The Global Ocean Observing System

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Essential Ocean Variable Specification Sheet

Sea Turtles Abundance & 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

Sea turtles are a key endangered marine organisms that are charismatic, keystone species. They occupy the top of the food web, help maintain the health of seagrass and coral habitats, and facilitate the energy flow between ocean basins as well as between the ocean-land interface. Sea turtles also support human societies by helping sequester carbon in seagrasses, benefiting the fishing industry by controlling jellyfish populations and other nuisance species. They are a key part of socio-ecological systems, particularly within the 'Blue Economy,' and hold important cultural and recreational significance across diverse societies. The ecological integrity of their populations and critical habitats provide information about the viability and resilience of key ecosystems like the 'Blue Carbon Habitats' (seagrasses and mangroves). Nevertheless, sea turtles are threatened by predatory tourism, urban development, bad fishing practices, poaching, pollution, and climate change. Characterising the 'Sea turtles abundance & distribution' Essential Ocean Variable (EOV) requires networking, connecting stakeholders, and creating mutually beneficial partnerships in a context that weaves in indigenous and local knowledge to foster cooperation and collaboration. Monitoring this EOV can help inform The State of the World's Sea Turtles (SWOT), Marine Turtle Specialist Group (MTSG-IUCN) Regional Reports, and other regional networks. Also, in accordance with the complexity of sea turtle's life cycle, monitoring this EOV requires the assemblage of population indicators from in-water and land populations and their habitats.

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.

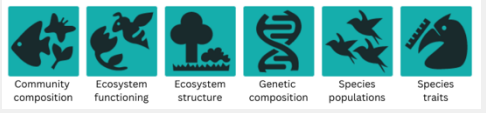
The Essential Biodiversity Variables (EBVs) defined and curated by the Group on Earth Observations Biodiversity Observation Network (GEO BON) complement the GOOS biological and ecosystem (BioEco) EOVs (Muller-Karger et al., 2018; Bax et al., 2019). The EOVs represent the basic observations of a particular parameter or process. EBVs are a 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: 

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1. EOV information

ESSENTIAL OCEAN VARIABLE (EOV)	Sea Turtles abundance & distribution
DEFINITION	Abundance refers to the number of individuals present in the monitored nesting and foraging sites per unit of time and is used to describe how populations change over time and across regions. Distribution refers to the occupancy range of critical habitats by their populations.
EOV SUB-VARIABLES - key measurements that are used to estimate the EOV * bare minimum	*Nesting success. Number of individuals in foraging habitats. Start, peak, and end week of the nesting season. Number of stranding records.
SUPPORTING VARIABLES - other measurements that are useful to provide scale or context to the sub-variables of the EOV	Sea surface temperature, nutrients, phytoplankton biomass and diversity, zooplankton biomass and diversity, hard coral cover and composition, seagrass cover and composition, sea surface currents, storms occurrence, precipitation, land surface temperature. **EOV related**: population's sex ratio, number of "major" nesting and foraging sites, number of "minor" nesting and foraging sites, number of nesting individuals per year, size structure of the population, length of nesting beaches, temperature of nests, quantitative surveying effort indicator for nesting and foraging habitats, proportion of neophytes and remigrant individuals, habitat quality for satisfying ecological needs, location of aggregation hotspots, migratory corridors.
DERIVED PRODUCTS - outputs calculated from the EOV and sub-variables, often in combination with the supporting variables	Changes in phenology patterns, changes in geographic distribution, nature provisioning, seagrass cover, sea turtles critical habitats and hotspots, migratory corridors, population recent and historical trends, percentage of historic (30 years ago) population, spatial occupancy of coastal and in-water critical habitats per Regional Management Units (Wallace et al., 2023), population trends in short and long terms.

