<u>FILAMO Grant</u> — Connecting Field work and Laboratory experiments to numerical Modelling in a changing marine environment

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<u>Report on my experience</u>

I asked for FILAMO Grant aiming to get hands-on experience with Dynamic Optimization (DO) modelling under the supervision of Dr Christian Jørgensen. Briefly, I could say that this grant and the subsequent two months-long stay have given me the opportunity of getting conceptual background and technical skills to formulate and analyse DO models, a conceptual, theoretical framework of which I had no previous knowledge.

My background before arriving:

My PhD project is closely related to fish behaviour and bioenergetics functioning. I aim to disentangle the mechanistic relationships between (1) behaviour/activity pattern, (2) food assimilation rate, (3) growth and (4) reproductive potential, and to define the technicalities of applying a bioenergetics model (e.g., the Dynamic Energy Budget (DEB) framework) to link behavioural and life history traits (LHTs). For this purpose, I first focused on modelling individual relationships between repeatable movement behaviour (behavioural types; BTs), particularly home range (HR) BTs, and bioenergetics at the individual level. I aimed to understand how individual LHs emerged from bioenergetics rules and behavioural performance, and in addition, how state-variables dynamics may shape back behavioural performance as well.

Then, focusing on these relationships, I aimed to analyse what sort of combinations among behavioural and bio-energetic (or physiological) parameters increased the individual fitness in different scenarios. Hence, from an individual-based approach, I wanted to shift to an eco-evolutionary one. However, from here, I could not have gone ahead without this stay in Bergen. My research group lacked the expertise and knowledge about DO modelling.

Until then, my theoretical-related work so far had focused on the level of the individual (i.e., on the processes connecting individually the behaviour with the LHTs). I developed expertise in DEB modelling and growing proficiency in R programing, Bayesian statistical skills and some abilities in Matlab. However, I still lacked knowledge on eco-evolutionary-related models, in order to be able to evaluate evolutionary trends of behaviour in different environmental-variable scenarios.

What I did and learnt in Bergen:

First, I came to the knowledge base related to the conceptual and mathematical basis of the DO models (i.e., state variables, constraints, decisions, trade-offs, expected lifetime reproductive success, fitness, survivor, dynamic programming and computer implementation). Then, I started struggling with Fortran-language programming and developed my own DO model to my case

study. By the end of the stay, I learnt to include environmental stochasticity to optimize parameters in different selective-dynamic systems, knowledge that I am still developing and improving for the last part of my PhD research project.

The working plan was full of motivating and revealing discussions with different scientists and PhD students. Working in such a network was something inspiring to pick up ideas from different people. Alongside these discussions, the essential reading of Mangel's books and the preliminary analyses of some codes developed by other students gave me the opportunity to discuss my own ideas and implement them in my own code. I can write here some of the followed steps in my learning processes:

- [*First week*] During the first week, we decided that the best option to work with my individual-based model would be to work with an **unscaled version of the DEB-HR (the core of my PhD project)** model, since it would be easier to figure out what patterns (and their meaning) will be expected in ecological terms.

- [*From second to fourth week*] After un-scaling my DEB-HR individual model, I started thinking about how to model survivor. First, I tried to model mortality dependent on length, energy conductance (a DEB parameter), the HR explored area and consequently on movement parameters (from the movement-related HR model). **Defining the survivor functions** for each parameter was not an easy issue and it opened many discussions. Actually, I am still improving these relationships introduced in my DO model.

- [*From second to fourth week*] Then, **exploring the model** by introducing different ranges of the parameters of interest (one by one, in the beginning, and by two or all together by the end) along with the survivor functions.

- [*From second to fourth week*] Those preliminary explorations lead me to find out whether a given parameter could had an unbalanced weight in the total expected reproductive life with respect the others. It also allowed me to realize whether the survivor functions were showing the expected trade-offs for every parameter following our hypothesis and field and laboratory data, or not (and this second situation was the one I had to struggle longtime).

- [*Second month*] By the middle of the stay, connecting together a DEB model, a HR model and a DO model opened doubts about the way I was modelling **encounter rate (ER)**, which defines the velocity of finding either food or predators in a given context when certain movement-related parameters describing the HR behaviour of the animal. Parallel discussions with researchers that I could meet in the workshop "Trait-based Approaches to Ocean Life" helped to improve the survivor functions that eventually are defining fitness.

- [*Second month*] By the end of the stay, I could develop the technicalities to introduce stochasticity in the DO model. At this point, a lot of sensitivity analysis, re-formulation of survivor function and more detailed-exploration of the model are required.

- Right now, since my return, I am going ahead with those steps in Spain.

In addition to the beforehand working plan, I joint two other activities that were enriching academically and contributed to enlarge my knowledge in the modelling field. Aiming to encourage the development of communicative and working bridges between modellers/theorists and experimental/field scientists were their main goals, which, from my point of view, are important topics in the nowadays science. First, the FILAMO workshop entitled "Obstacles in communication between field-, lab- and modelling work" brought me the change of meeting

worldwide researchers working in fieldwork, laboratory experiments and numerical modelling, and discussing together about the common obstacles in communication between these fields. Then, the workshop "Trait-based Approaches to Ocean Life", which focused on trait based approaches to study ocean life as powerful tools for understanding complex dynamic systems, brought me the chance to meet experienced researchers whose work had some cues related with my questions and doubts. Hence, I could take part in group discussions and informal "chalk talks" where I asked for ideas to solve my research issues (part of them arising from my first exploration of the DO model I was working on).

To sum up, the key milestone of the stay (i.e., the implementation of a DO model in my case study) was successfully achieved. It has brought me the required knowledge to be able to work autonomously in the final implementation of the DO model, which I am still developing and improving it through the skills that I learnt in Bergen.

A short conclusion about my experience:

I arrived to Bergen looking for the technicalities that would help me to answer these kind of questions framed in my PhD project:

- *What trade-offs do BTs play in a fisheries selection context?*
- *What would LHTs endpoints be expected in a fisheries behaviour-dependent selection context?*
- *How may evolutionary endpoints change if we consider a behavioural process of vulnerability instead of a simply size-dependent vulnerability process in fisheries?*
- *How does behavioural selection affect evolution, LH and population dynamics? How does selection on behaviour make a difference compared to mere selection on size?*

I have not answered them yet, but now I can go ahead in the search of the answers.

Getting perfect knowledge and proficiency in DO models is a long-way, and I am just in the beginning. However, I developed enough skills to be able to broaden the perspective of my study and jump from an individual-based approach to an eco-evolutionary one. This shift is allowing me to relate behavioural traits (BTs) with bioenergetics within an eco-evolutionary frame, to analyse what sort of combination of BTs and physiology-related parameters defining (all together) the life history (LH) of individuals (or population) could co-evolve together in different variable environments; which I find is an outstanding and amazing ecological question. Besides, this stay has benefit me to integrate a multidisciplinary view in the field of marine ecology, which is an essential paradigm nowadays.

I am thankful of having had this opportunity and I feel fortunate for that. Taking advantage of this short report, I would like to thank all the research team in the Theoretical Ecology Group and particularly to Dr Christian Jørgensen for dedicating part of his time to spread his knowledge and introducing me to this amazing methodological and theoretical world.