

Supplement S1. ODD model description

We describe the model following the ODD (Overview, Design concepts, and Details) protocol for individual-based models (Grimm et al., 2006; Grimm et al., 2010). The model was implemented in NetLogo 4.1.3 and released under NetLogo 5.3.1 (Wilensky, 1999; Railsback and Grimm, 2012). An overview of the interface is provide in Fig. A.1.

A.1. Purpose

The proximate purpose of the model is to understand how the features of the South-West Indian Ocean (SWIO) regional landscape, such as nesting site locations, distribution of feeding patches and oceanic currents, constrain the migratory and foraging patterns of green turtles; its ultimate purpose is to reveal foraging and nesting sites of high conservation value. The model implements the processes of foraging, migration and nesting (Fig. A.2) to study how they affect the reproductive potential of the main regional rookeries. To go further, the model also explores how different foraging and nesting strategies may affect reproductive output and hence population survival in a heterogeneous landscape.

A.2. Entities, state variables and scales

The entities of the model are adult female green turtles, square grid cells forming a grid that covers the SWIO region (25°E-65°E; 30°S-10°N; Figure 1), and perturbations. The turtles' state variables are: location (grid cell), current preferred feeding patch, nesting site, internal state ("feeding"; "pre-nesting", *i.e.* on the way to the nesting site; "post-nesting", *i.e.* on the way from the nesting to a feeding patch; "nesting"; "foraging-migration", *i.e.* moving between feeding patches), energy level, foraging strategy, and nesting strategy. Each individual also has a coast avoidance direction that determines whether it will avoid the coast to the left or to the right when it is encountered. That direction is reverted depending on whether the turtle is in pre- or post-nesting migration (see Fig. A.3).

Grid cells are characterized by their location. They can be of four different types: terrestrial, nesting site, feeding patch, or just ocean. Terrestrial cells are barriers to movement. Nesting sites represent main regional rookeries (Fig.1 of main article; Table A.1). They are dispersed across the region with a higher concentration in the northwest of the map (north of the Mozambique Channel). Feeding patches, derived from telemetry mapping (Fig.1 of main

article; A.6.2), are characterized by their resource level reflecting the availability of seagrass, the main forage for green sea turtles. The resource level of each feeding patch is constantly updated (growth or depletion) depending on the number of turtles feeding on it. Most of the feeding patches occur in larger clusters along continental shelves.

Under one simulation scenario, turtle movement is affected by oceanic currents derived from climatology maps: the turtle's velocity vector is resulting from the turtle's motor velocity vector plus the oceanic current velocity vector at turtle location (see A.7.4). Ocean currents are represented via colour coding of oceanic grid cells, in the RGB (red, green, blue) tuple: the red and blue components were used to represent respectively the eastward and the northward components of the sea surface currents (see A.6.3). Feeding patches are possibly exposed to perturbations that alter their productivity. Perturbations are represented by a latitude coordinate and a spatial range of action. The growth rates of feeding patches located within the perturbations' spatial range are diminished with the amount of reduction depending on the feeding patch's distance to the perturbation's latitude (see A.7.8).

Each simulation lasts for approximately 50 years (36,500 time steps). The first two years (1,500 times steps) are considered as a burn-in period where no model output is recorded. Grid cell dimension is approximately 7x7 km; the entire model world consists of 567x577 grid cells, corresponding to 3,969x4,039 km.

A.3. Process overview and scheduling

At each time step, which corresponds to half a day, first all green turtles and then all feeding patches are processed, both in randomized order and with immediate updating of their state variables. In the following, the names of submodels, which are described in detail in the ODD element "Submodels", are given in parentheses.

The task a green turtle has to perform depends on its internal state: if the internal state is "feeding", it feeds (win-energy) and then possibly switches its internal state to "foraging-migration" (foraging-migration-start) which includes selecting another feeding patch (allocate-new-feeding-patch), or possibly switches to "pre-nesting" (prenesting-migration-start); if the internal state is "pre-nesting", the turtle moves towards the nesting site (move-one-step-towards) if it is still outside the detection range of the nesting site, otherwise the internal state switches to "nesting"; if the internal state is "post-nesting", it moves toward its current preferred feeding patch (move-one-step-towards) if it is still outside the detection

range of the feeding patch, otherwise the state switches to “feeding”; if the internal state is “nesting”, the turtle nests (nests), which includes a possible switch to the state “post-nesting”; if the internal state is “foraging-migration”, the turtle moves between feeding patches in the same way it moves on its way towards and back from its nesting site (move-one-step-towards).

At each time step, the turtles’ energy level is updated by either gaining energy while feeding or losing energy while nesting or migrating. Individual actions rely on two decision strategies: foraging strategy and nesting allocation strategy. The foraging strategy specifies whether and when a turtle leaves its feeding patch for another one depending on the resource level of the actual feeding patch. The nesting strategy controls the amount of internal energy invested at each nesting event. We modelled the range of possible strategies in both processes, by a single indices ranging from 0 to 1. A foraging patch fidelity strategy close to 1 leads to a ‘stayer strategy’ while a foraging patch fidelity strategy S_F close to 0 leads to a ‘mover strategy’ (see A.7.2, Fig. A.4). A nesting strategy close to 1 leads to an ‘investment strategy’ while a nesting strategy close to 0 leads to a ‘conservative strategy’ (see A.7.6). We ran sets of simulations with various combinations of foraging and nesting strategies.

