Context of the study

The hydrosystems of tropical islands are generally constituted by young oligotrophic rivers that undergo alternating floods and droughts of varying intensity, linked to alternating wet and dry seasons. These frequent meteorological events, along with an important anthropic pressure, regularly provoke strong decreases in the abundance of the fauna of the rivers going sometimes to the point of extinction. These seasonal hydrological particularities explain why the island rivers of the Indo-Pacific region are home to many species of diadromous organisms. Diadromy is a particular type of migration in which organisms migrate between two radically different biomes (i.e. freshwater vs. ocean) during their life cycle. Amphidromy, on the other hand, characterizes a type of diadromy in which the change of biomes is independent of the reproductive event. Amphidromy is thus particularly adapted to tropical island rivers because these organisms are the only ones capable of naturally colonizing or re-colonizing rivers via post-larvae that return to the rivers after a marine dispersal phase, which has protected them from the climatic hazards experienced in rivers. Thus, the persistence of these species on an insular and/or regional scale depends on the exchanges between the spawning areas in the river and the growth area at sea, exchanges which are based on the dispersive larval stages. Nevertheless, these larvae will undergo the stochastic processes inherent to the marine environment within which they disperse for a few weeks to a few months before returning to colonize the rivers. This environmental stochasticity induces variability in larval recruitment, both in terms of abundances and age, weight, and size at recruitment (Teichert et al, 2016; Thomas et al, 2018).

The species targeted by this study are the amphidromous gobies: *Sicyopterus lagocephalus*, a wide-range species distributed throughout the Indo-Pacific basin, which is found in sympatry in Reunion with *Cotylopus acutipinnis*, endemic to the Mascarene Archipelago, in Mayotte with *Cotylopus rubripinnis*, endemic to the Comoros Archipelago, and in Tahiti with *Sicyopterus pugnans*, endemic to Polynesia. The life cycles of these 4 species are similar: spawning takes place in rivers; pro-larvae hatch from the eggs and drift to the sea in a few hours; at sea, they develop into marine larvae and are carried away by the currents for a few months before colonizing rivers at the post-larval stage during the recruitment stage; they then metamorphose into juveniles and grow up in the rivers where they reach the adult stage.

In these regions of the Indo-Pacific basin, the faunal biodiversity of the rivers relies mainly on these amphidromous gobies. However, these species are subject to various stresses, both anthropogenic (pollution of rivers, fragmentation of their habitat, fisheries) and environmental (climate in the context of global change, volcanic with, for example, the subsidence of the island of Mayotte which is sinking into the Indian Ocean due to the siphoning of the magma pocket underlying the island, which feeds the formation of an underwater volcano located further offshore) likely to weaken the stocks and compromise the persistence of these species, in particular the endemic ones. It is therefore crucial to study and understand the dynamics of these populations with such a complex life cycle, and in particular their migration trajectories which depend essentially, if not exclusively, on marine currents and other physical factors influencing larval dispersion.

Objectives of the project

This project is structured around 3 axes, based on multidisciplinary approaches and innovative and original techniques. These three axes aim, together, to determine the origin of post-larvae that recruit in the rivers of the three islands during the two austral seasons and to study the influence of physical forcing on their marine dispersion during the larval phase. This is a multidisciplinary study based on (1) an ecology axis targeting the population dynamics of the four species of interest, (2) a hydrodynamic modeling axis that will allow to investigate the possible migration trajectories, at sea, of the larvae of the four species, according to the spawning periods and the rivers where the post-larvae recruit, and (3) a microchemical analysis of the otolith material, which will allow, by identifying the composition in elements and trace elements of the otolith, to elucidate the origin of the larvae and to validate, among the possible migration trajectories, those which seem the most probable regarding the material included into the otolith.

