The following supplement accompanies the article

A sex-influenced flexible foraging strategy in a tropical seabird, the magnificent frigatebird

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Supplement 1.

Summary of morphometric data

Table S1. Summary of morphometric measurements (mean ± SD) of male (n = 10) and female (n = 8) frigatebirds tagged and recovered from the population on Little Cayman, Cayman Islands between March and July, 2017.

Measurement	Females	Males
Wing length (mm)	64.9 ± 0.8	62.3 ± 1.1
Bill length (mm)	122.9 ± 5.5	118.0 ± 21.9
Bill width (mm)	32.8 ± 1.1	28.9 ± 1.3
Bill depth (mm)	30.8 ± 1.6	27.1 ± 1.1
Tarsus length (mm)	80.5 ± 1.7	73.3 ± 5.36
Tail length (mm)	455.6 ± 13.2	426.3 ± 60.4
Mass (g)	1372.5 ± 48.9	1090.0 ± 66.0

Behavioural classification using Hidden Markov Models

Hidden Markov Models (HMMs) with a mixture of Gaussians were fitted to ground speed and turning angle values from GPS data, using the HMM toolbox in Matlab (Murphy 1998), following methods developed in Dean et al. (2013). HMMs were trained on a subset of tracks (n = 15) from 15 birds (not subsequently used in kernel density estimation). Parameter priors were obtained from K-means clustering and improved using the Baum-Welch algorithm. To determine to number of hidden states to use in the final model, models were fitted with states ranging from 2 to 6, and negative log-likelihoods of the candidate models were compared. The greatest decrease occurred between 2 and 3 states, providing support for a 3-state HMM (Fig. S1; see Table S2 for state transition matrix). State assignments were validated using behavioural data from an individual that was simultaneously tracked with GPS and video (Tables S3 and S4). The trained model was then applied to the remaining foraging data (n, birds = 22, trips = 90), using the Viterbi algorithm, which estimates the most probable

sequence of states (Dugad & Desai 1996). See Fig. 2 in the main article for state assignments in example track segments.

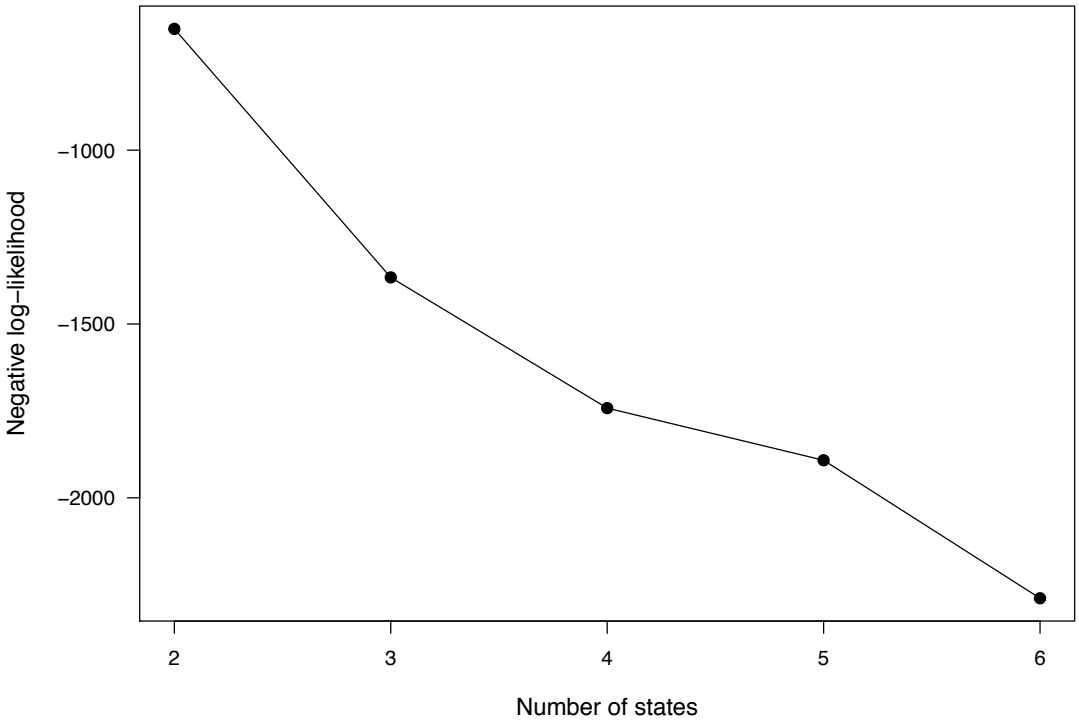

Fig. S1. Negative log-likelihood of Hidden Markov Models (HMM) containing between 2 and 6 states.

