Individual Based Modeling of Green Turtle Spatial Dynamics in the Southwest Indian Ocean

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Introduction

Southwest Indian Ocean (SWIO) represents a noteworthy region to study green turtle Chelonia mydas spatial ecology. Indeed, spatial complexity of the region and presence of numerous nesting sites (mostly islands) as well as vast nesting areas (mostly East-Africa and Madagascar) is a unique opportunity to understand the role of space in turtle ecology. For more than twenty years now, a number of effective studies have been conducted locally in major areas. Due to recent progress in wildlife tracking, movements of marine turtles between those sites are starting to be well-documented. Here, we propose an original approach to integrate this knowledge using a spatially explicit individual-based model.

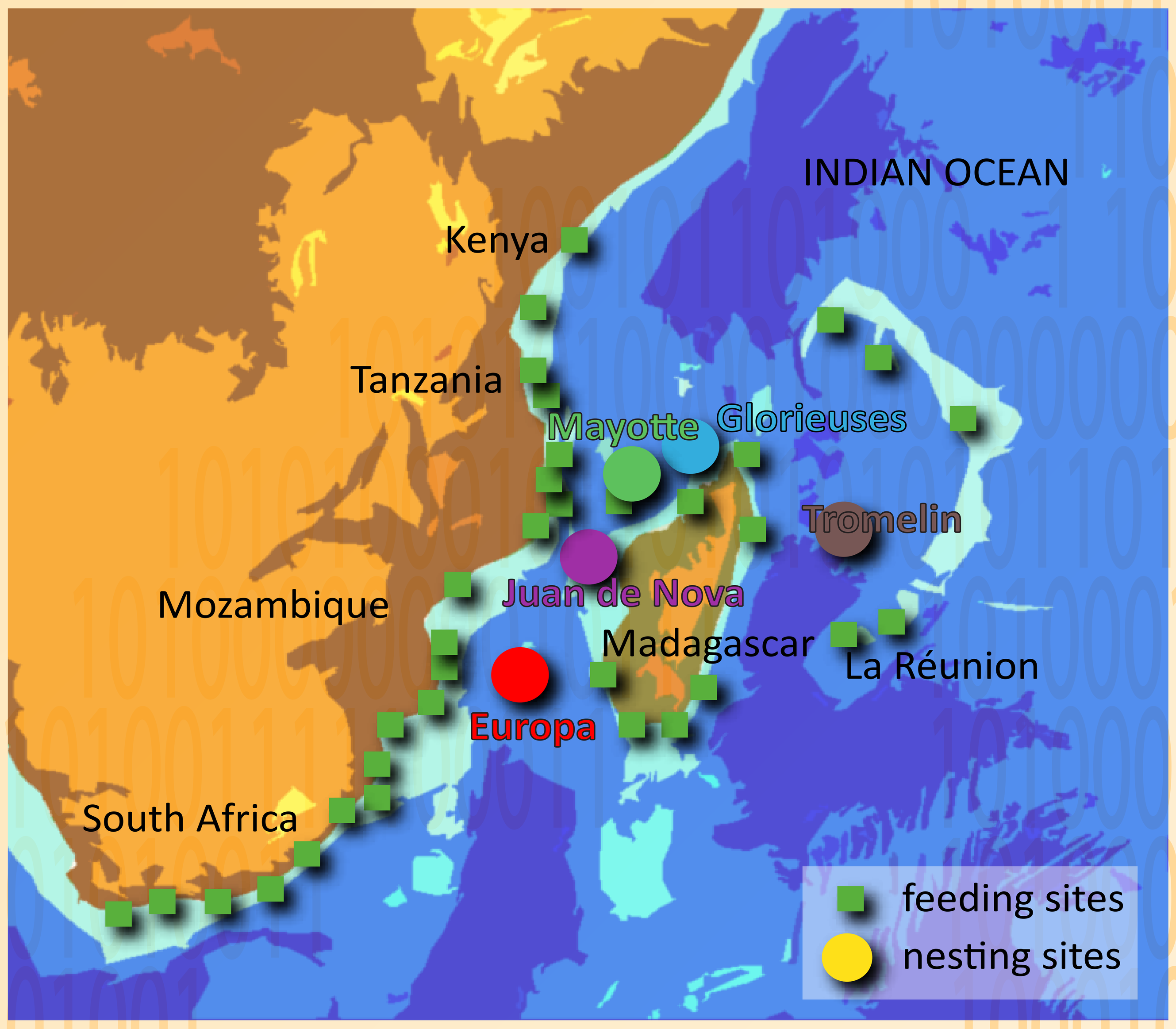

Fig. 1 : Map of the Soutwest Indian Ocean.

