The following supplements accompany the article

Influence of shelf oceanographic variability on alternate foraging strategies in long-nosed fur seals

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Supplement 1. Extra Tables and Figures

Table S1. Sources and their URLs of environmental data used in this study.

Source	URL
NOAA Optimum Interpolation daily Sea Surface Temperature Anomaly	https://www.ncei.noaa.gov/erddap/griddap/ncdc_oisst_v2_avhrr_by_time_zlev_lat_lon.html
IMOS Optimal Interpolated daily Gridded Sea Level Anomaly	https://portal.aodn.org.au/
IMOS Animal Tracking Facility	https://portal.aodn.org.au/
NOAA daily Antarctic Oscillation index	http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/aao/aao.shtml
NOAA ESRL PSD	https://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.surfaceflux.html

Table S2. Candidate binomial generalised linear mixed models for investigating the effect of environmental predictors on the type of foraging trip (shelf vs non-shelf). Wind, alongshore wind stress; sal, subsurface salinity; t, subsurface temperature; SSHA, sea surface height anomaly; sam, Southern Annular Mode; SD, standard deviation.

Candidate models	logLik	AICc	dLogLik	dAICc	df	weight
sal_mean + SSHA_mean + sal_mean:SSHA_mean + (1 | id)	-82.3	175	25.5	0.00000	5	1
sal_mean + SSHA_mean + (1 | id)	-92.1	192	15.7	17.4	4	0
sal_mean + SSHA_mean + wind_mean + (1 | id)	-91.5	193	16.2	18.5	5	0
t_mean + sal_mean + SSHA_mean + wind_mean + (1 | id)	-90.84	194	16.9208	19.2603	6	0
t_mean + sal_mean + SSHA_mean + wind_mean + year + (1 | id)	-90.39	196	17.3659	20.5604	7	0
t_mean + sal_mean + SSTA_mean + SSHA_mean + wind_mean + year + (1 | id)	-89.94	197	17.8159	21.8801	8	0
t_mean + sal_mean + sam + SSTA_mean + SSHA_mean + wind_mean + year + (1 | id)	-89.67	199	18.0851	23.5916	9	0
t_mean + sal_mean + sam + SSTA_mean + SSHA_mean + wind_mean + wind_SD + year + (1 | id)	-89.52	201	18.2381	25.5659	10	0
1 + (1 | id)	-107.8	220	0	44.623	2	0