Movement is represented as direct movement towards a selected site, which is modified when barriers (islands, mainland) are encountered and possibly by passive drift due to oceanic currents. Movement is energetically costly, so that swimming between foraging patches or foraging further from the nesting site has to be balanced by a gain in foraging conditions. For the feeding patches, growth, depletion by turtles, and possibly perturbation of the amount of seagrass is considered (seagrass-stock-regrowth; Fig. A.5). Perturbation represents potential natural or anthropogenic impacts (e.g. climate change, habitat destruction, oil spill); its strength depends on latitude relative to the perturbation’s location. Feeding patches that are not within the spatial range of action of the perturbation are not affected.

Finally, plots and file outputs are updated. Output analyses comprised spatial foraging and migrating pattern as well as reproductive output at the population scale in response to the turtle’s strategies. It should be noted that the model did not include mortality or the turtles’ life cycles; calculation of the population’s reproductive output calculation was based on the number of nesting events and the energy individuals invested into eggs when nesting.

Fig. 2a of main article summarizes the flow charts of processes as implemented in the model. Model parameters are specified in Table 1 of main article. When possible the model

was parameterized with field data. Otherwise, parameters were determined by inverse model fitting to the most realistic and biologically relevant observations.

A.4. Design concepts

A.4.1. Basic principles

We assume that turtles have a spatial memory of their preferred feeding patch and their nesting site. A basic energy budget of energy gains during feeding and losses during migration and egg production determines migration patterns, reproductive output, and return intervals to the nesting sites. Preferred feeding patches will be left in the search of better patches if feeding efficiency falls below a certain threshold; this can happen because too many turtles are feeding on this patch or if regrowth of the forage, sea grass, is slow due to perturbations.

A.4.2. Emergence

Foraging (stayer or mover) or nesting (investment or conservative) strategies directly determine rookery reproductive output via individual behaviour. Intuitively, the best individual strategy would be to feed on feeding patches close to the rookery, thus reducing the cost of migration. However, with conspecifics depleting the close patches, different strategies might be beneficial. The rookeries' reproductive outputs consequently emerged from individual behaviour while searching for patches and deciding on nesting energy allocation. Furthermore, the time interval between every breeding event emerged from energetic constraints, as well as the distribution of the spatial feeding patch usage that we could compare with tracking data from field surveys.

A.4.3. Sensing

At any time step, a migrating turtle could assess the direction of the migration target (its feeding patch or its nesting site) and has the ability to head towards it. In addition, a turtle could sense and avoid any coastal area located within 100km of its actual location. Turtles did not have the ability to sense or anticipate the oceanic currents. Turtles perceived the resource level of the feeding patch where they were feeding on. The decision to leave the feeding patch was taken in response to this level.

A.4.4. Interaction

There was no direct interaction between individuals in the model. However, indirect interaction between individuals was included indirectly via resource competition at feeding patches.

A.4.5. Stochasticity

Initial feeding patches are assigned randomly according to decreasing exponential probability function of the distance to the nesting site. The initial spatial distribution of the turtle on feeding patches is therefore variable between simulations although it is impacted by the regional landscape. During the course of the simulation, foraging behaviour also leads to temporal and spatial stochasticity. The decision of leaving a feeding patch for another is a probability function that relies on the foraging strategy and on the resource level of the feeding patch. Thus, individuals, although they share the same foraging strategy for a given simulation, won't leave the feeding patch simultaneously. Some individuals will randomly leave the patch earlier, therefore causing other individuals to remain in the patch. Furthermore, the choice of the new feeding patch is also a decreasing exponential function of the distance to the patch that is left. Turtles leaving a given patch won't travel to the same feeding patch affecting the occupation of the feeding patches.

The stochasticity here is implemented to reflect sources of variations that may actually occur during foraging phases. Stochasticity in turtle's distribution over the feeding patches will affect spatial usage of the oceanic areas as migratory corridors but also reproductive output of nesting sites. Over numerous simulations, we may identify areas that are of interest for feeding or migration, despite possible sources of random variations in spatial behaviour. On the other hand, we may also identify robust tendencies in reproductive output variations between rookeries.

A.4.6. Simulation experiments

We ran simulations under three environmental scenarios (Table 2 of main article): scenario 1, without oceanic currents; scenario 2, with oceanic currents; scenario 3, without oceanic currents but with perturbations that represent potential natural or anthropogenic impacts (e.g. climate change, habitat destruction, oil spill). For each scenario, we ran five repetitions for combinations of different nesting and foraging strategies, respectively conservative/investment tendencies (0.2, 0.4, 0.6, 0.8; Fig.3 of main article) and mover/stayer

tendencies (0.2, 0.4, 0.6, 0.8; Fig.3 of main article). Overall, we ran three scenarios, four foraging strategy values, four nesting strategy values, and five repetitions for each configuration leading to a total of 240 simulation runs.

A.4.7. Observation

Focusing on model purposes, model outcomes comprised spatial foraging and migration pattern as well as reproductive output at the population scale in response to the turtle's strategies. To study foraging and migration patterns, we respectively measured feeding patch usage and mapped corresponding migration pathways. For this, we pooled for each environmental scenario the results from all combinations of the two behavioural strategies. We further observed the remigration interval as well as energy storage from which we deduced a reproductive output at rookeries. This was done separately for each behavioural strategy.

