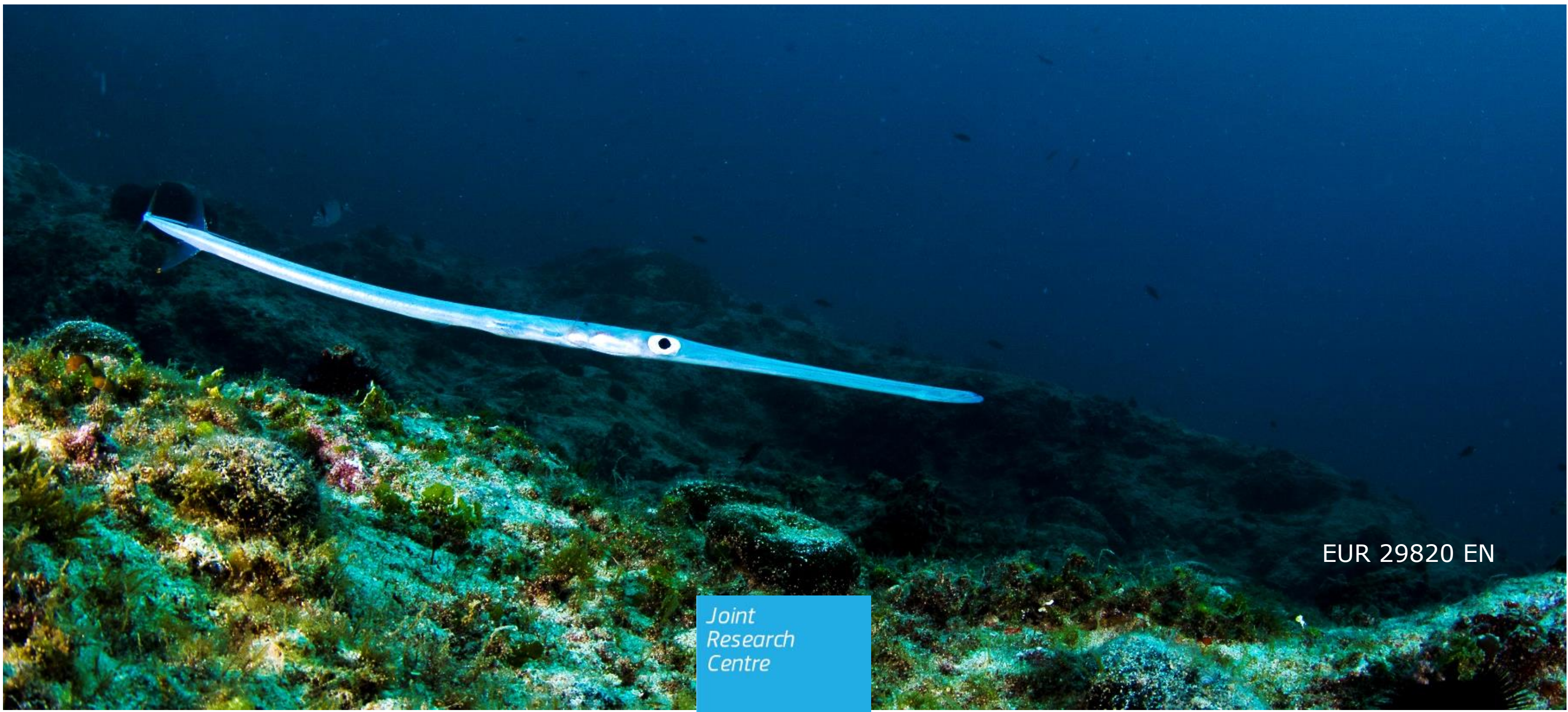
JRC TECHNICAL REPORTS

# Indicators for status assessment of species, relevant to MSFD Biodiversity Descriptor

*Identifying methods to set thresholds for the GES assessment.*

Palialexis A., D. Connor, D. Damalas, J. Gonzalvo, D. Micu, I. Mitchel, S. Korpinen, A. F. Rees, F. Somma

2019



EUR 29820 EN

**Contact information**
Name: Andreas Palialexis
Address: Via E. Fermi 2749, TP 270, I-21027 Ispra (VA) - Italy
Email: **andreas.palialexis@ec.europa.eu**
Tel.: +39 0332 78 9206

**EU Science Hub**
https://ec.europa.eu/jrc

JRC117126

EUR 29820 EN

PDF ISBN 978-92-76-09156-1 ISSN 1831-9424 doi:10.2760/282667

Luxembourg: Publications Office of the European Union, 2019



How to cite this report: Palialexis A., D. Connor, D. Damalas, J. Gonzalvo, D. Micu, I. Mitchel, S. Korpinen, A. F. Rees and F. Somma. *Indicators for status assessment of species, relevant to MSFD Biodiversity Descriptor*. EUR 29820 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-09156-1, doi:10.2760/282667, JRC117126.

## Contents

***Authors***


- Andreas Palialexis (European Commission JRC)
- Dragos Micu (Romanian Waters National Authority, Dobrogea - Black Sea Basin Administration)
- Samuli Korpinen (Finnish Environment Institute)
- Ian Mitchel (Joint Nature Conservation Committee)
- Dimitris Damalas (Hellenic Centre for Marine Research)
- Joan Gonzalvo (Tethys Research Institute)
- Alan F. Rees (Independent sea turtle researcher and consultant)
- Francesca Somma (European Commission JRC)
- David Connor (DG Environment)

## Abstract

The inconsistency in the determination of the Good Environmental Status for species assessment under the first cycle of the EU's Marine Strategy Framework Directive emerged in a harmonisation exercise. This exercise was launched with the species' identification of MSFD Descriptor's 1 concern and the collection of the operational or developing indicators and methods for the status assessment and classification of marine species. The latter was materialised with this report, by collecting information from several sources including the Regional Sea Conventions and the relevant marine and environment EU policies. The methodological standards and the threshold setting processes can be harmonised at three levels, to achieve consistent GES determination for the species assessed under the MSFD: i) MSFD criteria; ii) species groups, and iii) spatial scale. The next step will be to further evaluate the operability and suitability of these indicators and methods, associate them with data availability and propose the best possible option for the status classification of species at those three levels.

## Introduction

This work reviews the existing methods to set thresholds, which determine good environmental status (GES) for the species groups mentioned in the Marine Strategy Framework Directive (MSFD; European Commission, 2008). It congregates and describes operational or developing indicators focused on methods to set threshold values for the status classification of marine species. The main sources of information include EU environmental and marine policies considered by the Marine Strategy Framework Directive, as well as the scientific approaches and good practices, which are developed under the Regional Sea Conventions (RSC).

Most of the methods listed in this report have been developed for particular species and their generalization is a matter to explore. Lack of data limits the development and application of these methods to more species or different regional seas. Consequently, these data gaps can prioritise the planning of the EU Member States to update their monitoring programmes.

The selected indicators cover the MSFD species biodiversity criteria and the MSFD species group, reflecting the currently available data and knowledge. Priority goes to the methods fitting to the MSFD requirements and concepts, as listed in Article 4 of the Commission Decision 2017/848/EU (European Commission, 2017). Thus the listed methods are organised, firstly, at the level of MSFD criteria and secondly, at the level of species groups. Potential methods with broader operability, like the Habitat Directive's or IUCN methods, are listed at higher level. Some indicators with potential to cover current gaps are included in the inventory, even if they were not developed or tested by the RSC.

The last part of the list is dedicated to fish and cephalopods' indicators that were developed by the CFP (EU Common Fisheries Policy) community. These have a great potential to be applied for the MSFD D1 criteria, considering that the CFP provided a vast amount of information for the MSFD (Palialexis et al., 2014). However, the fact that different communities are developing fisheries and environmental indicators did not allow yet to fully considering them for the MSFD Descriptor 1 work.

The inventory of indicators and their methods to set threshold values for species status classification provides advice and best practices towards harmonization of these methods and enhance collaboration across EU Member States. The follow up work will be to evaluate those methods in relation to the challenges and objectives derived from the Commission Decision 2017/848/EU (European Commission, 2017). The evaluation of the threshold setting approaches should be in-line with the endogenous concepts of the Decision 2017/848/EU (European Commission, 2017) in relation to the Good Environmental Status (GES) determination. Eventually, common agreed methods for setting thresholds will secure the harmonisation in the GES determination for the MSFD species.

## D1C1 Mortality rate from incidental bycatch

OSPAR has developed a general legal framework in relation to the species by-catches (OSPAR, 2018), that summarizes the status and the links of D1C1 with other policies. By-catch data are primarily collected through observer schemes that should operate for each of the fisheries specified in the Annexes of the European Union Council Regulation (EC) 812/2004 (European Union, 2004). However, coverage of several métiers in several regions is generally low for numerous reasons, e.g. the vast number of artisanal vessels in the Mediterranean. The EC Council Regulation 812/2004 (European Union, 2004) imposes monitoring of by-catch species for the protection of whales, dolphins and porpoises against incidental catch, for vessels longer than a defined length, whereas significant effort is taking place also from smaller vessels, with unknown impact to the total by-catch. For instance, the European gillnet fleet is monitored for vessels more than 15m. Most vessels in the European gillnet fleet are smaller than 15 m and the gillnet fleets of some Member States are very large, comprising hundreds of vessels (OSPAR, 2018). In addition, there are obligations for monitoring under the EU Data Collection Multiannual Plan (DC-MAP; European Union, 2017a), as well as under the Article 12 of the European Union Habitats Directive (92/43/EEC; European Union, 1992).

European Union (2017) defines D1C1 as: "The mortality rate per species from incidental bycatch is below levels which threaten the species, such that its long-term viability is ensured." In the specifications and standardized methods for monitoring and assessment states that: "[…] data shall be provided per species per fishing métier for each ICES area or GFCM Geographical Sub-Area or FAO fishing areas for the Macaronesian biogeographic region, to enable its aggregation to the relevant scale for the species concerned, and to identify the particular fisheries and fishing gear most contributing to incidental catches for each species".

The following indicators and the way they set thresholds are evaluated for the incidental by-catch threshold setting. According to the European Union (2017) "[…] The extent to which GES has been achieved shall be expressed for each area assessed as follows: - the mortality rate per species and whether this has achieved the threshold values set."

| | |
|---|---|
| **HELCOM:** | **C1.1 Number of drowned mammals and waterbirds in fishing gear** |
| **OSPAR:** | **C1.2 Harbour Porpoise Bycatch** |
| **UNEPMAP:** | **C1.3 Indicator M6 - Marine mammal bycatch** |
| **BSC:** | **C1.4 Bycatch of vulnerable and non-target species (EO1 and EO3; CI2)** |
| | **C1.5 As part of the "Reach of sustainable stocks status of threatened / endangered species"** |

***HELCOM indicators***

### C1.1 Number of drowned mammals and waterbirds in fishing gear

**Definition of GES**: Good status is achieved if the incidental by-catch numbers of all assessed species within a given assessment unit are below the removal target used as the threshold value taking also other human-induced mortality into account. Besides assessing incidental by-catch on a population scale, it may be desirable for management purposes to downscale information to implement measures on a smaller scale (e.g. sub-basin, HELCOM scale 2). For this indicator there are no agreed threshold values. It is essential to coordinate activities for this indicator with OSPAR (HELCOM, 2018).