Objectives

The main objective of the model is to study the influence of SWIO topology to the reproductive potential of green turtle rookeries. As a matter of fact, spatial arrangement of nesting and feeding areas affects population viability. Proximity and accessibility of feeding sites is likely to favor reproduction by reducing the cost of the migration. On the other side overpopulated feeding sites might delay reproduction event through food competition. Thus, population reproductive potential and therefore viability may be a resulting balance between the accessibility of the sites and the number of individuals that share this site.

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Material and Methods

Individual-based modeling

Individual-based or agent-based models (IBM) generically refer to models that infer the global dynamic of a system by modeling and simulating the constituents of that system. In ecology, IBMs are models that derivate the properties of ecological systems from the properties of the individuals constituting these systems. This "bottom-up" approach allows the understanding of unexplained properties at population scale from a good knowledge of what is happening at individual scale. We used the publicly available platform NetLogo to implement the model.

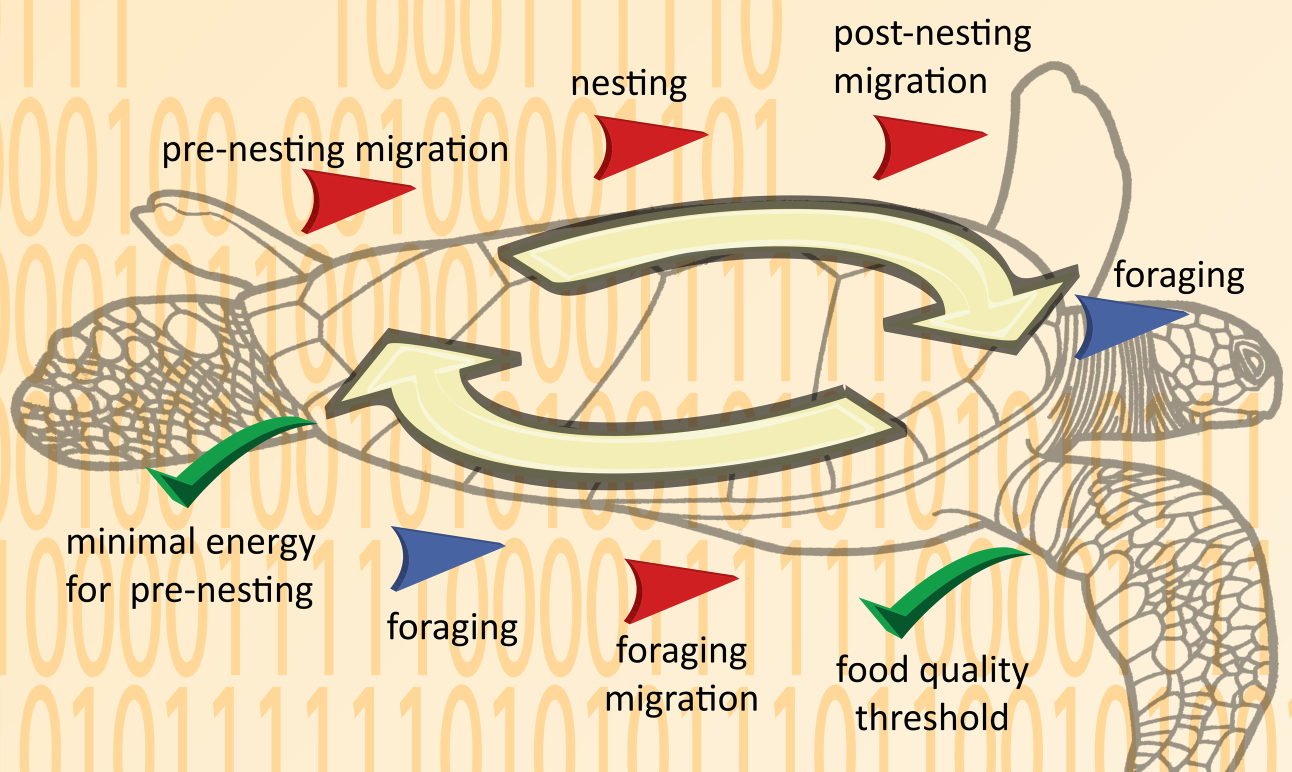

Fig. 2 : Individual energy budget cycle.