A.4.7.1. Feeding patch usage

We studied spatial patterns of three foraging statistics: (1) time usage, i.e. the sum, over all time steps, of the number of turtles present on a feeding patch at each time step, (2) number of post-nesting visits, i.e. the number of times that a turtle arrived in a feeding patch following post-nesting migration, and (3) number of foraging visits, i.e. the number of times that a turtle arrived in a feeding patch following foraging migration.

In addition, we also studied the foraging patterns in relation to the preferred nesting sites of the foraging turtles. For this we computed two additional metrics: (1) the number of nesting sites from which nesters originated in a given feeding patch and (2) the diversity index of nesting sites from which nesters originated in a given feeding patch. Diversity index calculation H_p is derived from Shannon's diversity index based on the number of post-nesting visits:

$$H_p = (\sum_{NN} r_{p,n} * \ln(r_{p,n})) / \ln(N_N) \quad (1)$$

with $r_{p,n}$ is the relative proportion of post-nesting visits of patch p by turtles from nesting site n , and N_N is the number of nesting sites present in the model.

A.4.7.2. Migration pathways

Turtle's pre-nesting and post-nesting migrations were recorded by randomly sampling individual's locations approximately every 500 time steps. Foraging migrations were not recorded. Migration pathways were then studied using kernel methods for density estimation on sampled locations (Worton, 1995).

A.4.7.3. Energy at nesting, remigration interval and reproductive output

Only the six main nesting sites (Europa, Aldabra, Mayotte, Mohéli, Tromelin, Glorieuses; see Table A.1 for corresponding references) were considered in the study of the reproductive parameters. For each nesting site, the three following statistics were computed: (1) the mean individual remigration interval defined as the mean duration between successive nesting phases per each individual; (2) the mean individual energy level at nesting defined as the mean energy level of turtles after the nesting event; (3) the rookery overall reproductive output which was calculated as a function of the number of nests, the remigration intervals and the energy level at nesting.

To compute these statistics, at each time k a turtle i nested at nesting site n , we recorded the date $T_{i,k}$ and the corresponding energy level after nesting $\varepsilon_{i,k}$. We computed the remigration interval as the time difference since the previous nesting event, $T_{i,k} - T_{i,k-1}$. We computed the overall reproductive output RO_n of each nesting site n as directly proportional to the energy levels at nesting $\varepsilon_{i,k}$ and the nesting investment S_N :

$$RO_n = \sum_i \sum_k \varepsilon_{i,k} / (T_{i,k} - T_{i,k-1}) S_N \quad (2)$$

A.5. Initialization

The landscape, in particular the number and location of nesting and feeding patches, remained identical within and between simulations and was taken from input maps. Initial resource level of the feeding patch was either set to a random positive value sampled from a uniform distribution between zero and maximum resource level Φ_{max} or, if no depletion by turtles was considered, to Φ_{max} .

Most simulations were run with 7,000 turtles. At the beginning of each simulation, the turtles' nesting sites were allocated randomly with the constraint of ensuring that realistic proportions were distributed over the nesting sites (see A.6.1 and Table A.1). The initial feeding patch was also assigned randomly assuming that the probability of a feeding patch to be assigned to a turtle is inversely proportional to the distance separating this site from the turtle's nesting site. This probability was calculated in the same way as the choice of a new feeding patch during foraging (procedure “allocates-new-feeding-patch”).

At initialization, all turtles have the internal state “feeding” and are released at the location of their feeding patch. The initial internal energy level ε_0 is randomly attributed by

sampling from a positive uniform distribution between 0 and the total energy required for a whole nesting cycle (see A.7.6).

A.6. Input data

Main inputs for the model are the functional habitat map (rookeries maps for nesting sites and seagrasses for feeding patches) and the map of oceanic currents.

A.6.1. Rookeries

Rookery locations are mapped from local knowledge and using the latest available estimates of the number of annual nesting females (respective studies used are cited in Table A.1). We are using the upper limit field estimation of nesting female's number to compute the proportion of individuals associated to each rookery in the model. The proportion of individuals assigned to each rookery is shown in Table A.1. A minimum of 45 turtles is allocated to the smallest rookeries. Exact locations of nesting sites are reported Table A.1.

A.6.2. Feeding patches

Locations of feeding patches were set up by combining maps from two distinct sources: the World Atlas of Seagrasses (Green and Short, 2003) and the Agulhas and Somali Current Large Marine Ecosystem project (ASCLME ; www.asclme.org). Mapped sea grass beds were transformed into feeding patches (grid cells) at locations corresponding to the location of the main mapped sea grasses beds. Additional feeding patches were added along the coast of Somalia as this place is known to host vast areas of sea grass bed that are not mapped in the cited datasets (S. Andréfouët, *pers. communication*).

A.6.3. Oceanic currents

To model oceanic currents we are using an annual climatology map that reflects the mean current velocities in the region. This map was computed by combining GEKCO surface current daily datasets (Sudre et al., 2013). We did not consider any seasonal effect at this stage. To represent the 2D currents vector maps in the model, in the RGB (red, green, blue) tuple that is used to encode colours in NetLogo, the green component was left at zero and the values of the red and blue component were used to represent respectively the eastward and the northward components of the sea surface currents (Fig. 1 of main article).

