The Global Ocean Observing System

DRAFT

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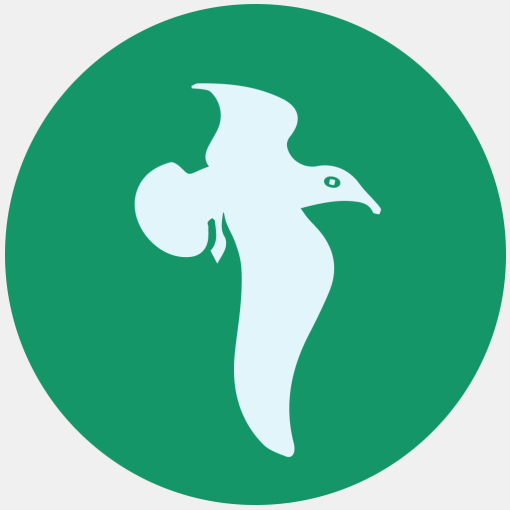
Essential Ocean Variable Specification Sheet

Seabirds abundance and distribution



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EOV Specification Sheet curated by:

Biology and Ecosystems Panel

DETAILED INFORMATION ON HOW TO READ THE SPECIFICATION SHEET CAN BE FOUND IN THIS GUIDE

Background and justification

Seabirds are vital indicators of ocean health due to their mobility and reliance on diverse marine ecosystems. As top predators, most seabirds integrate information across large spatial and temporal scales, making them essential for monitoring changes in ocean conditions, such as shifts in prey availability or habitat degradation caused by pressures like overfishing, climate change, and pollution. Seabird population dynamics, breeding success, and foraging behavior reflect the health of marine environments, providing early warnings about broader ecosystem disruptions. This makes seabirds a critical Essential Ocean Variable (EOV), helping assess the impacts of human activities on marine biodiversity, fisheries, and coastal communities.

Seabirds are one of the most threatened groups of birds and several species are protected by national and international regulations to prevent extinction. It is crucial to assess population numbers and trends, to establish efficient warning systems for population declines. As long-lived, K-selected organisms, seabirds are particularly vulnerable to human impacts and are severely impacted by fisheries, both through reduction of their prey species and incidental capture (bycatch), they are also impacted at-sea by pollution and climate change. Seabirds can be susceptible to plastic ingestion and contaminants that bio-accumulate or accumulate up the food chain. Thus, tracking seabird population trends and distribution offers valuable insights into ecosystem risks, to identify biodiversity hotspots and contribute to global conservation goals, directly supporting the management and sustainability of marine environments. Seabird declines or distribution changes can signal underlying threats to marine ecosystems, including habitat loss, pollution, or unsustainable fishing. Their role in ecosystem services, such as nutrient cycling, further underscores their importance. Seabird population size estimates (censuses) and population changes (trends) are of ecological and political concern to conservationists, planners, and policy makers, and provide important indicators of large-scale changes in the ocean. Data on population numbers and trends also provide the basis for assessments of the conservation status of species for the IUCN Red List and for the Agreement on the Conservation of Albatrosses and Petrels (ACAP/UN).

Integration with Global Observation Frameworks

The Global Climate Observing System (GCOS) developed the Essential Climate Variable (ECV) framework to define necessary observations for monitoring Earth's climate (Bojinski et al., 2014). Some EOVs, including ocean physics, biogeochemistry, and biology/ecosystems variables (GCOS, 2022a; GCOS, 2022b), are also ECVs.

The Essential Biodiversity Variables (EBVs) defined and curated by the Group on Earth Observations Biodiversity Observation Network (GEO BON) complement the GOOS biological and ecosystem (BioEco) EOVs (Muller-Karger et al., 2018; Bax et al., 2019). The EOVs represent the basic observations of a particular parameter or process. EBVs are time series of biodiversity observations across genes, species populations, communities, or ecosystems. Thus, EOVs may be seen as the building blocks for GEO BON EBVa.

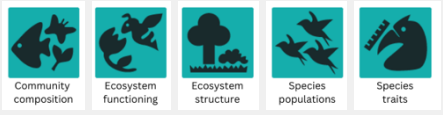
The EOVs can be used to synthesise the EBVs as time series of BioEco EOV sub-variables at one location, or as time series of gridded, mapped, or modelled EOVs (Jetz et al., 2019).

