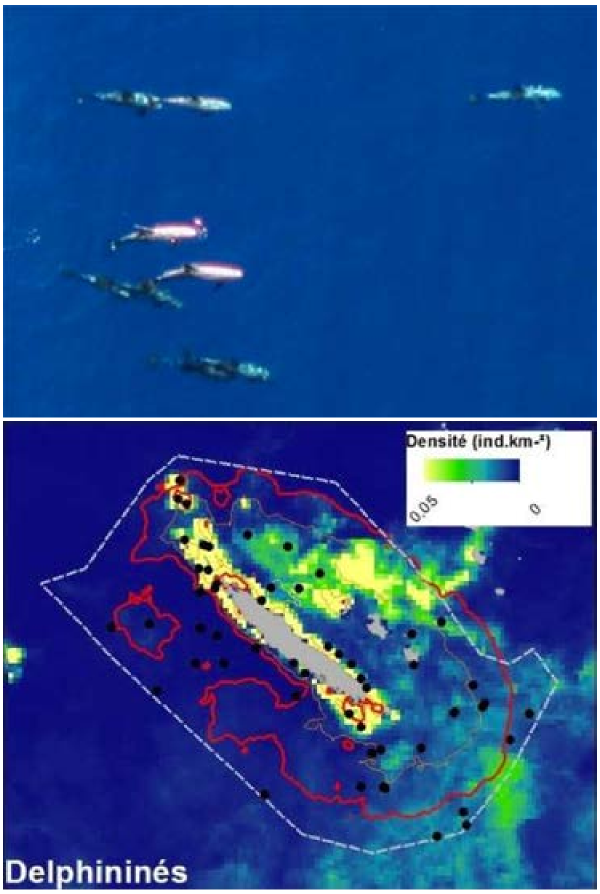

Figure 9. An example of a Risso's dolphin observation recorded during the REMMOA expedition (top) and an abundance map produced with all the observations made for Delphininae (bottom), with heavy abundances in yellow and low ones in blue (figure reproduced from Laran et al. 2016).

Finally, seabirds also eat micronekton. Given that their way of getting around and their feeding strategies differ greatly from other marine predators, it is supposed that the distribution of their prey has a different effect on seabirds. It is more complicated to make abundance estimates for seabirds; therefore, their behaviour will be studied via a GPS tracking unit. For the moment, efforts are focused on the wedge-tailed shearwater (*Ardenna pacifica*), and a team of IRD scientists have attached GPS units to these birds (Fig. 10).

During their breeding period, seabirds return to land on a regular basis (every one to five days) to feed their chicks. So, it is quite simple to find the birds that have been equipped with the GPS units and recover the equipment units and valuable data recorded on them (e.g. the bird's position, altitude and speed). Initial data indicate that some seabirds stay close to their colonies (Fig. 11, orange route), while other seabirds leave for several days to travel to the west and northeast of New Caledonia (Fig. 11, blue and green routes). Currently, about 50 seabirds have been been fitted with GPS units.

Figure 10. Photos of a shearwater and the GPS unit glued to the animal in the Pindai colony in New Caledonia (images: Karen Bourgeois)

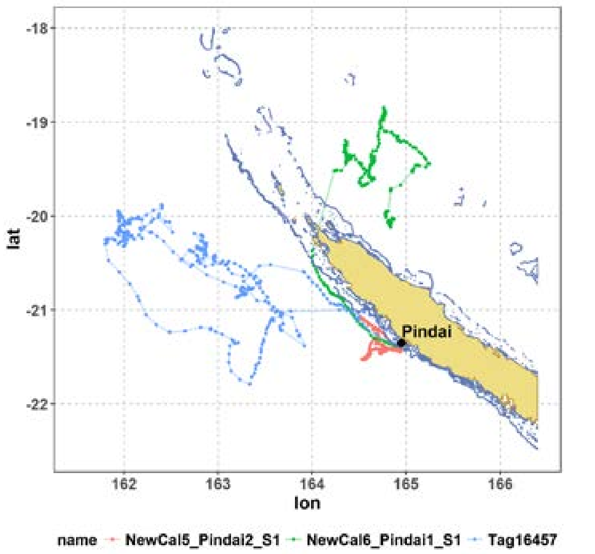

Figure 11. Example of three shearwater flight paths over New Caledonia's EEZ.

Micronekton abundance maps (Fig. 6 – bottom) will be compared to the distributions of top-level predators or with seabird feeding zones. Among other things, this will make it possible to identify biodiversity hotspots, which could assist in selecting new marine protected areas or to better manage fishing boats in those areas.

Finally, the goal is to describe the vertical and horizontal distributions of micronekton in the pelagic ecosystem, and to describe its interactions with other key trophic groups. This study will provide a better picture of the pelagic ecosystem as a whole. The data used and the interactions studied during the project are shown in Figure 12.

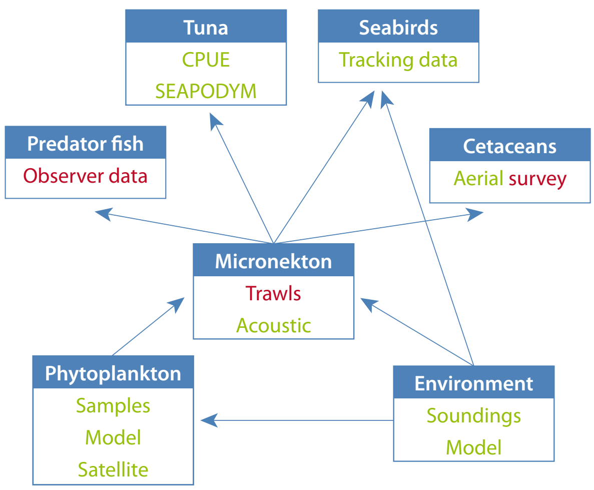

Figure 12. Summary of the data available for the New Caledonia exclusive economic zone study and some of the interactions that will be studied. Data in red will be used to study diversity and data, while those in green will be used to study the distribution and dynamics aspects (note: aerial survey data will serve both purposes).

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