A.7. Submodels

A.7.1. Win-energy

When at time t turtle i feeds on patch p , its internal energy level $\varepsilon_{i,t}$ is increased:

$$\varepsilon_{i,t+1} = \varepsilon_{i,t} + \Delta\varepsilon_{i,p,t} \quad (3)$$

with $\Delta\varepsilon_{i,p,t}$ being the net gain from patch p at time t . We do not explicitly consider metabolic costs for maintenance as this was assumed a constant variable independent from internal state.

The net gain per time step $\Delta\varepsilon_{i,p,t}$ depends on the resource level of the feeding patch $\Phi_{p,t}$:

$$\Delta\varepsilon_{i,p,t} = \alpha \cdot \Phi_{p,t} \quad (4)$$

with α being the depletion coefficient.

A.7.2. Foraging-migration-start

The probability $P_{leave,i}$ for turtle i to leave the actual feeding patch for another one depends on the resource level of the actual patch $\Phi_{p,t}$ and on its own foraging patch fidelity strategy S_F . The functional relationship was modelled with a logistic curve:

$$P_{leave,i} = (1 - 1 / (1 + \exp((\Phi_{p,t} + b) / a))) / 1000 \cdot (1 - S_F) \quad (5)$$

where a modulates the steepness of the reaction and b is the leaving threshold. A foraging patch fidelity strategy S_F close to 1 leads to a ‘stayer strategy’. A foraging patch fidelity strategy S_F close to 0 leads to a ‘mover strategy’. Values for parameters a and b are given in Table 1. The resulting probability of leaving a feeding patch depending on foraging strategy S_F and feeding patch resource level $\Phi_{p,t}$ is illustrated in Fig. A.4.

A.7.3. Allocate-new-feeding-patch

The selection of a new feeding patch was distance-dependent with selection probability $P_{selection}$ determined by an exponential decay function:

$$P_{selection} = (1 - d_{relative})^\lambda \quad (6)$$

where $d_{relative} = (d - d_{min}) / (d_{max} - d_{min})$ is calculated from d , the distance between a new feeding patch and the current feeding patch, and d_{min} and d_{max} , the minimum and maximum distance between feeding patches. λ is an arbitrary exponential decay coefficient. This model assumes that choice of a new feeding patch is based rather on the turtles’ better knowledge of the location of feeding patches nearby than by those feeding patch resource levels, which they cannot know. The minimum and maximum possible distances are not known to the turtles, but used to scale the spatial scale of knowledge.

A.7.4. Move-one-step-towards-with/without-currents

At each time step and for each turtle in migration, spatial location was updated with a fixed speed of 2.7 km h^{-1} (65 km day^{-1}) and a heading towards the selected patch when not facing the coast. Speed value was derived from in-situ satellite tracking measurement (Dalleau, 2013). Effective traveling speed and direction may however be impacted by oceanic currents at the turtle's location.

During pre-nesting, post-nesting or foraging migration, at each time step t a turtle i moves towards a selected patch p , it loses a fixed amount of energy $\Delta\epsilon_{i,m}$ (Table 1):

$$\epsilon_{i,t+1} = \epsilon_{i,t} - \Delta\epsilon_{i,m} \quad (7)$$

At each time step t , a turtle i attempts to move one step in the direction of the target, which is either its nesting site in the case of pre-nesting migration or its current preferred feeding patch in the case of post-nesting or foraging-migration.

For avoidance of coastal grounds, we implemented a simple wall-following algorithm (Fig. A.3). At a given time step, if moving a turtle forward causes this turtle to encounter a coastal grid cell (patch-ahead-is-coast?), its swimming direction is modified incrementally (angle-step) up to the minimum angle that allows to move forward without encountering a terrestrial grid cell (see next paragraph regarding the direction of rotation). The turtle then moves forward. At the following time step, if possible, the swimming direction is first modified incrementally (angle-step) to a direction closer to the direction of the target (the feeding patch or the nesting site) that allows moving forward without encountering a grid cell. If the direction of the target can be reached, the swimming direction of the turtle is set to the target's direction. Contrarily, if the swimming direction cannot be modified and if the turtle cannot moves forward, then the swimming direction is once again modified incrementally (angle-step) by the minimum angle that allows to move forward without encountering a terrestrial grid cell. At the next time step, the same process is repeated. This algorithm leads the turtle to follow the coast until it can freely move in the direction of the target once again.

Regarding the rotation direction (to the left or to the right), the first time that a turtle encounters a coast, it corresponds to the direction that leads to the least turning angle required to avoid the coast. The rotation direction is then memorized (gt-avoidance-rotation-direction) and will remain the same during the duration of a given migration. Nevertheless, the rotation direction is reverted when a turtle starts a pre- or a post-nesting migration. This reversion is implemented to favour, at least partially, symmetrical migration trajectories between pre- and

post-nesting migration. Additionally, the rotation direction is also reset each time that a turtle start and stop a foraging migration since these migrations are independent from nesting migrations and since they modify the current feeding patch of the turtle.

