Supporting Information

Sequeira *et al*.

Convergence of marine megafauna movement patterns in coastal and open oceans

Contents

Page no

Supporting Materials and Methods

Tracking datasets. The mean number of individual tracks per species was 53.4 (median = 24 tracks), ranging from 2 to 321 (for pilot whales and Northern elephant seals, respectively), with tracks collected over periods ranging from < 1 to 14 years (median = years; Table S1). As a large collaborative effort between researchers worldwide, the data were collected with a range of technologies with spatial resolutions from ≤ 10s m for Global Positioning System (GPS) transmitters (88 individual tracks), to 100s m for ARGOS (advanced research and global observation satellite) linked transmitter (2160 individual tracks), and coarser for light-level geolocation tags (GLS; 168 individual tracks). Data were also provided raw or processed in different forms ranging from implementation of simple speed filters (1) to Kalman filters (2) and state-space models (3). For some species, tracking datasets were obtained using both ARGOS and GPS, so we were able to run preliminary tests to compare results on these species to ensure that our analysis of displacements was comparable and independent of the data resolution (detailed below). These sensitivity analyses were possible for Australian and Cape fur seals, California and Galapagos sea lions, Northern elephant seal, Laysan albatross and polar bear (Figure S4). Because a similar assessment was not possible for GLS data, we have not included in our analysis species for which only GLS data were available. For ARGOS data, we also compared results obtained across datasets with different levels of pre-processing (*e.g.*, raw or filtered data). For this comparison, we used raw ARGOS locations compared with the same datasets after processing with a state-space model for three species: Southern elephant seal, Australian sea lion, and Macaroni penguin (Figure S5). We also evaluated whether the results of the analysis would differ by using each type of data individually (Figure S6) and confirmed that the mixing of datasets did not impact on the results. After data checking and preliminary analysis, we were able to proceed with tracking data for 38 species (2248 individual tracks).

Probabilistic analysis of displacements. After calculating the displacements as the shortest great circle distance between two locations, we obtained the scaling properties of the displacements with time. The root-mean-square displacement ($d_{\mathrm{RMS}} = \sqrt{\langle d^2 \rangle}$) scaled as a power law of time in most cases, $d_{\mathrm{RMS}} \sim T^{\mu}$. The exponent μ is well-defined for Brownian and ballistic linear motion, taking values 0.5 and 1, respectively (4). We then compiled and compared the resulting distributions of the probability density functions (PDF) of the displacements obtained from each individual when fixing the time window at 1 day (T = 1). For comparison of the probability density functions (PDF) obtained from each individual when fixing the time window at 1 day, we considered the moments of the distributions, *i.e.*, the quantitative measures representing the shape of the resulting distributions. To that effect, we used the coefficient of PDF spread (CS) defined as the ratio between the second moment and the square of the first moment (*i.e.*, square of the mean): $\frac{<d^2>}{<d>^2}$, where 'd' is the displacement in km. Our CS is related with the defined coefficient of variation (CV): $CS = (CV)^2 + 1$. The CS is a dimensionless measurement and can be used for comparison across all individuals irrespective of scale, providing an estimate of the spread of the resulting distribution normalized by the square of the average displacement. CS values $\gg 1$ are therefore indicative of wide distributions with heavy tails decaying much more slowly than would be expected in a Gaussian distribution. Despite the conceptual differences between distributions with heavy tails, such as lognormal or power laws, this method served our need to compare patterns across different sized animals because the distributions generally indicate high probability for relatively small displacements, with very large displacements also likely to be observed but with low probability.

To partially account for potential differences associated with different life history stages, we did not mix stages for a selection of species (e.g., only lactating female California sea lions, males in non-breeding season for New Zealand fur seals). For other species for which we knowingly included more "stages" or "stage phases", we ran preliminary tests showing that the coefficient of PDF spread (CS) and RMS exponents were mostly similar across all stages and trips considered (Table S5).

Assessing coastal affinity. We classified depths between 0 – 150 m according to the general bathymetric chart of the oceans (GEBCO; gebco.net). All other depths were considered off-shelf or open ocean habitat. When considering three groups, the coastal affinities of 0.3 and 0.7 were used for the split, and the species within each group were: (*i*) low coastal affinity: black footed albatross, blue shark, king penguin, Laysan albatross, leatherback turtle, northern elephant seal, northern fur seal, long-nosed fur seal, pilot whale, Southern right whale, southern elephant seal, and whale shark; (*ii*) mixed coastal affinity species: California sea lion, cape fur seal, crabeater seal, Galapagos sea lion, humpback whale, macaroni penguin, mako shark, New Zealand sea lion, polar bear, short-tailed shearwater, tiger shark, weddell seal, and western gull; and (*ii*) high coastal affinity species: Australian sea lions, Australian fur seal, beluga, bottlenose dolphin, bull shark, dugong, flatback turtle, great hammerhead shark, green turtle, little penguin, loggerhead turtle, West Indian manatee and southern sea lion.

Boosted regression trees. We fitted BRT models (following 5) with a combination of learning rate (lr) and tree complexity (tc) of 0.003 and 10, respectively, which achieved minimum predictive error in preliminary cross validation procedures (*i.e.*, using random subsets of data for model training and the remainder as testing datasets for prediction). Models were developed using the *gbm* and *dismo* package in R (6) and adapting code previously published (5). The total number of trees (nt) was ~ 1500, and we used a bag fraction of 0.5 to select 50 % of the data randomly in each tree. We then used gbm.simplify (5) to see which variables could be excluded from the model and re-ran the BRT model with the simplified predictor set using the same combination of parameters (lr, tc, and bag fraction). We extracted the relative importance of variables using the *summary* function for the simplified model and then assessed the model fits using partial dependence plots (*i.e.*, the effect of a variable on the response after accounting for the average effects of all other variables in the model). To quantify interactions, we used the function *gbm.interactions* form of the dismo package in R, which indicates the relative strength of interaction fitted by BRT (zero indicating that no interaction effects are fitted).

Dendrogram of movement. With the resulting matrix, we used the neighbour-joining method (7) to produce a dendrogram that includes all species. To assist interpretation of the observed branch patterns, we then contrasted the resulting tree with the predictors identified in the highest ranked models for CS by colour coding the dendrogram based on *coastal affinity*.

Supporting Acknowledgments

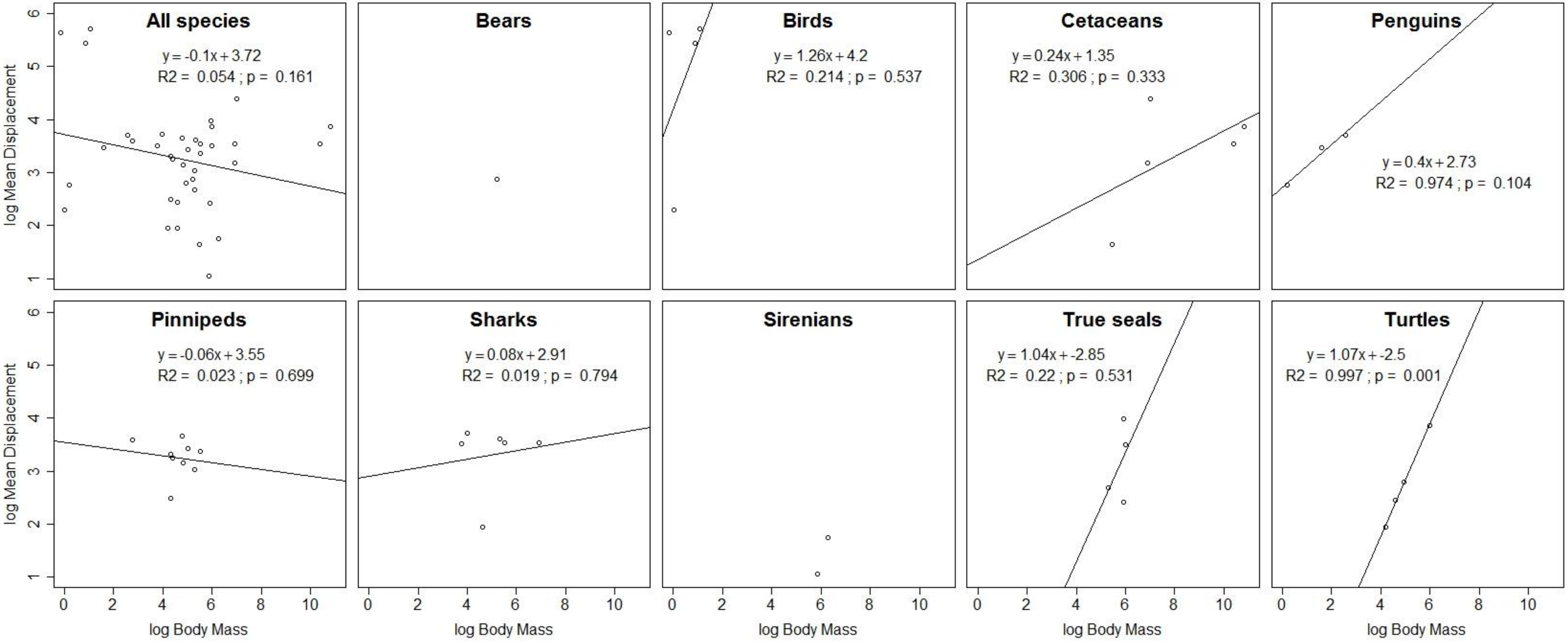
We are thankful to all involved in data collection, including the Bardi Jawi Rangers (dugong data), as well as J Werry (shark tracking data from the QLD Large Shark Tagging Program). GCH thanks G Schofield, N Esteban, and J Houghton for invaluable help with fieldwork in the Mediterranean, Indian Ocean and Atlantic respectively and also Ernesto and Kirsty Bertarelli, and the Bertarelli Foundation, for their support of his research in the Chagos Archipelago and the BIOT Administration for assistance and permission to carry out research. M-AL thanks T Gelatt, the NRC Research Associateship Program and the NOAA, Alaska Fisheries Science Centre, Marine Mammal Lab. RHC thanks Sea to Shore Alliance. Elephant seal tracking datasets were collected as part of IMOS, a national collaborative research infrastructure, supported by the Australian Government and operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent, and MEOP-BR, funded by the Brazilian Science, Technology and Innovation Ministry (CNPq, Grant № 520196/2006-6). Other data were obtained by: Dauphin Island Sea Lab's Marine Mammal Research Program with funding from the Alabama Division of Wildlife and Freshwater Fisheries, Mobile Bay National Estuary Program, and Northern Gulf Institute (West Indian manatee); Office of Naval Research and Dolphin Quest Inc. (Bottlenose dolphin); NOAA's John H. Prescott Marine Mammal Rescue Assistance Grant Program (pilot whale); and U.S. Geological Survey with funds also provided by the USGS Ecosystems and Climate and Land Use Change Mission Areas (polar bear). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Blue and mako shark data was funded by the UK Natural Environment Research Council (NERC) Oceans 2025 Strategic Research Programme (D.W.S.), the Save Our Seas Foundation (D.W.S.), a Marine Biological Association Senior Research Fellowship (D.W.S.), European Regional Development Fund (FEDER) via the Programa Operacional Competitividade e Internacionalização (COMPETE), National Funds via Fundação para a Ciência e a Tecnologia (FCT) under PTDC/MAR/100345/2008 and COMPETE FCOMP-01-0124-FEDER-010580 (to N.Q. and D.W.S.) and FCT Investigator Fellowships IF/01611/2013 (to N.Q.).