The GOOS Biology and Ecosystems Panel collaborates with the Physics and Climate and Biogeochemistry Panels to advance EOVs, advocating for the need for biological observations, information management, and applications. GOOS, MBON, GEO BON, and OBIS work together to standardise guidelines and data management for EOVs, EBVs, and ECVs.

Current observing networks and coordination

Diverse networks and communities are collecting observations of biology and ecosystems EOVs at different scales and in different regions. An initial baseline survey conducted in 2019/20 identified 203 active, long-term (>5 years) observing programs systematically sampling marine life. These programs spanned about 7% of the ocean surface area, mostly concentrated in coastal regions of the United States, Canada, Europe, and Australia (Satterthwaite et al 2021). This information can be found in the GOOS BioEco Metadata Portal, which is continually updated. To consult the latest information, please visit: https://bioeco.goosocean.org

Contributes to (please click on the symbol for more information):

EBV: 

SDG: 

CBD: 

Other: 

1. EOV information

ESSENTIAL OCEAN VARIABLE (EOV)	Seabirds abundance and distribution
DEFINITION	Abundance refers to the number of individuals within a population, while distribution refers to the geographic or spatial extent of habitats used by individuals from the population. Both are evaluated on a species level for GOOS
EOV SUB-VARIABLES - key measurements that are used to estimate the EOV	Species-specific: - Species population census or count data (individual, breeding pairs, nests) - Species presence/absence (mortality events) - Repeated individual presence (tracking/resights - spatial distribution)
SUPPORTING VARIABLES - other measurements that are useful to provide scale or context to the sub-variables of the EOV	Environmental Temperature and salinity (surface and sub surface), dissolved oxygen, suspended particulates, ocean colour, primary and secondary productivity, prey availability / diet (e.g. fish).
	EOV related Demographic traits (age and sex) Nesting behaviour - surface nesting, burrow nesting Annual or biannual reproduction

DERIVED PRODUCTS - outputs calculated from the EOV and sub-variables, often in combination with the supporting variables

- population estimates, including total number of individuals per colony or island group
- population status and trends (increasing, decreasing, stable)
- Red List status change
- hotspots
- home range
- migration pathways
- habitat maps (distribution shifts and patterns of habitat use)
- documentation of mass mortality events*

*More recently high pathogenicity avian influenza has increased the number of seabirds mass mortality around the globe. Estimating and counting mass mortality events to understand the causes and establish baselines are crucial to understand anthropogenic effects on seabirds and their ecosystems.

2. Phenomena to observe - what we want to observe with this EOV

This section presents examples of priority phenomena for GOOS that can be (partly) characterised by this EOV's sub-variables. This list is not exhaustive but serves to provide general suggestions on how observation efforts can structure their planning and implementation to observe certain phenomena.

The GOOS application area(s) the phenomena are relevant for are depicted as follows: Climate  , ocean health  , operational services 

PHENOMENA TO OBSERVE		Population status and trends 	Mass mortality 	Distribution shifts 
PHENOMENA EXTENT	HORIZONTAL	Local, regional (ocean basin)	Local, regional (ocean basin)	Local, regional (ocean basin)
	VERTICAL	surface to upper ocean (on shore)	surface to upper ocean (on shore)	surface to upper ocean
	TEMPORAL	seasonal to decadal	monthly and annually	seasonal to decadal
RESOLUTION TO OBSERVE PHENOMENA	HORIZONTAL	1km-1,000s km	1km-1,000s km	1km-1,000s km
	VERTICAL	<1km - 5km	<1km - 5km	<1km - 5km
	TEMPORAL	seasonal to decadal	monthly and annually	seasonal to decadal
SIGNAL TO CAPTURE		*Change in IUCN category*	two or more dead animals clustered in space and time of a noteworthy nature	a defined change in latitudinal or longitudinal range that is persistent across a defined time period
SUB-VARIABLES NEEDED TO MEASURE		Count data	Species presence/absence, Count data	Species presence/absence, , repeated individual presence (tracking/resights)
SUPPORTING VARIABLES NEEDED		age, Sex	Sex, cause of death (if known)	Age, Sex, Count data

3. GOOS Observing Specifications or Requirements

This section outlines ideal measurements for an optimal observing system for this Essential Ocean Variable (EOV). It offers guidance on creating a long-term system to observe key phenomena related to the EOV. These values are not mandatory, and no single system is expected to meet all requirements. Instead, the combined efforts of various observing systems should aim to meet these goals. Observations at different scales are also valuable contributions to global ocean observation if shared openly.