In case the effect of oceanic currents on movement is considered, migration direction is modified according to the oceanic current velocity at actual turtle position. The final velocity vector is resulting from the turtle's motor velocity vector towards the target plus the oceanic current velocity vector at turtle location. Computationally, this is simply implemented by artificially displacing the target site (feeding patch or nesting site) at each time step. The 'artificial' target site (x' , y') is located at the location of the turtle (x , y) to which we added the vector sum of the velocity vector in the absence of current (dx , dy) and the current velocity vectors (xc , yc). It was calculated as follows:

$$x' = x + dx + xc \quad (8a)$$

$$y' = y + dy + yc \quad (8b)$$

The algorithms to move one step forward and to avoid the coastal grounds are then similar than in the absence of currents.

A.7.5. Prenesting-migration-start

The decision to start pre-nesting migration depends on the estimated level of energy necessary to complete the entire nesting process, i.e. the turtles stop feeding only if they gained a sufficient amount of energy to complete a round-trip migration to the nesting site and nesting action. A turtle therefore starts pre-nesting migration (from its current feeding patch to its nesting site) when its energy level $\epsilon_{i,t}$ reaches approximately the total energy level needed to complete the cycle, ϵ_{cycle} :

$$\epsilon_{cycle} = 2 \cdot \epsilon_{migration} + \epsilon_{nesting} = 2 \cdot \Delta\epsilon_{i,m} \cdot d_{i,n} / c + S_N \cdot T_{n,max} \cdot \Delta\epsilon_{i,n} \quad (9)$$

where $\Delta\epsilon_{i,m}$ is the energy lost on each time during migration, $d_{i,n}$ the distance from the current feeding patch to the nesting site, and c migration velocity.

A.7.6. Nests

Depending on the nesting strategy considered, an individual could either invest a large amount of energy into nesting ('investment strategy' - the big spender), thereby trading off between high nesting investment and low nesting frequency. This might possibly result in large intervals between nesting, thereby reducing fitness when considered over lifetime average. Alternatively an individual could invest only a limited fraction of energy for nesting

(‘conservative strategy’ - bank saver), thereby reducing the nesting investment with lower numbers of eggs produced but shortening the interval between nesting phases.

The number of time steps spent at nesting sites depends on the value of the parameter characterizing the nesting strategy S_N :

$$T_{n,i} = S_N \cdot T_{n,max} \quad (10)$$

During nesting, at each time step t spent at a nesting site i , an individual loses $\Delta\epsilon_{i,n}$:

$$\epsilon_{i,t+1} = \epsilon_{i,t} + \Delta\epsilon_{i,n} \quad (11)$$

A nesting strategy S_N close to 1 leads to an ‘investment strategy’. A nesting strategy S_N close to 0 leads to a ‘conservative strategy’. After completing the nesting event, the turtle goes back to its last preferred feeding patch.

A.7.7. Seagrass-stock-regrowth

We considered regrowth of sea grass feeding patches based on a logistic function. Uptake resources by turtles was density-dependent (see Bjorndal et al., 2000 for example of in situ density-dependance), i.e. the individual uptake per time step decreased as the number of turtles actually foraging on the patch increased. Depending on its foraging strategy, a turtle could tolerate a low patch resource level and avoid costly foraging migration (‘stayer’ tendency); or could rather leave a feeding patch when its resource level is too low (‘mover’ tendency). At each time step t , the resource level $\Phi_{p,t}$ of the feeding patch p is updated:

$$\Phi_{p,t+1} = \Phi_{p,t} + \Delta\Phi_{p,t} \quad (12a)$$

where $\Delta\Phi_{p,t}$ the net growth of patch p at time t which depends on depletion by $N_{p,t}$ turtles foraging on this patch at time t and regrowth according to a logistic growth model:

$$\Delta\Phi_{p,t} = \beta \Phi_{p,t} (1 - \Phi_{p,t} / \Phi_{max}) - \alpha N_{p,t} \Phi_{p,t} \quad (12b)$$

where α is the depletion coefficient. The coefficient β was adjusted to (a) maintain the amount of resources relatively constant across the simulation; (b) make the long-term average resource level being about half of the maximum resource level common to all feeding patches, this level was chosen arbitrarily but was shared across all simulations; (c) assuming that the turtles are evenly distributed over the feeding patches.

Mathematically this means for all patches p :

$$\Delta\Phi_{p,t} = 0(i) \quad (13a)$$

$$\Phi = \Phi_{max}/2(ii) \quad (13b)$$

$$N_{p,t} = N_T / N_F(iii) \quad (13c)$$

which gives:

$$\beta = \alpha \cdot N_T / N_F \cdot \Phi_{max} / (\Phi_{max} - \Phi_{max}/2) = 2 \cdot \alpha \cdot N_T / N_F \quad (14)$$

The development of the resource level $\Phi_{p,t}$ of a feeding patch depending on the number of turtles $N_{p,t}$ foraging on it is illustrated on Fig. A.5.