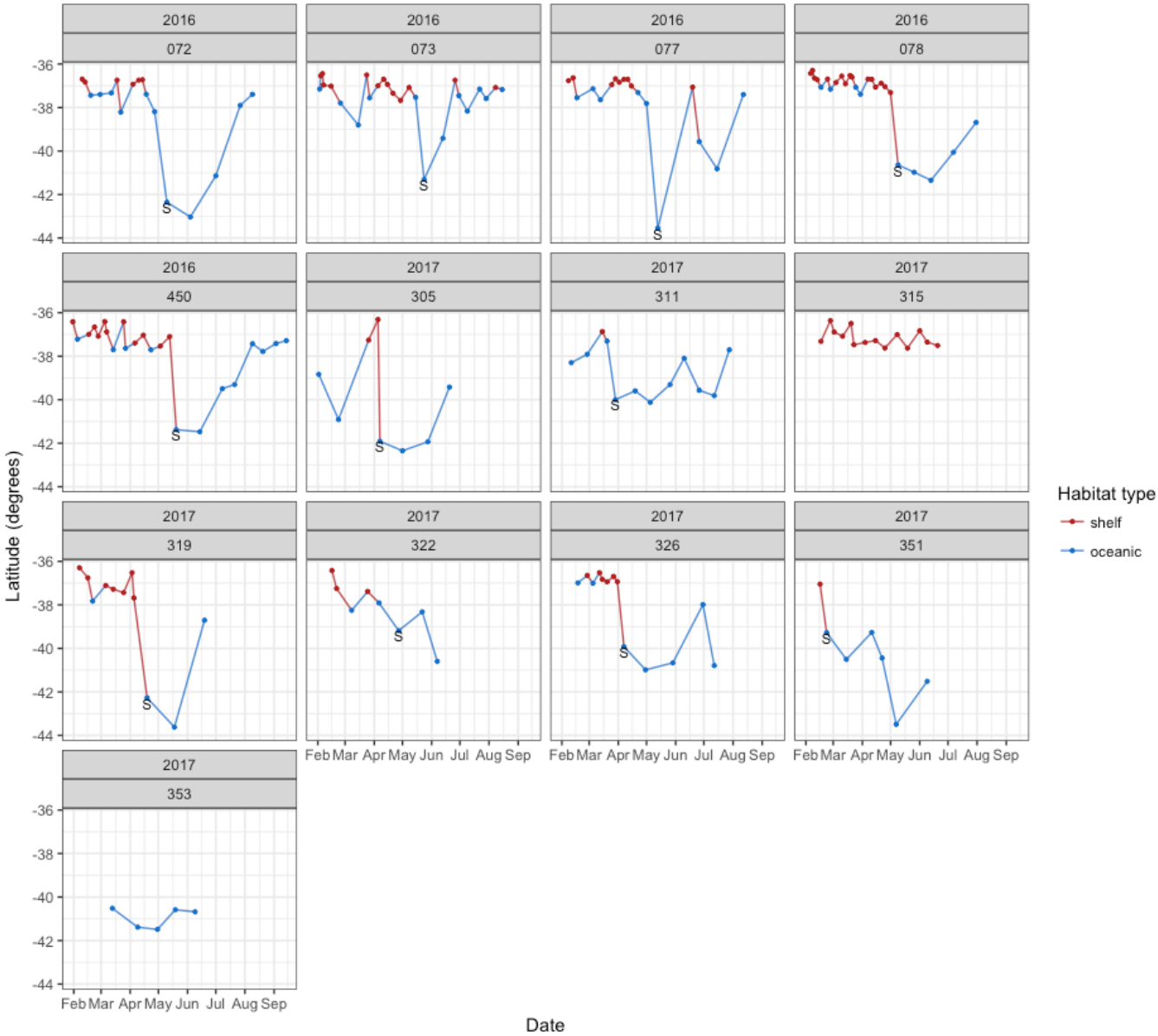

Fig S1. Maximum latitude travelled for each foraging trip of each individual lactating female Long-nosed fur seal. Trips identified as the switch trip where individuals switch from predominantly shelf or near-shelf foraging to oceanic are labelled "S". Individual #315 and #353 did not have any switch trips. Only individual #077 had a shelf foraging trip immediately after the switch trip.