Supporting Figures

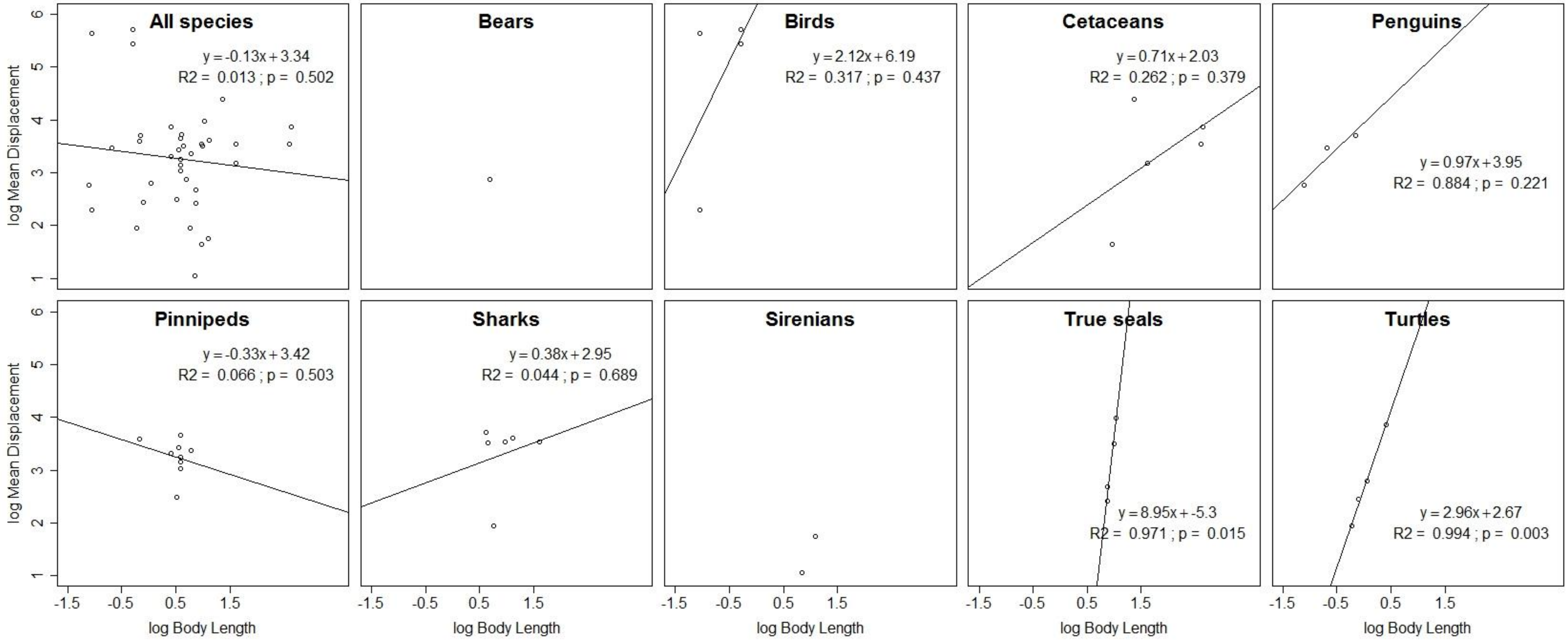
Sup Figure 1: Allometric relationships for mean effective speed (km/day)

(A) and for the coefficient of PDF spread of the probability density functions (B) with body mass. Top left plot in each panel shows the relationship across all species, while each guild is presented in the other plots. Relationships and R^2 shown only for guilds with more than 2 species.

A)

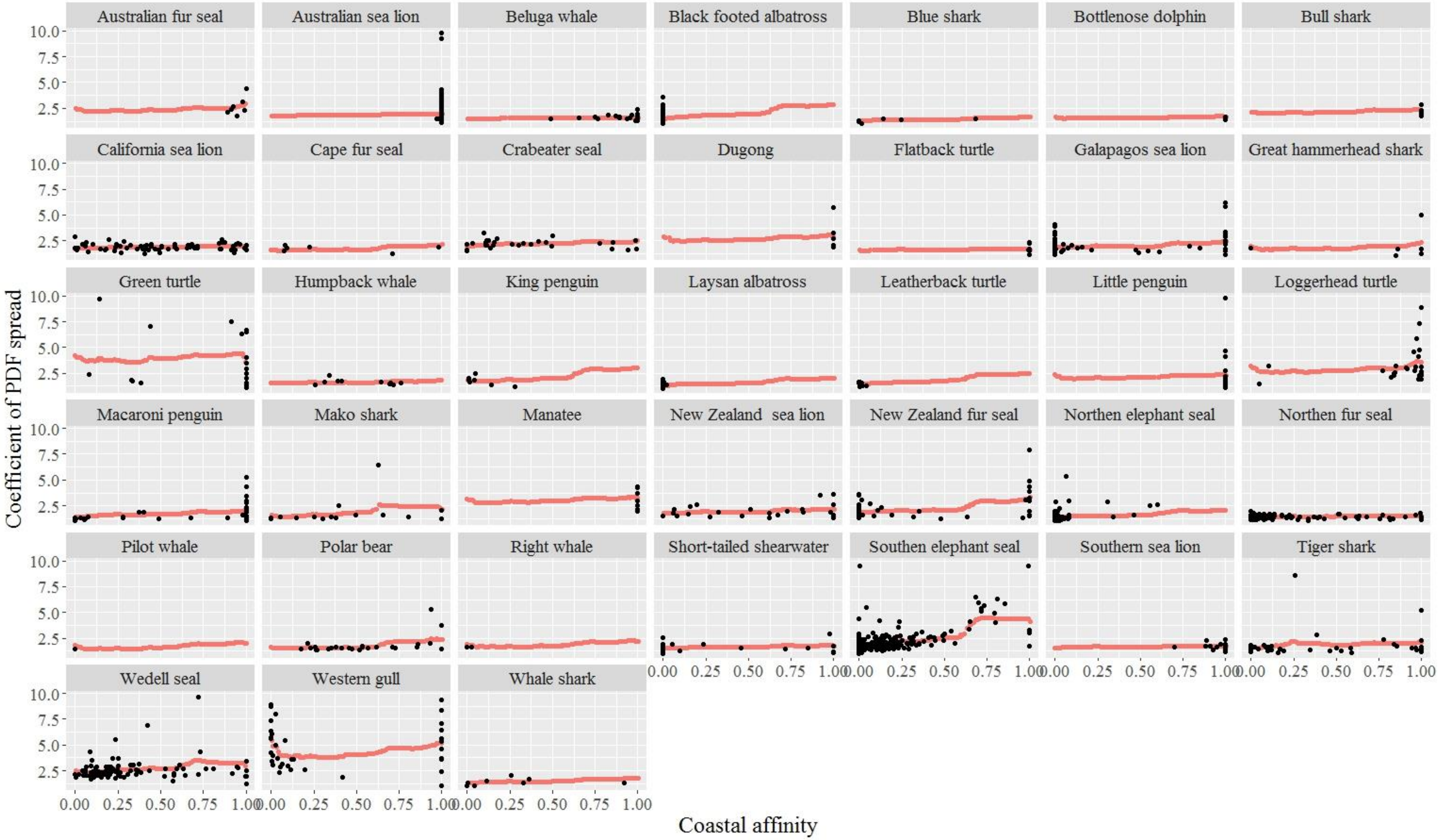


B)