A.7.8. Perturbation

Perturbation is defined by a latitude position σ_y , an intensity level σ_i and a maximum range of action $d_{\sigma,max}$. The impact of perturbation on a given feeding patch depends on its relative latitude p_y to perturbation latitude σ_y . Perturbation effect on feeding patch resource level is inversely proportional to the latitudinal distance $d_{p,\sigma}$ from the perturbation latitude position σ_y and is also depends on the regrowth rate of a feeding patch. At each time step, the patch resource level is perturbed as follow:

$$\text{if } d_{p,\sigma} < d_{\sigma,max}: \Phi_{p,t+1} = \Phi_{p,t} - \Delta\Phi_{p,t} \quad (15a)$$

with:

$$\Delta\Phi_{p,t} = \sigma_i \cdot \beta \cdot d_{\sigma,max} / d_{p,\sigma} \cdot \Phi_{p,t} \quad (15b)$$

$$d_{p,\sigma} = p_y - \sigma_y \quad (15c)$$

Figures



Fig. A.1. Overview of the model interface.

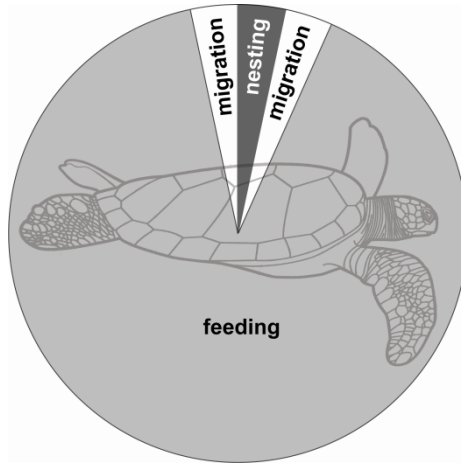


Fig. A.2. Schematic nesting cycle of adult sea turtles as considered in the model. Between two nesting periods of 3-4 years, turtles spend approximately 90% of the time on foraging, 6% on migration and 4% on nesting.

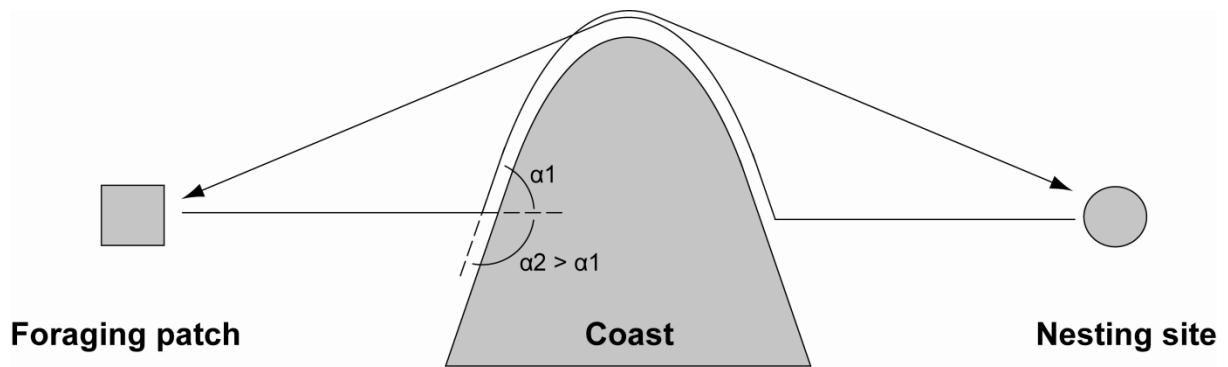


Fig. A.3. Schematic representation of coast avoidance trajectories. Direction of coast avoidance is determined during first pre-nesting migration (alternatively foraging migration) by prioritising the least turning angle (to the left following α_1 in this example). During post-nesting migration individual will avoid the coast by turning in the opposite direction compared to pre-nesting migration (to the right in this example). An individual stops following the coast when it is able to move without obstacle in the direction of the target. This may possibly lead to different trajectories during pre-nesting and post-nesting migration.