1st axis: Spatio-temporal variability of post-larval recruitment (supervised by Céline Ellien)

Through this axis, we plan to study and compare the life-history traits of post-larvae recruitment for the four species of amphidromous gobies, between the three islands and the two seasons (southern summer and winter). The rivers are selected according to their geographical location on the windward or leeward coast, the leeward coast being characterized by a drier climate than the windward coast. This will give us a first answer to verify if the recruitment traits vary according to the shoreline facies. Sampling will be done on a seasonal basis in Mayotte. In Reunion Island, post-larvae of the two species of gobies found in Mascarene archipelago, will be provided by the Observatory of Migratory Flows (DYNAPOP project, in which the main supervisor of the thesis participates as a member of the scientific and technical committee and as the main scientific collaborator), in the framework of which monthly sampling is planned, at the mouths of the rivers. In Tahiti, monthly sampling at river mouths is planned as part of the "Ina'a" project (title: Fishing for gobiid post-larvae in French Polynesia: the case of the ina'a fishery on the island of Tahiti) in which the main supervisor is participating as a workpackage PI. Each sample will include 50 individuals, which will be weighed and measured. Their age will be estimated by otolithometry. Otoliths are calcareous concretions in the inner ear of teleost, composed of layers of aragonite and proteins deposited at a daily frequency during the larval stage. Knowing that the nucleus is already present in the egg, the number of increments indicates the age of the post-larva at the time of its capture, and thus the duration of its marine dispersion (PLD for Planktonic Larval Duration).

2nd axis: Hydrodynamic modeling (Stéphane Pous/Céline Ellien)

During their marine phase, larvae depend on marine currents, to which they are unable to resist. These hydrodynamic currents condition the structure and dynamics of these particular species. A hydrodynamic modeling study, integrating the date of spawning estimated by otolithometry, and the location of recruitment (i.e. rivers where the post-larvae were sampled) will allow to identify the possible migration trajectories, according to the currents and other physical forcing undergone by the larvae along their dispersion pathways. For this axis, we will use the GLORYS ocean reanalysis, derived from the NEMO model, which provides a time series of ocean properties. To model larval dispersal, the individual-based model ICHTHYOP will be used to compute the probable migration trajectories, from the results of the GLORYS reanalysis. This Lagrangian model is a relevant and powerful tool to test the hypotheses of a structuration of *S. lagocephalus* populations into metapopulations, and to identify source and sink populations, knowing that a population genetics study has highlighted possible migrant flows between Reunion and Mayotte for this species (Lord et al., 2012). For the Pacific Ocean, we will also be able to follow possible migration paths, between the islands of Polynesia, although our data on PLD will be estimated exclusively from post-larvae collected in Tahiti.

In every case, this modeling tool will allow, on the one hand, to determine the possible geographical origin of the post-larvae, which is an essential preliminary step to the elaboration of adapted conservation plans, and on the other hand to verify to what extent the larvae disperse offshore, or remain in the coastal zone, which can contribute to explain the widespread distribution vs. the endemism of the target species. This type of analysis combining biological data and hydrodynamic modeling has been successfully conducted previously on eels in the Indian Ocean (Pous et al., 2010).

Moreover, we will be able to quantify the relative importance of meteorological and hydrodynamical forcing and biotic factors (dates and locations of spawning, PLD) on larval dispersal.