All species
y = -0.13x + 3.34
R2 = 0.013 ; p = 0.502
Bears
Birds
y = 2.12x + 6.19
R2 = 0.317 ; p = 0.437
Cetaceans
y = 0.71x + 2.03
R2 = 0.262 ; p = 0.379
Penguins
y = 0.97x + 3.95
R2 = 0.884 ; p = 0.221
Pinnipeds
y = -0.33x + 3.42
R2 = 0.066 ; p = 0.503
Sharks
y = 0.38x + 2.95
R2 = 0.044 ; p = 0.689
Sirenians
True seals
y = 8.95x + -5.3
R2 = 0.971 ; p = 0.015
Turtles
y = 2.96x + 2.67
R2 = 0.994 ; p = 0.003
log Mean Displacement
log Body Length

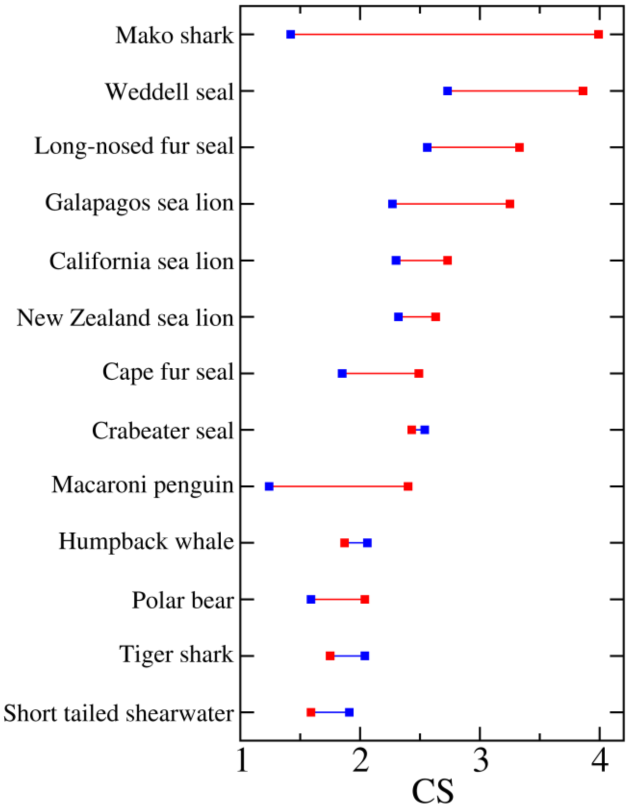
Sup Figure 2: Interaction between coastal affinity and species

Representation of the interaction between each species and coastal affinity as derived from the boosted regression trees. Red lines show the model predictions and black dots show data values for each individual tracking dataset analysed.



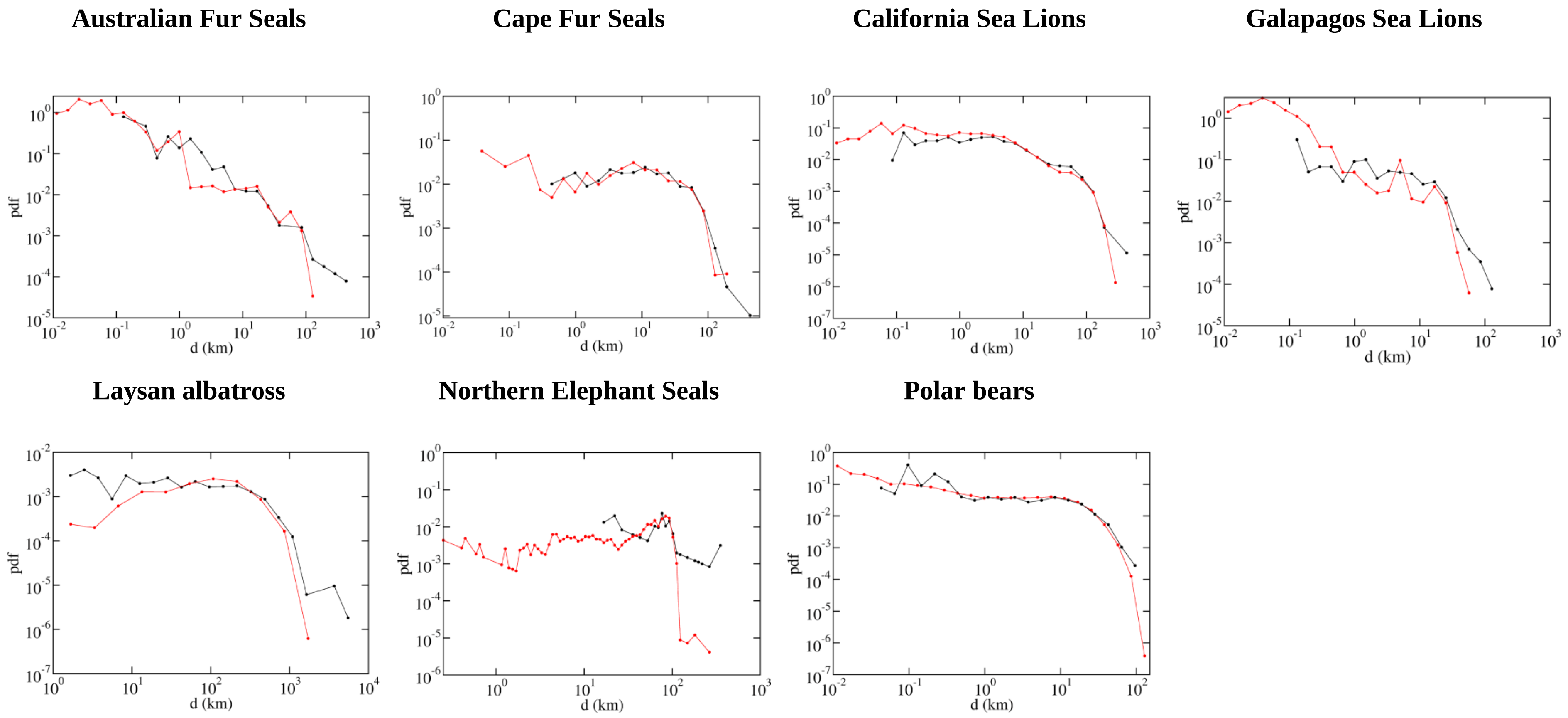
Sup Figure 3: CS for species with mixed shelf affinity

The plot shows the value for all displacements taking place in open (blue) and coastal (red) environments separately. Lines connecting the CS values are red (or blue) when coastal (or open) ocean CS values are higher, respectively.



Sup Figure 4: Comparison of results obtained from ARGOS (black) and GPS (red) positions.

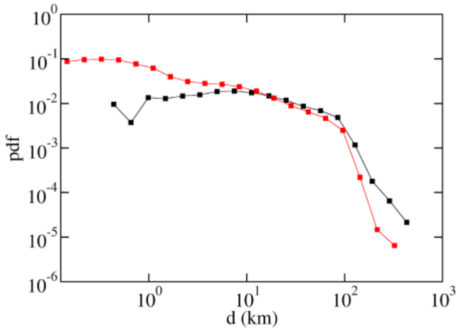
PDFs are shown for all species for which both types of data were available, including Australian and Cape fur seals, California and Galapagos sea lions, Laysan albatross, Northern elephant seals, and polar bears. Plots show high similarity in the PDFs of displacements obtained with GPS and ARGOS linked transmitters highlighting that, for the purpose used here, the results obtained from both technologies were comparable.



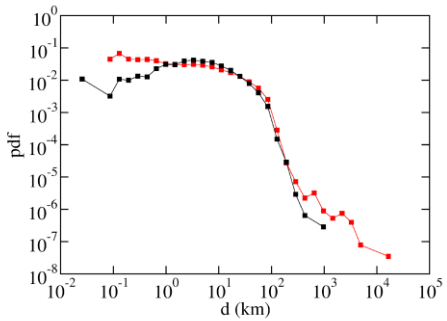
Sup Figure 5: Comparison of results obtained from datasets with raw (black) and processed (red) data.

Results are shown for species for which both raw and processed data were available: Australian sea lions, Southern elephant seals and Macaroni penguins. Plots show high similarity in the PDFs of displacements obtained when using raw or processed data highlighting that, for the purpose used here, the results obtained from both data types were comparable.

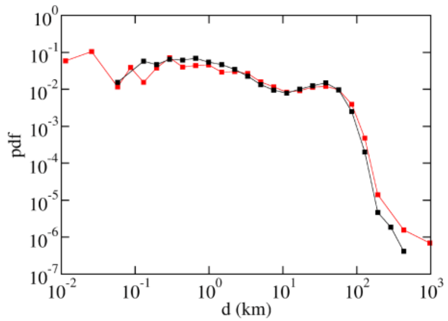
Southern Elephant Seals



Australian Sea Lions



Macaroni Penguins



Sup Figure 6: Replication of main results presented in the manuscript when using subsets of the global satellite tracking dataset.