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 guidance 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 	Distribution shifts 	Phenological changes 
PHENOMENA EXTENT	HORIZONTAL	One to hundreds of kilometers.	One to hundreds of kilometers.	Tens to hundreds of kilometers.
	VERTICAL	1 to 100 m.	1 to 100 m.	1 to 100 m.
	TEMPORAL	Months to decades.	Months to decades.	Lustrum to decadal.
RESOLUTION TO OBSERVE PHENOMENA	HORIZONTAL	One to tens of kilometers.	Tens to hundreds of kilometers.	Tens to hundreds of kilometers.
	VERTICAL	1 to 10 m.	1 to 100 m.	1 to 10 m.
	TEMPORAL	Monthly to annual.	Annual.	Annual.
SIGNAL TO CAPTURE		Change in IUCN Red List category.	Changes in species occurrence to occupy sites outside their known geographic range.	Shift in nesting season's parameters.
SUB-VARIABLES NEEDED TO MEASURE		Nesting success. Number of individuals in foraging habitats.	Nesting success. Number of individuals in foraging habitats. Number of stranding records.	Start, peak, and end week of the nesting season.
SUPPORTING VARIABLES NEEDED		Nesting population size structure, proportion of	Number of "major" and "minor" nesting and foraging sites, habitat	Sea surface temperature, temperature of nests,

	neophytes and remigrant individuals, population's sex ratio, number of nesting individuals per year, quantitative surveying effort indicator for nesting and foraging habitats.	quality for satisfying ecological needs, location of aggregation hotspots, migratory corridors, length of nesting beaches, nutrients, phytoplankton biomass and diversity, zooplankton biomass and diversity, hard coral cover and composition, seagrass cover and composition, sea surface currents, storms occurrence.	precipitation, land surface temperature.

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	Sea turtles abundance & distribution
PHENOMENA	Population status and trends, distribution shifts
EOV SUB-VARIABLE	Nesting success.
DEFINITION	It evaluates the nesting activity and its magnitude per year at distinct levels of detail according with the variety of monitoring protocols (Dow-Piniak and Eckert, 2011; SWOT Scientific Advisory Board, 2011), and uses the 'nesting beach' extension as the operational management unit for this sub-variable. The 'nesting beach' geographic description and the monitoring protocol have to be specified in the metadata files.

	Resolution			Timeliness	Uncertainty Measurement	Stability	Sampling approach	References
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	Number of nesting individuals per species per year at 'nesting beaches'.	N/A	Per year.	N/A	Time and spatial extent of monitoring effort per month.	N/A	Recommended Monitoring Protocols for sea turtle nesting beaches.	Dow-Piniak and Eckert, 2011; SWOT Scientific Advisory Board, 2011.
DESIRABLE	Number of nests per species per	N/A	Per year.	N/A	Time and spatial extent of	N/A		

	year at 'nesting beaches'.				monitoring effort per month.			
MINIMUM	Number of crawls per nesting beach.	N/A	Historic (time lapse will depend on the monitoring project) .	N/A	Indicator of potential duplicated counting rate and the proportion of false and true crawls.	N/A		

EOV SUB-VARIABLE	Number of stranding records.				**DEFINITION**		This sub-variable refers to the number of records of stranded individuals on the beach, both dead and alive individuals (Geraci & Lounsbury, 1993). The records are georrefered for purposes of assessing distribution shifts.	
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	Number of stranded (live and death, decompositi on condition for death ones) individuals per species and the possible cause of stranding is described.	N/A	Per month.	N/A	Indicator of temporal and spatial recording effort; and the description of diagnostic features for the possible causes of stranding.	N/A	Direct beach surveys; participative and citizen recording.	Geraci & Lounsbury, 1993; Jacobson, 1999; Shaver & Teas, 1999

DESIRABLE	Number of stranded (live and dead) individuals per species .	N/A	Per year.	N/A	Indicator of temporal and spatial recording effort.	N/A		
MINIMUM	Number of stranded individuals.	N/A	Historic (time lapse will depend on the monitoring project).	N/A	Indicator of temporal and spatial recording effort.	N/A		

PHENOMENA	Distribution shifts							
EOV SUB-VARIABLE	Number of individuals in foraging habitats per unit area.				**DEFINITION**		Number of records of presence (crawls at nesting beaches, and number of individuals in foraging grounds) of individuals referred to a spatial unit of context (B3 hexagons), per unit of time or season.	
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	Number of individuals per 10-km diameter hexagons.	Intensity of use of each five-meters depth bins.	Seasonal.	N/A	Indicator of temporal and spatial recording effort, and the specification of sampling approach.	N/A	Direct and indirect surveys.	Elayam et al., 2022; Perera-Valderrama et al., 2020; Rodriguez-Viñas et al.., 2023.