EOV	Seabird abundance and distribution							
PHENOMENA	Population status and trends							
EOV SUB-VARIABLE	Species population census or count data			**DEFINITION**		Count of living individuals, breeding pairs or active nests at breeding sites A baseline data for estimating seabird population numbers and trends can be provided by counts at breeding sites, where the presence of the species is recorded as well as the number of individuals.		
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	local	NA	Monthly or Seasonal (breeding)	NA	Low/medium/high (depending on the species – burrow and surface nesters)		Visual counts at a colony, and newer methods to census seabirds in breeding sites as acoustic monitoring, drone and satellite counts	Bibby et al. 1992
DESIRABLE	Every colony level	NA	annual	NA	Low/medium/high (depending on the species – burrow			Larue, et al. 2024. Advances in remote sensing of emperor

					and surface nesters)			penguins: first multi-year time series documenting trends in the global population. Proceedings of the Royal Society B, 291(2018), 20232067. https://doi.org/10.1098/rspb.2023.2067 Fretwell, et al. 2017. Using super‐high resolution satellite imagery to census threatened albatrosses. Ibis, 159(3), 481-490. https://doi.org/10.1111/ibi.12482
MINIMUM	One colony level	NA	Every 5 years	NA	Low/medium/high (depending on the species – burrow and surface nesters)			Buxton, R. T., & Jones, I. L. 2012. Measuring nocturnal seabird activity and status using acoustic recording devices: applications for island restoration. Journal of Field Ornithology, 83(1), 47-60. https://doi.org/10.1111/j.1557-9263.2011.00355.x

PHENOMENA	Mass mortality							
EOV SUB-VARIABLE	Species presence/absence (dead seabirds)				**DEFINITION**		This variable is the count of dead seabirds stranded ashore or detected within breeding sites.	
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	local	NA	Monthly	NA			Visual counts of carcasses, necropsy wherever possible (to assess cause of death)	Glencross et al. 2021. A proposed framework for reporting mass mortality (wreck) events of seabirds. ICES Journal of Marine Science, 78(6), 1935-1942. https://doi.org/10.1093/icesjms/fsab046 Vanstreels et al. 2023. Health and diseases. In Conservation of Marine Birds (pp. 131-176). Academic Press.https://doi.org/10.1016/B978-0-323-88539-3.00003-0
DESIRABLE	regional compilation	NA	Monthly and annually	NA				Uhart et al. 2018. Review of diseases (pathogen isolation, direct recovery and antibodies) in albatrosses and large petrels worldwide. Bird Conservation International, 28(2), 169-196. https://doi.org/10.1017/S0959270916000629

								Jones et al. 2023. Marine bird mass mortality events as an indicator of the impacts of ocean warming. Marine Ecology Progress Series. https://doi.org/10.3354/meps14330
MINIMUM	One location	NA	Annual	NA				Bennison et al. 2024. A case study of highly pathogenic avian influenza (HPAI) H5N1 at Bird Island, South Georgia: the first documented outbreak in the subantarctic region. Bird Study, 1-12. https://doi.org/10.1080/00063657.2024.2396563