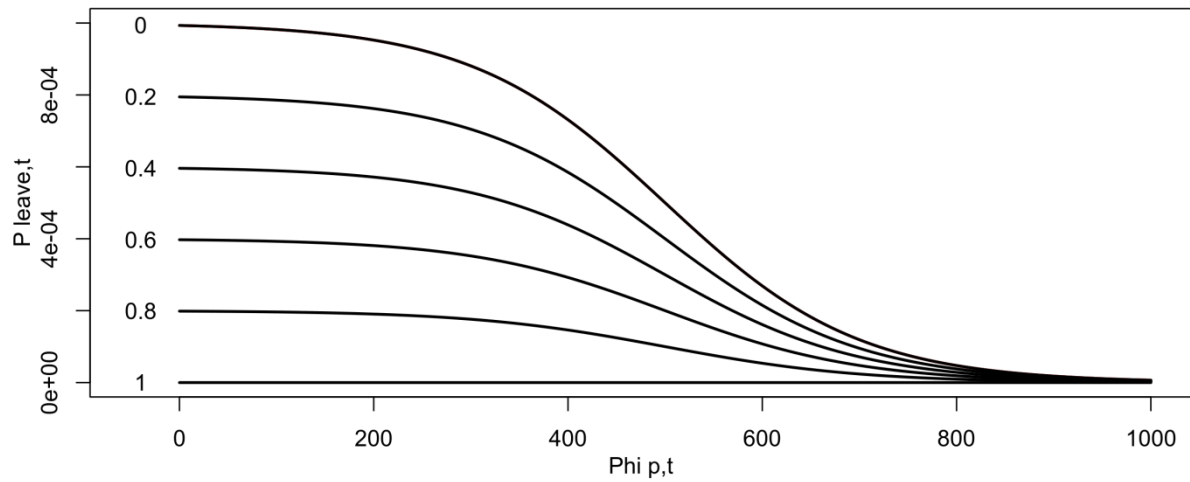


Fig. A.4. Foraging patch fidelity strategies and their functional relationships. This figure illustrates the probability $P_{\text{leave},t}$ for a turtle i to leave a patch p depending on its foraging patch fidelity strategy $S_{F,t}$ and patch resource level $\Phi_{p,t}$. The x-axis represents the resource level $\Phi_{p,t}$ of the patch p . The y-axis is the level of probability $P_{\text{leave},t}$ of leaving the patch at time t . Each curve depicts the probability $P_{\text{leave},t}$ of leaving the patch depending on actual level of patch resource. Turtle foraging fidelity patch strategy $S_{F,t}$ is fixed across a single simulation. A foraging patch fidelity strategy closed to 0 (higher curves) leads to an overall higher probability to leave the patch (mover strategy). A strategy closed to 1 (lower curves) leads to an overall smaller probability of leaving the patch (stayer strategy).

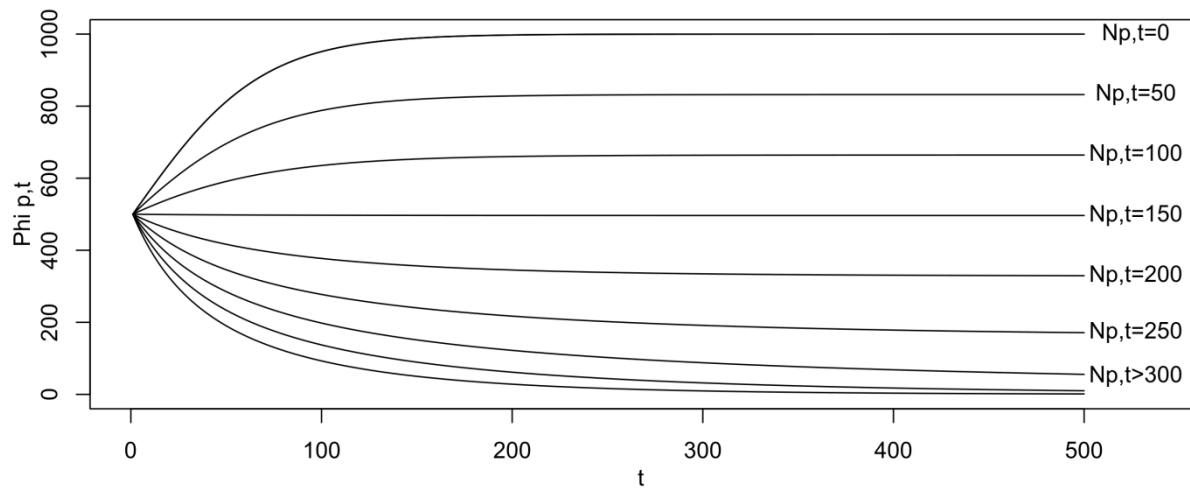


Fig. A.5. Temporal development of patch resource level $\Phi_{p,t}$ as a function of time t and number of sea turtle feeding on patch N_p . The y-axis represents the resource level $\Phi_{p,t}$ of the patch p . The x-axis represents the time t . Each curve describe how the resource level $\Phi_{p,t}$ evolves depending on the number of turtles N_p . During simulations, the resource level of a patch is not likely to evolve smoothly as suggested by these curves as the number of turtles feeding on the patch may change between time steps.

Tables

Table A.1. Estimated number of nesting females for each nesting sites as available in the literature and relative proportion of nesting females assigned to each nesting site in the model. Absolute number of females actually assigned to each nesting site in the model was calculated, in respect of the relative proportion indicated here, ensuring that the total number of individuals in the model equals NT (7000 individuals). This data need to be taken with caution and need to be justified by the papers cited. Comparisons need to be done with caution because estimation methods vary for all sites. (***Major nesting sites**)

Site	Trigram	Area of estimation	Estimated number of females per year	Sources	Adjusted number of females per year	Relative proportion of females assigned in the model
Europa*	EUR	All	6,000-11,000	Le Gall et al. (1986)	11,000	10000
Aldabra*	ALD	All	3,000-5,000	Mortimer et al. (2011b)	5000	5000
Mayotte*	MAY	All	3,000-5,000	Bourjea et al. (2007)	5000	5000
Mohéli*	MOH	6 beaches	4,410	Bourjea et al. (In prep.)	5000	5000
Tromelin*	TRO	All	1,430	Lauret-Stepler et al. (2007)	2000	2000
Glorieuses*	GLO	60%	1,480	Lauret-Stepler <i>et al.</i> (2007)	2000	2000
Tanzania	TAN	All	120-150	Muir (2005)	150	200
Iranja	IRA	All	100-150	Bourjea et al. (2006)	150	200
Juan de Nova	JUA	All	<80	Lauret-Stepler et al. (2010)	70	200
Seychelles (Except Aldabra)	SEY	-	13-24	Mortimer et al. (2011a)	150	200
Mozambique (Vamizi Island)	VAM	85%	50	Garnier et al. (2012)	60	200
La Réunion	RUN	All	<5	Ciccione and Bourjea (2006)	5	200