**Threshold values**: No quantitative threshold values are currently set. The assessment values (in **Table 1**) applied as initial threshold values (to indicate the shortcomings in their development) for the species and populations assessed (HELCOM, 2018) in this indicator.

**Table 1.** Initial threshold values based on removal targets for the species and populations assessed in HELCOM's D1C1 relevant indicator (modified from HELCOM, 2018).

| **Species** | **Initial threshold value** |
|---|---|
| **Harbor porpoise**<br>**Baltic Proper population** | Zero incidental by-catch |
| **Harbor porpoise**<br>**Western Baltic, Belt Sea and Kattegat population** | < 1 % incidental by-catch of the best abundance estimate |
| **Long tailed-duck**<br>**Western Palearctic population** | PBR = 22.600 birds (including oiling and hunting, recovery factor = 0,1) |
| **Greater scaup**<br>**Western Palearctic population** | PBR = 3.700 birds (including oiling and hunting, recovery factor = 0,1) |
| **Common guillemot**<br>**Baltic-breeding population** | PBR = 620 birds (including oiling) |

**Definition Removal targets** are based on 'unacceptable mortality levels' for the indicator species. Levels of 'unacceptable interactions' are related to the total human induced mortality of which incidental by-catch is an unknown fraction that may differ regionally. These levels of 'unacceptable interactions' should not be misinterpreted as 'acceptable levels' if the values are below the reference points (HELCOM 2018).

**Definition Conservation targets** are focused on the state of biological management units (i.e. stocks or populations). A target for a safe human-induced mortality limit (as a consequence of the removal target) is usually the outcome of a simulation over a certain time period using a suitable population dynamic model. During the time period, the conservation target for the stock size is to be reached with a given certainty in a predefined fraction of the simulation time (e.g. at least 95 % likelihood of reaching at least 80 % of carrying capacity within 100 years (from HELCOM 2018).

**Setting threshold values:** The concept to apply threshold values supported by species-specific **removal and conservation targets** has been developed in other contexts, including ongoing work carried out under the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS), concluded under the auspices of the Convention on Migratory Species (ASCOBANS, 2015). This approach requires setting species-specific conservation targets and defining reference points (removal targets) for the annual incidental by-catch rate. Details on removal targets and conservation targets provided by HELCOM (2018), ICES reports of the Working Group on By-catch (WKBYCS) and ASCOBANS's reports cited there.

In the long-term, mortality in a healthy population must not exceed the birth rate (natality) to sustain the population. In seriously depleted populations, the human-related mortality must be close to zero to allow for recovery. All the highly mobile indicator species have a slow reproductive rate (K-strategists), and thus the 'unacceptable' mortality due to drowning in fishing gear must be set at a low level, to avoid serious long-term implications for the populations. Since the indicator species are affected by several pressures from various human activities, the general aim must be to minimize incidental by-catch of marine mammals and waterbirds as much as possible (from HELCOM, 2018).

**THRESHOLD VALUES FOR HARBOUR PORPOISE**

For improved management of the harbour porpoise populations in the Baltic Sea, removal targets in the form of 'safe' human-induced mortality limits (including incidental bycatch) should be modelled for the distribution range of each population. It would be appropriate to determine targets primarily using the Catch Limit Algorithm (CLA) or possibly the Potential Biological Removal (PBR) approach as these take the uncertainty of data into account. As soon as the results of such simulations are available, the 1% target should be re-evaluated for the population of the Western Baltic, Belt Sea and Kattegat (HELCOM, 2018).

**THRESHOLD VALUES FOR SEALS**

So far, there are no threshold values for incidental by-catches of seals. However, existing data would allow the development of PBR or CLA for some seal species to begin with (HELCOM, 2018). Demographic and abundance data as well as population boundaries have been quite well examined. For grey seals, an incidental bycatch estimate is available but based on high uncertainty, as reliable monitoring does not exist (Vanhatalo et al. 2014).

**THRESHOLD VALUES FOR WATERBIRDS**

In northern Europe, the impact of incidental by-catch on population dynamics has so far only been estimated for three species by applying the PBR approach. The main advantage of the PBR approach is that it relies on those demographic parameters, which are easiest to obtain for many bird species. Further, it is ready for use whereas specific demographic models still have to be developed for species concerned. PBR approach is applied in provisional assessments in this indicator because there is data available for three waterbird species of concern (HELCOM, 2018**Error! Reference source not found.**). CLAs have not b een applied to waterbird populations and would require information on population trends currently unavailable for the majority of Baltic waterbirds. As in harbour porpoises, priority should be given to develop CLA for the most vulnerable waterbird species. Additional demographic data such as survival rates may be needed for the relevant bird species to improve simulations (HELCOM, 2018). A complete list of the available data for further development of threshold values based on PBR and/or CLA values, for all relevant bird species can be found in HELCOM (2018).

***OSPAR Indicators***

## C1.2 Harbour Porpoise Bycatch

The estimates of total bycatch of harbour porpoise in each Assessment Unit (AU) were compared against the **best abundance estimate**. The ICES advice (2016a) used for this assessment is based on output from the ICES Working Group on Bycatch of Protected Species (WGBYC) (ICES, 2015b, 2016b).

**Assessment method**: Observations of bycaught animals are collated over several years to ensure sufficient geographical coverage. The number of observed dead animals is divided by the number of days that fishing activity was observed, to produce a 'bycatch rate' (see below). Bycatch rate is then multiplied by the number of days fished by vessels in a specific area during the entire year, to produce an estimate of total annual bycatch for that section of the fleet. A Bycatch Risk Assessment approach was adopted that aims to "*identify sea areas or fisheries that may pose the greatest threat to non-target species in the absence of reliable data that would be needed to quantify the bycatch of that species in a statistically rigorous manner"* (ICES, 2015b).

The Bycatch Risk Assessment approach estimates the total annual bycatch of species in a region using the following parameters:

***Total bycatch (number of animals caught) = fishing effort × bycatch rate***

where:

***Bycatch rate (number of animals caught per day) = total number of bycaught animals observed / number of observer days***

and,

***Fishing effort = number of days at sea (for relevant gear types*)**

**Threshold values**: **The estimates of total bycatch of harbour porpoise in each AU were compared against the best abundance estimate.** This indicator assessment has not used an assessment value. ASCOBANS in the Baltic, North East Atlantic, Irish and North Seas recommends that 'total anthropogenic removal' of harbour porpoise should not exceed 1.7% of the best available estimate of abundance, with the precautionary objective of reducing bycatch to less than 1% and ultimately 0%.

More details for this indicator:

| |
|---|
| OSPAR (2018)<br><br>Method: **the estimates of total bycatch of harbour porpoise in each AU were compared against the best abundance estimate.**<br><br>Gap: **This indicator assessment has not used an assessment value.** The Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) recommends that 'total anthropogenic removal' of harbour porpoise should not exceed 1.7% of the best available estimate of abundance, with the precautionary objective of reducing bycatch to less than 1% and ultimately 0%. |

The ASCOBANS value of 1.7% of the best available abundance estimate is derived from work undertaken by a working group convened by the International Whaling Commission and ASCOBANS (IWC, 2000). This was a very simple deterministic population dynamics model, which assumed a 'biological' population with independent population dynamics and no uncertainties in any parameter. Consequently, where the population dynamics are not independent, the management limits calculated based on independent biological populations are unlikely to be appropriate.

Some remarks to improve the methods:

1. The use of 'Net meter per day' could provide a more accurate record of fishing effort than 'days at sea', especially in the case of net types (e.g. set gillnets) that are more likely to catch harbour porpoise than mobile gear (e.g. trawls).
2. The ASCOBANS value of 1.7% of the best available abundance estimate is questionable because of the assumption made (OSPAR, 2018). An alternative to improve the threshold setting approach is the bycatch management procedures (adapted Catch Limit Algorithm (CLA) approach) developed under the Small Cetaceans in the European Atlantic and North Sea; SCANS-II and Cetacean Offshore Distribution and Abundance in the European Atlantic; CODA projects (Winship, 2009).
3. ICES advices that the CLA (catch limit algorithm) is the most appropriate method to set limits on the by-catch of harbour porpoises or common dolphins. However, specific conservation objectives must first be specified (ICES 2010, from OSPAR, 2018). According to HELCOM (2018) for harbour porpoise the most appropriate method to set anthropogenic mortality limits ASCOBANS sets as interim conservation objective 'to allow populations to recover to and/or maintain 80% of carrying capacity in the long term'.

Fishing effort data were collated by the Scientific, Technical and Economic Committee for Fisheries (STECF) and others (see ICES, 2015b, 2016b).

Note that data on fishing effort (i.e. days at sea) were collated across all 'net' level 4 métiers: trammel nets, set nets, and driftnets, across all seasons and all vessel length categories (ICES, 2015b, 2016b).

The data on fishing effort (in number of days at sea) are likely to be underestimated as effort from smaller commercial vessels (particularly <10 m in length), from recreational vessels and from fisheries from the beach is not represented. This would lead to underestimates in bycatch.

## C1.3 Indicator M6 - Marine mammal bycatch

**Threshold values**: No consensus and threshold values agreed, because of the uncertainty in the current bycatch estimates and the gap in the bycatch monitoring data (OSPAR, 2016).

***UNEP/MAP Indicators***

## C1.4 Bycatch of vulnerable and non-target species

UNEP/MAP Common Indicator 12 "Bycatch of vulnerable and non-target species" is the most relevant to D1C1, having the following **GES definition**: The abundance/trends of populations of **seabirds, marine mammals, sea turtles and sharks key species** (selected according to their actual and total dependence on the marine environment, and to their ecological representativeness) is stable or not reducing in a statistically significant way taking into account the natural variability compared to the current situation.

**Related Operational Objective**: Incidental catch of vulnerable species (i.e. sharks, marine mammals, seabirds and turtles) are minimized. This indicator reports on the catch rate of turtles, marine mammals, sharks and seabirds in the Mediterranean and Black Sea. **The trends analysis** (i.e. occurrence, spatial distribution, abundance etc.) of the incidental catch rates of those vulnerable species, will demonstrate the impact that different fisheries activities have on this component of the marine ecosystem.

**Threshold values** are under development for this indicator (Barcelona Convention, 2017).

**Methodology for indicator calculation** (UNEPMAP, 2018**)**

Bycatch data (discards and incidental catch of vulnerable species) can be obtained from different sources and are usually derived from a combination of catch reports, logbooks, observers on board, observed at landing and/or market, dedicated surveys, questionnaires, self-sampling by fishers, market and/or landing survey. The indicator produces the following estimates:

- Incidental catch (weight and number) of vulnerable species by main fleet segments and areas
- Trends in abundance
- Trends in spatial distribution
- Trends in temporal occurrence
- Identification of risky areas
- Record strandings of vulnerable species due to incidental catch

**Expected assessments outputs**

-Identification of the incidental catch (e.g. vulnerable species composition, quantities, period of the year, etc.) of the main fleet segments (per GFCM sub-region, countries and GSA, see attached Appendix L);

-Describe the typology of the current fishing practices pertaining to these fisheries that lead to bycatch (e.g. fishing area, seasonality, fishing gears);

-Find out the most important factors that could determine the incidental catch amounts (including ecological and technical factors).

-Trend analysis (by quarter and year).