PHENOMENA	Distribution shifts							
EOV SUB-VARIABLE	Repeated individual presence(tracking/resights)				**DEFINITION**		Distribution shifts represent a change in latitudinal or longitudinal range that is persistent across a defined time period. Distribution shifts can be assessed for different life stages - e.g. breeding and non-breeding, or across the entire life-cycle by tracking seabirds using different types of loggers, as GPS, GLS, other PTTs,…	
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	Local / colony	NA	Seasonal	NA			Breeding and non-breeding distributions determined from at-sea counts; tracking data analysis	UK Marine Online Assessment Tool, available at: https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/birds/distribution/
DESIRABLE	regional	NA	Annual	NA				Kuletz, Cushing, & Labunski 2020. Distributional shifts among seabird communities of the Northern Bering and Chuchi seas in response to ocean warming during 2017-2019. https://doi.org/10.1016/j.dsr2.2020.104913
MINIMUM	Regional	NA	Every 5 years	NA				Carneiro et al. 2020. A framework for mapping the distribution of seabirds by integrating tracking, demography and phenology. https://doi.org/10.1111/1365-2664.13568

4. Observing approach, platforms and technologies

This table provides examples of approaches and technologies used to collect this EOV to help observe priority phenomena

APPROACH / PLATFORM	colony count	tracking	mass mortality
EOV SUB-VARIABLE(S) MEASURED	species presence / absence, population estimates	repeated individual presence (tracking/resights)	species presence / absence
TECHNIQUE / SENSOR TYPE	visual observers, acoustic, digital imagery, drone	Different types of loggers (GPS, GLS, other PTTs, …)	visual observers, digital imagery, drone
SUGGESTED METHODS AND BEST PRACTICES	Bibby et al. 2000	Carneiro et al. 2020	Simpson & Fisher 2017
SUPPORTING VARIABLES MEASURED	age, sex, demography traits	age (adult v juvenille)	age, sex, cause of death

5. Data and information management

Access to data and information is at the core of an ocean observing system. This section provides essential information on how to contribute data to the GOOS

GOOS approach to data management is aligned with open data and FAIR (Findable, Accessible, Interoperable, Reusable)[1] practices. All EOV data and information is valuable, thus effective data management practices are essential to ensure it remains accessible and (re)usable for future generations.

In this section you will be directed to resources that explain how you can contribute data to global ocean observing and ensure your data and information is accessible, interoperable and sustained. This resource has instructions for different scenarios: an individual submitting data, or existing data centres connecting to the system.

Please follow these practices carefully, as BioEco EOV data FAIRness relies on compliance with these guidelines.

Before proceeding, please note these important points:

1. As a **minimum**, you must ensure information describing your EOV data (i.e. metadata) are visible in the Ocean Data and Information System (ODIS)[2]. Regardless of where the actual data is stored, evidence of its existence must be findable within ODIS.
2. BioEco EOV data is successfully managed if it is discoverable in the **GOOS BioEco Portal.** The BioEco Portal is the central point of access and coordination of BioEco EOV observing programmes. Data visible in ODIS will automatically be visible in the BioEco Portal and vice versa.

3. If data is published to OBIS[3], it will also be visible in ODIS and the BioEco Portal. You do not need to also add it elsewhere, unless there is extra information you would like to include.

The main data management steps are as follow:

1. Become discoverable: ensure the data producers (e.g., organisation, programme, project, etc.) and datasets are visible in ODIS
2. Prepare the required metadata about the data producer and the datasets
3. Publish EOV data (e.g. OBIS)
4. Verify discoverability in ODIS

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[1] Wilkinson et al. 2016 https://doi.org/10.1038/sdata.2016.18
[2] ODIS, part of IOC-UNESCO's International Oceanographic Data and Information Exchange (IODE), is a global federation of data systems sharing interoperable (meta)data about holdings, services, and other resources to enhance cross-domain data accessibility.
[3] OBIS is a global biodiversity database and IOC-UNESCO IODE component, connecting +30 nodes, +1000 institutions, and 99 countries, interoperating with other major biodiversity hubs like GBIF and makes data visible in ODIS as an ODIS node.

Not all steps may be relevant for you, but **Step 1 is the minimum required** to ensure your data contributes to EOVs. .

TO CONTRIBUTE DATA AND METADATA TO THE GLOBAL OBSERVING SYSTEM, PLEASE GO TO: https://iobis.github.io/eov-data-management/

Figure 2. Map of OBIS Nodes. See https://obis.org/contact/ for a complete list.