Replication of main outputs presented in Figure 2 (A), 3 (B) and 4 (C), after replicating all data analyses and modelling using only Argos (left column), raw (middle column) and processed (right column) datasets. Details presented in the captions of Figure 2, 3 and 4 also apply here to A, B and C respectively. Results obtained were similar across all tests performed, except for the angles distribution with processed data only:

A) Highlights an expected increase in the coefficient of PDF spread (CS) with increased coastal affinity (CA), as detailed in the inset plot. The results from the boosted regression trees showed that species group and coastal affinity always had the highest relative importance with values: 68.9 % and 27.4 %, respectively with a small interaction size of 9 for Argos datasets only, 68.6 % and 23.9 %, respectively with interaction size of 22.67 for raw datasets only, and 74.0 % and 21.5 %, respectively with interaction size of 36.04 for processed datasets only.

B) The distribution of angles for displacements taking place in coastal and open oceans (red and blue respectively) all show higher probability of directed movement with angles of 0° in open ocean and higher probability of 'returns' (angles > 45° often peaking at 180°) in the coastal ocean. This is also the case for processed datasets which contained no individuals with high CS values, and where the peak at 180° did not occur, but the lines (red and blue) cross at ~ 30° and 330°, still showing a higher probability of 30° ≤ angles ≤ 330° for coastal displacements.

C) The dendrograms obtained with each subset of the global satellite tracking dataset all show a split between an upper and lower branch generally consistent with species having lower and higher coastal affinities, respectively.

<table>
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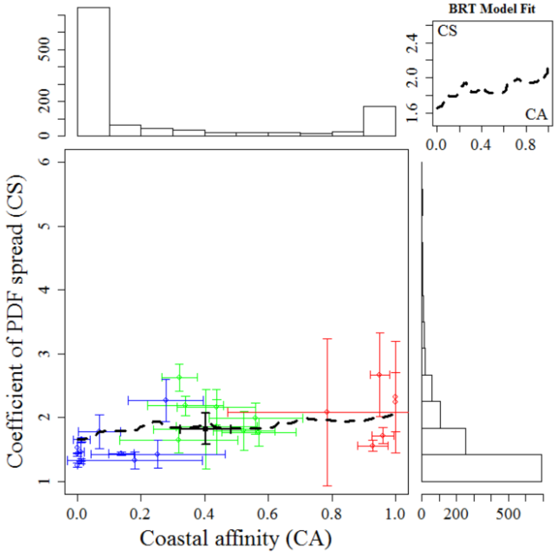
<td>
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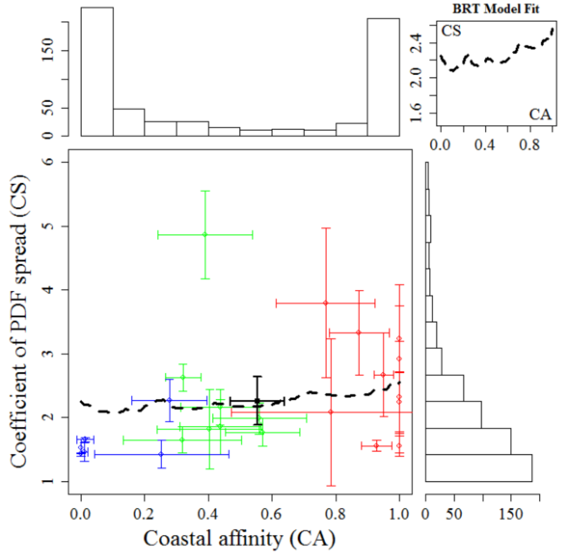
<td>
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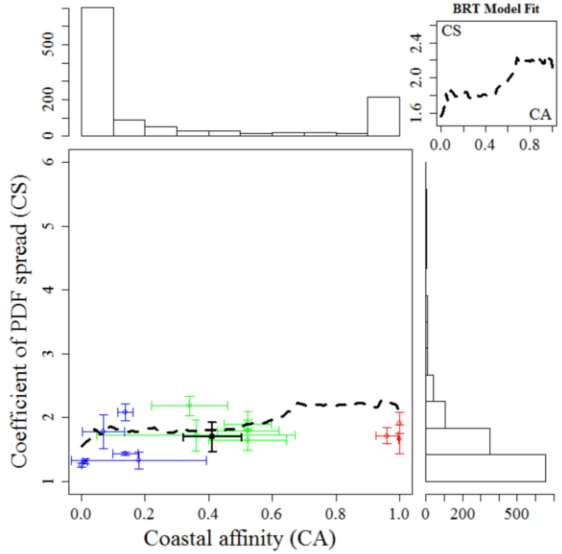
<td>
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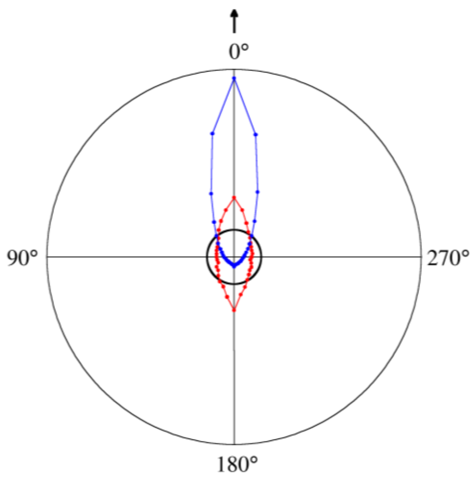
<td>
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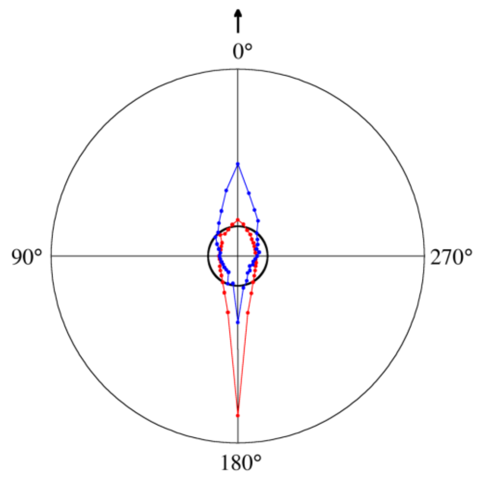
<td>
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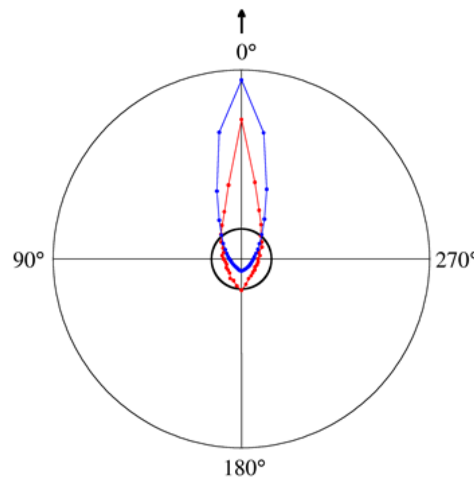
<td>
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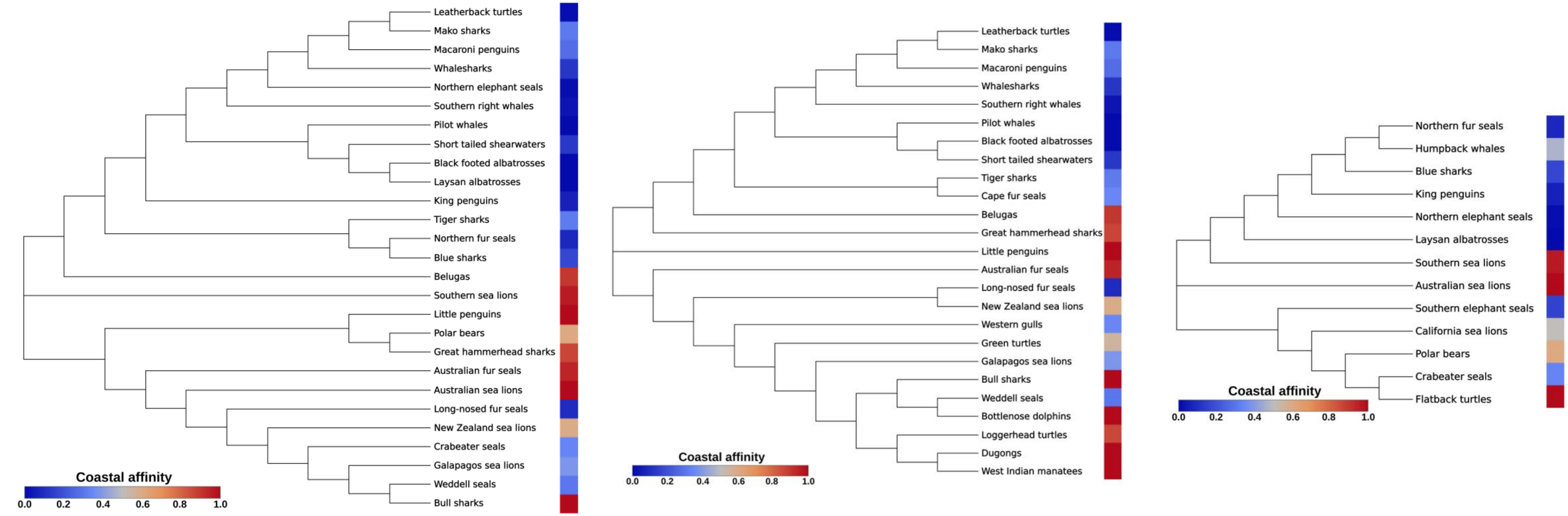
C) Replicated Figure 4



Supporting Tables

Sup Table 1: Summary of species-specific datasets representing nine taxonomic groups including bears, flying and swimming birds, cetaceans, pinnipeds (true and eared seals), sharks, sirenians and turtles.