DESIRABLE	Number of individuals per 25-km diameter hexagons.	Intensity of use of each ten-meters depth bins.	Annual.	N/A	Indicator of temporal and spatial recording effort.	N/A		
MINIMUM	Number of individuals per 50-km diameter hexagons.	Use of oceanic and neritic habitats.	Historic (10 years or older).	N/A	Indicator of temporal and spatial recording effort.	N/A		

PHENOMENA	Phenological changes							
EOV SUB-VARIABLE	Start, peak, and end week of the nesting season.				**DEFINITION**		The start of the nesting season is that natural (7-days) week when the number of nests (or number of crawls) reached the 5% or more of the total recorded in a specific year; while the end of the nesting season is that week when it was recorded 97% or more of the nesting indicator (Neeman et al., 2015). The duration of the nesting season is the number of weeks between the start and end weeks.	
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	Standardized historic (>30 years) spatial operative nesting survey unit	N/A	Annual.	N/A	Indicator of temporal and spatial recording effort.	N/A	Recommended Monitoring Protocols for sea turtle nesting beaches.	SWOT Scientific Advisory Board, 2011; Neeman et al., 2015

	(‘nesting beach’).							
DESIRABLE	Standardized historic (>10 years) spatial operative nesting survey unit (‘nesting beach’).	N/A	Annual.	N/A	Indicator of temporal and spatial recording effort.	N/A		
MINIMUM	Standardized historic (>5 years) spatial operative nesting survey unit (‘nesting beach’).	N/A	Historic averages (10 years or more).	N/A	Indicator of temporal and spatial recording effort.	N/A		

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	Remote sensing: other	Fixed-point: other	Autonomous: animal telemetry/tags
EOV SUB-VARIABLE(S) MEASURED	Number of crawls on nesting beaches, Number of individuals in foraging habitats per unit area, Start, peak, and end week of the nesting season.	Number of crawls on nesting beaches, Number of individuals in foraging habitats per unit area, Number of stranding records, Start, peak, and end week of the nesting season.	Number of individuals in foraging habitats per unit area.
TECHNIQUE / SENSOR TYPE	Aerial census (airplane, drones); fixed cameras to record areas of special interest in nesting beaches and in-water habitats.	On-site (beach monitoring, diving transects, nets); Participative records (mapping, interviews, citizen science).	Telemetry.
SUGGESTED METHODS AND BEST PRACTICES	Henwood and Epperly, 1999; Schroeder and Murphy, 1999; Fuentes et al., 2015; Sykora-Bodie et al., 2017; Warden et al., 2017; Rees et al., 2018; Schofield et al., 2019; Yaney-Keller et al., 2021; Papazekou et al., 2024.	Bell et al., 2009; National Research Council et al., 2010; SWOT, 2011; Eckert and Eckert, 2012; Williams et al., 2015; Rathanyake, 2016; Cuevas et al., 2018; Becker et al., 2019; Casale et al., 2020; Perera-Valderrama et al., 2020.	Schofield et al., 2007; Godley et al., 2008; Weber et al., 2013; Hussey et al., 2015; Hays & Hawkes, 2018; Hardin & Fuentes, 2021.
SUPPORTING VARIABLES MEASURED	Sea surface temperature.	Storms occurrence, precipitation, land surface temperature .	Sea surface temperature.

APPROACH / PLATFORM	Ship-based: other	APPROACH #2	APPROACH #3
EOV SUB-VARIABLE(S) MEASURED	Number of individuals in foraging habitats per unit area.		
TECHNIQUE / SENSOR TYPE	Distance sampling method, based on the recording of sea turtle individuals from a vessel (boat) along survey transects.		
SUGGESTED METHODS AND BEST PRACTICES	Beavers & Ramsey, 1998; Thomson et al., 2012; Bovery & Wyneken, 2015; Strindberg et al., 2016.		
SUPPORTING VARIABLES MEASURED	Sea surface temperature, nutrients, phytoplankton biomass and diversity, zooplankton biomass and diversity, sea surface currents, storms occurrence, precipitation.		