***BSC Indicators***

## C1.5 As part of the "Reach of sustainable stocks status of threatened/endangered species"

There are no developed methods for thresholds for the BSC indicators related to D1C1, therefore no agreed thresholds for the mortality rate of by-catch species. However, under the Ecological Objective 1b of the BSC it is considered within the preparatory action for the target of the descriptor (Reach of sustainable stocks status of threatened/endangered species) to "Reducing bycatches of vulnerable and non-target species including cetaceans" (BSC, 2017). In parallel, BSC (2017) sets the relevant parameter for selected species to be monitored from the contracting parties, for the bycatch estimation.

## D1C2 Population abundance

### Habitat and Birds Directives' assessments for population abundance

European Commission (2017) provides guidance about establishing threshold values for D1C2 for species covered by the Directive 92/43/EEC (Habitat Directive, HD; European Union, 1992). These shall be consistent with the Favourable Reference Population (FRP) values established by the Member States (MS) under HD. This section provides an overview of the concepts underpinning the development of threshold values for species population in the HD. The overview will facilitate:

- To identify potential discrepancies with the MSFD requirements;
- Identify good practices that can harmonize the threshold setting process and support the comparability of the GES determination;
- Explore the possibility to generalise this approach to species not included in HD annexes, for the sake of consistency;
- Explore the concepts and the challenges that this approach brings.

Under the HD the results of the assessments of the status of Populations are classified into four categories: 'favourable' (FV), 'unfavourable-inadequate' (U1), 'unfavourable-bad' (U2) and 'unknown' (XX), while MSFD has GES or not GES (or unknown status). HD conservation status is assessed at two levels: country/biogeographical (or marine) region and EU/biogeographical (or marine) region; criteria and methodology are direct translations of article 1 of the directive (European Union, 1992) and is given in the assessment matrices (one for species, one for habitat types).

In addition, the revised MSFD Commission Decision (European Commission, 2017) states: "Wherever possible, the assessments under [Birds] Directive 92/43/EEC, […] shall be used for the purposes of this Decision." However, ICES (2017) point out that unlike the Habitats Directive, the Birds Directive does not require Member States to assess the status of individual species or to assess population size or distribution against baselines, targets or thresholds. Hence, there are no Birds Directive assessment methods as such that could be used to assess equivalent GES criteria under MSFD (i.e. D1C2 population size and D1C4 distribution). The EC performs a post hoc analysis of Birds Directive national reports to assess progress toward EU targets under the Convention on Biodiversity. The Birds Directive reporting and the MSFD bird assessments can certainly make use of the same data on population size and distribution, collected by the same monitoring schemes. Table 2 shows the threshold setting approaches and assessment methods followed by the MSFD and HBD.

**Table 2.** Determination of threshold values and assessment methods for MSFD, HD and BD

| | MSFD | HD | BD | Notes |
|---|---|---|---|---|
| **Threshold values for criteria** | To be determined by Member States in co-operation with others within the region or subregion and based on reference condition. | Favourable reference values for range and area of habitats and for range and population size for species are determined by Member States. | None | The values adopted under MSFD and HD define the boundary between good and poor status at the criterion level. These values are specified by Member States for HD, but need to be agreed (sub)regionally, and be consistent with those used under HD, for MSFD, considering the different scales of assessments. |

| | | | | |
|---|---|---|---|---|
| **Assessment per species and habitat (integration of criteria)** | For mammals, reptiles: as HD FCS reporting guidelines<br><br>For commercial species: as D3 (to be agreed at Union level)<br><br>For birds, non-commercial species: to be agreed at Union level<br><br>For habitats: to be agreed at Union level | For each species and habitat: one-out-all-out on criteria (FCS reporting guidance) | Not required | The integration of the criteria defines whether good status is achieved at the species or habitat level. The integration methods used for HD species should be the same for the MSFD as well (i.e. all mammals and reptiles, any HD fish).<br><br>For non-HD species, and for habitats, the MSFD integration method has to be defined.<br><br>There is no assessment of FCS carried out by Member States under BD so there are no within species integration rules specified in the Directive's guidance.<br><br>For MSFD, it is necessary to determine GES for the species groups, based on the species assessed within each group. |

### HD overview of assessment parameters

The following table shows the HD conservation status of species (modified from Appendix 1 of the ETC/BD, 2014 and DG Environment, 2017). The aim is to briefly show the definition of the HD parameters and list the threshold values set for the status of each parameter.

**Table 3.** HD conservation status and parameters (adjusted from ETC/BD (2014) and DG Environment (2017))

| ***Species*** **Parameter** | **Conservation Status** | | | |
|---|---|---|---|---|
| | **Favourable ('green')** | **Unfavourable - Inadequate ('amber')** | **Unfavourable - Bad ('red')** | ***Unknown (insufficient information to make an assessment)*** |
| **Range**<br><br>(within the biogeographical region concerned) | Stable (loss and expansion in balance) or increasing AND not smaller than the 'favourable reference range' | Any other combination | Large decline: Equivalent to a loss of more than 1% per year within period specified by MS OR more than 10% below favourable reference range | *No or insufficient reliable information available* |

| | | | | |
|---|---|---|---|---|
| **Population** | Population(s) not lower than 'favourable reference population' AND reproduction, mortality and age structure not deviating from normal (if data available) | Any other combination | Large decline: Equivalent to a loss of more than 1% per year (indicative value MS may deviate from if duly justified) within period specified by MS AND below 'favourable reference population' OR More than 25% below favourable reference population OR Reproduction, mortality and age structure strongly deviating from normal (if data available) | *No or insufficient reliable information available* |
| **Habitat for the species** | Area of habitat is sufficiently large (and stable or increasing) AND habitat quality is suitable for the long-term survival of the species | Any other combination | Area of habitat is clearly not sufficiently large to ensure the long-term survival of the species OR Habitat quality is bad, clearly not allowing long term survival of the species | *No or insufficient reliable information available* |
| **Future prospects** (as regards to population, range and habitat availability) | Main pressures and threats to the species not significant; species will remain viable on the long-term | Any other combination | Severe influence of pressures and threats to the species; very bad prospects for its future, long-term viability at risk. | *No or insufficient reliable information available* |
| **Overall assessment of CS** | All 'green' OR three 'green' and one 'unknown' | One or more 'amber' but no 'red' | One or more 'red' | Two or more 'unknown' combined with green or all "unknown" |

Complementary remarks for Unfavourable- inadequate (U1) (DG Environment, 2017):

1. The evaluation matrix does not include explicit criteria for 'unfavourable-inadequate' status of Population. However, considering the criteria for 'favourable' and 'unfavourable-bad', the status of Population should be considered 'unfavourable-inadequate' if:

- a moderate decline equivalent to a loss of less than 1 % per year and equal to or below 'favourable reference population'; or
- a large decline equivalent to a loss of more than 1 % per year and above or equal to 'favourable reference population'; or
- population size is less than 25 % below favourable reference population; or
- age structure somehow different from a natural, self-sustaining population.

2. The trend over the short-term trend period should be used for the status assessment.

**Favourable Reference Values (FRV)**

Favourable Reference Values are key concepts in the evaluation of Conservation Status. The reporting format requires Member States to identify threshold values for range and area for the habitat types of Annex I and for range and population for the species of Annexes II, IV & V in order to evaluate whether the actual range, area, or population are sufficiently large to conclude the parameter is 'favourable' or 'unfavourable', and, if 'unfavourable', whether the status is 'inadequate' or 'bad' (ETC/BD, 2011).

**Favourable reference population (FRP) for species**

**Definition:** Population in a given biogeographical region considered the minimum necessary to ensure the long-term viability of the species; favourable reference value must be at least the size of the population when the Directive came into force; information on historic distribution/population may be found useful when defining the favourable reference population; 'best expert judgement' may be used to define it in absence of other data (ETC/BD, 2011).

There are basically two approaches to set FRP (DG Environment, 2017): **Model-based methods** are built on biological considerations, such as those used in Population Viability Analysis (PVA) or on other estimates of Minimum Viable Population (MVP) size. **Reference-based** approaches are founded on an indicative historical baseline corresponding to a documented (or perceived by conservation scientists) good condition of a particular species or restoring a proportion of estimated historical losses. Data availability and quality determines the selection of the proper approach between reference-based and model-based (DG Environment, 2017).

If an operator is used to estimate an FRP it should be compared with the minimum population estimate (ETC/BD, 2011). It is important to understand that the operator "less than" can only be used in exceptional circumstances, where a species might have developed - due to exceptional circumstances such as supplementary feeding - an exceptionally high population level far beyond that considered as favourable in normal circumstances and which is unlikely to be sustainable or which may even be detrimental to other species or habitats. A careful assessment of such situations needs to be undertaken and an explanation of the reasoning why this operator has been used should be given in the field "other" relevant information (ETC/BD, 2011; DG Environment, 2017).

The data used to estimate population size can be grouped in the following categories in the HD reporting (DG Environment, 2017):

- Complete survey or a statistically robust estimate
- Estimate based on partial data with some extrapolation and/or modelling
- Estimate based on expert opinion with no or minimal sampling
- Absent data

FRP can be reported as an estimated population size (with unit), as operators (using symbols ≈, >, >>, <) or 'x' if FRP is unknown (DG Environment, 2017a). The following equations summarise the concepts of the FRP:

**Minimum viability population < FRP < potential population**

**Where FRP is equal to:**

- estimate
- historical level
- based on population viability study
- based on suitable habitat potential

The period for short-term trend is recommended to be 12 years (two reporting cycles). For the 2019 reports, this means a period of 2007-2018 or a period as close as possible to this. The short-term trend should be used for the assessment. The direction of the short-term trend can be: i) stable; ii) increasing; iii) decreasing; or iv) unknown. The percentage change over the period reported, if it can be quantified should be given as a precise figure (e.g. 27 %) or a banded range (e.g. 20-30 %) (ETC/BD, 2011; DG Environment, 2017). The long-term trend is recommended to be evaluated over a period of 24 years (four reporting cycles). For the 2013 reports, this information is optional. Period, 'long term trend direction' and 'long term trend magnitude' should be reported as for short-term trend (ETC/BD, 2011; DG Environment, 2017).

## D1C2 RSCs relevant indicators per species group

The following indicators and the way they set thresholds were evaluated for species population. According to the European Commission (2017), "The population abundance of the species is not adversely affected due to anthropogenic pressures, such that its long-term viability is ensured. Member States shall establish threshold values for each species through regional or sub-regional cooperation, taking account of natural variation in population size and the mortality rates derived from D1C1, D8C4 and D10C4 and other relevant pressures. For species covered by Directive 92/43/EEC, these values shall be consistent with the Favourable Reference Population values established by the relevant Member States under Directive 92/43/EEC."

- **Marine Mammals**

The following indicators and the way they set thresholds are evaluated for the species population abundance for marine mammals.

| | |
|---|---|
| **HELCOM:** | **C2.1 Population trends and abundance of seals** |
| **OSPAR:** | **C2.2 Harbour Seal and Grey Seal Abundance** |
| | **C2.3 Pilot Assessment on Abundance and Distribution of Killer Whales** |
| | **C2.4 Abundance and Distribution of Coastal Bottlenose Dolphins** |
| **UNEPMAP:** | **C2.5 Abundance and Distribution of Cetaceans** |
| | **C2.6 Species population abundance (marine mammals, Common Indicator 4)** |

***HELCOM Indicators***

## C2.1 Population trends and abundance of seals

**Definition of GES**: Good status is achieved for each species, when: i) the abundance of seals in each management unit is has attained a Limit Reference Level (LRL) of at least 10,000 individuals to ensure long-term viability; and ii) the species-specific growth rate is achieved indicating that abundance is not affected by severe anthropogenic pressures (HELCOM, 2018b).