Male and female adult (A) individuals were tracked and used for most species; where this was not the case, it is indicated with the following superscripts in front of the species common name: F – females only, Fl – fledglings only, &Fl – fledglings also, &J – juveniles also, M – males only, P – pups only, SA – sub-adults only, &SA – sub-adults also, U – unknown. 'n' indicates the number of compiled tracks per species. Tracks were obtained across various life stages for each species. The corresponding life history phase is indicated with superscripts following the number of tracks (# tracks): All – all phases represented, B – breeding, CR – chick rearing, F – foraging; G – guard stage, Inc – incubation, Lac – lactation, M –migration, NA – not applicable, NB – non-breeding adults, PB – post-breeding, PC – post-calving, PF – post-fledgling, PM – post-moulting, PW – post-weaning; S – released from stranding, U – unknown. "Events" – number of positions obtained within all tracks for each species. 'Data' indicates whether the data were raw (R) or processed (P) with superscripts indicating the position data type. The five quantitative variables considered in the models are also displayed: mean body mass (Mass), length (Length), and mean diving depth (Dive) provided by experts, food energy requirements (Energy) derived from published literature (as detailed in Table S2), and 'coastal affinity' (Coast) calculated from the data for each individual as a fraction of observed displacements on the coast, and shown here as percentage for each species. As most individuals tracked were not weighed and measured, an average weight and size for each species was used. For species for which the tracked data included different genders or age classes, the mean across the groups was used. Similarly, mean diving depths for each species were used. GPS: global positioning system, ARGOS: advanced research and global observation satellite, GLS: global location sensor. Greyed rows indicate species not included in the analysis (GLS data or not enough positions to perform analysis).

Common name	Scientific name	# tracks	Events	# used	Data	Mass (Kg)	Length (m)	Dive (m)	Energy (kj kg^{-1} day^{-1})	Coast (mean %)
Bears										
Polar bear[F]	*Ursus maritimus*	62 [Lac]	102499	62	P[Argos]	182	2	0	294.9	0.523
Birds - Flying										
Black footed albatross[A, Fl]	*Phoebastria nigripes*	193 [All]	11741	72	R[Argos]	2.9	0.75	0	623.6	0.000
Crested tern	*Thalasseus bergii*	22 [CR]	11728	-	R[GPS]	-	-	-	-	-
Flesh-footed shearwater	*Ardenna carneipes*	3 [NA]	643	-	-	-	-	-	-	-
Laysan albatross[Fl]	*Phoebastria immutabilis*	122 [All]	13545	122	P[Argos]	2.4	0.75	0	662.4	0.000
Short tailed shearwater	*Ardenna tenuirostris*	48 [CR]	12649	47	R[Argos]	0.63	0.45	11	2036.4	0.319
Sooty shearwater	*Ardenna griseus*	27 [NA]	6977	-	-	-	-	-	-	-
Western gull	*Larus occidentalis*	41 [Inc]	221209	41	R[GPS]	1.02	0.35	0	1433.4	0.396
Birds - Swimming										
Emperor penguin[J]	*Aptenodytes forsteri*	56 [PF]	31922	-	R[Argos]	-	-	-	-	-
King penguin	*Aptenodytes patagonicus*	8 [CR]	13125	8	P[Argos]	13	0.85	55	543.9	0.069
Little penguin	*Eudyptula minor*	102 [CR]	5009	102	R[Argos]	1.2	0.33	12.7	1149.3	1.000
Macaroni penguin	*Eudyptes chrysolophus*	91 [G, NB]	18318	91	R[Argos]	5	0.5	42	734.2	0.571
Cetaceans										
Beluga	*Delphinapterus leucas*	31 [NA]	37089	31	R[Argos]	1000	5	450	249.6	0.928
Bottlenose dolphin	*Tursiops truncatus*	3 [All]	1681	3	R[Argos]	238	2.64	2	272.1	1.000
Franciscana/ La plata dolphin	*Pontoporia blainvillei*	4 [All]	804	-	-	-	-	-	-	-
Humpback whale[U]	*Megaptera novaeangliae*	15 [NA]	707	12	P[Argos]	32800	13.5	146	61.1	0.523
Pilot whale[M]	*Globicephala macrorhynchus*	2 [S]	510	2	R[Argos]	1100	3.92	50	129.8	0.000
Risso's dolphin	*Grampus griseus*	1 [NA]	76	-	-	-	-	-	-	-
Rough-toothed dolphin[M]	*Steno bredanensis*	4 [NA]	528	-	-	-	-	-	-	-
Southern right whale[F]	*Eubalaena australis*	3 [PC]	1130	3	R[Argos]	50000	14	121	12.8	0.013
Pinnipeds – True seals										

Crabeater seal	*Lobodon carcinophaga*	30 [NA]	12614	30	P[Argos]	200	2.4	61	53.2	0.340
Northern Elephant[F]	*Mirounga angustirostris*	321 [PM, PB]	1027839	321	P[Argos]	380	2.8	516	198.9	0.012
Southern Elephant	*Mirounga leonina*	273 [PM]	554003	272	P[Argos]	402	2.7	450	219.9	0.138
Weddell seal[F]	*Leptonychotes weddellii*	96 [PM]	62873	96	R[Argos]	372	2.4	300	45.8	0.320
Pinnipeds – Eared seals										
Antarctic fur seal[F]	*Arctocephalus gazella*	132 [PB]	61264	-	-	-	-	-	-	-
Australian fur seal[M]	*Arctocephalus pusillus doriferus*	8 [PM]	1342	8	R[Argos]	200	1.8	69.3	98.9	0.953
Australian sea lion[A, SA]	*Neophoca cinerea*	236 [All]	85507	236	P[Argos]	81	1.8	50	640.1	1.000
California sea lion[F]	*Zalophus californianus*	75 [Lac]	52333	75	P[Argos&GPS]	84	1.6	80	183.6	0.522
Cape fur seal	*Arctocephalus pusillus*	6 [NA]	1066	6	[Argos&GPS]	120	1.8	70	500	0.360
Galapagos sea lion[F]	*Zalophus wollebaeki*	64 [B,PB]	14896	64	R[Argos]	74	1.67	95	352.5	0.436
Long-nosed fur seal[AF, SAM, J, M]	*Arctocephalus forsteri*	102 [B]	23502	102	R[Argos]	106	1.7	52.1	126.4	0.320
New Zealand sea lion[AF, SAM, J]	*Phocarctos hookeri*	26 [NA]	25256	26	R[Argos]	124.4	1.8	92.5	367.5	0.560
Northern fur seal[P]	*Callorhinus ursinus*	158 [PW]	80863	158	P[Argos]	15.6	0.84	13	527.8	0.139
Southern sea lion[F]	*Otaria flavescens*	20 [B]	17448	20	P[Argos]	150	1.75	64	106.3	0.959
Sharks (Elasmobranchs)										
Blacktip shark	*Carcharhinus limbatus*	1 [NA]	167	-	-	-	-	-	-	-
Blue shark[J]	*Prionace glauca*	6 [NA]	1755	6	P[Argos]	43.5	1.91	350	171.7	0.181
Bull shark[A, SA]	*Carcharhinus leucas*	34 [NA]	1301	26	R[Argos]	100	2.14	30	23.9	1.000
Great hammerhead shark[A, SA]	*Sphyrna mokarran*	34 [NA]	1059	20	R[Argos]	250	2.64	150	96	0.785
Mako shark[SA]	*Isurus oxyrinchus*	16 [NA]	16153	16	R[Argos]	54	1.84	80	171.7	0.404
Manta ray	*Manta alredii*	2 [NA]	151	-	-	-	-	-	-	-
Scalloped hammerhead shark	*Sphyrna lewini*	5 [NA]	151	-	-	-	-	-	-	-
Silky shark	*Carcharhinus falciformis*	1 [NA]	7	-	-	-	-	-	-	-
Tiger shark[SA]	*Galeocerdo cuvier*	75 [NA]	10430	70	R[Argos]	207	3.05	150	30.6	0.438

Whale shark[SA]	*Rhincodon typus*	26 [NA]	3350	16	R[Argos]	1000	5	110	21.5	0.253
Sirenians										
Dugong	*Dugong dugon*	6 [NA]	3728	6	R[GPS]	350	2.34	5.5	94.2	1.000
West Indian manatee	*Trichechus manatus*	10 [All]	121668	10	R[GPS]	530	3	2	52.3	1.000
Turtles										
Flatback turtle[F]	*Natator depressus*	11 [All]	12205	11	P[Argos&GPS]	100	0.9	30	34.1	0.999
Green turtle[F]	*Chelonia mydas*	19 [All]	13901	19	R[GPS]	140	1.05	10	100.5	0.721
Leatherback turtle[F]	*Dermochelys coriacea*	6 [All]	72805	32	R[Argos]	400	1.5	100	257	0.012
Loggerhead turtle	*Caretta caretta*	32 [All]	5863	6	R[GPS]	68	0.8	10	34.1	0.873

Sup Table 2: Food energy requirements

A mean value was used whenever a range was provided in the literature. For values provided in kj day^{-1} with individual body mass not specified in reference, we assumed a mean weight (included in Table S1) to calculate food energy requirements per kg. Unless otherwise indicated, units below are in kj kg^{-1} day^{-1}. Conversion between calories and joules was made using kilocal = 4.1868 kjoule.