Table S2. State transition matrix from the three-state Hidden Markov Model, showing the probability of changing from state at time *t* to state at time *t* +1. Proportion of locations in state: 1 = 0.20, 2 = 0.38, 3 = 0.42.

State at *t*	1	2	3
1	0.959	0.008	0.033
2	0.008	0.928	0.064
3	0.055	0.082	0.864

Table S3. Mean (± SD) speed and turn angles of locations assigned to the three behavioural states by Hidden Markov Models, and the proportion of time spent in foraging activity (assigned from video footage) that fell into the three states.

State	Speed (ms^{-1})	Turn angle (°)	Foraging time
1	4.33 ± 0.53	2.76 ± 1.78	0.19
2	0.61 ± 0.50	0.75 ± 0.80	0
3	0.65 ± 0.73	25.04 ± 2.76	0.81

Ethogram of behaviours used to analyse video data

Table S4. Classes used to classify behaviour in video data collected from a chick-rearing magnificent frigatebird during foraging trips from Little Cayman, Cayman Islands in 2017.

Behaviour	**Description**	**Foraging-related**
On nest	Bird on nest / roost site on land	No
Taking off	Bird leaves roost and takes flight	No
Directional flight	Bird engages in sustained flight while following a heading	No
Circling flight	Bird engages in circling movements or those with a regular change in heading	Yes
Agonistic behaviour	Bird displays aggressive interaction with conspecifc(s)	No
Kleptoparasitic interaction	Bird engages in interaction with other seabirds which suggests an attempt to steal food	Yes
Suspected foraging event	Bird engages in movements suggestive of prey detection or prey capture attempts (rapid change in direction / height / interactions with conspecifics or heterospecifics) but no prey is seen	Yes
Confirmed foraging event	Bird engages in movements suggestive of prey detection or prey capture attempts (rapid change in direction / height / interactions with conspecifics or heterospecifics) and prey is seen	Yes
Single or Multi-species aggregation	Bird is seen in aggregation of either conspecifics or heterospecifics, interacting close to the water's surface	Yes
Alone	Absence of consepcifics / heterospecifics in image	---