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

[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/

References

Background information

Bax, N. et al. 2019. A response to scientific and societal needs for marine biological observations. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2019.00395

Beavers, S.C., Ramsey, F.L. (1998). Detectability analysis in transect surveys. The Journal of wildlife management (1998): 948-957. https://doi.org/10.2307/3802547

Becker, S.L., Brainard, R.E., Van Houtan, K.S. (2019). Densities and drivers of sea turtle populations across Pacific coral reef ecosystems. PLoS ONE 14(4): e0214972. doi: 10.1371/journal.pone.0214972

Bell, C.D., Blumenthal, J.M., Austin, T.J., Ebanks-Petrie, G., Broderick, A.C., Godley, B.J. (2009). Harnessing recreational divers for the collection of sea turtle data around the Cayman Islands. Tourism in Marine Environments, 5(4): 245-257.

Bojinski, S. et al. 2014. The concept of essential climate variables in support of climate research, applications, and policy. Bull. Amer. Meteor. Soc., 95, 1431–1443, doi:https://doi.org/10.1175/BAMS-D-13-00047.1.

Bovery, C.M., Wyneken, J. (2015). Seasonal variation in sea turtle density and abundance in the southeast Florida Current and surrounding waters. PLoS ONE, 10(12): e0145980. doi: 10.1371/journal.pone.0145980

Casale, P, Ciccocioppo, A., Vagnoli, G., Rigoli, A., Freggi, D., Tolve, L., Luschi, P. (2020). Citizen science helps assessing spatio-temporal distribution of sea turtles in foraging areas. Aquatic Conservation: Marine and Freshwater Ecosystems, 30: 123-130. doi: 10.1002/aqc.3228

Cuevas, E., Guzmán-Hernández, V., Uribe-Martínez, A., Raymundo-Sánchez, A., Herrera-Pavón, R. (2018). Identification of potential bycatch hotspots using a spatially explicit approach in the Yucatan Peninsula, Mexico. Chelonian Conservation and Biology, 17(1): 78-93. doi: :10.2744/CCB-1263.1

Dow-Piniak, W.E., Eckert, K.L. (2011). Sea turtle nesting habitat in the Wider Caribbean Region. Endangered Species Research, 15: 129-141. doi: 10.3354/esr00375

Eckert, K.L., Eckert, S.A. (2012). Designing Surveys of Abundance at Sea Turtle Nesting Beaches. Wider Caribbean Sea Turtle Conservation Network (WIDECAST) Technical Report No. 15. Ballwin, Missouri. 52 pp.

Eckert, Karen L., and Adam E. Eckert. An atlas of sea turtle nesting habitat for the wider Caribbean region. Revised Edition. No. 19. WIDECAST Technical Report, 2019.

Elayam, M.M., Kerhoas, G., Lambert de Cursay, V., Ray, C., Ménard, A. (2022). On the Interest of Hexagonal Abstraction of Maritime Information. In OCEANS 2022, Hampton Roads, pp. 1-6. IEEE, 2022.

Fuentes, M.M.P.B., Bell, I., Hagihara, R., Hamann, M., Hazel, J., Huth, A., Seminoff, J.A., et al. (2015). Improving in-water estimates of marine turtle abundance by adjusting aerial survey counts for perception and availability biases. Journal of Experimental Marine Biology and Ecology, 471: 77-83. doi: 10.1016/j.jembe.2015.05.003

GCOS, 2022a. The 2022 GCOS Implementation Plan (GCOS-244). World Meteorological Organization, Geneva. https://library.wmo.int/records/item/58104-the-2022-gcos-implementation-plan-gcos-244.