*www.env.gov.bc.ca/wat/wq/reference/foodandwater.html

Common name	Scientific name	Food energy requirements	Reference
Bears			
Polar bear	*Ursus maritimus*	51600 kj day^{-1} for a 175 kg bear	(8)
Birds - Flying			
Black footed albatross	*Phoebastria nigripes*	7.933 x $M^{0.681}$	(9)
Laysan albatross	*Phoebastria immutabilis*	7.933 x $M^{0.681}$	
Short tailed shearwater	*Ardenna tenuirostris*	9.262 x $M^{0.765}$	
Western gull	*Larus occidentalis*	10.181 x $M^{0.717}$	
Birds - Swimming			
King penguin	*Aptenodytes patagonicus*	10.649 x $M^{0.686}$ (for all penguins)	(9)
Little penguin	*Eudyptula minor*		
Macaroni penguin	*Eudyptes chrysolophus*		
Cetaceans			
Beluga	*Delphinapterus leucas*	47.7x10 3 kcal day^{-1} / 800 kg	(10)
Bottlenose dolphin	*Tursiops truncatus*	45 – 65 and 60 – 90 kcal kg^{-1} day^{-1}	**
Humpback whale	*Megaptera novaeangliae*	437.7x10 3 kcal day^{-1} / 30000 kg	(10)
Pilot whale	*Globicephala macrorhynchus*	31000 kcal day^{-1} / 1000 kg whale	(11)
Southern right whale	*Eubalaena australis*	192 x $M^{0.75}$	(10)
Pinnipeds – True seals			
Crabeater seal	*Lobodon carcinophaga*	200 x $M^{0.75}$	(10)
Northern Elephant	*Mirounga angustirostris*	35-60 kcal kg^{-1} day^{-1}	*
Southern Elephant	*Mirounga leonina*	32100 MJ year^{-1} immature animal in captivity	(12)

Weddell seal	*Leptonychotes weddellii*	200 x $M^{0.75}$	(10)
Pinnipeds – Eared seals			
Australian fur seal	*Arctocephalus pusillus doriferus*	372 x $M^{0.75}$	(13)
Australian sea lion	*Neophoca cinerea*	35.6 and 68.1 MJ day^{-1} (females and males)	(13, 14)
California sea lion	*Zalophus californianus*	12500±1900 – 21000±2200 MJ $year^{-1}$	(15)
Cape fur seal	*Arctocephalus pusillus*	463.4 – 536.7 (for lactating females)	(16)
Galapagos sea lion	*Zalophus wollebaeki*	352.5 (for lactating females)	(17)
Long-nosed fur seal	*Arctocephalus forsteri*	372 x $M^{0.75}$	(13, 14)
New Zealand sea lion	*Phocarctos hookeri*	4 – 11 and 5 – 11 % of 377-43 and 115-44 kg (male and female) day^{-1} with food energy at 7 kj g^{-1}	(18)
Northern fur seal	*Callorhinus ursinus*	527.8±65.7	(19)
Southern sea lion	*Otaria flavescens*	372 x $M^{0.75}$	(10)
Sharks			
Blue shark	*Prionace glauca*	41 kcal kg^{-1} day^{-1}	(20)
Bull shar	*Carcharhinus leucas*	5.7 kcal kg^{-1} day^{-1}	(20)
Great hammerhead shark	*Sphyrna mokarran*	96 (value for scalloped hammerhead sharks)	(21)
Mako shark	*Isurus oxyrinchus*	(1) 27.9 g kg^{-1} d^{-1} with 4.51 kj g^{-1} (2) 41 kcal kg^{-1} day^{-1}	(1) (2)
Tiger shark	*Galeocerdo cuvier*	C/F/W * 100 = 0.561 % BW day^{-1}	(22)
Whale shark	*Rhincodon typus*	14931 and 28121 kj day^{-1} (for 4.34 and 6.22 m animal, respectively)	(23)
Sirenians			
Dugong	*Dugong dugon*	1.8 x that of manatee	(24)
West Indian manatee	*Trichechus manatus*	(1) 5 – 20 (2) 29000 kcal day^{-1} /300 kg	(**, 24)
Turtles			
Flatback turtle	*Natator depressus*	19.4-48.8	(25)
Green turtle	*Chelonia mydas*	202 kcal/kg/day but also 233 kcal day^{-1} / 9.58 kg based on SMR = 32 $W^{0.86}$	(26)
Leatherback turtle	*Dermochelys coriacea*	145-369	(27)
Loggerhead turtle	*Caretta caretta*	19.4-48.8	(25)

Sup Table 3: List of qualitative biological traits per species and taxonomic families based on expert knowledge.

Trip distance and time represent respective summaries of foraging trips and include five classes each. For distance: tens, hundreds, thousands or tens of thousands kilometres, or *in situ*, and for time: one day, several days, months, years, or *in situ*. *In situ* was used when there was not a defined start and end for the trip or when it is unknown. Four other qualitative traits were considered comprising breeding and foraging strategies and the distributional range of the species, including: 'Breeding strategy' classed as capital or income, 'Central place forager' classed as yes or no, 'Foraging social behaviour' classed as social or solitary, and species range ('Range') defined as temperate, tropical, polar or global.

Common name	Family	Trip distance (km)	Trip time	Breeding strategy	Central place forager	Foraging social behaviour	Range
Bears							
Polar bear	Ursidae	Thousands	Months	Income	No	Solitary	Polar
Birds - Flying							
Black footed albatross	Diomedeidae	Thousands	Months	Income	Yes	Solitary	Temperate
Laysan albatross	Diomedeidae	Thousands	Days	Income	Yes	Solitary	Temperate
Shearwater	Procellariidae	Thousands	Days	Income	Yes	Social	Global
Short tailed shearwater	Procellariidae	Thousands	Days	Income	Yes	Social	Global
Western gull	Laridae	Tens	Day	Income	Yes	Social	Temperate
Birds - Swimming							
King penguin	Spheniscidae	Hundreds	Days	Income	Yes	Solitary	Polar
Little penguin	Spheniscidae	Tens	Day	Income	Yes	Social	Temperate
Macaroni penguin	Spheniscidae	Tens	Day	Income	Yes	Social	Polar
Cetaceans							
Beluga	Monodontidae	Thousands	Months	Income	No	Social	Polar
Bottlenose dolphin	Delphinidae	Hundreds	Years	Income	No	Social	Global
Humpback whale	Balaenopteridae	Thousands	Months	Capital	No	Social	Global

Pilot whale	Delphinidae	Thousands	Months	Income	No	Social	Global
Southern right whale	Balaenidae	Thousands	Months	Capital	No	Solitary	Temperate
Pinnipeds – True seals							
Crabeater seal	Phocidae	*In situ*	*In situ*	Capital	No	Solitary	Polar
Northern elephant seal	Phocidae	Thousands	Months	Capital	No	Solitary	Temperate
Southern elephant seal	Phocidae	Tens thousands	Months	Capital	No	Solitary	Polar
Weddell seal	Phocidae	*In situ*	*In situ*	Capital	No	Solitary	Polar
Pinnipeds – Eared seals							
Australian fur seal	Otariidae	Hundreds	Days	Income	No	Solitary	Temperate
Australian sea lion	Otariidae	Hundreds	Days	Income	Yes	Solitary	Temperate
California sea lion	Otariidae	Hundreds	Days	Income	Yes	Solitary	Temperate
Cape fur seal	Otariidae	Hundreds	Days	Income	Yes	Solitary	Temperate
Galapagos sea lion	Otariidae	Tens	Days	Income	Yes	Solitary	Tropical
Long-nosed fur seal	Otariidae	Hundreds	Days	Capital	Yes	Solitary	Temperate
New Zealand sea lion	Otariidae	Tens	Days	Income	Yes	Solitary	Temperate
Northern fur seal	Otariidae	Thousands	Years	Income	No	Solitary	Temperate
Southern sea lion	Otariidae	Tens	Days	Income	Yes	Solitary	Temperate
Sharks							
Blue shark	Carcharhinidae	Thousands	Months	Income	No	Solitary	Global
Bull shark	Carcharhinidae	*In situ*	Months	Income	No	Solitary	Global
Great hammerhead shark	Sphyrnidae	*In situ*	Months	Income	No	Solitary	Global
Mako shark	Lamnidae	Hundreds	Years	Income	No	Solitary	Temperate
Tiger shark	Carcharhinidae	*In situ*	*In situ*	Income	No	Solitary	Tropical
Whale shark	Rhincodontidae	Thousands	Months	Income	No	Solitary	Tropical
Sirenians							
Dugong	Dugongidae	*In situ*	*In situ*	Income	No	Solitary	Tropical
West Indian manatee	Trichechidae	Thousands	Months	Income	No	Solitary	Tropical
Turtles							
Flatback turtle	Cheloniidae	Thousands	Years	Capital	No	Solitary	Tropical

Green turtle	Cheloniidae	Thousands	Months	Capital	No	Solitary	Tropical
Leatherback turtle	Cheloniidae	Tens thousands	Years	Capital	No	Solitary	Global
Loggerhead turtle	Cheloniidae	Thousands	Months	Capital	No	Solitary	Tropical

Sup Table 4: Summary statistics for CS and coastal affinity obtained for all individuals in the dataset.