Contact the OBIS Secretariat (helpdesk@obis.org) for help setting up your data workflows. To publish BioEco EOV data from systems like NCEI or ERDDAP to OBIS, consider becoming an OBIS node or collaborating with one. The OBIS Secretariat can help guide you through the process of becoming a Node, or connect you with an appropriate OBIS node (Figure 2).

Help Resources

- EOV Metadata Submission tool: https://eovmetadata.obis.org/

ODIS
- General help https://book.odis.org/index.html
- Connecting to ODIS https://book.odis.org/gettingStarted.html
- ODIS Catalogue of Sources: https://catalogue.odis.org/
- Ocean Info Hub: https://oceaninfohub.org/
- Schema.org framework https://schema.org/

OBIS
- OBIS Manual: https://manual.obis.org/
- OBIS YouTube data formatting and publishing videos: https://www.youtube.com/playlist?list=PLIgUwSvpCFS4TS7ZN0fhByj_3EBZ5lXbF
- Darwin Core term reference list: https://dwc.tdwg.org/terms/
- WoRMS taxonomy: https://www.marinespecies.org/
- Spreadsheet template generator https://www.nordatanet.no/aen/template-generator/config%3DDarwin%20Core
- BioData Guide with example code for transforming datasets to DwC: https://ioos.github.io/bio_data_guide/

GOOS BioEco Portal
- Documentation https://iobis.github.io/bioeco-docs/
- Access https://bioeco.goosocean.org/

EOV Seabirds
- Data exchange conventions and standards

1. The instruments that govern the operation of the Agreement Agreement on the Conservation of Albatrosses and Petrels - ACAP (www.acap.aq) has stablished standards for ACAP Parties to cooperate, having regard to the Action Plan, to develop systems for collecting and analysing data, and exchanging information. Population numbers and trends have been collected for 20 years under these terms.
2. Global Standard for the identification of Key Biodiversity Areas: https://portals.iucn.org/library/node/46259
3. Seabird Tracking Database: https://www.seabirdtracking.org/instructions/

- Data products

1. ACAP offer a complete list of albatrosses and petrel species assessments in the three languages at https://data.acap.aq/acap_species.cfm
2. ACAP offer a complete list of albatrosses and petrel breeding sites on islands or island groups at https://data.acap.aq/search_sites.cfm
3. Seabird Tracking Database from BirdLife International is a collaborative platform for seabird researchers to share and request satellite tracking data - https://www.seabirdtracking.org/. How this data has been used for conservation is outlined in: Carneiro *et al*. (2024). The BirdLife Seabird Tracking Database: 20 years of collaboration for marine conservation. Biological Conservation, 110813. https://doi.org/10.1016/j.biocon.2024.110813
4. Globally important areas: Key Biodiversity Areas (KBAs), including those identified for seabirds, are internationally recognised areas of global importance for the persistence of species that are assessed against a series of quantitative criteria: https://www.keybiodiversityareas.org/ Using KBAs as a focus for population monitoring relates to the Population status and trends. https://www.keybiodiversityareas.org/working-with-kbas/publications
5. Red List Assessment (global / regional): regular assessments on the extinction risk of species, including seabirds https://www.iucnredlist.org/assessment/process

- Data schemas and examples of websites providing additional guidance to facilitate comprehensive information sharing and streamline operational steps:

1. Data Portal of the Agreement on the Conservation of Albatrosses and Petrels available at https://data.acap.aq/
2. Seabird Tracking Database - https://www.seabirdtracking.org/instructions/
3. Key Biodiversity Areas - https://www.keybiodiversityareas.org/working-with-kbas/proposing-updating

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Acronyms and Abbreviations

CBD: Convention on Biological Diversity

EBV: Essential Biodiversity Variables

ECV: Essential Climate Variables

EOV: Essential Ocean Variables

GCOS: Global Climate Observing System

GEO BON: Group on Earth Observations Biodiversity Observation Network

GOOS: Global Ocean Observing System

IOCCP: International Ocean Carbon Coordination Project

MBON: Marine Biodiversity Observation Network

OBIS: Ocean Biodiversity Information System

ODIS: Ocean Data Information System

OCG: Observation Coordination Group

OOPC:Ocean Observations Physics and Climate Panel

SDG: Sustainable Development Goals

Glossary of terms

Derived products: outputs calculated from the EOV and sub-variables, often in combination with the supporting variables, that contribute to evaluating change in phenomena. For example, evaporation can be determined from sea surface temperature measurements; air-sea fluxes of CO2 can be derived from inorganic carbon EOV; fish stock productivity can be determined from fish abundance.