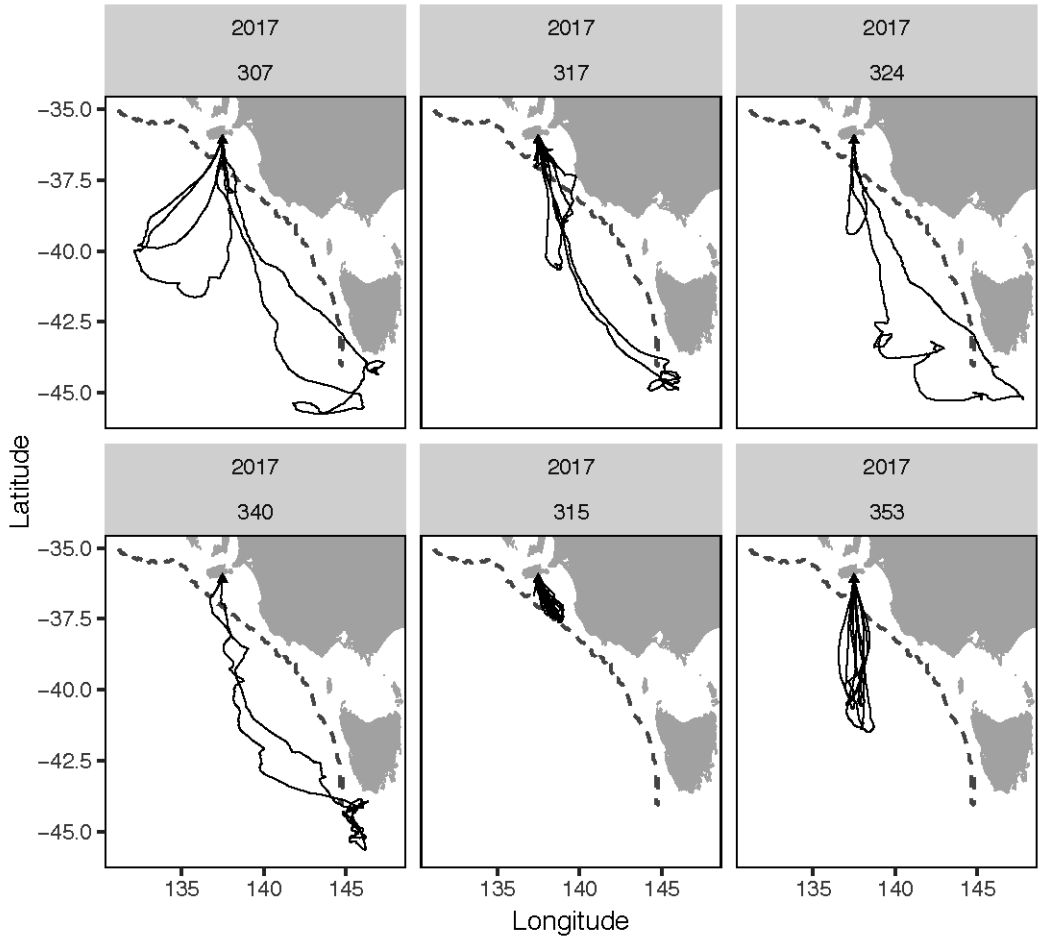

Fig. S2 Geolocation tracks of unconstrained (non-central place foraging; #307, #317, #324, #340) and non-switching (between shelf and oceanic foraging, #315, #353) adult female Long-nosed fur seals.