Coastal affinity is defined as the proportion of individuals tracks occurring within depths <= 150 m. Rows highlighted in blue indicate species with low coastal affinity, and in red species with strong affinity to coastal environments. Rows were left white for species with no clear preference for coastal or open ocean habitats (mixed affinity). CS indicates the coefficient of PDF spread and Coastal affinity the proportion of observed displacements occurring within coastal habitats (considered to be within 0 and 150 m of depth). Mean values are highlighted in bold.

Common name	**CS**						**Coastal affinity**					
	Min	Q1	Median	**Mean**	Q3	Max	Min	Q1	Median	**Mean**	Q3	Max
Bears												
Polar bear	1.34	1.45	1.582	**1.795**	1.682	5.316	0.177	0.270	0.496	**0.523**	0.715	1.000
Birds - Flying												
Black footed albatross	1.02	1.17	1.302	**1.525**	1.698	3.583	0.000	0.000	0.000	**0.000**	0.000	0.000
Laysan albatross	1.02	1.11	1.198	**1.254**	1.347	1.908	0.000	0.000	0.000	**0.000**	0.000	0.021
Shearwater	1.01	1.36	1.563	**1.649**	1.883	2.908	0.000	0.000	0.027	**0.319**	0.747	1.000
Western gull	1.08	3.18	4.587	**4.865**	6.082	9.367	0.000	0.010	0.099	**0.390**	1.000	1.000
Birds - Swimming												
King penguin	1.15	1.61	1.819	**1.777**	1.909	2.437	0.007	0.010	0.030	**0.069**	0.071	0.281
Little penguin	1.08	1.31	1.733	**2.321**	2.081	9.770	1.000	1.000	1.000	**1.000**	1.000	1.000
Macaroni penguin	1.05	1.15	1.380	**1.769**	2.022	5.221	0.000	0.022	0.893	**0.571**	1.000	1.000
Cetaceans												
Beluga	1.27	1.43	1.498	**1.558**	1.633	2.350	0.488	0.895	0.998	**0.928**	1.000	1.000
Bottlenose dolphin	1.39	1.50	1.612	**1.552**	1.633	1.654	1.000	1.000	1.000	**1.000**	1.000	1.000
Humpback whale	1.35	1.52	1.604	**1.645**	1.712	2.263	0.259	0.353	0.528	**0.523**	0.696	0.760
Pilot whale	1.43	1.43	1.438	**1.438**	1.439	1.440	0.000	0.000	0.000	**0.000**	0.000	0.000
Southern right whale	1.63	1.64	1.652	**1.652**	1.662	1.671	0.000	0.007	0.013	**0.013**	0.020	0.026
Pinnipeds – True seals												

Crabeater seal	1.50	1.95	2.197	**2.185**	2.382	3.289	0.000	0.111	0.175	**0.340**	0.496	0.994
Northern elephant seal	1.02	1.13	1.257	**1.310**	1.384	5.334	0.000	0.000	0.000	**0.012**	0.005	0.602
Southern elephant seal	1.02	1.53	1.827	**2.082**	2.169	9.548	0.000	0.000	0.069	**0.138**	0.183	1.000
Weddell seal	1.23	2.10	2.490	**2.631**	2.775	9.600	0.000	0.120	0.218	**0.320**	0.429	1.000
Pinnipeds – Eared seals												
Australian fur seal	1.76	2.18	2.379	**2.672**	2.882	4.436	0.894	0.919	0.947	**0.950**	0.987	1.000
Australian sea lion	1.14	1.41	1.596	**1.916**	1.960	9.753	0.972	1.000	1.000	**1.000**	1.000	1.000
California sea lion	1.27	1.70	1.831	**1.897**	2.079	2.866	0.000	0.250	0.494	**0.522**	0.852	1.000
Cape fur seal	1.21	1.59	1.815	**1.722**	1.889	2.056	0.075	0.083	0.158	**0.360**	0.589	0.979
Galapagos sea lion	1.11	1.49	1.768	**2.162**	2.508	6.212	0.000	0.000	0.144	**0.436**	1.000	1.000
Long-nosed fur seal	1.23	1.56	1.910	**2.268**	2.651	7.897	0.000	0.000	0.000	**0.278**	0.516	1.000
New Zealand sea lion	1.33	1.57	1.840	**1.986**	2.157	3.578	0.000	0.187	0.623	**0.560**	0.935	1.000
Northern fur seal	1.08	1.32	1.437	**1.435**	1.541	2.020	0.000	0.005	0.025	**0.139**	0.123	1.000
Southern sea lion	1.19	1.60	1.694	**1.718**	1.825	2.363	0.700	0.937	1.000	**0.959**	1.000	1.000
Sharks												
Blue shark	1.05	1.25	1.344	**1.328**	1.465	1.500	0.000	0.004	0.079	**0.181**	0.221	0.684
Bull shark	1.77	1.94	2.165	**2.244**	2.467	2.867	1.000	1.000	1.000	**1.000**	1.000	1.000
Great hammerhead shark	1.06	1.36	1.692	**2.083**	1.806	4.953	0.000	0.853	0.931	**0.785**	1.000	1.000
Mako shark	1.21	1.29	1.445	**1.813**	1.595	6.414	0.000	0.124	0.365	**0.404**	0.636	1.000
Tiger shark	1.12	1.31	1.522	**1.856**	1.722	8.636	0.000	0.089	0.348	**0.438**	0.857	1.000
Whale shark	1.06	1.24	1.356	**1.426**	1.561	2.043	0.000	0.034	0.186	**0.253**	0.336	0.918
Sirenians												
Dugong	1.85	1.97	2.403	**2.917**	3.094	5.687	1.000	1.000	1.000	**1.000**	1.000	1.000
West Indian manatee	2.00	2.61	3.340	**3.233**	3.704	4.375	1.000	1.000	1.000	**1.000**	1.000	1.000
Turtles												
Flatback turtle	1.12	1.54	1.600	**1.654**	1.689	2.356	0.990	1.000	1.000	**0.999**	1.000	1.000
Green turtle	1.09	1.79	2.476	**3.794**	6.441	9.651	0.083	0.412	1.000	**0.768**	1.000	1.000
Leatherback turtle	1.20	1.29	1.547	**1.459**	1.607	1.661	0.000	0.001	0.006	**0.012**	0.017	0.040

Loggerhead turtle	1.45	2.33	2.732	**3.330**	3.236	8.838	0.050	0.843	0.968	**0.873**	0.996	1.000

Sup Table 5: Summary table with the coefficient of PDF spread (CS) and RMS exponents calculated when using stage- and trip-specific portions of the datasets for four species representative of three guilds.

The table shows similar results for RMS exponent and CS values across all stages/trips considered, with only two exceptions. These were for the CS of shearwaters' short trips, however, short trips corresponded only to 15 % of the displacements for the species, and for the RMS of "inter-nesting" turtles, however, the joint value was representative of all the other stages for the species.

Species	Stage	RMS	CS
Northern elephant seal	Post-breeding	0.94	1.21
	Post-moulting	0.94	1.43
	Together	0.95	1.37
Macaroni penguin	Non-breeding	0.85	1.34
	Guard	0.80	1.91
	Together	0.85	1.77
Short tailed shearwater	Short-trips while chick rearing (on shelf)	0.79	3.20
	Long-trips while chick rearing (oceanic)	0.77	2.02
	Together	0.74	2.07
Flatback turtle	Inter-nesting	0.50	1.71
	Migrating	0.92	1.19
	Foraging	0.75	1.73
	Together	0.83	1.77

Supporting information for accessing the datasets used in this publication.

Greyed rows indicate species not included in the analysis (GLS data or not enough positions to perform analysis).