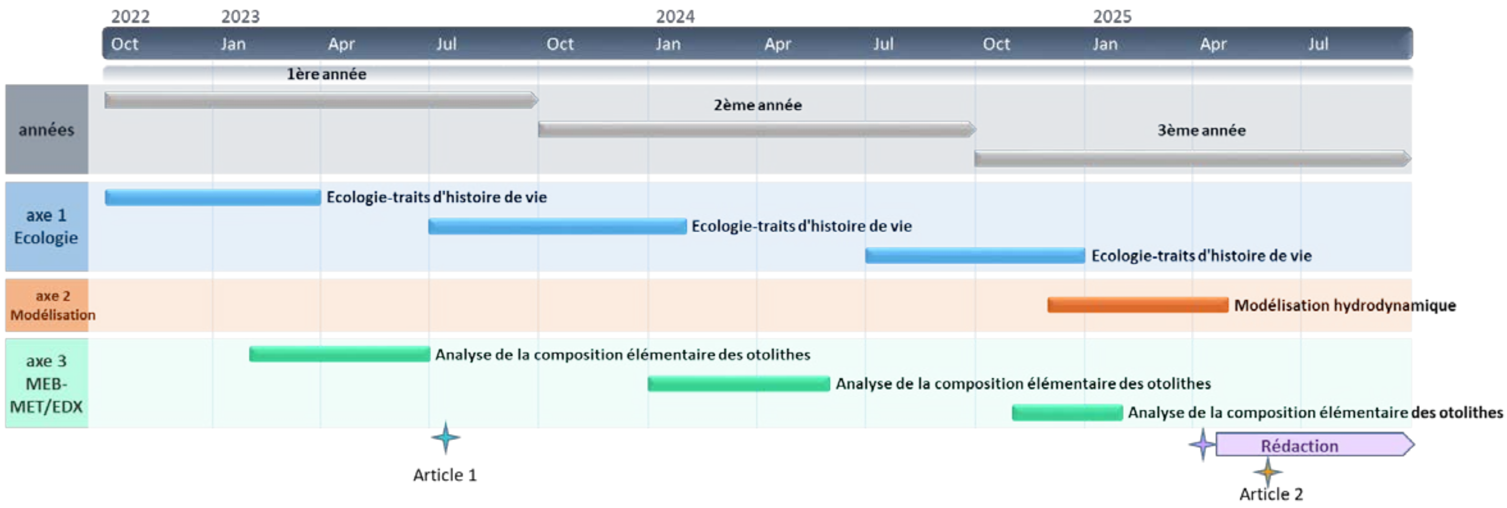
3rd axis: Elemental composition of otoliths (supervised by Cédric Baumier and Charles-Olivier Bacri)

This axis aims at determining the elemental composition of otoliths, from the nucleus to the periphery, in order to elucidate the geographical origin of post-larvae, as well as their migration routes. Using scanning and transmission microscopes, each equipped with EDX detectors (Bacri et al., 2017), we will be able to perform otolith mapping indicating how the different constituent elements are distributed in this biomineral structure. This method should provide clues on the life-history traits of individuals, but also to the elements that teleosts take up from their environment, and include into their bio-mineral structures: do they "passively" integrate all elements present, or are some elements "actively" excluded relative to others? Moreover, by targeting the nucleus, we will be able to determine the elements that are incorporated in this part of the otolith. Formed in the egg, it is likely that the nucleus incorporates elements from its original river. By comparing the elements that will be identified within the otolith with the elemental and trace element composition of the island rivers, in both seasons, we believe we can determine where the sampled post-larvae were spawned. In the same way, the composition of the growth increments should bring information on the possible migration routes of the larvae, and confirm or not those predicted by the hydrodynamical model, by deciding for example between a dispersion of the larvae offshore, or on the contrary, a larval phase that is maintained close to the coasts, leaving the larvae in a mixed influence of fresh water and sea water. Microchemical analyses of otoliths have already proven to be relevant for studying the life history of teleost fishes (Laugier et al., 2015). We are confident that the electron microscopy approach with EDX detectors, which is more powerful than the techniques usually used, will allow a major breakthrough in this type of transdisciplinary studies.

Feasibility:

The post-larvae will be collected monthly at the river mouths of: 1) Reunion Island, within the framework of the DYNAPOP project, financed for 3 years, renewable, as well as 2) at the mouths of Tahiti rivers within the framework of the Ina'a project, financed for 2 years, renewable. Concerning the sampling at the mouths of the rivers of Mayotte and Moheli (Comoros), a funding on long-term projects (SU ITE) as well as funding of projects within the lab of the principal supervisor (UMR BOREA), and from diverse other source, will be requested in order to finance the collection campaigns, on a seasonal basis (2 collections per year). The sampling will be carried out by the engineering office Océa Consult for Reunion and Comoros, and by the engineering office Ichthyo-Pacific for the Tahitian rivers, these two expert office being partners of the scientific projects listed above: the candidate will not have to carry out any field work. The project is therefore undoubtedly feasible in the allocated time.

Annex:


2022
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axe 1 Ecologie
Ecologie-traits d'histoire de vie
Ecologie-traits d'histoire de vie
Ecologie-traits d'histoire de vie
axe 2 Modélisation
Modélisation hydrodynamique
axe 3 MEB-MET/EDX
Analyse de la composition élémentaire des otolithes
Analyse de la composition élémentaire des otolithes
Analyse de la composition élémentaire des otolithes
Article 1
Rédaction
Article 2