Seasonally and spatially averaged stratification mixed layer temperature and chlorophyll-a around Northern Hemisphere seabird colonies from 1993 to 2019 (Stratification impacts on seabirds project)

Website: https://www.bco-dmo.org/dataset/985768
Data Type: Other Field Results
Version: 1
Version Date: 2025-10-02

Project
» Global analysis of stratification impacts on seabirds through food resources (Stratification impacts on seabirds)

Contributors	Affiliation	Role
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Abstract
This dataset provides seasonal averages of mixed layer temperature, water column stratification, and mixed layer chlorophyll-a content for coastal marine regions around the world using the Marine Ecoregions of the World (MEOW) framework. The MEOW framework spatially partitions coastal marine areas into a hierarchical, nested structure based on biogeographic and environmental characteristics. Seven ecosystems are represented in the dataset: the Arctic, Cold Temperate Northeast Pacific, Cold Temperate Northwest Pacific, Warm Temperate Northeast Pacific, Hawaii, Northern European Seas, and Cold Temperate Northwest Atlantic, which are roughly equivalent to Large Marine Ecosystems. Environmental data was extracted for the domain of these seven ecosystems using the GLORYS12V1 global ocean reanalysis, which resolves monthly ocean conditions at 1/12-degree, daily resolution across 50 vertical depth levels. This state-of-the-art reanalysis assimilates historical data from multiple sources, including satellite observations and buoy data, and covers the period from 1993 to 2019. We extracted temperature, mixed layer depth, and salinity for the upper 200 m of the water column, which were used to calculate coastal stratification. Stratification was quantified using the Potential Energy Anomaly (PEA), a robust metric that measures the energy required to thoroughly mix the water column and reflects seasonal stratification patterns. All environmental variables were spatially averaged over corresponding ecoregions and temporally averaged over the pre-breeding and breeding seasons of seabird colonies within the ecoregion. By offering detailed classifications and environmental characterizations, this dataset serves as a valuable resource for analyzing regional oceanographic patterns and understanding how physical processes shape seabird populations and marine ecosystems.

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Coverage

Location: Northern Hemisphere
Spatial Extent: **N**:74.2 **E**:175.924722 **S**:21.574688 **W**:-177.378195
Temporal Extent: 1993 - 2019

Dataset Description

The primary data file of this dataset (985768_v1_ocean_conditions_at_seabird_colony_sites.csv) contains seasonally and spatially averaged stratification, mixed layer temperature, and chlorophyll-a around Northern Hemisphere seabird colonies.

Methods & Sampling

The GLORYS12V1 global ocean reanalysis was used to characterize the marine environment of the study ecoregions and ecosystems. This high-resolution model (1/12° horizontal resolution, daily temporal resolution, 50 vertical depth levels) assimilates historical data from 1993 to 2019 and has been validated against independent observations. Environmental variables—including temperature, mixed layer depth, and salinity—were extracted for the upper 200 m to calculate coastal stratification using the Potential Energy Anomaly (PEA). The PEA, a robust metric for seasonal stratification, is particularly useful in shallow, coastal regions where permanent stratification may be disrupted by tidal and wind mixing. For full methodological details, see Killeen et al. (2025, in review).

Data Processing Description

Spatial and temporal averaging to provide ecoregional monthly values: Data within each ecoregion were extracted by masking the dataset with ecoregion polygons defined by the Marine Ecoregions of the World (MEOW). All values within a polygon were averaged to produce monthly ecoregion means for the period 1993 to 2019.

Monthly values for each variable were then averaged over the periods corresponding to the pre-breeding (on-colony arrival to mean egg-laying date) and breeding (mean egg-laying date to mean fledging date) seasons of seabird colonies in the Northern Hemisphere subset of the Global Seabird Breeding Success Dataset. The resulting joined dataset includes yearly seabird breeding success and productivity estimates per seabird time series, along with corresponding mixed layer temperatures, stratification, and chlorophyll-a content during the pre-breeding and breeding periods. Seasonal, ecoregional averages were then standardized by subtracting the mean and dividing by the standard deviation for each ecoregion. To examine seabird breeding responses to interannual variability in environmental variables, quadratic detrending was applied to temperature, stratification, and chlorophyll-a.