GCOS, 2022b. The 2022 GCOS ECVs Requirements (GCOS 245). World Meteorological Organization, Geneva. https://library.wmo.int/records/item/58111-the-2022-gcos-ecvs-requirements-gcos-245

Geraci, J.R. & Lounsbury, V.J. (1993). Marine mammals ashore, A Field guide for strandings. A Texas A&M Sea Grant Publication (TAMU-SG-93-601), Galveston, USA. 309 p. https://repository.library.noaa.gov/view/noaa/39015/noaa_39015_DS1.pdf

Godley, B.J., Blumenthal, J.M., Broderick, A.C., Coyne, M.S., Godfrey, M.H., Hawkes, L.A., Witt, M.J. (2008). Satellite tracking of sea turtles: where have we been and where do we go next? Endangered Species Research, 4: 3-22. doi: 10.3354/esr00060

Hardin, E.E., Fuentes, M.M.P.B. (2021). A systematic review of acoustic telemetry as a tool to gain insights into marine turtle ecology and aid their conservation. Frontiers in Marine Science, 8:765418. doi: 10.3389/fmars.2021.765418

Hays, G.C., Hawkes, L.A. (2018). Satellite tracking sea turtles: opportunities and challenges to address key questions. Frontiers in Marine Science, 5:432. doi: 10.3389/fmars.2018.00432

Henwood, T.A., Epperly, S.P. (1999). Aerial surveys in foraging habitats. In: K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (Editors). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 1999.

Hussey, N.E., Kessel, S.T., Arestrup, K., Cooke, S.J., Cowley, P.D., Fisk, A.T., Harcourt, R.G., et al. (2015). Aquatic animal telemetry: a panoramic window into the underwater world. Science, 348(6240): 1221-1231. doi: 10.1126/science.1255642

Jacobson, E.R. (1999). Tissue sampling and necropsy techniques. In: K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (Editors). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 1999.

Jetz, W. et al. 2019. Essential biodiversity variables for mapping and monitoring species populations. Nature Ecology & Evolution. 3, p. 539–551. Doi: 10.1038/s41559-019-0826-1.

Miloslavich, P et al. 2018. Essential Ocean Variables for sustained observations of marine biodiversity and ecosystems. Global Change Biology. Volume 24, Issue 6. Pages 2416-2433. http://dx.doi.org/10.1111/gcb.14108.

Muller-Karger, F. 2018. Advancing Marine Biological Observations and Data Requirements of the Complementary Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) Frameworks. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2018.00211.

National Research Council, et al. (2010). Assessment of sea-turtle status and trends: integrating demography and abundance. National Academies Press.

Neeman, N., Robinson, N.J., Paladino, F.V., Spotila, J.R., O'Connor, M.P. (2015). Phenology shifts in leatherback turtles (*Dermochelys coriacea*) due to changes in sea surface temperature. Journal of Experimental Marine Biology and Ecology, 462, 113--120. https://doi.org/10.1016/j.jembe.2014.10.019

Papazekou, M. Kyprioti, A., Chatzimentor, A., Dimitriadis, C., Vallianos, N., Mazaris, A.D. (2024). Advancing sea turtle monitoring at nesting and near shore habitats with UAVs, data loggers, and state of the art technologies. Diversity, 16: 153. doi: 10.3390/d16030153

Perera-Valderrama, S., Herrera-Pavón, R., Zamora-Vilchis, I., Cerdeira-Estrada, S., Martell-Dubois, R., Rosique-de la Cruz, L.O., Caballero-Aragón, H., Alva-Basurto, J.C., Francisco-Ramos, V., Ressl, R. (2020). Capítulo V: Tortugas marinas. In: Perera-Valderrama, S., S. Cerdeira-Estrada, R. Martell-Dubois, L.O. Rosique-de la Cruz, H. Caballero-Aragón, R. Ressl (coords.). Protocolos de monitoreo de la biodiversidad marina en áreas naturales protegidas del Caribe mexicano. Conabio. México, pp. 123-140.

