Science Advances
AAAS

advances.sciencemag.org/cgi/content/full/7/10/eabd7225/DC1

Supplementary Materials for

Global political responsibility for the conservation of albatrosses and large petrels

Martin Beal*, Maria P. Dias, Richard A. Phillips, Steffen Oppel, Carolina Hazin, Elizabeth J. Pearmain, Josh Adams, David J. Anderson, Michelle Antolos, Javier A. Arata, José Manuel Arcpos, John P. Y. Arnould, Jill Awkerman, Elizabeth Bell, Mike Bell, Mark Carey, Ryan Carle, Thomas A. Clay, Jaimie Cleeland, Valentina Colodro, Melinda Conners, Marta Cruz-Flores, Richard Cuthbert, Karine Delord, Lorna Deppe, Ben J. Dilley, Herculano Dinis, Graeme Elliott, Fernanda De Felipe, Jonathan Felis, Manuela G. Forero, Amanda Freeman, Akira Fukuda, Jacob González-Solís, José Pedro Granadeiro, April Hedd, Peter Hodum, José Manuel Igual, Audrey Jaeger, Todd J. Landers, Matthieu Le Corre, Azwianewi Makhado, Benjamin Metzger, Teresa Militão, William A. Montevecchi, Virginia Morera-Pujol, Leia Navarro-Herrero, Deon Nel, David Nicholls, Daniel Oro, Ridha Ouni, Kiyoaki Ozaki, Flavio Quintana, Raül Ramos, Tim Reid, José Manuel Reyes-González, Christopher Robertson, Graham Robertson, Mohamed Salah Romdhane, Peter G. Ryan, Paul Sagar, Fumio Sato, Stefan Schoombie, R. Paul Scofield, Scott A. Shaffer, Nirmal Jivan Shah, Kim L. Stevens, Christopher Surman, Robert M. Suryan, Akinori Takahashi, Vikash Tatayah, Graeme Taylor, David R. Thompson, Leigh Torres, Kath Walker, Ross Wanless, Susan M. Waugh, Henri Weimerskirch, Takashi Yamamoto, Zuzana Zajkova, Laura Zango, Paulo Catry

*Corresponding author. Email: martinbeal88@gmail.com

Published 3 March 2021, *Sci. Adv.* **7**, eabd7225 (2021)
DOI: 10.1126/sciadv.abd7225

The PDF file includes:

Other Supplementary Material for this manuscript includes the following:

(available at advances.sciencemag.org/cgi/content/full/7/10/eabd7225/DC1)

Supplementary Materials

Supplementary Materials and Methods

GLS filtering and sensitivity analysis

We did not standardize the processing of the raw light-level geolocation (GLS) underlying the data sets analyzed herein. However, the majority of data sets have already been published in species-specific accounts whereby authors used accepted methods ranging from state-space models and incorporation of sea-surface temperature for refinement of latitudes (*41*) to speed-distance-angle thresholds for filtering (*42*), or expert judgement of light-level interference (*43*). In order to set a common standard of reliability across GLS data sets, a series of filters were used to remove obviously erroneous fixes. For all data sets, fixes above 65°N and below -75°S latitude were removed, as albatrosses and large petrels do not frequent these latitudes. An additional equatorial filter was applied to three data sets from Black-footed Albatross, Laysan Albatross, and Grey Petrels. These were applied so as to remove false positives of species occurrence in countries in the wrong hemispheres (Southern: Black-footed and Laysan; Northern: Grey Petrel). These fixes were deemed erroneous, rather than true vagrancy movements, by close inspection of individual trajectories. All fixes falling within landlocked countries were removed, to reduce the detection of false positive species occurrence in these jurisdictions. Species-specific filters were used to remove fixes during breeding which were located further than the known maximum foraging range of *C. diomedea* plus the average error of GLS devices (i.e. max. forage range + 186 km) from the breeding colony (*25*, *35*, *43*). These filters removed a mean of 0.45% (+/- 1.52) of all fixes for each breeding site-species combination.

Since latitudinal estimates from GLS data are unreliable around the equinoxes, an asymmetrical filter was also used to remove fixes during these periods (March equinox: -21, +7

days; September equinox: -7, +21 days) (*44*). As GLS data sets from 4 species (*Ardenna bulleri*, *A. carneipes*, *A. grisea*, *Procellaria parkinsoni*) used sea-surface temperature (SST) to estimate latitudes, fixes during the equinox periods were retained in these cases.