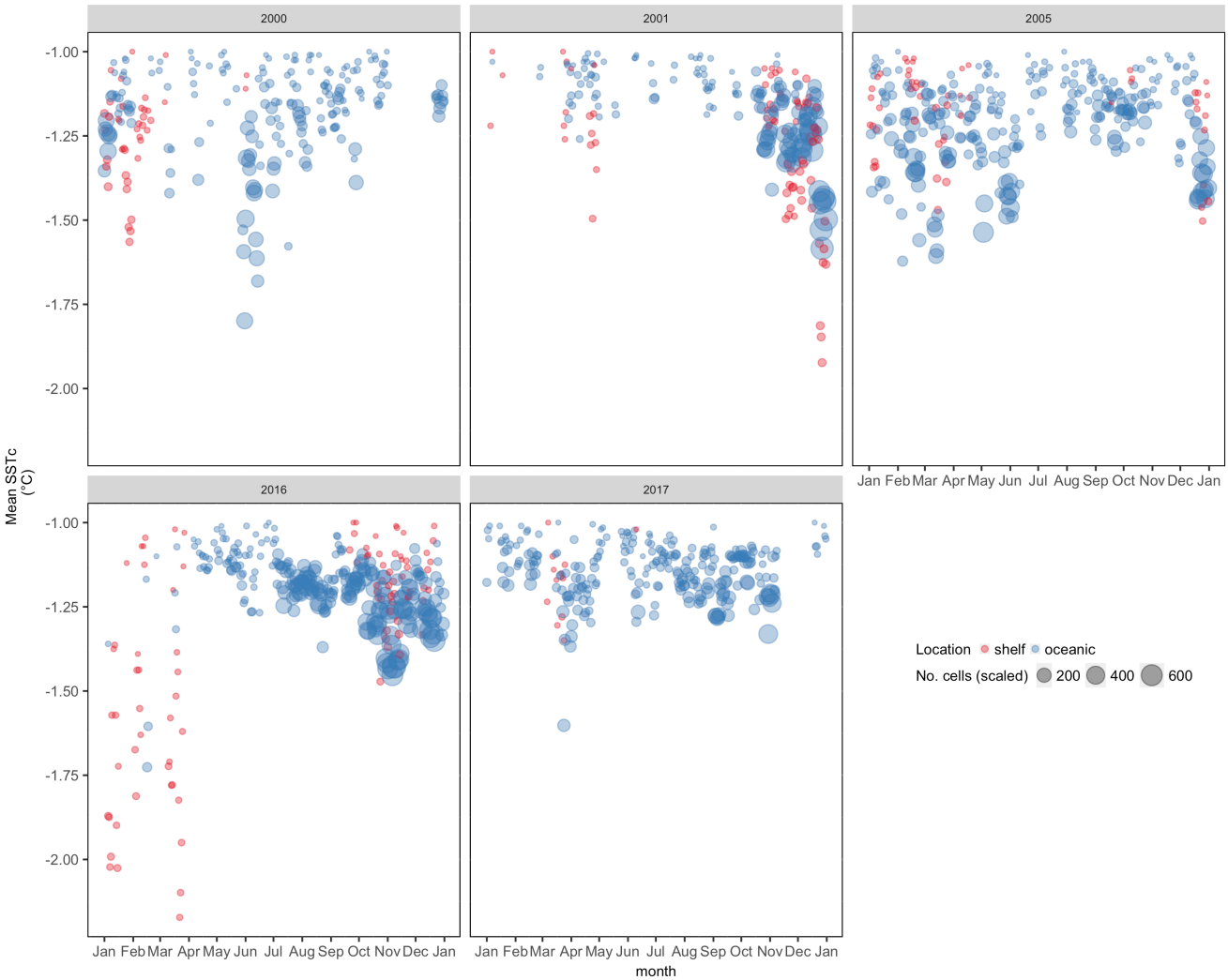

Figure S3. Inter-annual comparison of the strength (average SSTc) and area (no. of cells) of anomalously cool SST (SSTc, proxy of upwelling-favourable conditions) for shelf (red) and oceanic (blue) regions within the foraging range lactating LNFS. Previous study on the same LNFS colony was done in 2000-2001 and 2005.

Supplement 2. Validation of SGAT R Package

Methods

In July 2017, five lactating female long-nosed fur seals (*Arctocephalus fosterii*) were randomly selected and captured using a hoop-net at Cape Gantheaume (36°04′S, 137°27′E), Kangaroo Island, South Australia. Seals were anaesthetised using Isoflurane (Veterinary Companies of Australia, Artarmon, New South Wales, Australia), administered via a portable gas anaesthetic machine (Stinger™, Advanced Anaesthesia Specialists, Gladesville, NSW, Australia). The seals were weighed (± 0.5 kg) and their body length (nose to tail) and axial girth were measured (±1 cm). Geolocation (GLS, Intigeo-C330, 17 x 19 x 8 mm, 3.3 g, Migrate Technology Ltd, Cambridge, UK) loggers and Satellite-linked GPS/Argos transmitters (TGM-4310-3, 10x6.5x3.7 cm, 190 g, Telonics Inc, Arizona, USA) were deployed on all five female seals. The transmitter records a mix of Argos and GPS-type locations depending on the satellite signal availability and seal surfacing behaviour. It was programmed to transmit 8 hours a day which led to around 4 locations per day. Using Telonics' Quick Fix technology, GPS locations can be obtained in as little as about 3 seconds. The GLS loggers were attached to the flipper tag as described by Arthur et al. (2015). Transmitters were glued to the fur on the dorsal midline, using a 2-part quick-setting epoxy (RS Components Pty Ltd, New South Wales, Australia). All instruments were recovered after one foraging trip. Seals were recaptured using similar methods for their initial capture.

The GLS loggers measured ambient light every 5 minutes and recorded the maximum value for every 4-hour period. The loggers also sampled sea temperature (0.125°C resolution, ±0.5°C accuracy) after 20 minutes of being continuously wet and recorded the minimum, maximum and mean temperature for every 4-hour period. The loggers also sampled the time when an activity (wet or dry) state change occurred. Each logger was activated and left in an open area at the study site for approximately 5-7 days either immediately before or after deployment to obtain solar elevation estimates necessary for instrument calibration.
Location estimation for light data

All analyses were done using the R program (R Core Team 2017). Locations were estimated from the raw light data by first using the *BAStag* package (Wotherspoon et al. 2016a) to estimate times of twilight (dawn and dusk). Next, the *SGAT* package (Wotherspoon et al.

2016b) was used to create Markov Chain Monte Carlo simulations within a Bayesian framework to estimate the final posterior mean of two primary locations *per* day while incorporating temperature and land-mask constraints (Sumner et al. 2009; Lisovski et al. 2012). Additionally, seals were assumed to be back at the colony when the GLS logger was continuously dry for ≥ 4 h, which usually corresponded with messy light curves due to the animal periodically shading the light sensor on-shore (Arthur et al. 2015). We made this assumption because lactating LNFS are not known to haul-out at other locations during a foraging trip (Page et al. 2006; Baylis et al. 2012). Hence, locations were fixed to the colony during dry logger periods and validated with ad-hoc observations of seal attendance at the colony where possible. The duration of a foraging trips were thus determined as the wet period between dry periods inferred from the GLS data.