Rathanyake, R.M.W. (2016) 'Turtle Watching': A strategy for endangered marine turtle conservation through community participation in Sri Lanka. Ocean & Coastal Management, 119: 199-207. https://doi.org/10.1016/j.ocecoaman.2015.10.014

Rees, A.F., Avens, L., Ballorain, K., Bevan, E., Broderick, A.C., Carthy, R.R., Christianen, M.J.A., et al. (2018). The potential of unmanned aerial systems for sea turtle research and conservation: a review and future directions. Endangered Species Research, 35: 81-100. doi: 10.3354/esr00877

Rodriguez-Viñas, J., Ortega-Fernandez, I., Sotos Martínez, E. (2023). Hexanonymity: a scalable geo-positioned data clustering algorithm for anonymisation purposes. IEEE European Symposium on Security and Privacy Workshops (EuroS&PW). IEEE, 2023.

Satterthwaite et al. 2021. Establishing the Foundation for the Global Observing System for Marine Life. *Front. Mar. Sci. 8.* https://doi.org/10.3389/fmars.2021.737416

Schofield, G., Bishop, C.M., MacLean, G., Brown, P., Baker, M., Katselidis, K.A., Dimopoulos, P., et al. (2007). Novel GPS tracking of sea turtles as a tool for conservation management. Journal of Experimental MArine Biology and Ecology, 347: 58-68. doi: 10.1016/j.jembe.2007.03.009

Schofield, G., Esteban, N., Katselidis, K.A., Hays, G.C. (2019). Drones for research on sea turtles and other marine vertebrates - A review. Biological Conservation, 238: 108214. doi: 10.1016/j.biocon.2019.108214

Schroeder, B., Murphy, S. (1999). Population surveys (ground and aerial) on nesting beaches. In: K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (Editors). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 1999.

Shaver, D.J., Teas, W.G. (1999). Stranding and salvage networks. In: K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (Editors). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 1999.

Strindberg, S., Coleman, R.A., Burns Perez, V.R., Campbell, C.L., Majil, I., Gibson, J. (2016). In-water assessments of sea turtles at Glover's Reef Atoll, Belize. Endangered Species Research, 31: 211-225. doi: 10.3354/esr00765

Sykora-Bodie, S.T., Bezy, V., Johnston, D.W., Newton, E., Lohmann, K.J. (2017). Quantifying nearshore sea turtle densities: Applications of unmanned aerial systems for population assessments. Scientific Reports, 7: 17690. doi: 10.1038/s41598-017-17719-x

SWOT Scientific Advisory Board. 2011. The State of the World's Sea Turtles (SWOT) Minimum Data Standards for Nesting Beach Monitoring, version 1.0. Handbook, 28 pp. Available at: https://www.seaturtlestatus.org/minimum-data-standards [Accessed 22 January 2025]

Thomson, J.A., Cooper, A.B., Burkholder, D.A., Heithaus, M.R., Dill, L.M. (2012). Heterogeneous patterns of availability for detection during visual surveys: spatiotemporal variation in sea turtle dive-surfacing behaviour on a feeding grounds. Methods in Ecology and Evolution, 3: 378-387. doi: 10.1111/j.2041-210X.2011.00163.x

Wallace, B.P., Posnik, Z.A., Hurley, B.J., DiMatteo, A.D., Bandimere, A. ,Rodriguez, I., Maxwell S.M., et al. (2023). Marine turtle regional management units 2.0: an updated framework for conservation and research of wide-ranging megafauna species. Endangered Species Research, 52: 209-223. doi: 10.3354/esr01243

Warden, M.L., Haas, H.L., Richards, P.M., Rose, K.A., Hatch, J.M. (2017). Monitoring trends in sea turtle populations: walk or fly? Endangered Species Research, 34: 323-337. doi: 10.3354/esr00855

Weber, N., Weber, S.B., Godley, B.J., Ellick, J., Witt, M., Broderick, A.C. (2013). Telemetry as a tool for improving estimates of marine turtle abundance. Biological Conservation, 167: 90-96. doi: 10.1016/j.biocon.2013.07.030

Williams, J.L., Pierce, S.J., Fuentes, M.M.P.B., Hamann, M. (2015). Effectiveness of recreational divers for monitoring sea turtle populations. Endangered Species Research, 26: 209-219. doi: 10.3354/esr00647

Yaney-Keller, A., San Martin, R., Reina, R.D. (2021). Comparison of UAV and boat surveys for detecting changes in breeding population dynamics of sea turtles. Remote Sensing, 13: 2857. doi: 10.3390/rs13152857