To test the potential effect of the spatial error of GLS devices on the quantification of species richness and time spent, we performed in iterated re-sampling procedure. For each iteration, we re-sampled all GLS points by combining a random direction drawn from a uniform distribution (0-360) with a distance drawn from a normal distribution (mean=0, SD=186 km) and then calculated the species richness and time spent by albatrosses and large petrels. The results of this analysis are presented in fig S3.

Supplementary Figures

fig. S1

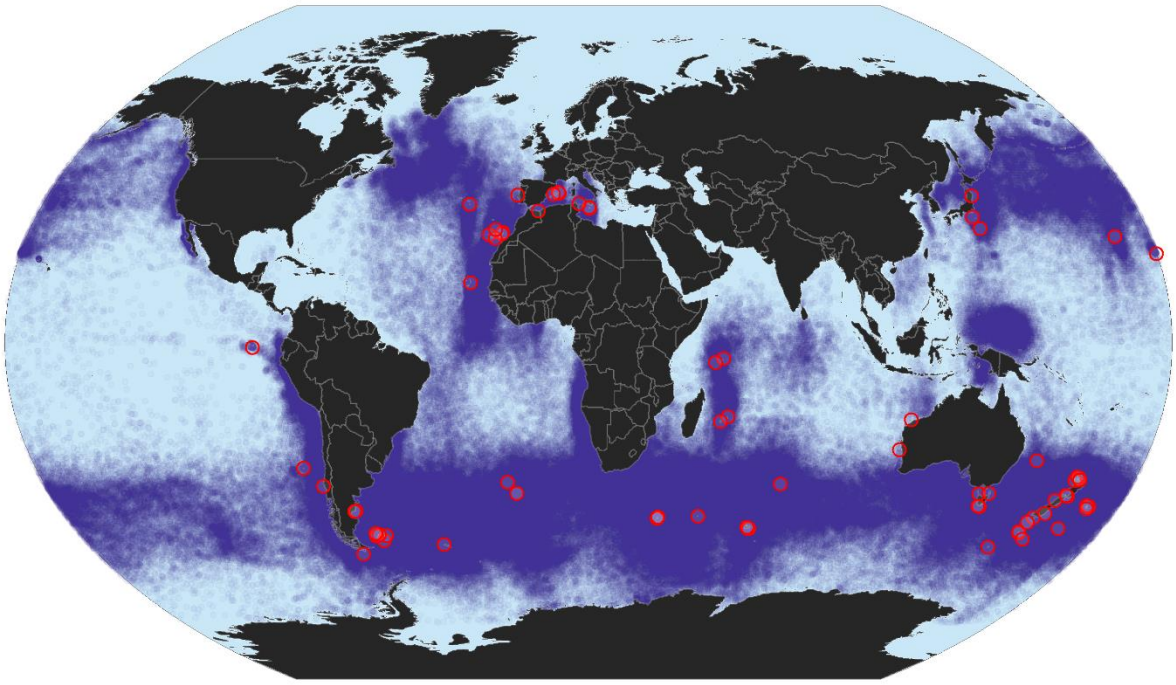


fig. S1. Global map of tracking data set. Red circles are 87 different tagging locations, and purple dots signify the resultant tracking data, post-filtering, used to analyze annual distributions of albatrosses and large petrels with respect to political borders.