Common name	Information for data access	Contact person and email
Bears		
Polar bear	U.S. Geological Survey, DOI: 10.5066/F7RV0MK4	Anthony Pagano apagano@usgs.gov
Birds – Flying		
Black footed albatross	Archived at http://www.seabirdtracking.org/	Scott Shaffer scott.shaffer@sjsu.edu
Crested tern	SARDI Aquatic Sciences, PO Box 120, Henley Beach, South Australia, 5022	Simon Goldsworthy simon.goldsworthy@sa.gov.au
	Archived at SARDI Aquatic Sciences, PO Box 120, Henley Beach, South Australia, 5022. Presented in McLeay, L.J. *et al.* (2010). Fine-scale foraging behaviour and habitat use of a short-ranging seabird, the crested tern. Marine Ecology Progress Series 411:271-283 www.int-res.com/abstracts/meps/v411/p271-283/	Lachlan McLeay Lachlan.McLeay@sa.gov.au
Flesh-footed shearwater	N/A	Scott Shaffer scott.shaffer@sjsu.edu
Laysan albatross	Archived at http://www.seabirdtracking.org/	Scott Shaffer scott.shaffer@sjsu.edu
Short tailed shearwater	SARDI Aquatic Sciences, PO Box 120, Henley Beach, South Australia, 5022	Simon Goldsworthy simon.goldsworthy@sa.gov.au
Sooty shearwater	Archived at http://www.seabirdtracking.org/	Scott Shaffer scott.shaffer@sjsu.edu
Western gull	Published in: Shaffer, S.A., Cockerham, S., Warzybok, P., Bradley, R., Jahncke, J., Clatterbuck, C.A., Lucia, M., Jelincic, J., Cassell, A., Kelsey, E.C., and Adams, J. (in press) Population-level plasticity in foraging behavior of western gulls (*Larus occidentalis*). *Movement Ecology.*	Scott Shaffer scott.shaffer@sjsu.edu
Birds – Swimming		

Emperor penguin	N/A	Barbara Weinecke Barbara.Wienecke@aad.gov.au
King penguin	http://south-atlantic-research.org/ims-gis	Alastair Baylis ammbaylis@gmail.com
Little penguin	South Australian tracks: SARDI Aquatic Sciences, PO Box 120, Henley Beach, South Australia, 5022	Simon Goldsworthy simon.goldsworthy@sa.gov.au
Macaroni penguin	N/A	Mark Hindell Mark.hindell@utas.edu.au
Cetaceans		
Beluga	Maurice Lamontagne Institute / Fisheries and Ocean Canada, 850 route de la Mer, Mont-Joli, Quebec G5H 3Z4, Canada	Mike Hammill Mike.Hammill@dfo-mpo.gc.ca
Bottlenose dolphin	Published in part: Wells, R.S. *et al*. 2013. Evaluation of potential protective factors against metabolic syndrome in bottlenose dolphins: Feeding and activity patterns of dolphins in Sarasota Bay, Florida. Front. Endocrinol. 4:139. DOI: 10.3389/fendo.2013.00139	Randall Wells rwells@mote.org
Franciscana/ La plata dolphin	N/A	Randall Wells rwells@mote.org
Humpback whale	Data are available by contacting the author/contributor	Ari Friedlaender: ari.friedlaender@ucsc.edu
Pilot whale	Published in part: Wells, R. S. *et al.* 2013. Movements and dive patterns of short-finned pilot whales, Globicephala macrorhynchus, released from a mass stranding in the Florida Keys. Aquatic Mammals 39(1): 61-72.	Randall Wells rwells@mote.org
Risso's dolphin	N/A	Randall Wells rwells@mote.org
Rough-toothed dolphin	N/A	Randall Wells rwells@mote.org
Southern Right whale	SARDI Aquatic Sciences, PO Box 120, Henley Beach, South Australia, 5022	Simon Goldsworthy simon.goldsworthy@sa.gov.au
Pinnipeds – True seals		

Crabeater seal	Antarctic Peninsula tracks: UCSC, Santa Cruz, CA 95060	Daniel Costa costa@ucsc.edu
Northern Elephant seal	UCSC, Santa Cruz, CA 95060	Patrick Robinson patrick.robinson@ucsc.edu Daniel Costa costa@ucsc.edu
Southern Elephant seal	https://portal.aodn.org.au/	Rob Harcourt robert.harcourt@mq.edu.au
	Antarctic Peninsula, UCSC Santa Cruz, CA 95060	Daniel Costa costa@ucsc.edu
	MEOP-CTD database publicly accessible through the MEOP data portal (http://meop.net)	Monica Muelbert monica.muelbert@furg.br
		Mark Hindell Mark.hindell@utas.edu.au
Weddell seal	Ross Sea, UCSC Santa Cruz, CA 95060	Daniel Costa costa@ucsc.edu
	https://portal.aodn.org.au/	Rob Harcourt robert.harcourt@mq.edu.au
Pinnipeds – Eared seals		
Antarctic fur seal	IMAS, University of Tasmania	Mary-Anne Lea MaryAnne.Lea@utas.edu.au
Australian fur seal	UCSC Santa Cruz, CA 95060	Daniel Costa costa@ucsc.edu
Australian sea lion	SARDI Aquatic Sciences, PO Box 120, Henley Beach, South Australia, 5022	Simon Goldsworthy simon.goldsworthy@sa.gov.au
	https://portal.aodn.org.au/	Rob Harcourt robert.harcourt@mq.edu.au
California sea lion	ATN Data Assembly Centre: http://oceanview.pfeg.noaa.gov/ATN/	Michael Weise michael.j.weise@navy.mil
	UCSC Santa Cruz, CA 95060	Elizabeth McHuron emchuron@ucsc.edu

	UCSC Santa Cruz, CA 95060	Daniel Costa costa@ucsc.edu
Cape fur seal	UCSC Santa Cruz, CA 95060	Daniel Costa costa@ucsc.edu
Galapagos sea lion	UCSC Santa Cruz, CA 95060	Stella Villegas-Amtmann: stella.villegas@gmail.com
Long-nosed fur seal	SARDI Aquatic Sciences, PO Box 120, Henley Beach, South Australia, 5022	Simon Goldsworthy simon.goldsworthy@sa.gov.au
	https://portal.aodn.org.au/	Rob Harcourt robert.harcourt@mq.edu.au
New Zealand sea lion	N/A	Mark Hindell Mark.hindell@utas.edu.au
Northern fur seal	IMAS, University of Tasmania	Mary-Anne Lea MaryAnne.Lea@utas.edu.au
Southern sea lion	http://south-atlantic-research.org/ims-gis	Alastair Baylis ammbaylis@gmail.com
Sharks **(Elasmobranchs)**		
Blacktip shark	N/A	Neil Hammerschlag/ nhammerschlag@miami.edu
Blue shark	Not publicly archived	Nuno Queiroz nuno.queiroz@cibio.up.pt
Bull shark	CRIOBE USR3278, PO Box 1013 Papetoai, French Polynesia	Eric Clua Eric.clua@univ-perp.fr
	Data archived in seaturtle.org and published in Hammerschlag *et al.* 2012 (PLOS ONE), Graham *et al.* 2016 (Diversity & Distributions)	Neil Hammerschlag/ nhammerschlag@miami.edu
Great hammerhead shark	Data archived in seaturtle.org and published in Graham *et al.* 2016 (Diversity & Distributions)	Neil Hammerschlag/ nhammerschlag@miami.edu
Mako shark	Data archived in seaturtle.org and published in Queiroz *et al.* 2016 (PNAS)	Neil Hammerschlag/ nhammerschlag@miami.edu
Manta ray	N/A	Camrin Braun cbraun@whoi.edu

Scalloped hammerhead shark	Data archived in seaturtle.org and published in Queiroz *et al.* 2016 (PNAS)	Neil Hammerschlag/ nhammerschlag@miami.edu
Silky shark	N/A	Neil Hammerschlag/ nhammerschlag@miami.edu
Tiger shark	CRIOBE USR3278, PoBox 1013 Papetoai, French Polynesia	Eric Clua Eric.clua@univ-perp.fr
	Data archived in seaturtle.org and published in Hammerschlag *et al.* 2015 (Ecology) and Graham *et al.* 2016 (Diversity & Distributions)	Neil Hammerschlag/ nhammerschlag@miami.edu
Whale shark	Data archive of the Australian Institute of Marine Science, Western Australia 6009, Australia	Mark G. Meekan M.Meekan@aims.gov.au
	N/A	Camrin Braun cbraun@whoi.edu
Sirenians		
Dugong	https://researchdata.ands.org.au/bluenet/678609	Richard Campbell Richard.Campbell@nlc.org.au
West Indian manatee	A. Aven and Carmichael, R.H. (2017). GPS tracking of West Indian manatees (Trichechus manatus latirostris) tagged in Mobile Bay, Alabama (2009-2015). Dauphin Island Sea Lab: Data Management Centre. Available at http://cf.disl.org/datamanagement/metadata_folder/DISL-Carmichael-Aven-001-2017.xml	Ruth Carmichael rcarmichael@disl.org
Turtles		
Flatback turtle	Australian Institute of Marine Science, Western Australia 6009, Australia	Michele Thums M.Thums@aims.gov.au
Green turtle	Indian Ocean tracks, Deakin University, Victoria Australia	Graeme Hays g.hays@deakin.edu.au Michele Thums M.Thums@aims.gov.au
Leatherback turtle	Atlantic tracks, Deakin University, Victoria Australia	Graeme Hays g.hays@deakin.edu.au
Loggerhead turtle	Mediterranean tracks, Deakin University, Victoria Australia	Graeme Hays g.hays@deakin.edu.au

Supporting References

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