Individual cycle

We decided to consider only adult female migration cycle. Every turtle individual owns an energetic level. Similarly feeding sites is associated with a feeding quality. Turtle can intake energy only at feeding site simultaneously affecting the feeding quality of this site. While nesting or migrating every individual expends a relative amount of energy. Three different types of migration are implemented. pre- and post-nesting migrations are go and return movements between a feeding and a nesting site, foraging migration is a movement between two feeding sites. When the energetic level of an individual reaches over a minimum threshold, it starts a pre-nesting migration. When the quality of a feeding site goes under a minimum threshold, the individual starts foraging migration.

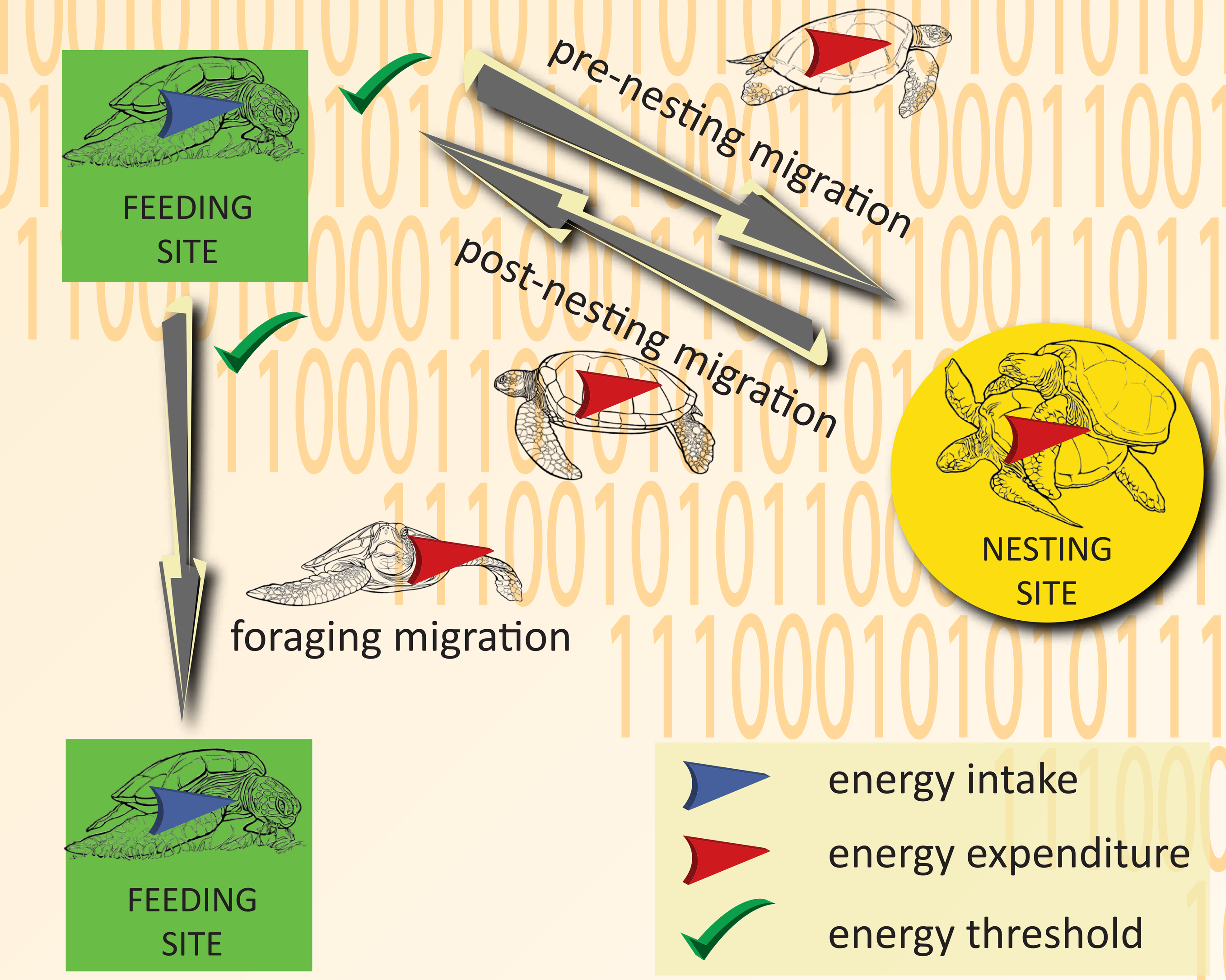

Fig. 3 : Spatial cycle of adult female

Feeding and nesting sites

We choose to study strategically located nesting sites. Those are the French Eparses islands and Mayotte. It should be noted that any nesting sites could easily be added to the model. Feeding sites have been located according to expert knowledge of the region.