Foraging strategy classification using Gaussian Mixture Models

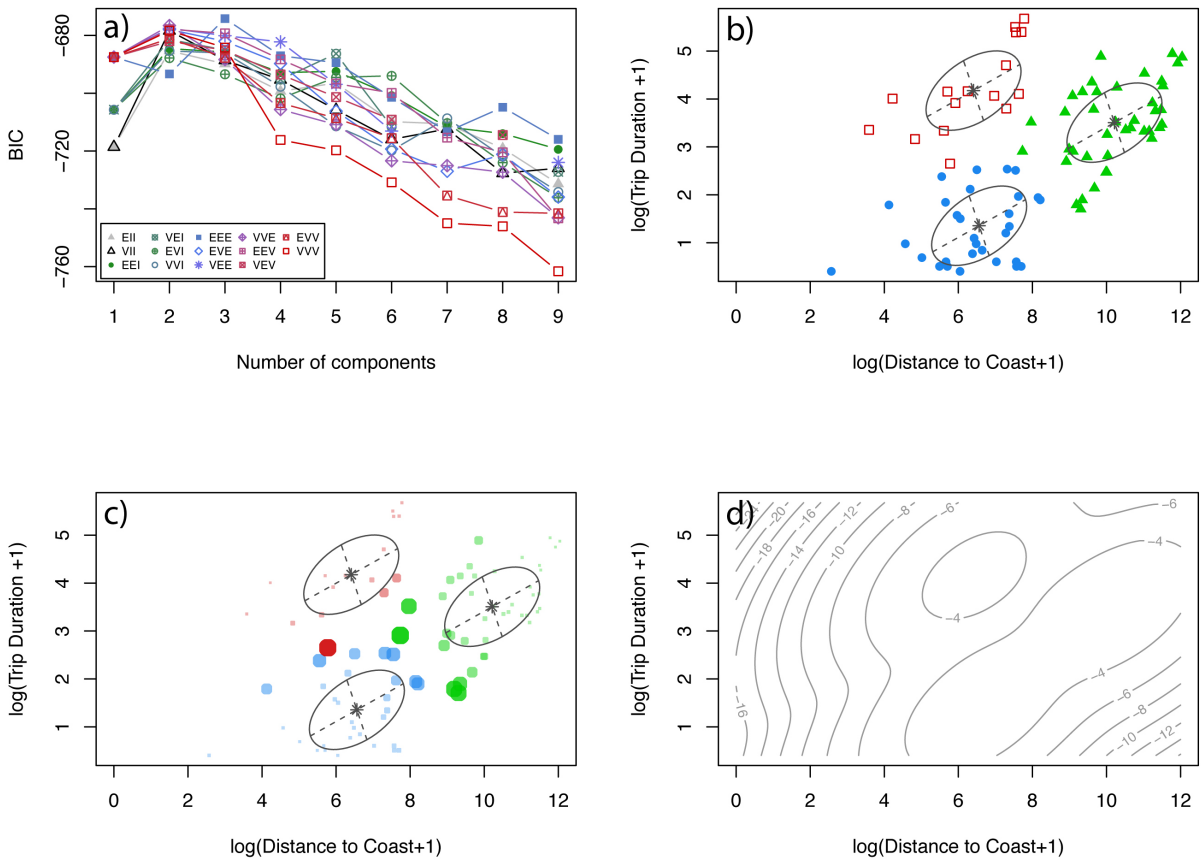

Fig. S2. a) Bayesian Information Criteria (BIC) for candidate Gaussian Mixture Models (GMMs) with 1 to 9 components, b) GMM-assigned clusters based on distance to coast and trip duration values, c) uncertainty of belonging to one of the three GMM-assigned clusters and d) estimated density based on distance to coast and trip duration. State: red = 1, green = 2, blue = 3.

Table S5. Mean (±SD) trip characteristics of foraging magnificent frigatebirds that engaged in three foraging tactics defined by Gaussian Mixture Models. c = coastal strategy, p = pelagic strategy.

Tactics	Maximum distance (km)	Distance from coast (km)	Total distance (km)	Trip duration (hr)
1 (*n* =30; c)	227.7 ± 59.9	8.9 ± 2.1	813.1 ± 199.5	97.7 ± 22.7
2 (*n* = 40; p)	164.5 ± 25.5	43.9 ± 6.0	470.2 ± 69.2	44.0 ± 5.7
3 (*n* = 16; c)	11.8 ± 2.5	1.4 ± 0.3	34.6 ± 7.3	3.7 ± 0.6