The indicator 'Trends and abundance' consists of two parameters, and results for these are shown separately. However, 'good status' for the indicator requires that the threshold value is achieved for both parameters.

The growth rate aspect of the threshold value is assessed separately for populations at and below the Target Reference Level (TRL) (HELCOM, 2018b):

- For populations at TRL, good status is defined as 'No decline in population size or pup production exceeding 10% occurred over a period up to 10 years'.
- For populations below TRL, good status is defined as 3% below the maximum rate of increase for seal species, i.e. 7% annual rate of increase for grey seals and ringed seals and 9% for harbour seals. For good status, 80 % statistical support for a value at or above the threshold is needed.

**Threshold values for the Limit Reference Level**

**The limit reference level (LRL) corresponds to the safe biological level and minimum viable population size**. HELCOM has set an LRL of 10,000 individuals for grey seals, ringed seals and harbour seals in each of their management units, respectively, understanding that the haul-out fraction during moult surveys is 70%. The LRL of 10,000 implies a population with approximately 5,000 adult seals (and thus 2,500 adult female seals). LRL has been calculated based on estimates of minimum viable population sizes of each seal species based on different extinction risk levels (1, 3, 5 and 10%) for genetically and ecologically isolated populations (HELCOM, 2018b).

- Approach for defining the threshold value for growth rate for populations close to carrying capacity (Target Reference Level)

All growing populations will eventually be affected by density dependent factors (such as decreased availability of food and lack of haul-out sites) and the population size will stabilize at the carrying capacity of the ecosystem. Population sizes of marine mammals can fluctuate around the carrying capacity due to annual changes in food abundance and other external factors (Svensson et al. 2011). In this situation, the ICES and OSPAR frameworks proposed that good status is achieved when there is **'No decline in population size or pup production exceeding 10% occurred over a period up to 10 years'. The same level is used in the Baltic Sea for the purposes of this core indicator** (HELCOM, 2018b).

- Approach for defining the threshold value for growth rate for populations below carrying capacity

A Bayesian approach is used to evaluate if observed rates of increase close to intrinsic rates are supported. **The threshold value for population growth rate is set to a value 3% lower than the maximum rate of increase.** Time series of data for each seal species and each management unit are used as input values in Bayesian analysis with uninformative priors, where it is evaluated whether observed data support the set threshold value. In this process, **80% support for a growth rate ≥ the threshold value is required**. If the unit fails to achieve good status, the probability distribution is used to evaluate the confidence of the assessment.

***OSPAR indicators***

Grey seals and harbour seals are surveyed when they come ashore ('haul-out') and can be most easily counted.

## C2.2 Harbour Seal and Grey Seal Abundance Assessment Values (Method for assessment including pup production for grey seal)

**Population size estimation** (OSPAR, 2018b)**:** Pup production estimates and prior knowledge of life history parameters (e.g. pup survival, adult survival, fecundity) were incorporated into a Bayesian state-space model currently used by the Seal Mammal Research Unit (SMRU) in the United Kingdom to estimate total population size and life history parameters (SCOS, 2014). **The population model provides estimates of total grey seal abundance** for several OSPAR areas and the model outputs were then 'checked' with another form of information: the total number of grey seals estimated from summer counts in a single year.

**Baselines** (OSPAR, 2018b): The **baseline used was the abundance estimate for each species in 1992**, which is the baseline year used by some Member States for seals under the Habitats Directive (European Union, 1992). For harbour seal, data for 1992 were not available in all AUs; in such cases, **the start of the data time series was used as the**

**baseline**. Indicator assessment values were set as a deviation from the baseline value (Method 3; OSPAR, 2012).

The arbitrarily assigned baseline does not necessarily reflect a state without impacts, thus, it is not possible to assess the status of seals in relation to the concept of a "favourable conservation status". Instead, **trends in the seal populations were assessed**. The **rolling baseline (6-years cycle) provides a means to indicate change in population size compared with the previous six-year assessment period, rather than relying solely on an historical fixed baseline, which probably reflects a point in time when the population is already subject to anthropogenic pressures.** A potential issue with this type of quantitative trend thresholds, known as **'shifting baselines'** is that each successive assessment uses a different starting point as the basis for comparison. This could result in a substantial cumulative decrease occurring over more than one six-year assessment period not being flagged as a problem, because in each six-year period the rate of decline remained below the assessment value (OSPAR, 2012). **Use of the two types of baseline and associated assessment values seeks to provide an indicator that would warn against both a slow but long-term steady decline (the problem of 'shifting baselines' associated with only having a rolling baseline) and against a recovery followed by a subsequent decline (potentially missed with a fixed baseline set below reference conditions)**.

**Assessment Value 1:** No decline in seal abundance of > 1% per year in the previous six-year period (a decline of approximately 6% over six years).

This uses **a rolling baseline** based on the previous six-year period which seeks to identify if seal populations are maintained in a healthy state, with no decrease in population size with regard to the baseline (beyond natural variability) and to identify if efforts are needed to restore populations, where they have deteriorated due to anthropogenic influences, to a healthy state.

To estimate the annual increase or decrease in the number of animals counted within the previous six-year reporting round, a **trend was fitted** to **the sum of all available data in each AU** for the period 2009–2014. **Generalised linear models (GLMs) were fitted to count data with a quasi-Poisson error distribution and log link**. **Annual growth rate (%) and 80% confidence intervals were estimated for each AU.** Although no formal hypothesis testing was conducted, **80% confidence intervals were calculated to reflect the choice to set the statistical significance level, α, equal to 0.20 or 20%.**

**Assessment Value 2:** No decline in seal abundance of >25% since the fixed baseline in 1992 (or closest value).

To **avoid the problem of shifting baselines** when using the rolling baseline applied in assessment value 1, an assessment value relating to a fixed baseline is needed (assessment value 2). The baseline chosen was 1992, as used by some Member States for seals under the Habitat Directive (European Union, 1992) (or if such data are not available, the start of the data series). The 25% chosen for the second assessment value currently approximates to 1% a year since 1992. Testing shows that there is sufficient monitoring to assess against this assessment value with confidence.

To determine the change in the abundance of seals since the baseline year, **generalised linear models (GLMs) or generalised additive models (GAMs) were fitted to the sum of count data within an AU with a quasi-Poisson error distribution and log link using all available annual survey data in the range 1992 to 2014.** The percentage change in abundance since baseline year ($\Delta_{baseline}$) and 80% confidence intervals were calculated from fitted values. Although no formal hypothesis testing was conducted, 80% confidence intervals were calculated to reflect the choice to set the significance level, α, equal to 0.20 or 20% (Equation 1).

$$\Delta_{abundance} = \frac{B - A}{A} \times 100$$

**Equation 1**: Calculation of long-term trend in abundance

Where A is the count fitted by the model in the baseline year and B is the count fitted by the model in the most recent survey year (OSPAR, 2018b).

## C2.3 Pilot Assessment on Abundance and Distribution of Killer Whales

No assessment units (AUs) have been agreed for killer whale (*Orcinus orca)*. However, there are distinctions between some groups based on photo-ID surveys, studies of well-known populations, genetic studies (biopsies and investigation of stranded animals) and on prey specialisation. Due to the lack of suitable data it is not possible to assess trends in abundance.

The conservation status of killer whales has been assessed by the European Environment Agency (EEA) as 'favourable' in terms of range and 'unknown' in terms of population under the HD.

## C2.4 Abundance and Distribution of Coastal Bottlenose Dolphins

The indicator (OSPAR, 2018c) is based on the trend in abundance per Assessment Unit (AU). As bottlenose dolphins are long-lived animals, with an estimated generation time of 23 years (Taylor et al., 2007), assessments of a temporal trend in the population should be carried out over a relatively long period (e.g. Thompson et al., 2004; Englund et al., 2007). Assessments based on very short time series may give misleading results. It is recommended to base assessment of trends in the population on a time series covering at least the last ten years, with a minimum of four counts during that period (ICES, 2015b).

**Baselines:** Although the baseline could derive from historical data, such data are not available for any cetacean species. Historical abundance and distribution are therefore unknown. Even if numbers are suspected to have declined, they could probably not realistically be restored because today's marine environment is very different, in part due to climate change and human impact. Consequently, a **recent baseline must be used**, which should then be assessed for being in good status or for being already known to be degraded. In this assessment, the **start of the data time series for each AU has been used as the baseline, with trends identified as a deviation from that baseline value**.

**Abundance:** The abundance for coastal bottlenose dolphin populations has been calculated for each assessment unit where sufficient data exist. Abundance estimates were made largely using Photo-ID capture-recapture methods, and an indication is given about the trend in the population since the start of monitoring: stable, declining, increasing or unknown.

**Distribution:** Records of sightings and strandings were used to identify where populations of coastal bottlenose dolphins existed historically.

**Assessment Value:** No assessment value has been applied in this assessment.

**Definition of Trends:** Declining is defined as a decreasing trend of ≥5% over ten years (significance level $p<0.05$). Increasing is defined as an increasing trend of ≥5% over ten years (significance level $p<0.05$). Stable is defined as population changes of <5% over ten years. **This percentage (i.e. 5%) is derived from the International Union for the Conservation of Nature (IUCN) criterion to detect a 30% decline over three generations for a species, which equates to slightly less than 0.5% per year for Odontocetes.**

## C2.5 Abundance and Distribution of Cetaceans

**Abundance:** Abundance of animals per species has mostly been estimated using data collected from large-scale purpose-designed aerial or shipboard surveys using line-transect distance sampling methods (Buckland et al., 2001); these are known as design-based estimates (e.g. Hammond et al., 2013). Some abundance estimates come from models fitted to these data to generate a density surface from which abundance is derived; these are known as model-based estimates (e.g. Gilles et al., 2016).

**Species Distribution**: Density surface models have been used to predict the distribution of those species for which sufficient data are available from large-scale purpose-designed surveys. For recent data for which results from density surface models are not yet available, maps of observed sightings provide information on distribution.

**Baselines:** Although the baseline could derive from historical data, such data are not available for any cetacean species, similarly to the bottlenose dolphin indicator. Consequently, a recent baseline must be used, which should then be assessed as being in good or already degraded status. The most useful baselines for wide-ranging cetacean species derive from the results of large-scale surveys (e.g. CODA, 2009; Hammond et al., 2002, 2013).

**Assessment Value:** No assessment value has been applied in this assessment.

**Definition of Trends:** Declining means a decreasing trend of ≥5% over 10 years (significance level $p<0.05$). Increasing means an increasing trend of ≥5% over 10 years (significance level $p<0.05$). Stable means population changes of <5% over 10 years. **This percentage (i.e. 5%) is derived from the International Union for the Conservation of Nature (IUCN) criterion to detect a 30% decline over three generations for a species, which equates to slightly less than 0.5% per year for Odontocetes.**

**Power Analysis:** Power analyses were performed for species for which there are three or more comparable estimates of regional abundance from SCANS and other surveys, using previously estimated coefficients of variation (CV). The datasets comprised abundance estimates from three surveys over 22 years for harbour porpoise, three surveys over 22 years for white-beaked dolphin, and eight surveys over 27 years for minke whale. These data have 80% power (the conventional acceptable level) to detect an annual rate of change, at a significance level (p value) of 0.05, of 1.5% for harbour porpoise, 2.5% for white-beaked dolphin, and 0.5% for minke whale. **The power to detect trends could be improved by increasing the frequency of the large-scale surveys**.