BCO-DMO Processing Description

* Special characters have been removed from the parameters/column names in the primary data file (985768_v1_ocean_conditions_at_seabird_colony_sites.csv) and replaced with underscores ("_").
* Latitude and longitude values have been rounded to six decimal places.
* Originally, the primary data file only contained common name representations of observed species. Scientific names have been added to the data file, along with corresponding AphiaID and LSIDs from the World Register of Marine Species (WoRMS) database.

Problem Description

No dataset problems or issues have been noted by the dataset authors.

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Data Files

File
985768_v1_ocean_conditions_at_seabird_colony_sites.csv (Comma Separated Values (.csv), 1.24 MB) MD5:7413e85e53ea28aacecca22929cde39d Primary data file for dataset ID 985768, version 1

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Related Publications

Holt, J., Harle, J., Wakelin, S., Jardine, J., & Hopkins, J. (2022). Why Is Seasonal Density Stratification in Shelf Seas Expected to Increase Under Future Climate Change? Geophysical Research Letters, 49(23). Portico. https://doi.org/10.1029/2022gl100448 https://doi.org/10.1029/2022GL100448
Methods

Jean-Michel, L., Eric, G., Romain, B.-B., Gilles, G., Angélique, M., Marie, D., Clément, B., Mathieu, H., Olivier, L. G., Charly, R., Tony, C., Charles-Emmanuel, T., Florent, G., Giovanni, R., Mounir, B., Yann, D., & Pierre-Yves, L. T. (2021). The Copernicus Global 1/12° Oceanic and Sea Ice GLORYS12 Reanalysis. Frontiers in Earth Science, 9. https://doi.org/10.3389/feart.2021.698876
Methods

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., Halpern, B. S., Jorge, M. A., Lombana, A., Lourie, S. A., Martin, K. D., McManus, E., Molnar, J., Recchia, C. A., & Robertson, J. (2007). Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. BioScience, 57(7), 573–583. doi:10.1641/B570707
Methods

Verezemskaya, P., Barnier, B., Gulev, S. K., Gladyshev, S., Molines, J., Gladyshev, V., Lellouche, J., & Gavrikov, A. (2021). Assessing Eddying (1/12°) Ocean Reanalysis GLORYS12 Using the 14-yr Instrumental Record From 59.5°N Section in the Atlantic. Journal of Geophysical Research: Oceans, 126(6). Portico. https://doi.org/10.1029/2020jc016317 https://doi.org/10.1029/2020JC016317
Methods

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Related Datasets

References

European Union-Copernicus Marine Service. (2018). *Global Ocean Physics Reanalysis* [Data set]. Mercator Ocean International. https://doi.org/10.48670/MOI-00021 https://doi.org/10.48670/moi-00021

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Parameters

Parameter	Description	Units
idnum	Row number index.	exp_id
year	Year corresponding with breeding observation.	years
spp	Seabird species common name.	unitless

ScientificName_accepted	Scientific name that corrisponds with the represented species common name (spp).	unitless
AphiaID	AphiaID associated with the represented scientific name of the observed seabird species, matched from the World Register of Marine Species (WoRMS) database.	unitless
LSID	LSID associated with the represented scientific name of the observed seabird species, matched from the World Register of Marine Species (WoRMS) database.	unitless
site	Seabird colony site name.	unitless
sppsite	Concatenated species and site variable.	unitless
site_lat	Latitude value of the geographic coordinate representing the site in decimal degrees; a positive value indicates a northern coordinate.	decimal degrees
site_lon	Longitude value of the geographic coordinate representing the site in decimal degrees; a negative value indicates a western coordinate.	decimal degrees
PROVINCE	Factor defining the province for each seabird site in the Marine Ecoregions of the World (MEOW) framework.	unitless
ECOREGION	Factor defining the province for each seabird site in the Marine Ecoregions of the World (MEOW) framework.	unitless
bs	Breeding success (number of fledglings per femail per year).	unitless
pr_failure	Binomial value describing the probability of breeding failure (breeding success = 0).	unitless
nyear	Number of years seabird data in the corresponding time series (sppsite).	years
pre_breeding_temp	Mixed layer temperature during the pre-breeding season.	degrees Celcius
breeding_temp	Mixed layer temperature during the breeding season.	degrees Celcius
pre_breeding_chl	Mixed layer chlorophyll-a content during the pre-breeding season.	mg/m^3
breeding_chl	Mixed layer chlorophyll-a content during the breeding season.	mg/m^3