fig. S2

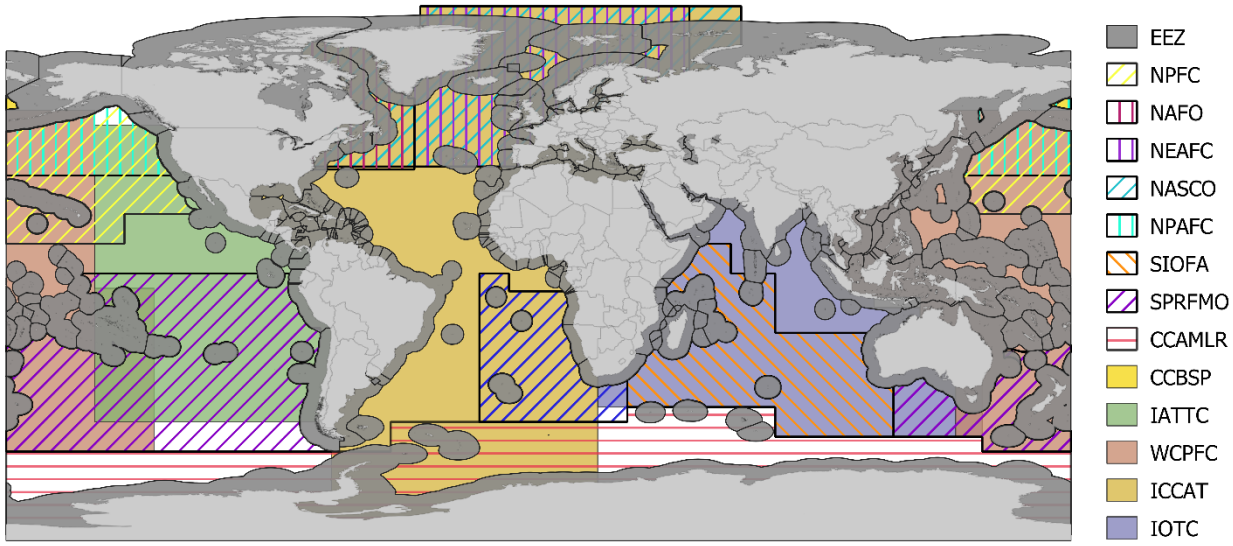


fig. S2. Areas of competence of Regional Fisheries Management Organizations. Dark gray polygons outlined in black represent Exclusive Economic Zones of countries. Outside this, areas variably colored and patterned represent Areas of Competence for RFMOs. *NPFC=North Pacific Fisheries Commission, NAFO=Northwest Atlantic Fisheries Organization, NEAFC=North East Atlantic Fisheries Commission, NASCO=North Atlantic Salmon Conservation Organisation, SEAFO=South East Atlantic Fisheries Organisation, NPAFC = North Pacific Anadromous Fish Commission, SIOFA=Southern Indian Ocean Agreement, SPRFMO=South Pacific Fisheries Management Organisation, CCAMLR=Convention on the Conservation of Antarctic Living*

Marine Resources, CCBSP=Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea, IATTC=Inter-American Tropical Tuna Commission, WCPFC=West Central Pacific Fisheries Commission, ICCAT=International Commission for the Conservation of Atlantic Tunas, IOTC=Indian Ocean Tuna Commission

fig. S3

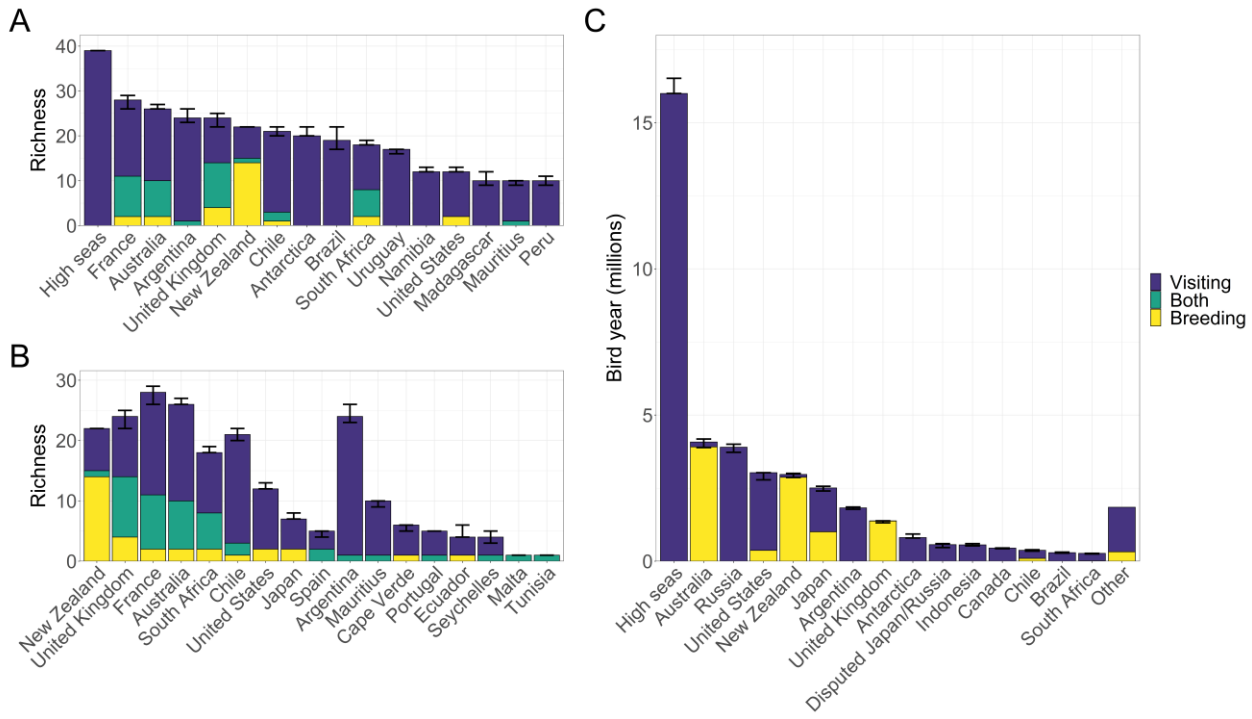
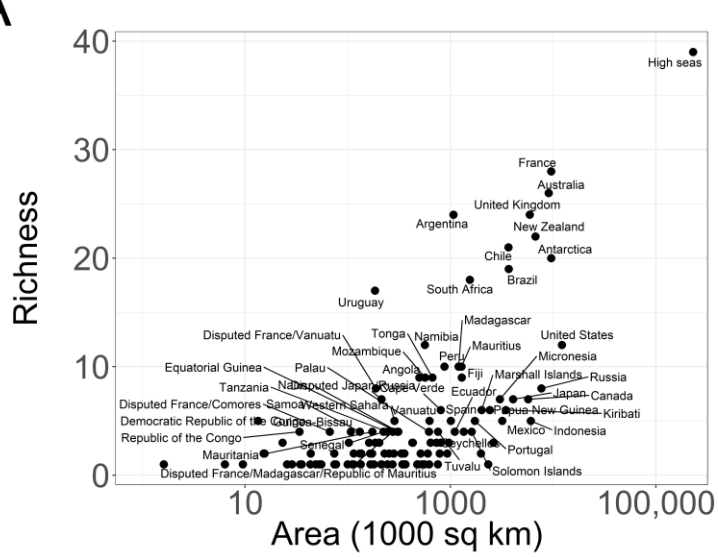