***UNEPMAP indicators***

## C2.6 Species population abundance (marine mammals, Common indicator 4)

Eleven species of cetaceans are considered to regularly occur in the Mediterranean area: short-beaked common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), harbour porpoise (*Phocoena phocoena*), long-finned pilot whale (*Globicephala melas*), rough-toothed dolphin (*Steno bredanensis*), Risso's dolphin (*Grampus griseus*), fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*) and killer whale (*Orcinus orca*). Two of these species have very limited ranges: the harbour porpoise, possibly representing a small remnant population in the Aegean Sea, and the killer whale, present only as a small population of a few individuals in the Strait of Gibraltar. The Mediterranean is also the habitat of pinniped species; namely the Mediterranean monk seal (*Monachus monachus*).

**Indicator Definition** (UNEPMAP, 2017; 2018)**:** This indicator provides information about the abundance of marine mammal's population. It is intended to determine the abundance and density of cetaceans and seals species that are present in Mediterranean waters, with a special focus on the species selected by the Convention's Contracting Parties.

**Methodology for indicator calculation** (UNEPMAP, 2017; 2018)**:** Information on density and abundance of cetaceans may be obtained through dedicated ship and aerial surveys, acoustic surveys, platform of opportunities (e.g. whale watching operators, ferries, cruise ships, military ships), as well as mark-recapture methodologies. As for the Mediterranean monk seal, information on density and abundance may be obtained through coastal cave surveys, counting of animals and pups, mark/recapture using photo-ID when possible. For pinnipedes, the better methodology to obtain the information about density and abundance is to perceive when they reach the coast (haul out/resting/nursing sites) rather than out at sea. In any case, once dealing with a subregional implementation approach for cetacean surveying campaigns, this should be carried out in line with agreed common, regional methodologies, using existing and shared Protocols, with the facilitation, as appropriate, of ACCOBAMS.

**Statistical analysis and basis for aggregation** (UNEPMAP, 2017; 2018): Values of density and abundance of cetaceans and other large marine vertebrates can be estimated using design-based and model-based methodologies. Both methods present very similar and comparable results. Power analysis for detecting trends in density or abundance should be also applied. The expected assessments outputs include trend analysis (monthly, seasonally, yearly), density maps, statistical frameworks applied. This approach is similar to OSPAR's abundance and distribution of Cetaceans.

- **Marine Birds**

The aim of the Birds Directive (European Union, 2009) is to take measures to maintain the population of wild bird species at a level, which corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or to adapt the population of these species to that level (Art.2).

While, as discussed above, the Birds Directive uses far less precise terms than FCS, Commission guidance, interpreting the directive, has stated that "(…) the principles underpinning FCS are equally applicable in relation to the objective of [the Birds Directive." (European Commission 2008; DG Environment, 2017b; Epstein et al., 2016).

The trends in population size in the Birds Directive reports are expressed as percentage changes over time (see guidance in http://cdr.eionet.europa.eu/help/birds_art12/). However, in order to meet the requirements of MSFD, and the criterion D1C2, some context to the trends is required to assess if the species is being impacted by anthropogenic pressures or is responding to changing climatic conditions. In the OSPAR Common Indicator assessment of marine bird abundance, annual abundance estimates are compared against a baseline. The baseline for each species should be set at a population size that is considered desirable for each individual species within each geographical area. Ideally a baseline should be set at a 'Reference level', where we would expect the population size to be if anthropogenic impacts were negligible (this can be derived from known population sizes either historically or from within time-series) (ICES, 2017).

Likewise, Birds Directive reporting of the current breeding distribution (as map) and on percentage changes in distributional range need to undergo an assessment against baselines or targets to be used under MSFD. Member States reported few data on changes in distribution in 2012 under Art 12 of the Birds Directive. This is probably because changes in distribution are not straightforward to measure or detect. Furthermore, an additional step would be required under MSFD D1C4 to assess if a species' distributional range or pattern is in line with prevailing physiographic, geographic and climatic conditions. To carry out such an assessment, one would need to know the 'ideal' range and distribution of species, which would need to be derived from modelling of the species' climate and habitat requirements (ICES, 2017).

The following indicators and the way they set thresholds are evaluated for the species population abundance for marine birds.

| | |
|---|---|
| **HELCOM:** | **C2.7 Abundance of wintering waterbirds in the Baltic Sea** |
| **OSPAR:** | **C2.8 Marine Bird Abundance** |
| **UNEPMAP:** | **C2.9 Population size of selected species (of seabirds) is maintained** |

***HELCOM indicators***

## C2.7 Abundance of wintering waterbirds in the Baltic Sea

This core indicator (HELCOM, 2018a) evaluates the status of the bird species breeding in the Baltic Sea area by assessing trends in abundance. Good status is achieved when the abundance of 75% of the considered species making up a species group do not decline by more than 30% (20% in species laying only one egg per year) compared to a baseline which is the mean abundance of the reference period 1991-2000.

The indicator evaluates the status by aggregating annual single species index values for all waterbird species and on the basis of aggregated indices for five species groups (wading feeders, surface feeders, pelagic feeders, benthic feeders, grazing feeders).

This threshold concept follows the concept of the OSPAR Indicator 'Marine bird abundance' (ICES 2013, OSPAR 2018f). The status is evaluated by examining the proportion of wintering waterbird species for which the abundance deviates more than 30% (20% in species laying only one egg per year) downwards from the abundance in the reference period.

Owing to both natural and anthropogenic influences, breeding bird numbers have fluctuated over the past decades. Therefore, it is difficult to define 'natural' population sizes or pristine conditions, which could serve as reference levels. **For practical reasons, a preliminary modern baseline is set based on a reference period as the average abundance during the starting period of data compilation (1991-2000), but future work on the indicator may find more appropriate solutions by setting species-specific reference periods for defining the baseline against which the status is assessed, which reflect the pressures affecting the populations** (HELCOM, 2018a)**.**

To calculate the yearly indices and trends, Generalised Additive Modelling framework (Hastie & Tibshirani 1990; Wood 2006) was used. Models explaining the observed abundance in each site by site, year and mean temperature a week before the counts was created for each species using approach similar to the one suggested by Fewster et al. (2000), but accounting for serial correlation in the data. Inclusion of the temperature data allowed to reduce the variation in observed abundance due to observation conditions. If temperature effects were not significant, the model without temperature in the model formula was calculated (HELCOM, 2018a).

The mean predicted abundance in the period 1991-2000 was used as the point of reference (when the index is 1). To obtain the index, predicted abundances in each separate year were divided by this reference value. Thus, an index above 1 (or 100%) means population increase compared to the reference and an index below 1 represents a decline. The confidence intervals for each index value were obtained analytically. The geometric mean of index values from 2011-2016 was used to assess the status of a species compared to the reference level. The MSI tool (Soldaat et al. 2017) was used to calculate and classify the linear trends from the GAM-based indices (HELCOM 2018a).

The multiplicative overall slope estimate calculated by the MSI-tool is converted into one of the following categories, depending on the overall slope as well as its 95% confidence interval (= slope +/- 1.96 times the standard error of the slope) (HELCOM, 2018a):

- **Strong increase - increase significantly more than 5% per year (5% meaning a doubling in abundance within 15 years).** Criterion: lower limit of confidence interval >1.05.
- **Moderate increase - significant increase, but not significantly more than 5% per year.** Criterion: 1.00< lower limit of confidence interval <1.05.
- **Stable - no significant increase or decline, and it is certain that trends are less than 5% per year.** Criterion: confidence interval encloses 1.00 but lower limit >0.95 and upper limit <1.05.
- **Moderate decline - significant decline, but not significantly more than 5% per year.** Criterion: 0.95< upper limit of confidence interval <1.00.
- **Steep decline - decline significantly more than 5% per year (5% meaning a halving in abundance within 15 years).** Criterion: upper limit of confidence interval <0.95.

***OSPAR indicators***

## C2.8 Marine Bird Abundance

Abundance is estimated in numbers of adult birds or pairs at breeding colonies (OSPAR, 2018f). For seabirds, this assessment is constructed mainly from data on 'breeding abundance'. For waterbirds (wildfowl and waders) this assessment is constructed mainly from data on 'non-breeding abundance' (numbers of birds using intertidal and inshore areas during migration or over winter). Annual estimates of breeding or non-breeding abundance of each are compared against assessment values that are designed to reflect the **resilience** of different species to population decline. Relative abundance is the number of adult birds or breeding pairs estimated each year as a proportion of a baseline.

***relative abundance = annual abundance / baseline abundance***

It is desirable for the annual 'relative abundance' of a species to be above 0.8 (80% of the baseline) for species that lay one egg or 0.7 (70% of the baseline) for species that lay more than one egg. If 75% or more of species assessed exceed their individual assessment values, an assemblage of bird species is considered to be healthy. To remove the monitoring bias in the variation of population, the annual estimates of breeding and non-breeding abundance in each country were weighted according to the size of the population in that country. **Baselines of the relative breeding abundance was calculated using a baseline equal to the abundance in the second year of the time series (i.e. 1992).**

The Species-specific assessment values use two different assessment values that are designed to reflect the resilience of different species to declines in their population (see ICES 2008, 2010, 2011). It is desirable for the annual relative abundance of a species to be above, either:

- 0.8 (i.e. 80% of the baseline) – for species that lay one egg; or
- 0.7 (i.e. 70% of the baseline) – for species that lay more than one egg.

The reason for having two assessment values is because species that lay only one egg are expected to recover more slowly from declines in population size than species that can potentially produce more than one chick per year. If relative abundance is below the appropriate assessment value, it is considered to be in 'poor' status and further research and/or management is recommended, depending on what is appropriate.

***UNEPMAP indicators***

## C2.9 Population size of selected species (of seabirds) is maintained.

**GES determination** (UNEPMAP, 2017; UNEPMAP, 2018): The species population has abundance levels allowing to qualify to Least Concern Category of IUCN (less than 30% variation over a time period equivalent to 3 generation lengths).

**Indicator Definition**: The index of population abundance reflects the variation over time of the total population size (counted or estimated) of selected species. Population size is the number of individuals present in a population at the appropriate scale.

**Methodology for indicator calculation:** To calculate an index of population abundance, the Species Trends Analysis Tool for birds (BirdSTATs) is the standard software used across Europe by the European Bird Census Council (EBCC). The BirdSTATs tool is programmed to use and automatically run the program TRIM (TRends and Indices for Monitoring data) in batch mode to perform the statistical analysis for series of bird counts in the dataset. In this way it is suitable for use in all European countries participating in the Pan European Common Bird Monitoring Scheme (PECBMS). For data available at lower frequencies (e.g., every 6 years), a linear trend can be estimated using simple arithmetic methods. This option increases the level of uncertainty, so an extra warning of caution must be added when making interpretations based on this kind of data (UNEPMAP, 2018).

**Indicator units:** The index of population abundance is a numerical value of species population abundance relative to the population size at base time. The average breeding population size during at least a decade is suggested as the base level (UNEPMAP, 2018).

- **Marine Reptiles**

The following indicators and the way they set thresholds are evaluated for the species population abundance for marine reptiles.