pre_breeding_strat	Potential energy anomaly during the pre-breeding season.	J/m^3
breeding_strat	Potential energy anomaly during the breeding season.	J/m^3
stbs	Standardized seabird breeding success z-score.	unitless
stpb_temp	Standardized mixed layer temperature during the pre-breeding season z-score.	unitless
stb_temp	Standardized mixed layer temperature during the breeding season z-score.	unitless
stpb_strat	Standardized potential energy anomaly during the pre-breeding season z-score.	unitless
stb_strat	Standardized potential energy anomaly during the breeding season z-score.	unitless
stpb_chl	Standardized mixed layer chlorophyll-a content during the pre-breeding season z-score.	unitless
stb_chl	Standardized mixed layer chlorophyll-a content during the breeding season z-score.	unitless
d_stbs	Detrended, standardized seabird breeding success z-score.	unitless
d_stpb_temp	Detrended, standardized mixed layer temperature during the pre-breeding season z-score.	unitless
d_stpb_chl	Detrended, standardized mixed layer chlorophyll-a content during the pre-breeding season z-score.	unitless
d_stpb_strat	Detrended, standardized potential energy anomaly during the pre-breeding season z-score.	unitless
d_stb_temp	Detrended, standardized mixed layer temperature during the breeding season z-score.	unitless
d_stb_chl	Detrended, standardized mixed layer chlorophyll-a content during the breeding season z-score.	unitless

d_stb_strat	Detrended, potential energy anomaly during the breeding season z-score.	unitless

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Project Information

Global analysis of stratification impacts on seabirds through food resources (Stratification impacts on seabirds)

Coverage: global

NSF Award Abstract:
Global warming is affecting the world's oceans by altering marine habitats, yet the effects on marine life vary by ocean region. One factor that may explain these observations is that ocean surface waters have warmed faster than deeper waters. Temperature differences may act as a physical barrier to mixing, thereby impeding deeper nutrients from reaching the sunlit surface where they are used by ocean plants in photosynthesis. With less mixing, the upper layers of the ocean may have become less productive, which may in turn impact marine fish, bird, and mammal populations of economic and cultural (ecological) value to society. To conduct this study, the investigators are examining the effects of ocean warming by depth on the abundance of plankton, small fish, and the breeding success of marine birds across the world using existing long-term data. They are developing mathematical relationships to understand how ocean warming at various depths is linked to plankton, fish, and bird productivity. Results will provide key information for selecting which seabird species may be best suited as ecological indicators of change for different ecosystems across the globe, and therefore has implications for remote-ocean monitoring. The project will contribute new scientific understanding for upcoming United Nation assessment reports and enhance public awareness of ocean health through outreach materials centered on popular seabirds such as puffins and penguins. It will support early career and postdoctoral scientists.

Ocean thermal stratification is an important factor determining primary productivity in epipelagic zones of the world's oceans. A recent global analysis showed declining trends in the breeding productivity of fish-eating seabirds that forage in the epipelagic zone, but increasing stratification has yet to be investigated as an explanatory factor. The primary objective of this project is to test the hypothesis that seabird species groups vary in their responses to increasing thermal stratification through the indirect effects of stratification on epipelagic food resource availability and/or prey use by the birds. The investigators are testing the prediction that thermal stratification has the largest effect on breeding productivity of piscivorous, surface-foraging species. They are integrating a new global database on seabird productivity with high-resolution data on thermal stratification available from the European GLORYS model, as well as satellite-based chlorophyll-a data from NASA. They are using Generalized Linear Mixed Models to test for variation between seabird groups and Structural Equation Models to test direct and indirect pathways of response from stratification through prey availability to seabird productivity, focusing on mid-to-high latitude ecosystems across ocean basins in both the northern and southern hemispheres. Results will improve understanding of how seabirds respond to increasing thermal stratification in relation to fundamental differences in seabird life history traits. The retrospective analysis will advance knowledge of how seabirds that feed on different prey, and in different epipelagic habitats of the world's oceans, have responded to recent increases in stratification. More generally, the study will contribute insight into how physical changes in the upper ocean affect predators through the availability of food resources.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

Location Description:
Data to be analyzed are from around the world and contributed from numerous local providers and other groups. The study area is the global ocean. Analysis will be done at the Farallon Institute, located in Petaluma, California.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2142918

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