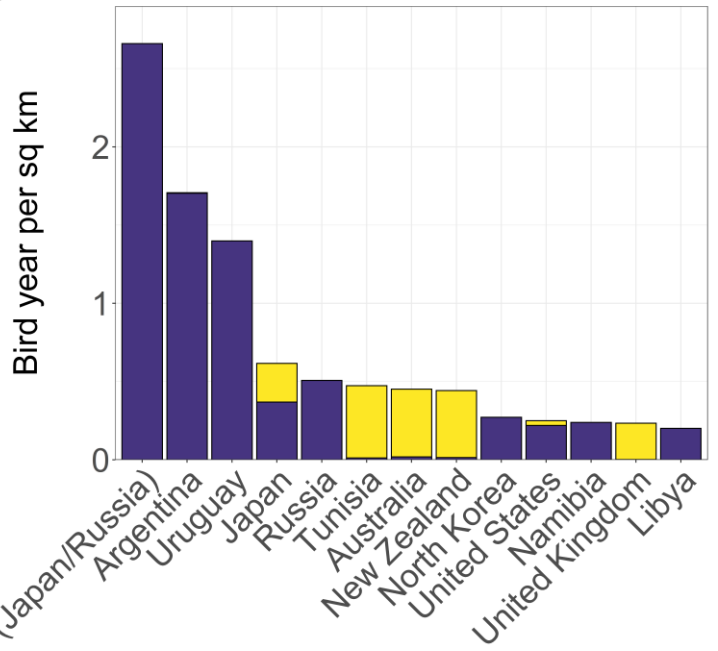
fig. S3 Sensitivity of importance measures to GLS spatial error

Importance of political areas to albatrosses and large petrels, measured in terms of species richness (A-B) and total annual time spent (C). Error bars show the range in the total estimated richness and time spent (ignoring visiting or breeding categories) for each political area calculated across 100 iterations, wherein GLS points were re-sampled to simulate the effect of GLS spatial error, which has an average effect of +/- SD 186 km displacement from the estimated location.

A


Richness
Area (1000 sq km)
High seas
France
Australia
United Kingdom
Argentina
New Zealand
Chile
Antarctica
Brazil
South Africa
Uruguay
Madagascar
Disputed France/Vanuatu
Tonga
Namibia
Mauritius
United States
Mozambique
Peru
Micronesia
Equatorial Guinea
Palau
Angola
Fiji
Marshall Islands
Russia
Tanzania
Disputed Japan/Russia
Cape Verde
Ecuador
Japan
Canada
Disputed France/Comores
Samoa
Western Sahara
Vanuatu
Spain
Papua New Guinea
Kiribati
Democratic Republic of the Congo
Guinea-Bissau
Mexico
Indonesia
Republic of the Congo
Senegal
Seychelles
Portugal
Mauritania
Tuvalu
Solomon Islands
Disputed France/Madagascar/Republic of Mauritius

B


Bird year per sq km
(Japan/Russia)
Argentina
Uruguay
Japan
Russia
Tunisia
Australia
New Zealand
North Korea
United States
Namibia
United Kingdom
Libya