**UNEPMAP: C2.10 Population abundance (Reptiles; Common Indicator 4)**

***UNEPMAP indicators***

## C2.10 Population abundance (Reptiles; Common Indicator 4)

The index of population abundance (UNEPMAP, 2017; UNEPMAP, 2018) is a numerical value of species population abundance relative to the population size at base time. The average breeding population size during at least a decade is suggested as the base level (based on International Union for Conservation of Nature Red List minimal criteria for sea turtles). However, the breeding population in a given year excludes non-breeding adults and all juveniles; thus, a more comprehensive database is required.

For the base data used to calculate the index of population abundance, the following units are suggested (UNEPMAP, 2018):

- For population size at breeding colonies, number of females, number of nests or number of tracks, with appropriate modelling to extrapolate population numbers depending on the method used;
- For total number of nesting sites, number of sites (n);
- For average nesting site size, size of the nesting area versus number of females, number of nests or number of tracks, with appropriate modelling to extrapolate population numbers depending on the method used (i.e. to obtain density/km);
- For non-breeding animals at wintering/foraging/developmental sites, number of individuals (n) with appropriate modelling to extrapolate population numbers taking into account individuals that are not observed due to low surfacing frequency in the marine environment;
- For all size/age classes that are being injured/killed, the number of individuals (n) will be documented via the stranding network/bycatch data.

The assessment of the conservation status of a sea turtle species by the IUCN is defined "endangered" and "critically endangered" when there is over 50% and 80% decline in a population, respectively, over the most recent 10-year period (or 3 generations). These decisions are based on extrapolations of nest-associated data, either counts of females, their nests or tracks, and do not take into account adult males or the juvenile component of the population. Thus, the level of detectability in different habitats (coastal and oceanic) and under different conditions (sea depths, sea state, and sea visibility) needs to be incorporated into analyses. A long series (at least 10 years, to conform to IUCN criteria) would be necessary to potentially detect clear tendencies.

Expected assessments outputs (UNEPMAP, 2018): This indicator will be largely built on establishing counts of sea turtles of different size/age classes and sexes (adults only) at nesting (breeding), wintering, and foraging/developmental habitats. The main output of the monitoring will be therefore:

- Models providing estimates of abundance in all areas where turtle presence is detected;

- Changes (trends) in the number of individuals in each habitat over time.

In addition to national or sub-regional indices, trends can be computed to indicate whether long-term changes in turtle populations are strongly increasing, moderately increasing, stable, uncertain, moderately declining or steep declining.

- **Fish**

The following indicators and the way they set thresholds are evaluated for the species population abundance for fish.

| | |
|---|---|
| **HELCOM:** | **C2.11 Abundance of salmon spawners and smolt** |
| | **C2.12 Abundance of sea trout spawners and parr** |
| | **C2.13 Abundance of key coastal fish species** |
| **OSPAR:** | **C2.14 Recovery in the Population Abundance of Sensitive Fish Species** |
| | **C2.15 Fish abundance (Common Indicator FC1)** |

*HELCOM indicators*

## C2.11 Abundance of salmon spawners and smolt

This indicator (HELCOM 2018c) evaluates the status of the Baltic Sea area based on salmon smolt production in rivers flowing into the sea, also making use of additional supporting data on numbers of adult spawners. Determination of whether the threshold value corresponds to good status is based on a comparison of estimated smolt production with an estimated potential smolt production capacity (PSPC) and the **threshold value is defined as 75% of the PSPC**. **This level of production compares to a stock size at maximum sustainable yield (MSY) practically for all stocks**.

The PSPC is estimated using **a life history model** developed by the International Council for the Exploration of the Sea Assessment Working Group on Baltic Salmon and Trout (ICES WGBAST). Some uncertainty in the method still exists, and thus the potential production capacity may be over-estimated for some river areas. Accordingly, the precautionary principle is applied when making estimates of the PSPC against the threshold value, and there is a small risk of falsely evaluating a river as being below the threshold value. Hence, when evaluating the status of an assessment unit that includes several rivers, a one-out-all-out approach is considered unsuitable and a weighted evaluation is applied instead.

## C2.12 Abundance of sea trout spawners and parr

This core indicator HELCOM (2018d) evaluates the status of coastal sea areas of the Baltic Sea based on the abundance of sea trout parr in rivers where they breed. Good status is achieved when the moving parr density in **average remains above 50% of the reference parr density. Consequently, the threshold value is a moving average of parr densities over 4-5 years**. **The threshold values have mainly been defined based on expert judgement and long-term data on reference conditions, and therefore the confidence of the target is considered to be moderate to high.**

## C2.13 Abundance of key coastal fish species

This core indicator (HELCOM 2018e) evaluates the abundance of typical species of fish, such as perch and flounder, in the coastal areas of the Baltic Sea, to assess environmental status. Good Status is achieved when key species abundance is above a specified threshold value. **The quantitative threshold values for coastal fish are based on location-specific baseline conditions, where time series covering more than 15 years are available (ten-year baseline + five or more years evaluation period). In areas where shorter time series are available, a trend-based approach (<15 years) is used.**

**The period used to define the baseline needs to cover at least ten years in order to extend over more than twice the generation time of the typical species represented in the indicator** and thus cater for natural variation in the indicator value, due for example to strong and weak year classes. For the period used to determine the **baseline to be relevant, it must also be carefully selected to reflect time periods with stable environmental conditions**, as stated within the MSFD (HELCOM 2018e).

*OSPAR indicators*

## C2.14 Recovery in the Population Abundance of Sensitive Fish Species

Greenstreet *et al*. (2012) proposed **a trends-based approach to setting assessment values related to population recovery** for each sensitive species sampled by a survey and/or the halting of further population decline**. A binomial distribution is then used**

**to determine whether population recovery had occurred among a significant fraction of the suite of sensitive fish species sampled in any given survey**.

The required estimate for the assessment is the species population abundance density ($N_s$/km$^2$) in each year for each survey. Two different sensitivity metrics were used to identify species considered to be sensitive to fishing mortality. The Average Life-history Trait (ALHT) metric (Greenstreet et al. 2012) and the 'Proportion Failing to Spawn' (PFS). Both metrics rely on the availability of several life-history trait parameters for each species. For example, maximum recorded length ($L_{max}$), von Bertalanffy ultimate body length or length infinity ($L_{inf}$), von Bertalanffy growth term ($K$), length at maturity ($L_{mat}$), and age at maturity ($A_{mat}$).

**Baselines:** None of the surveys extend sufficiently far back in time as to provide an adequate reference period to establish species abundance levels commensurate with acceptable status. **A trends-based assessment approach, relying on the use of trends-based assessment values, was therefore adopted**. By virtue of their sensitivity to additional human-related mortality, the **population abundance** of each sensitive species sampled by each survey **is assumed to have declined** because of past human activities.

Thus, trends-based assessment values related to population recovery constituted the primary basis for assessment; sensitive species should be increasing in abundance. However, should this primary assessment give an unacceptable outcome, or the results prove uncertain, a secondary assessment can be performed. The secondary assessment addresses an alternative question of whether further decline in the population abundance of sensitive species has at least been halted (Greenstreet et al., 2012).

**Primary Assessment: Recovery**

Assessment value: **abundance in the *assessment year* must lie in the upper 25% of all abundance values observed throughout the time series. A non-parametric approach has been used for the abundance trends and the entirety of each survey time series acts as the reference period.** The metric meets or exceeds the assessment value when it is within the upper 25$^{th}$ percentile of all the abundance data over the whole survey time series, up to and including the year defined as the *assessment year*.

**Secondary Assessment: Halt Further Decline**

Similar with the recovery except that for each sensitive species in each survey, abundance in the *assessment year* must lie outside the lower 25% of all abundance values observed throughout the time series for the metric to meet its assessment value.

Two integration approaches, 'probabilistic' and 'averaging' were applied to determine integrated assessment outcomes at the regional scale.

## C2.15 Fish abundance (Common Indicator FC1)

**Common Indicator FC1: Population abundance in a suite of selected fish species**

**Assessment value**: The indicator-level assessment value indicates that the number of 'sensitive' fish species that are recovering is significantly greater, than the number that would be expected simply by chance. The indicator-level assessment value is the number of species that are required to meet their species-specific metric level assessment values (S-sMLTs) for this to represent a significant departure from the Binomial Distribution ($p<0.05$). For each species, the species-specific metric-level assessment value is that the "assessment year value lies in the upper 25%ile of the range of values observed over the entire time series", similar to the Greenstreet (2012) and OSPAR C2.14 approach. Species are selected based on their 'sensitivity' to additional mortality associated with anthropogenic activities (ICES 2015; 2016).

# D1C3 Demographic characteristics

- **Marine Mammals**

The following indicators and the way they set thresholds are evaluated for the species demographic characteristics for marine mammals.

| | |
|---|---|
| **HELCOM:** | **C3.1 Reproductive status of seals** |
| **OSPAR:** | **C3.2 Grey Seal Pup Production** |
| **UNEPMAP:** | **C3.3 Population demographic characteristics (Common Indicator 5)** |

***HELCOM Indicators***

## C3.1 Reproductive status of seals

Good status is achieved when the annual reproductive rate (i.e. the proportion of females pregnant/showing postpartum pregnancy signs per year) is at least 90% for harbour seals of five years and older, and grey and ringed seals of six years and older (HELCOM 2018f). A **reproductive rate of 90% is defined as the threshold for each of these parameters as this is indicative of increasing populations**. The overall status assessment is evaluated based on the average ratio (pregnancy rate or inferred birth rate % divided by the threshold) for the two parameters, where a value below one is deemed to fail the threshold for the combined parameters. However, it should be noted that should a population be defined as at carrying capacity, it may exhibit a lower reproductive rate due to the prevailing conditions and population stability or equilibrium (HELCOM 2018f).

The concept for defining threshold values for reproductive rates of seals is derived from the general management principle in the HELCOM Recommendation 27/28-2, which states that the population size is to be managed with the long-term objective of allowing seal populations to recover towards carrying capacity levels. The Recommendation further states that the long-term goal is to reach a healthy status that ensures the future persistence of marine mammals in the Baltic. Reproductive rate is an important aspect of population status, affecting population growth rate. **A modern baseline approach is applied for establishing the threshold value for all species of seals, since pristine conditions are unknown. The modern baseline is based on the first available data, and data on reproductive rates from populations with minimal impacts from human activities are used in this indicator**.

***OSPAR Indicators***

## C3.2 Grey Seal Pup Production

**Baselines** (OSPAR, 2018d): A fixed-baseline year (1992) was used, which is the baseline year used by some European Union Member States for seals under the Habitats Directive (European Union, 1992). A short-term rate-based assessment value was also adopted that uses a rolling baseline (Method 1; OSPAR, 2012). Use of the two types of baseline and associated assessment values seeks to provide an indicator that would warn against both a slow, but long-term steady decline (the problem of 'shifting baselines' associated with only having a rolling baseline) and against a recovery followed by a subsequent decline (potentially missed with a fixed baseline set below reference conditions) (OSPAR, 2018d).

**Indicator assessment values** were set as a percentage deviation from the baseline value (Method 3; OSPAR, 2012). Associated with the above baselines, two assessment values were used to assess grey seal pup production in each AU:

- ***Assessment value 1:*** No decline in grey seal pup production of >1% per year in the previous six-year period (a decline of approximately 6% over six years).
- ***Assessment value 2:*** No decline in grey seal pup production of >25% since the fixed baseline in 1992 (or closest year).