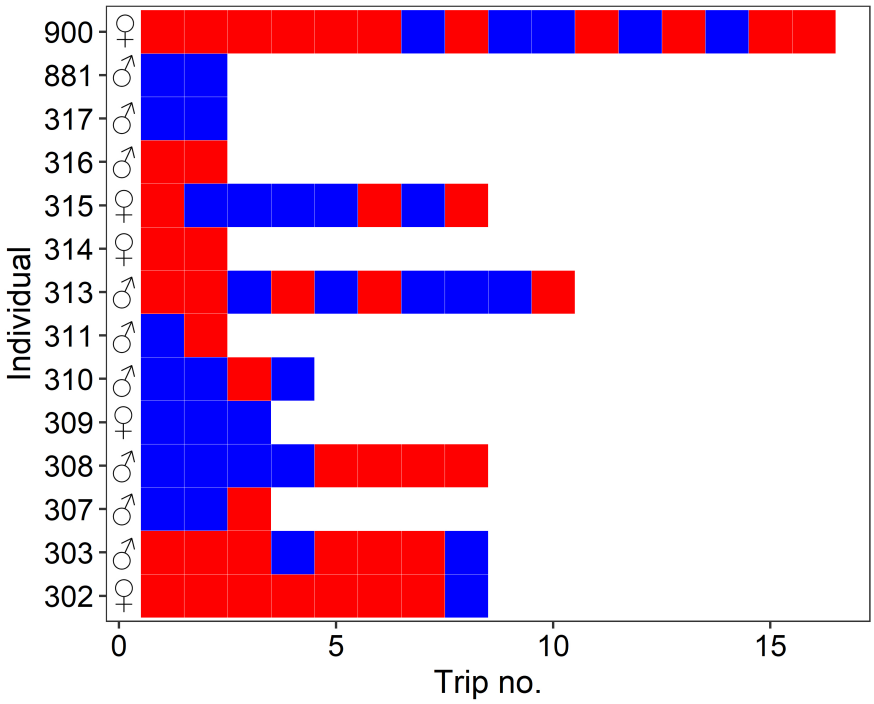

Fig. S3. Summary of the pattern of foraging strategies used by individual chick-rearing magnificent frigatebirds tracked with GPS-GSM loggers from Little Cayman during 2017. Red = coastal, blue = pelagic.

Summary of deployments and recoveries

Table S6. Summary of the number of magnificent frigatebirds tagged and recovered from the population on Little Cayman, Cayman Islands between March and July, 2017.

Logger type	No. birds
GPS-GSMs	19/22*
Archival GPS	4/20
Cameras	1/4
Accelerometers	3/16
Birds resighted	18/29†
Birds recaptured	4
Proportion resighted	0.62
Proportion recovered (excluding GSMs)	0.20
No. complete foraging tracks (igotu)	12
No. complete foraging tracks (GSMs)	82
Total complete	**94**

**no. of GSMs yielding data*

†Resighting only attempted for 29 nests

Foraging behaviour of failed breeders

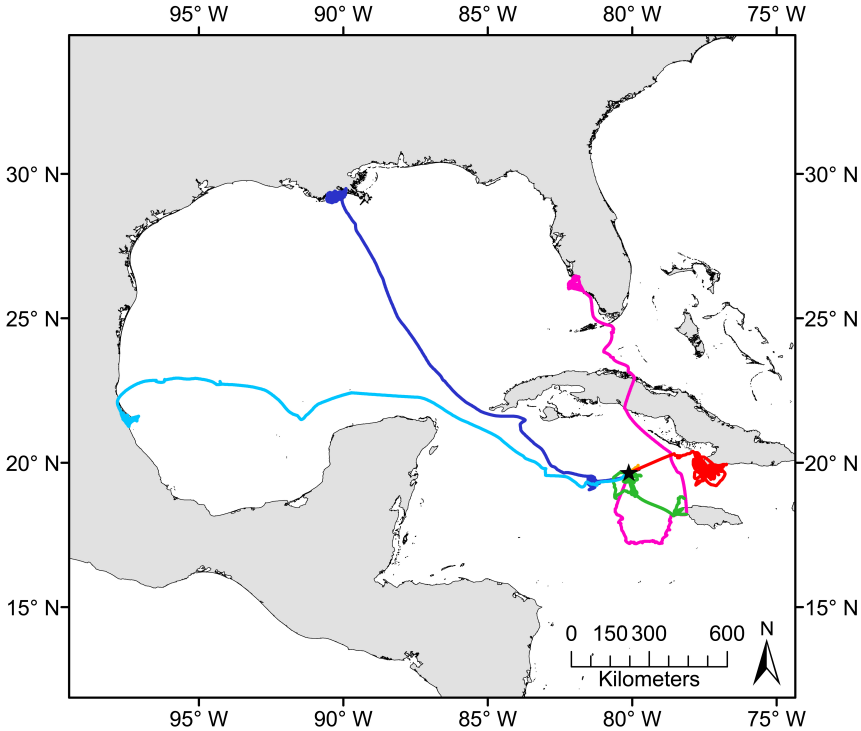

Fig. S4. Map of foraging trips of failed breeders from the Little Cayman breeding colony in 2017 (n = 5).

References

Dean B, Freeman R, Kirk H, Leonard K, Phillips RA, Perrins CM, Guilford T (2013) Behavioural mapping of a pelagic seabird: combining multiple sensors and a hidden Markov model reveals the distribution of at-sea behaviour. J R Soc Interface 10:20120570 https://doi.org/10.1098/rsif.2012.0570

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