GPS location processing

Recovered GPS/Argos tags allows access to all the GPS locations recorded and stored on-board the tag's memory. Hence, we only use GPS locations obtained from recovered tags. Unresolved Quick Fix Positions were removed from analyses due to the magnitude of their error.

Comparison of GLS and GPS/Argos locations

To characterise the error of the locations estimated by SGAT, we followed methods detailed in Bindoff et al. (2018). First, we calculated the mean longitude and latitude for each day of the GLS and GPS/Argos tracks to get one location per day for each type of track. Second, we calculated the root-mean-squared-error of the GLS tracks for each daily longitude and latitude as such:

$$\text{RMSE} = \sqrt{\frac{1}{n} \cdot \sum (g - G)^2}$$

where g is the GLS longitude or latitude, G is the GPS/Argos longitude or latitude, and n is the total number of daily locations.

Third, we calculated the average and standard deviation of the minimum great circle distance (km) of each GLS location to the nearest GPS location on each day.

Results

Tags from four seals were recovered and used for analyses. A total of 1049 GPS positions were obtained. The average foraging trip duration was 27 days (± 5.67, 23 – 35 days).

Table S3. The root-mean squared error (RMSE) and mean great circle distance (GCD) between the estimated position from light data processed in SGAT R package and the reference position (GPS) on each day.

Seal ID	RMSE Lon (°)	RMSE Lat (°)	GCD Mean (km)	GCD SD (km)
356	0.4	0.65	63.0	32.5
357	0.1	0.33	27.9	20
358	0.19	0.41	33.3	26.2
359	0.23	0.6	54.7	37
Mean	0.23	0.498	44.7	28.9

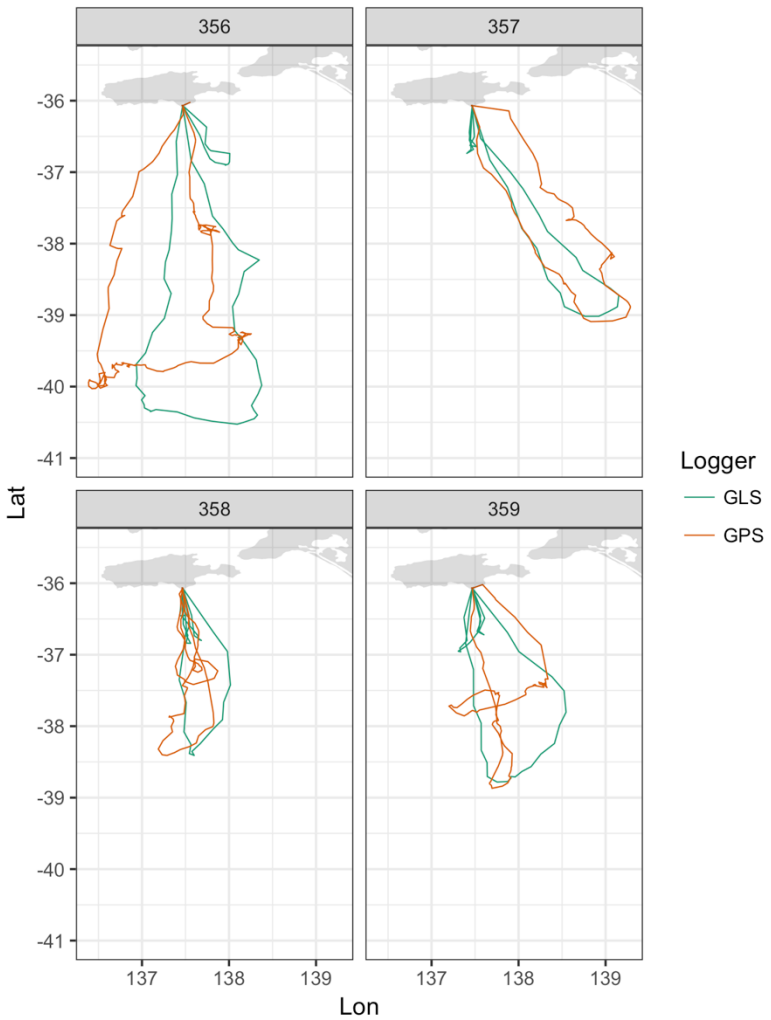

Figure S4. Tracks of double-tagged (GPS/Argos and GLS) lactating long-nosed fur seals from a single foraging trip.

Literature Cited

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