To determine the change in pup production since the baseline year, generalised linear models or generalised additive models were fitted to the sum of pup production data within an AU with a quasi-Poisson error distribution and log link using all available annual survey data for the period 1992–2014. The percentage change in pup numbers since the baseline year (Equation 2; $\Delta_{abundance}$) and 80% confidence intervals were calculated from fitted values. Although no formal hypothesis testing was conducted, 80% confidence intervals were calculated to reflect the choice to set the significance level, ɑ, equal to 0.20 or 20%.

$$\Delta_{abundance} = \frac{B - A}{A} \times 100$$

**Equation 2**: Calculation of long-term trend in abundance

**Calculation of long-term trend in abundance,** where A is the count fitted by the model in the baseline year and B is the count fitted by the model in the most recent survey year.

To estimate the annual change in pup production over the previous six-year reporting round, a linear trend was fitted to the sum of all available data in each AU for the reporting round 2009–2014. GLMs were fitted to the sum of pup production data within an AU with a quasi-Poisson error distribution and log link. Annual growth rate (%) and 80% confidence intervals were estimated for each of the AUs. Although no formal hypothesis testing was conducted, 80% confidence intervals were calculated to reflect the choice to set the significance level, ɑ, equal to 0.20 or 20%.

Indicator metrics and associated confidence intervals were assessed against two thresholds: 1) the average annual growth rate (%) and 80% confidence intervals within the last reporting round were less than -1% per year, and 2) the percentage change in abundance since baseline year ($\Delta_{baseline}$) and 80% confidence intervals were less than -25%. If the 80% confidence intervals encompassed the threshold, the assessment was classified as 'inconclusive' (OSPAR, 2018d).

***UNEPMAP Indicators***

## C3.3 Population demographic characteristics (Common Indicator 5)

**Relevant GES definition** (UNEPMAP, 2017; UNEPMAP, 2018)**:**

Cetaceans: Species populations are in good condition, at low human induced mortality, balanced sex ratio and no decline in calf production. Preliminary assessment of incidental catch, prey depletion and other human induced mortality followed by implementation of appropriate measures to mitigate these threats.

Monk seal: Species populations are in good condition, at low human induced mortality, appropriate pupping seasonality, high annual pup production, balanced reproductive rate and sex ratio. Decreasing trends in human induced mortality (e.g., direct killings, pupping/resting habitat occupation).

The main demographic parameters are defined in the following units:

- adult survival probability: range between 0 and 1;

- juvenile survival probability: range between 0 and 1;

- fecundity, or breeding productivity: average no. of young produced per breeding pair per year;

- age class distribution: percentage of each age class;

- sex ratio: percentage.

**Expected assessments outputs** (UNEPMAP, 2017; UNEPMAP, 2018)**:** Demographic studies can supply useful tools to the management and the conservation of threatened species. Population models, based on life-history tables and transition matrices, allow to assess population performance, to project population trends overtime and thus to foster the conservation of the studied populations, suggesting specific measures for their protection.

For this indictor there are no applied method for threshold setting.

- **Marine Birds**

The following indicators and the way they set thresholds are evaluated for the species demographic characteristics for marine birds.

| | |
|---|---|
| **OSPAR:** | **C3.4 Marine Bird Breeding Success / Failure** |
| **UNEPMAP:** | **C3.5 Population demographic characteristics (Seabirds; Common indicator 5)** |

***OSPAR Indicators***

## C3.4 Marine Bird Breeding Success/Failure

Breeding failure is the extreme event of almost no chicks being produced by a seabird colony in a single breeding season. This assessment describes changes in breeding failure rates in seabird colonies throughout the North-East Atlantic. The assessment is based on how many chicks are fledged (having wing feathers that are large enough for flight) annually, per pair, clutch or nest. For tern species, widespread breeding failure occurs when the percentage of colonies failing per year exceeds the mean percentage for the preceding 15 years. For all other species, widespread breeding failure occurs when the percentage of colonies failing per year exceeds 5%. Frequent breeding failure corresponds when breeding failure occurs for at least four years out of six (2010-2015 inclusive).

### Assessment method

The assessment values applied for this indicator were developed by Cook et al. (2014) and were agreed to be technically appropriate by the Joint OSPAR/ICES/HELCOM Working Group on Marine Birds (ICES 2015). The rationale and values are described in the following sections.

### Parameter / metric

'Annual colony failure rate', that is, the percentage of colonies failing per year, per species (from Cook *et al.* 2014a).

Cook et al. (2014a) quantify failure as when the mean annual productivity of a breeding colony is 0.1 or less chicks per pair, clutch or nest. The assessment value used for determining failure can be adjusted according to knowledge of the colony in question.

Ideally, the assessment value should be obtained from any clear response to important environmental factors such as low food availability (e.g. Cury *et al*. 2011). The assessment value of 0.1 chicks per pair, clutch or nest should be used as the default assessment value, unless there is good evidence to show that 'failure' of some species in some areas should be set at a different level (ICES 2015c).

**Trend analysis**

The assessments for each species are constructed from a time series of annual estimates of breeding success at a sample of colonies. Missing annual observations were predicted using a Generalised Linear Model (GLM) framework with a binomial error structure (after Cook *et al*. 2014 and 2014a). Breeding success for each colony in each year was calculated, and where this value was 0.1 or less chicks per pair, clutch or nest, the colony was assessed as having failed in that year. Breeding success or failure was modelled in relation to year and site, because not all sites were covered in all years. The coefficient for each year was then taken to represent the probability of breeding failure occurring at any given site within that calendar year. The parameter 'Year' was included in the GLM as a fixed effect factor, rather than a random effect, so that the coefficients would not be constrained to follow a normal distribution.

**Breeding failure for each species was assessed in two stages:**

1. Assessing if colony failure is widespread - the annual colony failure rate (the percentage of colonies experiencing breeding failure) can be considered to be 'widespread' if it exceeds the **assessment values** set for each species (see below).

2. Assessing the frequency of widespread breeding failure occurrence. Widespread breeding failure will be considered to be frequently occurring if it occurs in four years or more out of six.

**Assessing if colony failure rate is widespread**

The annual colony failure rate (the percentage of colonies failing) of each species was assessed against one of the two upper assessment values below, depending on the species. This was done for each region:

a) terns: mean percentage of colonies failing per year, over the preceding 15 years;

b) all species except terns: 5% of colonies failing per year.

The aim of the assessment values for annual colony failure rate is to identify widespread breeding failures and to differentiate large-scale impacts from local problems, where only a small proportion of colonies fail per year. The above assessment values were taken from Cook et al. (2014a), who tested various assessment values for each species.

A different assessment value was applied to the breeding failure rate of terns because they often desert colonies, sometimes before laying eggs, in response to local disturbances or impacts on food supply (Shealer and Kress 1991; Holt 1994; Cook et al. 2011). The assessment value for terns is designed to identify years of unusually high rates of breeding colony failure.

**Assessing the frequency of widespread colony failure**

For each species, the frequency of widespread colony failure was assessed over the most recent six-year period from 2010 to 2015, inclusive. **A six-year period was chosen because it equals the length of the EU's MSFD reporting cycle**. To carry out an assessment of a species over a certain time period, there needed to be some observed data of breeding success at some colonies during the most recent year in the period (2015).

One or two years of widespread colony failure were considered as 'acceptable', given the wide range of possible natural and anthropogenic factors that could cause breeding failure in some species. The cumulative effect of widespread colony failure in four or more years out of six, was considered most likely to have a significant impact on recruitment into the regional population (Cook et al. 2014a). Low recruitment could lead to declines in population size and to affect the assessments of the OSPAR's indicator on marine bird abundance.

*UNEPMAP Indicators*

## C3.5 Population demographic characteristics (Seabirds; Common indicator 5)

**Relevant GES definition** (UNEPMAP, 2017; UNEPMAP, 2018): Natural levels of breeding success & acceptable levels of survival of young and adult birds.

Proposed Targets: Populations of all taxa, particularly those with IUCN threatened status are maintained long term and their average growth rate (λ) is equal or higher than one, as estimated by population models.

**Indicator Definition**: The indicator is population growth. Its simplest conceptual model is the equation

$N(t+1) = \lambda N(t)$,

Where N(t) is the number of individuals in the population in year t, and λ is the population growth rate, or the amount by which the population multiplies each. If there is no variation in the environment from year to year, then the population growth rate λ is a constant, and only three qualitative types of population growth are possible: if λ is greater than one, the population grows geometrically; if λ is less than one, the population declines geometrically to extinction; and if λ exactly equals one, the population neither increases nor declines, but remains at its initial size in all subsequent years.

The main demographic parameters are defined in the following units:

- adult survival probability: range between 0 and 1;
- juvenile survival probability: range between 0 and 1;
- fecundity, or breeding productivity: average no. of young produced per breeding pair per year;
- age class distribution: percentage of each age class;
- sex ratio: percentage.

**Statistical analysis and basis for aggregation** (UNEPMAP, 2017; UNEPMAP, 2018)

Where detailed demographic information is available, PVA most often rely upon population projection matrices based on data from individuals of known age and origin. Matrix models predict long-term population growth rates, transient population dynamics, and probabilities of extinction over time.

Use the matrix and the population vector to project the population forward in time, thus predicting the future size of the population, the long-term population growth rate, λ, and the risk of future extinction. This step involves simple rules of linear algebra.

- **Marine Reptiles**

The following indicators and the way they set thresholds are evaluated for the species demographic characteristics for marine reptiles.

**UNEPMAP: C3.6 Population demographic characteristics (Reptiles; Common indicator 5)**

## C3.6 Population demographic characteristics (Reptiles; Common indicator 5)

**Relevant GES definition (UNEPMAP, 2017; UNEPMAP, 2018)**: Low mortality induced by incidental catch, favourable sex ratio and no decline in hatching rate.

The same methods should be used as those described in "Common Indicator 4: Population abundance (Reptiles)". However, additional data are required to assess demography, such as age at sexual maturity, growth rate and age structure, fecundity (clutch size and numbers of hatchlings that emerge from nests and then reach the sea), mortality (death rates) for each stage/age class, sex ratios (in turtles: hatchling, juveniles, and adults).

**Methodology for indicator calculation:** A variety of population demography values are compiled for different components of the populations of the two species breeding on European coasts. **Analyses should be based on at least a decade of information as the base level** (following International Union for Conservation of Nature Red List minimal criteria for sea turtles).

The main parameters consist of:

- Number of individuals in relation to population estimates per population range or management unit, per year, per age and per sex;

- Mortality rate from by-catch, stranding;

- Breeding success/failure of marine turtles (Number of eggs that fail to hatch at marine turtle nesting sites per year. Number of emergences versus successful nests);

- Annual survival probability of adults and juveniles (i.e. different age/size classes) at different sites (breeding, feeding, wintering, developmental);

- Sex ratio of turtles of all age/size classes from hatchings to juveniles to breeding and non-breeding adults at wintering, breeding, foraging and developmental sites.

# D1C4 Distributional Range and pattern

## HD criterion assessment

**Favourable Reference Range** (ETC/BD, 2011): Range within which all significant ecological variations of the habitat/species are included for a given biogeographical region and which is sufficiently large to allow the long-term survival of the habitat/species. Favourable reference value must be at least the range (in size and configuration) when the Directive came into force. If the range was insufficient to support a favourable status the reference for favourable range should take account of that and should be larger (in such a case information on historic distribution may be found useful when defining the favourable reference range).'Best expert judgement' may be used to define it in absence of robust data availability.