Reproductive potential

The population reproductive potential was assess as the product of the number of nesting individuals by their energetic levels.

reproductive potential = number of nesting individuals x mean of energetic level at nesting

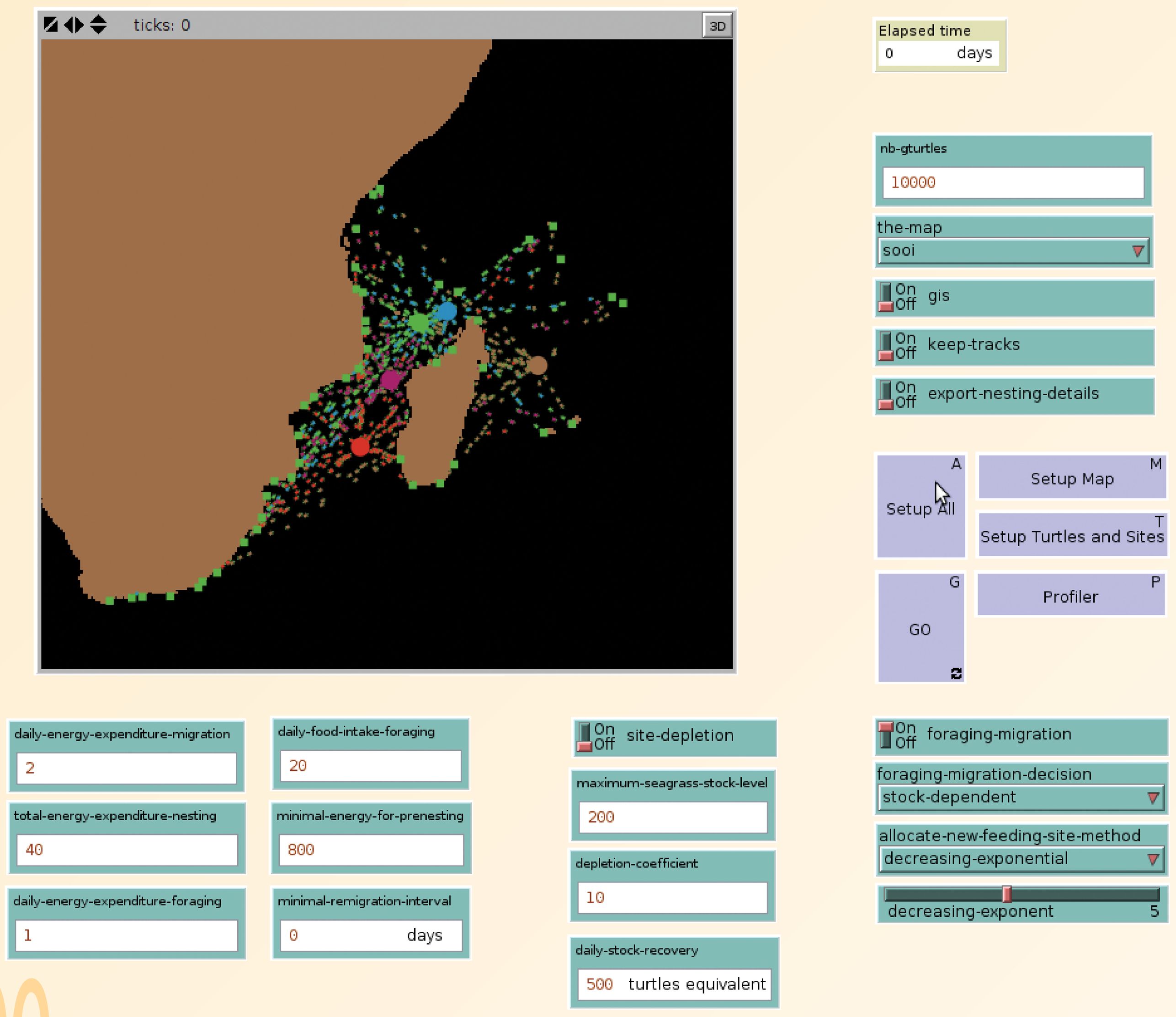

Fig. 5 : Model interface

Results

With a few number of simulated scenarios, the model already exhibits interesting patterns regarding reproductive potential of green turtle rookeries in the SWIO. Under moderate site depletion, an island (e.g. Tromelin) located far from the feeding sites areas generally displayed a lower reproductive potential while islands (e.g. Mayotte, Glorieuses) closely surrounded by numerous feeding areas displayed a higher reproductive potential. This can easily be explained, the migration cost being higher when turtles have to swim long distances. Indeed, lowering the energetic expenditure due to migration tends to homogenize rookeries reproductive potentials. Remarkably increasing the impact of individuals on feeding site quality also tends to reduce these differences. This is mainly because turtles from remote nesting islands make use of less frequented feeding sites. So our model suggests that longer reproductive migration can be compensated by a lower frequentation of the feeding areas. Further simulations should confirm these results and guide us in our understanding of the influence of the SWIO spatial topology on green turtles population.

