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Leach's Storm-Petrel Biparental Incubation Model
In collaboration with RAM and DD

(Apologies for any typos! Working Draft)

Running the Model

NOTE: Needs C++11 developer tools to compile correctly using g++

Linux/OSX:

Simple open up the lhsp.r file located in LHSP/src. After appropriately setting the working directory to the LHSP/src folder, running the available.r code should compile and run the C++ program, input the data into R, and present a basic visualization.

Windows:

The C++ code can be compiled either using Windows developer tools or separately in an IDE, at which point the R code can be run by skipping the "system()" lines and just reading in the .txt output file (still should be named Results.txt) as a csv and working with the data in R.

Sample size can be adjusted in Main.cpp, line 44.
For now (can easily be changed) iterations of RC and PC values

The current output of the model is the percentage success of each combination of MalePC/RC and Female PC/RC. In R, this is further simplified by grouping these values and presenting the mean success of just MalePC/RC combinations and Female PC/RC combinations. That is, the final figure in R right now is the percentage eggs successfully incubated by a petrel of the given sex averaged over all of the mates of the opposite sex. Obviously, this sort of analysis is temporary. To adjust output, work in Main.cpp (lines 51-53) or work with the C++ output using different R code.

Debugging/Analyzing Code

Documented code is available https://github.com/ltaylor2/LHSP

To view the current program, look at the Master branch.

If you want to look at the behavior more closely, a Debugging is available with print statements detailing the behavior of adults/eggs. This runs much more slowly, so output should be logged to a separate file (cmd: "./lhsp > test_output.txt") and sample sizes should be kept low.

In both branches, several areas of direct concern are marked with TODO. There may be other (perhaps terrible) bugs, and behavior will change as the model develops. The organization of the model is such that behavior and testing should be changed very easily for any given function or object.

Model Details

Egg (Egg.h and Egg.cpp)

Egg objects represent Leach's Storm-Petrel eggs. Eggs have a hatchDay and a counter for the current number of days. When the current day reaches the hatchDay, the egg attempts to hatch. At that point, an egg checks the maximum streak of neglect it has experienced, and probabilistically hatches successfully based on this neglect. Behavior happens during eggDay(), where an egg is sent the information about whether or not there is an adult incubating the burrow for that day. If there is an adult, the counter for the current day goes up by one and the neglect streak counter is reset to 0. If there is no adult ("neglect") the hatchDay goes up (corresponding with slowed development time) and the egg checks if the maximum neglect streak has increased for survival probability later on. If the egg is taking a very long time to hatch (the hatchDay has increased due to lots of incremental neglect) it fails.

Adult Storm-petrels (Petrel.cpp and Petrel.h)

Adult petrels are constructed with three values: PC and RC (see below) and Sex. Each breeding season, a petrel starts out with its constant base energy. The female petrel suffers a proportional loss of energy representing the cost of the egg. If a petrel's energy falls below a constant threshold, it is dead.

Adults have two states: Incubating and Foraging. The female starts in the Incubating state, and the male starts in the foraging state. When incubating, the petrel loses a constant amount of energy per day. When foraging, the petrel stochastically gains or loses energy based on parameterized data. The energy change from foraging is based on a normal curve where the mean is the center of the maximum and minimum values taken by solving the metabolic intake and output equations from Montevecchi et al. 1992. The standard deviation of this normal distribution is the distance to each of those endpoints. If the foraging change is randomly picked to be outside of the range of those min->max values, then the change is simple set to either the max or the min appropriately. This will almost certainly change to be more reasonable, but for now this process prevents adults from randomly dying in one day of foraging or getting, like, infinite energy.

Before acting out incubating or foraging, adults decide to change state. This is done based on the current energy and a threshold determined by RC and PC sensitivities. The effect of PC moves the threshold as a proportion of the energy petrels start with. This follows the assumption that an adult that is super sensitive to its own health would not want to drop below the energy level at which it started the reproductive season. These adults have a PC of 1, so their threshold is 1*BASE_ENERGY. Petrels with a PC of 0 do not care about their own energy, so their threshold is 0*BASE_ENERGY. The effects of RC work alongside PC. Adults with an RC of 0 never have any change in behavior based on mate behavior-- they do not care about the incubation patterns of their mate. Petrels with an RC < 0 are retaliatory. IFF the last incubation bout they underwent was longer than the mean of the incubation bouts they have experienced, they will increase their energetic threshold with a magnitude based on the magnitude of their RC. Petrels with an RC > 0 are compensatory, and they will decrease their energetic threshold IFF the last bout they underwent was longer than the mean of the incubation bouts they have experienced. For now, RC does not matter if the incubation bout was SHORTER than the usual bout.

RC and PC examples

“Retaliatory” Petrel, RC = -.5

The last incubation bout was 4 days. The mean incubation bout is 2 days. 100% difference from the mean, .5 magnitude retaliatory. RC Effect = BASE_ENERGY * .5 * 1

“Compensatory” Petrel, PC = .5

The last incubation bout was 4 days. The mean incubation bout is 2 days. 100% difference from the mean, .5 magnitude compensatory. RC Effect = BASE_ENERGY * .5 * -1

RC and PC can work together, or against each other. PC always influences (and, in fact, determines) the energetic threshold driving decision making. RC influences the energetic threshold IFF the conditions of mate behavior are met, and, depending on whether the adult is compensatory and retaliatory, may work to COMPOUND the effects of PC or COUNTERACT them completely, because rcEffect can be positive or negative.

Adults change there state based on (pcEffect + rcEffect). If an adult in incubating, it will switch to foraging if (current energy < (pcEffect + rcEffect)). If an adult is foraging, it will switch to incubating if (current energy > (pcEffect + rcEffect)). In summary, PC and RC determine the energy level that a given adult wishes to maintain through foraging.

Breeding (Main.cpp)

In the current model, a pairs of petrels are produced to test every combination of PC and RC values for each sex with one another. ThA “focal” petrel (currently and arbitrarily the male) is assigned its mate of the given PC and RC values and they go through a breeding season for a number of replicates. The breeding season ends if the egg hatches, the egg dies, or (for now) either parent dies. The program currently keeps track of the percentage success (#eggs hatched successfully / sampleSize) for each combination.

References

The source for parameters are cited within the code from the following sources:

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