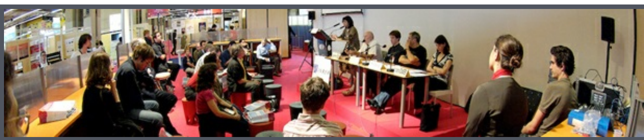
INTERNATIONAL RELATIONS



INTERNSHIP SUBJECT

2892 - Modeling how management policies affect kelp restoration

Context:

With a coastline of 6 435 km and the 11th largest exclusive economic zone, coastal maritime areas are a major concern in Chile. These coastal maritime areas are complex systems, which involve a number of research fields (e.g. oceanography, coastal engineering, marine biology, and socio-ecological dynamics). Hence, understanding and modeling the dynamics of ecosystems in such coastal maritime areas is a challenge, especially from the point of view of ecological preservation.

Noncompliance with harvesting regulations is a global threat that is strongly degrading marine ecosystems and undermining the sustainability of ecological and social dimensions. This challenge is under the umbrella of wicked and complex problems, in which interactions between different dimensions and fields (e.g. biological, economical, environmental, economical, engineering and mathematics) need to be considered. The Chilean Kelp fishery is an excellent study system as play key economical and ecological role.

Chilean kelps are an excellent complex system model as they play an important economic, ecological, and environmental role but are facing strong levels of noncompliance in their harvesting rules. Chile is the main global exporter of kelp raw material from natural populations, which is extracted by over 15 000 artisanal fishers. These fisheries have the largest landings within seaweed fisheries, representing between 55 to 73 percent of the total landings during the last ten years. On the other hand, kelps promote ecosystem biodiversity through the provision of food, refuge and nursing habitat, facilitating the recruitment of many harvested and non-harvested species and building complex networks of interactions.

This internship focuses on modeling the dynamics of kelp, a type of seaweed that can form so-called kelp forests (i.e. underwater areas with a high density of kelp). These kelp forest provide a unique habitat for a wide variety of marine organisms [1]. However, the growth of kelp is very sensitive to the presence of light, nutrients and warm temperatures [1]. Kelp forests are also vulnerable to herbivores (like sea urchins that can feed one them) [2] and to interactions with human, either directly (harvesting of kelp by fishermen) or indirectly (over-fishing of species that are natural predators to herbivores eating kelp) [3]. Hence, finding an optimal strategy to protect kelp forest and/or to favor kelp restoration in damaged areas is a key challenge [4]. Here, we focus on modeling the socio-ecological dynamics of kelp, considering the feedback between decision taking by fishers, the kelp population dynamics, and the network dynamic based on the interactions between kelps and other species (predators, competitors).

Objectives:

With respect to these challenges in kelp forest restoration, this internship proposes to develop a model that includes both the interaction with other marine species and the role of regulation policies. The objective is to help understanding the feedback between these different factors affecting the dynamics of kelp in coastal maritime areas, with a focus on management policies (related to ecological preservation, social and economic sustainability).

Methodology:

We rely here on an Allometric Trophic Network (ATN) model that has been recently used for Kelp dynamics [5,6]. This model describes the evolution in the biomass of a community of interacting species. The various species considered are sorted in terms of kelp and other algae, filter-feeders (which also use plankton and compete with algae for space), herbivores or omnivores (that feed on algae) and predators (that can feed on both herbivores and algae).

The evolution of biomass for each species is then described using a Population Balance-type of model. This means that the biomass for the ith-species, B_i, is described as:

$$dB_i / dt = N_{gain}(B,t) - N_{loss}(B,t)$$

where $N_{gain}(B,t)$ is the amount of biomass gained (e.g. due to reproduction, growth by feeding on nutrients/species) and $N_{loss}(B,t)$ is the amount of biomass loss (e.g. due to death, predation by other species, harvest by fishermen). Since the system is considered an open system, stochastic components are incorporated into its description and the behavior of the fishers

Required Skills

We are looking for candidates with a strong background in applied mathematics (Numerical methods, Numerical simulations, Statistics), marine ecology and /or environmental engineering.

Candidates should be fluent in English, have a good experience in programming.

We will appreciate candidates with the following skills (optional):

- Rigorous, autonomous and creative thinking
- Interest in marine/ecosystem applications.

The student will be encouraged to write a publication in an international journal at the end of the internship.

General Information

- **Research Theme :** Stochastic approaches
- **Locality :** Sophia Antipolis
- **Level :** Master
- **Period :** 1st January 2026 -> 1st April 2026 (3 months)

  ⚠ *These are approximative dates. Please contact the training supervisor to know the precise period.*

- **Deadline to apply :** 1st July 2025 (midnight)

Contacts

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More information

- **Inria Team :** CALISTO
- **Inria Center :** Centre Inria d'Université Côte d'Azur

is parameterized through a Wright–Fisher stochastic process.

In a spirit similar to what has been done recently at Universidad de Valparaíso (UV) and Universidad de Concepción (UdeC), we plan to extend this approach with a stochastic model that accounts for the interaction between fishermen and regulation policies accompanied by financial incentives (i.e. incorporating models for the behavior of fishermen depending on the price of the resource and on the state support/penalties).

Bibliography:

[1] Steneck, R. S., et al. (2002). Environmental conservation, 29(4), 436-459.
[2] Reis, B. et al. (2024). Scientific Reports, 14(1), 31217.
[3] Miller, K. I. et al. (2024). Restoration Ecology, 32(1), e14060.
[4] Eger, A. M. et al. (2022). Biological Reviews, 97(4), 1449-1475.
[5] Ávila-Thieme, M. I. et al. Scientific reports, 11(1), 1765.
[6] Navarrete, S. A. et al. (2023). Philosophical Transactions of the Royal Society B, 378(1881), 20220189.