# Methods

## Data processing

Data were analyzed using R version 4.1.2 ([R Core Team 2021](#_ENREF_5)).

Data from Rouzic, which are stored in the movebank database, were imported with the *move* R package ([Kranstauber *et al.* 2022](#_ENREF_3)) while data from Bass Rock were imported from csv files.

At-sea trips were discriminated from periods in the colony when the birds were > 1 km away from the colony for > 1h. Locations were linearly interpolated with a 15min time resolution using the *pastecs* package ([Ibanez & Grosjean 2018](#_ENREF_2))

Trip characteristics (maximal distance to the colony, total trip duration and total distance travelled) and time spent in the colony between at-sea trips were averaged for each individual and then averaged by colony (Table 1).

Linear mixed models were fitted separately for each colony to test whether log-transformed trip characteristics and nest attendance changed over time. Individuals were included as random effects.

## Inferring at-sea activities

A 3-state hidden Markov model (HMM) was fitted to the entire at-sea interpolated location dataset, using the *moveHMM* package ([Michelot *et al.* 2016](#_ENREF_4)). The states reflected 3 different activities at sea: (1) resting, characterised by a small step length and low turning angle, (2) travelling, characterised by a long step length and low turning angle and (3) foraging, characterised by an intermediate step length and a large turning angle. A set of different initial parameters was used to ensure that the global minimum in negative log-likelihood had been reached. The model was validated with the visual inspection of pseudoresiduals. The Viterbi algorithm was used to classify the most likely behaviour at each location and proportions of each activity occurring during one at-sea trip were calculated, averaged by individual and then, by colony. Logistic regressions were fitted on activity proportions using the *glmmTMB* package ([Brooks *et al.* 2017](#_ENREF_1)), to account for zero-inflated data.

# Results

|  |  |  |
| --- | --- | --- |
|  | Bass Rock | Rouzic |
| Nb of individuals | 10 | 13 |
| Total number of trips | 310 | 257 |
| Tracking period | 11/08/2022 - 12/10/2022 | 24/08/2022 – 28/09/2022 |
| Maximal distance to the colony (km) | 98 ± 8 | 62 ± 4 |
| Total distance travelled (km) | 254 ± 21 | 18 ± 1 |
| Trip duration (h) | 19 ± 2 | 171 ± 11 |
| Time spent resting during a trip (%) | 20.9 ± 2.3 | 41.7 ± 2.9 |
| Time spent foraging during a trip (%) | 25.2 ± 1.2 | 20.1 ± 1.7 |
| Time spent flying during a trip (%) | 54.0 ± 2.1 | 38.2 ± 2.5 |
| Time at the colony between at-sea trips (h) | 16 ± 1 | 11 ± 1 |

Table 1: Sample size, at-sea trip characteristics, percentage of activities and colony attendance of Northern gannets nesting in Rouzic and Bass Rock. Results are shown as mean ± SE.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Bass Rock | | | | Rouzic | | | |
|  | Estimate ± SE | df | t-value | p-value | Estimate ± SE | df | t-value | p-value |
| Maximal distance | **0.009 ± 0.005** | **307** | **2.03** | **0.043** | -0.003 ± 0.006 | 238 | 1.73 | 0.60 |
| Total distance travelled (km) | **0.011 ± 0.0048** | **307** | **2.34** | **0.02** | 1.81e10-5 ± 6.0e10-3 | 201 | 0.003 | 0.99 |
| Trip duration (h) | **0.013 ± 0.004** | **307** | **3.29** | **0.001** | 0.011 ± 0.006 | 238 | 1.73 | 0.09 |
| Time at the colony between at-sea trips (h) | -0.003 ± 0.003 | 297 | -0.77 | 0.45 | **-0.015 ± 0.007** | **233** | **-2.14** | **0.03** |

Table 2: Results from the models testing the effects of time on Northern gannet trip characteristics (linear mixed models), nest attendance and time spent in 3 states (logistic regressions). Individual identity is included as a random effect. Significant results (p < 0.05) are in bold.

Brooks, M., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, h.J., Maechler, M. & Bolker, B.M. (2017) glmmTMB balances speed and flexibility among packages for zero-inflated Generalized Linear Mixed Modelling. *The R Journal,* **9,** 378-400.

Ibanez, F. & Grosjean, P. (2018) pastecs: Package for Analysis of Space-Time Ecological Series. *R package version 1.3.21*.

Kranstauber, B., Smolla, M. & Scharf, A.K. (2022) move: Visualizing and Analyzing Animal Track Data.

Michelot, T., Langrock, R. & Patterson, T.A. (2016) moveHMM: an R package for the statistical modelling of animal movement data using hidden Markov models. *Methods in Ecology and Evolution,* **7,** 1308-1315.

R Core Team (2021) R: A language and environment for statistical computing. *R Foundation for Statistical Computing*. Vienna, Austria.