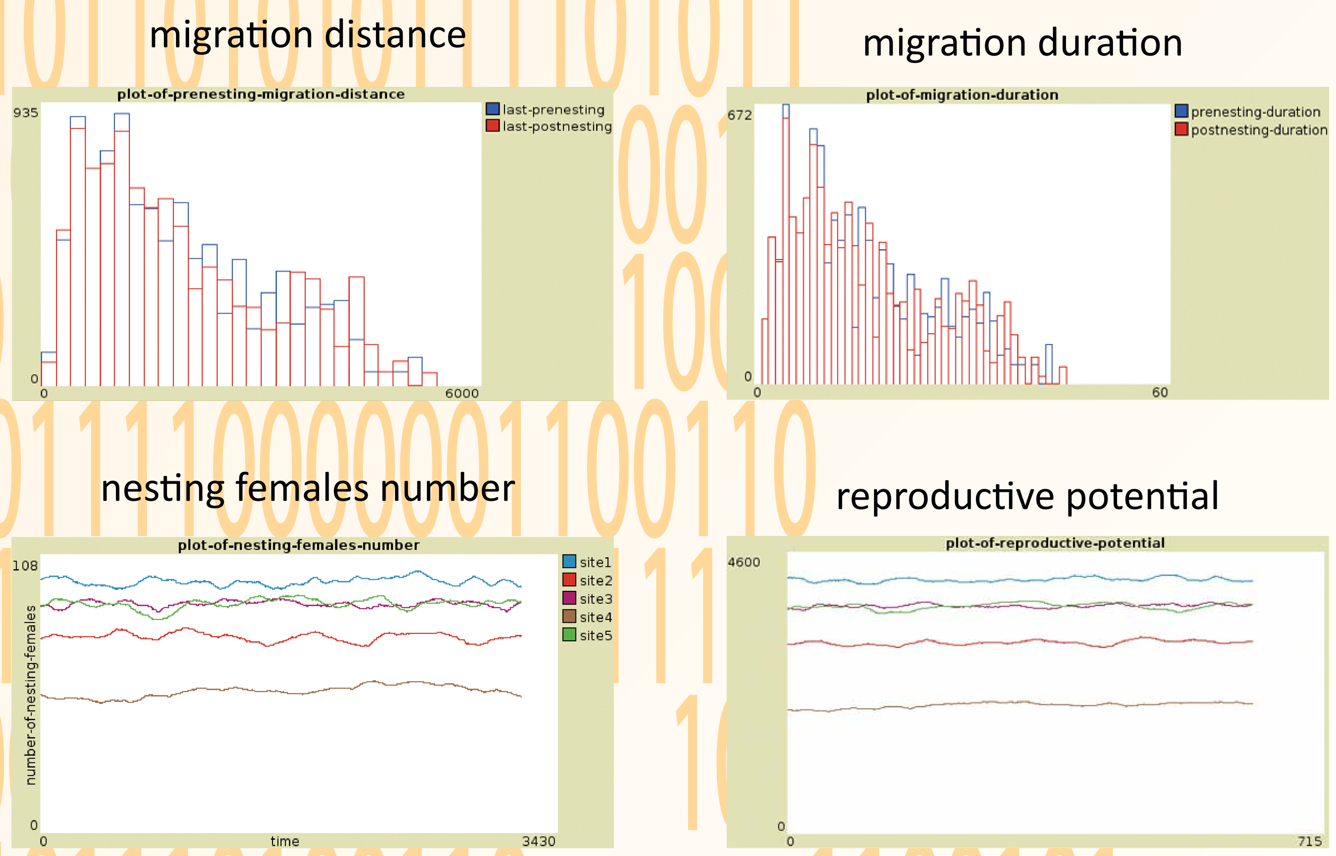

Fig. 5 : Model outputs

Discussions

Also this model showed very intuitive results, further investigation is needed at this stage to gain confidence in the results. Exploiting this model to its best requires a sensitivity analysis in particular to energetic parameters. Moreover, more individual variability could easily be implemented. We also plan to run more simulations under different case scenarios (e.g. altering local feeding sites quality). Oceanographic and environmental variables also play for sure an important role in the spatial dynamic of the green turtle in the SWIO and could be integrated.