Indicators: An indicator can be defined as a 'measure based on verifiable data that conveys information about more than just itself'. This means that indicators are purpose dependent - the interpretation or meaning given to the data depends on the purpose or issue of concern. (BIP definition)

Measurement Uncertainty: the parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand (GUM)1. It includes all contributions to the uncertainty, expressed in units of 2 standard deviations, unless stated otherwise

Phenomena: properties (e.g., of a species such as distribution), processes (e.g., of the ocean such as surface ocean heat flux), or events (e.g., such as algal blooms) that have distinct spatial and temporal scales, and when observed, inform evaluations of ocean state and ocean change

Stability: The change in bias over time. Stability is quoted per decade.

Supporting variables: other measurements that are useful to provide scale or context to the sub-variables of the EOV (e.g., pressure measurements to provide information on the depth at which subsurface currents are estimated, sea temperature to understand dissolved inorganic carbon, water turbidity to support estimations of hard coral cover).

Sub-variables: key measurements that are used to estimate the EOV (e.g., counts of individuals to provide an estimate of species abundance (such as fish, mammals, seabirds or turtles), partial pressure of carbon dioxide (pCO_2)to estimate ocean inorganic carbon, or wave height to estimate sea state).

Timeliness: The time expectation for availability of data measured from the data acquisition time.

Appendix - Additional information

A1. Applications

This table provides examples of applications of this EOV, including, contribution to other essential variable frameworks, multilateral environmental agreements, contribution to indicators and GOOS applications

EOV		Seabird abundance and distribution
CORRESPONDING ESSENTIAL VARIABLES	EBV	Species populations: Species distributions, Species abundances Species traits: Phenology, Movement, Reproduction Community composition: Community abundance, Taxonomic/phylogenetic diversity Ecosystem functioning: Ecosystem phenology, Ecosystem disturbances Ecosystem structure: Ecosystem distribution
GLOBAL INDICATORS EOV CAN CONTRIBUTE	SDG	Sustainable development goal 14: Target 14.7: By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism Target 14.a: Increase scientific knowledge, research and technology for ocean health Sustainable development goal 12: Target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources Target 12.a: Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production Sustainable development goal 5 Target 5.5: Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life.
	CBD GBF	Goal A: Protect and Restore Goal B: Prosper with Nature Target 1: Plan and Manage all Areas To Reduce Biodiversity Loss - IUCN Red list Target 4: Halt species extinction, manage human-wildlife conflicts - IUCN red list, proportion of populations within species with an effective population size, CITES Target 5: Ensure Sustainable, Safe and Legal Harvesting and Trade of Wild Species - IUCN Red list, CITES Target 9: Manage Wild Species Sustainably To Benefit People - IUCN Red list Target 11: Restore, Maintain and Enhance Nature's Contributions to People - Contributions to ecosystem services Target 20: Strengthen Capacity-Building, Technology Transfer, and Scientific and Technical Cooperation for Biodiversity Target 21: Ensure That Knowledge Is Available and Accessible To Guide Biodiversity Action: Growth in marine species occurrence records accessible through OBIS Target 23:Ensure Gender Equality and a Gender-Responsive Approach for Biodiversity Action

	CMS + daughter agreements	ACAP - Agreement on the Conservation of Albatrosses and Petrels: Population and trends of ACAP species CMS - Convention on Migratory Species / United Nations: Population and trends of species on Appendix I & II of CMS
	KBA	Key Biodiversity Areas (KBAs): https://www.keybiodiversityareas.org/
GOOS APPLICATIONS		Ocean Health

A2. Additional supporting material and literature

Suggested literature

Other material

A3. Readiness level assessment

Essential Ocean Variable Specification Sheet

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