Guides, best practices and methods

Standards and reference materials

Minimum Data Standards for Nesting Beach Monitoring, The State of the World's Sea Turtles: http://seaturtlestatus.org/minimum-data-standards

International Union for Conservation of Nature (IUCN), Marine Turtle Specialist Group (MTSG): https://www.iucn-mtsg.org/

Inter-American Convention for the Protection and Conservation of Sea Turtles: http://www.iacseaturtle.org/defaulteng.htm

Wider Caribbean Sea Turtle Network (WIDECAST): https://www.widecast.org/

Indian Ocean–South-East Asian (IOSEA) Marine Turtles: https://www.cms.int/iosea-turtles/en

Conservation of Marine Turtles in the Mediterranean Region: https://www.medmarineturtles.org/

Red Laúd del Océano Pacífico Oriental (LAUDOPO): https://laudopo.org/

Eastern Pacific Hawksbill Initiative (ICAPO): https://oceanfdn.org/projects/eastern-pacific-hawksbill-initiative-icapo/

Integrated EOV products and visualisations

OBIS - Spatial Ecological Analysis of Megavertebrate Populations: https://seamap.env.duke.edu/

Movebank: https://datarepository.movebank.org/home

Marine Megafauna Movement: https://megamove.org/about-us/

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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

SWOT: The State of the World's Sea Turtle

IUCN: International Union for Conservation of Nature

MTSG: Marine Turtle Specialist Group

WIDECAST: Wider Caribbean Sea Turtle Network

IOSEA: Indian Ocean–South-East Asian Marine Turtles

LAUDOPO: Red Laúd del Océano Pacífico Orienta

ICAPO: Eastern Pacific Hawksbill Initiative

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.

Sea turtle crawl: Tracks left in the sand when a gravid sea turtle female leaves the sea and crawls on a nesting beach, including both successful egg laying and failed laying attempts (Dow-Piniak and Eckert, 2011).

Stranded individual: It is any sea turtle found on land or floating in coastal waters, dead or alive (incapacitated), and specialized on-site personnel attended those events (Geraci & Lounsbury, 1993).

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		Sea turtle abundance & distribution
CORRESPONDING ESSENTIAL VARIABLES	EBV	Genetic composition - Genetic differentiation (number of genetic units and genetic distance), Effective population size. Species populations - Species distributions, Species abundances. Species traits - Phenology.
GLOBAL INDICATORS EOV CAN CONTRIBUTE	**SDG**	Sustainable Development Goal 14: Target 14.1. Prevent and significantly reduce marine pollution of all kinds. Target 14.2. Sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts. Target 14.4. Effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans. Target 14.5. Conserve at least 10 percent of coastal and marine areas. Target 14.b. Provide access for small-scale artisanal fishers to marine resources and markets. Target 14.c. Enhance the conservation and sustainable use of oceans and their resources by implementing international law.
	CBD	GOAL A. Protect and Restore. GOAL B. Prosper with Nature. Target 1. Plan and Manage all Areas To Reduce Biodiversity Loss. Target 2. Restore 30% of all Degraded Ecosystems. Target 3. Conserve 30% of Land, Waters and Seas. Target 4. Halt Species Extinction, Protect Genetic Diversity, and Manage Human-Wildlife Conflicts. Target 9. Manage Wild Species Sustainably To Benefit People. Target 11. Restore, Maintain and Enhance Nature's Contributions to People. 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.

	RAMSAR	Target 5. The ecological character of Ramsar sites is maintained or restored, through effective planning and integrated management. Target 7. Sites that are at risk of change of ecological character have threats addressed. Target 11. Wetland functions, services and benefits are widely demonstrated, documented and disseminated. Target 12. Restoration is in progress in degraded wetlands, with priority to wetlands that are relevant for biodiversity conservation, disaster risk reduction, livelihoods and/or climate change mitigation and adaptation. Target 14. Scientific guidance and technical methodologies at global and regional levels are developed on relevant topics and are available to policy makers and practitioners in an appropriate format and language.
	CCMS	Migratory reptiles
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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