C

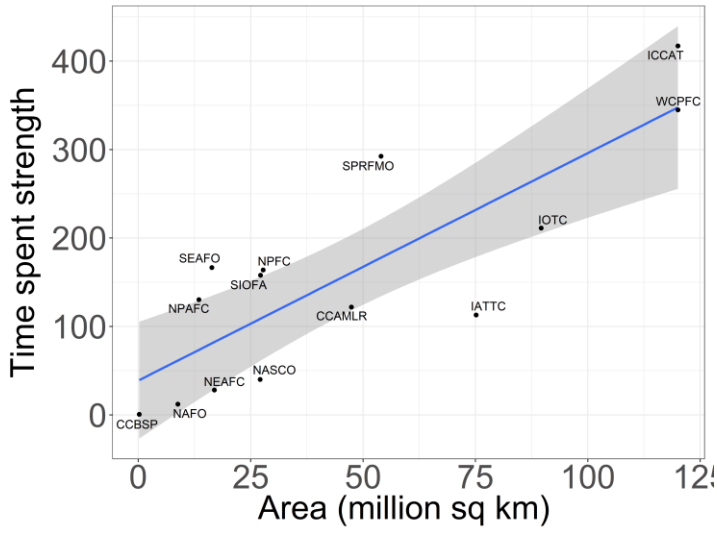

Time spent strength
Area (million sq km)
ICCAT
WCPFC
SPRFMO
IOTC
SEAFO
NPFC
SIOFA
NPAFC
CCAMLR
IATTC
NEAFC
NASCO
CCBSP
NAFO

fig. S4 Importance estimates and jurisdiction area

(A) Species richness estimated from tracking data and area of national jurisdictions and the high seas (log scale). (B) Estimated annual time spent in national jurisdictions per square kilometer of area. Sovereignty of jurisdictions in parentheses are disputed by the listed countries. (C) Time spent strength per area of legal competence for each RFMO against the size of the area. 'Time spent strength' is an index of importance calculated as the percentage of the species' annual time spent in an area, summed across all species visiting the area.

Other Supplementary Material

data file S1. (Excel) Estimated species richness of albatrosses and large petrels and annual time spent per country. (A) Breeding origin countries. (B) Countries visited that do not host breeding. "Total" is the total estimated richness, "Breeding" is the total richness of breeding species, "Visiting" is the total richness of species which visit from other countries. "Breed only" is the number of species which only occur via breeding populations located there. "Visit only" is the component of the total richness made up of species which occur in the country but do not have any breeding populations there. "Both" signifies the number of species whose occurrence in the country is made up of both birds that breed in the country and those that breed elsewhere. "Total breeders" is the number of total estimated individual breeding albatrosses and large petrels under each jurisdiction. "Total (Time Spent)" is the estimated total amount of annual time spent in the country by the global population of albatrosses and large petrels. "Breeders" is the annual time spent in the country by breeding populations originating in that country, and "Visitors" is the time spent by birds which breed in another jurisdiction. "True breeding richness" is the number of breeding species counted from all known breeding sites in the literature. "Diff" is the difference between the true and estimated richness based on available tracking data (column "Breeding").

data file S2. (Excel) All connections between breeding origin countries and other political areas. This is the full data set underlying Fig. 3. (A) All connections between breeding origins and other countries and the high seas. (B) All connections between breeding countries and high seas RFMO competence areas. N_{breed} is the number of albatross and large petrel species breeding in the country. Visited jurisdictions are in descending order of the relative strength of connection between the jurisdictional areas. Strength reflects the amount of annual time spent by the populations of large petrels breeding under the countries' jurisdiction, as well as the relative contribution of said populations to the global breeding population of each species. N_{visit} is the number of species which constitute this connection between political areas.

data file S3. (Excel) Population estimates. Island group and global population estimates for the populations and species of albatrosses and large petrels studied herein.

data file S4. (Excel) Summary of tracking data sets from each breeding population of albatrosses and large petrels after filtering steps. N_{tracks} is the number of tracks of a certain device-type ('Device'), collected from a total of N_{birds} in the population. D_{total} is the number of total tracking days, where Min and Max represent the range of track durations. $Y_{covered}$ and Y_{missed} are then, respectively, the resulting number of days of the year with and without tracking data for the population.

data file S5. (Excel) Estimated species richness and annual time spent with high data filtering threshold (A) and alternate sovereignty assignment (B).

data file S6. (Excel) All connections between breeding origin countries and other political areas with high data filtering threshold (A) and alternate sovereignty assignment (B).

movie S1. Animated global monthly distribution of time spent. Distribution of adult albatrosses and large petrels is calculated on a monthly basis, in terms of time spent in 452 sq. km grid cells across the world.