Kenya	KEN	-	unknown	Okemwa et al. (2004)	unknown	200
Mauritius (Chagos Archipelago)	CHA	-	-	-	-	200

References

- Bjorndal, K.A., Bolten, A.B., Chaloupka, M.Y., 2000. Green turtle somatic growth model: Evidence for density dependence. *Ecol. Appl.* 10, 269-282.
- Bourjea, J., Ciccione, S., Ratsimbazafy, R., 2006. Marine Turtles Surveys in Nosy Iranja Kely, North-Western Madagascar. *Western Indian Ocean Journal of Marine Science* 5, 209-212.
- Bourjea, J., Frappier, J., Quillard, M., Ciccione, S., Roos, D., Hughes, G., Grizel, H., 2007. Mayotte Island: another important green turtle nesting site in the southwest Indian Ocean. *Endangered Species Research* 3, 273-282.
- Bourjea, J., Marmoerx, C., A., M.S., Beudard, F., Frazier, J., Roos, D., Leport, G., Ciccione, S., In prep. Seasonality and increase in green turtle (*Chelonia mydas*) nesting activity at Mohéli island, Comoro archipelago, Indian Ocean.
- Ciccione, S., Bourjea, J., 2006. Nesting of Green Turtles in Saint Leu, Réunion Island. *Marine Turtle Newsletter* 112, 1-3.
- Dalleau, M., 2013. Ecologie spatiale des tortues marines dans le Sud-ouest de l'océan Indien. Apport de la géomatique et de la modélisation pour la conservation. Thèse de doctorat. Université de La Réunion, p. 330p.
- Garnier, J., Hill, N., Guissamulo, A., Silva, I., Witt, M., Godley, B., 2012. Status and community-based conservation of marine turtles in the northern Querimbas Islands (Mozambique). *Oryx* 46, 359-367.
- Green, E.P., Short, F.T., 2003. World Atlas of Seagrasses, in: Center, U.W.C.M. (Ed.). University of California Press, Berkeley, USA.
- Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., Goss-Custard, J., Grand, T., Heinz, S.K., Huse, G., Huth, A., Jepsen, J.U., Jorgensen, C., Mooij, W.M., Muller, B., Pe'er, G., Piou, C., Railsback, S.F., Robbins, A.M., Robbins, M.M., Rossmanith, E., Ruger, N., Strand, E., Souissi, S., Stillman, R.A., Vabo, R., Visser, U., DeAngelis, D.L.,

2006. A standard protocol for describing individual-based and agent-based models. *Ecol. Model.* 198, 115-126.

Grimm, V., Berger, U., DeAngelis, D.L., Polhill, J.G., Giske, J., Railsback, S.F., 2010. The ODD protocol: A review and first update. *Ecol. Model.* 221, 2760-2768.

Lauret-Stepler, M., Bourjea, J., Roos, D., Pelletier, D., Ryan, P., Ciccione, S., Grizel, H., 2007. Reproductive seasonality and trend of *Chelonia mydas* in the SW Indian Ocean: a 20 yr study based on track counts. *Endangered Species Research* 3, 217-227.

Lauret-Stepler, M., Ciccione, S., Bourjea, J., 2010. Monitoring of marine turtles reproductive activities in Juan de Nova, Eparses Islands, South Western Indian Ocean, based on tracks count and width. *Indian Ocean Turtle Newsletter* 11, 18-24.

Le Gall, J., Bosc, P., Château, D., Taquet, M., 1986. Estimation du nombre de tortues vertes femelles adultes *Chelonia mydas* par saison de ponte a Tromelin et Europa (Océan Indien) (1973-1985). *Océanographie Tropicale* 21, 3-22.

Mortimer, J.A., Camille, J.-C., Boniface, N., 2011a. Seasonality and Status of Nesting Hawksbill (*Eretmochelys imbricata*) and Green Turtles (*Chelonia mydas*) at D'Arros Island, Amirantes Group, Seychelles. *Chelonian Conservation and Biology* 10, 26-33.

Mortimer, J.A., von Brandis, R.G., Liljevik, A., Chapman, R., Collie, J., 2011b. Fall and Rise of Nesting Green Turtles (*Chelonia mydas*) at Aldabra Atoll, Seychelles: Positive Response to Four Decades of Protection (1968-2008). *Chelonian Conservation and Biology* 10, 165-176.

Authro, 2005. The Status of Marine Turtles in the United Republic of Tanzania, East Africa.

Okemwa, G.M., Nzuki, S., Mueni, E.M., 2004. The status and conservation of sea turtles in Kenya. *Marine Turtle Newsletter* 105, 1-6.

Railsback, S., Grimm, V., 2012. Agent-based and individual-based modeling : a practical introduction. Princeton University Press.

Sudre, J., Maes, C., Garçon, V., 2013. On the global estimates of geostrophic and Ekman surface currents. *Limnology & Oceanography: Fluids & Environments* 3, 1-20.

Wilensky, U., 1999. NetLogo in: Modeling, C.f.C.L.a.C.-B. (Ed.). Northwestern University, Evanston, IL, USA.

Worton, B., 1995. Using Monte Carlo Simulation to Evaluate Kernel-Based Home Range Estimators. *The Journal of Wildlife Management* 59, 794-800.