The following factors should be considered when estimating Favourable Reference Range (FRR) for both species and habitat types (ETC/BD, 2011):

- Current range;
- Potential extent of range considering physical and ecological conditions (such as climate, geology, soil, altitude);
- Historic range and causes of change;
- Area required for viability of habitat type/species, including consideration of connectivity and migration issues;
- Variability including genetics.

It should be noted that FRR is not necessarily equal to 'potential range': normally, FRR is smaller. For some wide-ranging species, the FRR may be the entire biogeographic region within a country.

By definition, Range and FRR are the same if the Range is sufficient to support the population in favourable status. Range itself is rather theoretical concept, derived from the distribution (population) map. Range covers: actual distribution and suitable and/or potential localities within the area of included gaps. The differences of Range interpretation among MS will be avoided by proposed automated calculation (IT tool for range maps under preparation) (ETC/BD, 2011).

Rough distinction between FRR and Range (using operators) could be based on estimated trend in the reporting period, if the precise data are missing. Decreasing range trend shows that FRR should be greater than Range.

**Favourable Reference Area:** "Total surface area in a given biogeographical region considered the minimum necessary to ensure the long-term viability of the habitat type; this should include necessary areas for restoration or development for those habitat types for which the present coverage is not sufficient to ensure long-term viability; favourable reference value must be at least the surface area when the Directive came into force; information on historic distribution may be found useful when defining the favourable reference area; 'best expert judgement' may be used to define it in absence of other data." (ETC/BD, 2011).

The following background information and parameters may be useful to set FRA (ETC/BD, 2011):

- Historic distribution and causes of change;
- Potential natural vegetation;
- Natural variation;
- Actual distribution and actual variation (including quality of habitat);
- Dynamics of the habitat type;

- Requirements of typical species (including gene flow).

If there is no information showing that enlarged area of the habitat type is necessary for either:

- typical species to reach favourable conservation status; or for
- the necessary structures or functions of the habitat type to exist,

then the FRA can be taken as the surface area of the habitat type when the directive came into force.

Favourable reference area is (despite of its theoretical weakness), a necessary field, with similar function and logic to FRP for species. In contrast to Area, historical (restorable) and possible (restorable) sites could be included (ETC/BD, 2011).

- **Marine Mammals**

The following indicators and the way they set thresholds are evaluated for the species distributional range and pattern for marine mammals.

| | |
|---|---|
| **HELCOM:** | **C4.1 Distribution of Baltic seals** |
| **OSPAR:** | **C4.2 Assessing Changes in Harbour Seal and Grey Seal Distribution** |
| **UNEPMAP:** | **C4.3 Species distributional range (marine mammals; Common indicator 3)** |

***HELCOM Indicators***

## C4.1 Distribution of Baltic seals

Good status is achieved when the threshold values for all considered parameters are achieved (HELCOM, 2018g). Good status is achieved when: 1) **the distributions of seals are close to pristine conditions (e.g. 100 years ago)**; 2) or where appropriate when **all currently available haul-out sites are occupied (modern baseline)**; and 3) when **no decrease in area of occupation occurs**. Three different parameters of distribution are given for all species of seals:

1. Breeding distribution on land or ice, the threshold value is achieved when available sites are occupied;

2. Distribution on land/ice for resting/moulting, the threshold value is achieved when available sites are occupied;

3. The area of occupancy, which includes sea areas used for transport and foraging, the threshold value is achieved when seals are not hindered in executing these activities.

The following criteria are used to evaluate whether the threshold value is achieved or failed:

- The distribution of breeding sites for each management unit of harbour seals are evaluated against pristine conditions. The threshold value is achieved when all previously used sites are colonized, and distribution is not diminishing;

- The distribution of haul-out sites used for resting and moult of harbour seals are almost identical to the distribution of breeding sites. The threshold value is achieved when all previously used sites are colonized;

• Grey seals are facultative land breeders that switch between breeding on land and ice, where ice is favoured if available (Jüssi et al. 2008). The threshold value is achieved when available land breeding sites are colonized, and distribution is not diminishing;

• Grey seal haul-out sites used for resting and moulting may differ considerably between breeding sites, as moulting and resting sites can be locked in by ice and thereby inaccessible during breeding. The threshold value is achieved when available haul-out sites are colonized and not diminishing;

• Ringed seals breed in lairs constructed in snow covered broken and consolidated ice. The sizes of the breeding areas display substantial inter-annual variation. The threshold value is achieved when the long-term breeding area is stable or not diminishing due to direct human activities;

• Ringed seals rest and moult on ice if available. During ice free conditions ringed seals haul out on rocks or small islands. The threshold value is achieved when ringed seals have access to all available haul-out sites and the numbers of haul-outs are not diminishing;

• For the area of occupancy, the threshold value is achieved when seals have access to all feeding grounds, and they can move freely among haul-out sites and the feeding grounds.

The modern baseline approach is applied, when pristine conditions cannot be achieved due to irreversible long-term environmental changes (e.g. sandbanks used for haul-out have vanished), or factors, such as multi-fold increased human exploitation of fish stocks that will persist for the foreseeable future. Since the environment has changed over the past century, and formerly used haul-out sites have disappeared in the Southern Baltic, current distributions are evaluated against colonization of currently available haul-out sites. This type of a modern baseline should be defined so that the species will thrive and persist in the future. Especially in cases where a modern baseline is applied, the additional criterion for evaluating whether good status is achieved 'distributional range is not diminishing’ can be applicable for populations above the limit reference level (LRL). The LRL has been agreed in HELCOM to be set at 10,000 individuals per management unit, understanding that the haul-out fraction during moult surveys is 70%. This HELCOM core indicator is comparable to the OSPAR common indicator M-1; 'Distributional range and pattern of harbour and grey seal haul-outs and breeding colonies', which also applies a modern baseline approach. The difference between the OSPAR 'common indicator' and the HELCOM 'core indicator' is that the latter also encompasses the range of seals at sea during foraging and transport.

***OSPAR indicators***

## C4.2 Assessing Changes in Harbour Seal and Grey Seal Distribution

The definition of distribution in OSPAR’s indicator for assessing its changes in harbour seal and grey seal (OSPAR 2018b) is the following:

**Distribution**: $\Delta_{occupacy}$ refers to the change in occupancy of sub-areas between the periods 2003–2008 and 2009–2014. This is marked as increasing if index is greater than 10%; or decreasing if index is negative and less than -10%; or otherwise, no change. The change in the number of subareas surveyed between the periods 2003–2008 and 2009–2014 is denoted by Survey effort. Shift index describes shifts in distributional pattern within an Assessment Unit.

Describing the distribution of seals from surveys that are designed primarily to assess abundance is problematic, because these are designed for when the seals are on land. Any distribution metric based on these data will have inherent limitations arising from three main issues:

Spatial coverage: Seal abundance surveys necessarily census animals seen hauled-out on land and do not address the distribution at sea. To estimate at-sea usage, long-term telemetry data are necessary (e.g. Jones et al., 2013 from OSPAR 2018b).

Sampling effort: Ideally, in studies of distributional change, a complete and standardized survey is conducted repeatedly in the area of interest. The areas of interest for this indicator assessment are the AUs. Not all AUs surveyed completely on an annual basis due to geographical and/or financial constraints. Surveys have been prioritised towards those areas of known and high seal occurrence. Statistically, this could lead to a bias in seal distribution metrics due to preferential sampling.

Temporal coverage: the surveys cover narrow time windows during key life-stages such as moulting, breeding and pupping. The distribution of seals can be different between these stages. Grey seals, for example, may completely vacate breeding areas for the rest of the year. The present analysis assesses changes in moulting distribution for harbour seals, and changes in breeding colony distribution for grey seals.

These general limitations are applicable to most studies of animal abundance and distribution (Fortin et al., 2005). Despite these limitations, survey data may be useful to detect large-scale contractions in population distributions in terms of reduced use or abandonment of haul-outs or breeding areas, depending on the spatial resolution with which presence / absence data are reported.

*1. Distributional pattern* – percentage change in occupancy between two periods for a given spatial unit:

$$\Delta_{\boldsymbol{distribution}} = \left(\frac{\boldsymbol{B}}{\boldsymbol{N}} - \frac{\boldsymbol{A}}{\boldsymbol{N}}\right) \times \mathbf{100}$$

**Equation 3**: Calculation of changes in distributional pattern

Where A is the number of spatial units (e.g. sub-areas, grid cells) in an AU occupied by seals during reference period A; B is the number of units occupied in a subsequent period B, and N is the total number of spatial units within the AU. For the present assessment, period A is 2003–2008 and period B is 2009–2014.

*2. Shift in occupancy* – an index to describe the overall shift in the seasonal distribution of seals between sub-areas or grid cells over time:

$$Shift = \frac{2(A\&B)}{A+B}$$

**Equation 4**: Calculation of shift index

Where A is the number of spatial units (e.g. sub-areas, grid cells) occupied by seals during reference period A; B is the number of units occupied in a subsequent period; A&B is the number of identical units occupied in both periods. For the present assessment, period A is 2003–2008 and period B is 2009–2014.

The shift index value is between 0 and 1: a value of 0 indicates that there has been a complete shift in the spatial units occupied; a value of 1 indicates there has been no shift.

***UNEPMAP Indicators***

## C4.3 Species distributional range (marine mammals; *Common indicator 3*)

Eleven species of cetaceans are considered to regularly occur in the Mediterranean area: short-beaked common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), harbour porpoise (*Phocoena phocoena*), long-finned pilot whale (*Globicephala melas*), rough-toothed dolphin (*Steno bredanensis*), Risso's dolphin (*Grampus griseus*), fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*) and killer whale (*Orcinus orca*). Two of these species have very limited ranges: the harbour porpoise, possibly representing a small remnant population in the Aegean Sea, and the killer whale, present only as a small population of a few individuals in the Strait of Gibraltar. The Mediterranean provides also key habitats for a pinniped species, the Mediterranean monk seal (*Monachus monachus*). The species occurs regularly in the eastern basin, mainly along the coasts of Greece and Turkey, although recent sightings have also been reported in neighbouring Adriatic and central Mediterranean sites (UNEPMAP, 2017; 2018).

**Data**: presence/absence of each species, the standardized 30 x 30 nautical mile grid map produced by FAO/GFCM or the 50 x 50 km grids used by the European Bird Census Council. Moreover, the ACCOBAMS Survey Initiative data may provide key information to have a better picture on species distribution and habitat preferences.

**Statistical analysis and basis for aggregation**: Standard regression methods (simple linear regression, generalized linear or additive models), power analysis for detecting trends should be applied.

**Expected assessments outputs**: I.e. trend analysis (monthly, seasonally, yearly), distribution maps, statistical frameworks applied.

No threshold values are currently available for this indicator (UNEPMAP, 2017; 2018).

- **Marine Birds**

The following indicators and the way they set thresholds are evaluated for the species distributional range and pattern for marine birds.

**UNEPMAP: C4.4 Species distributional range (Seabirds; Common indicator 3)**

***UNEPMAP Indicators***

## C4.4 Species distributional range (Seabirds; Common indicator 3)

The objective of this indicator (UNEPMAP, 2017; UNEPMAP, 2018) is to determine the species range of the seabirds that are present in Mediterranean waters. Thus, the indicator for breeding/wintering range would consist in the variation of occupied/lost areas in a standard grid in 6 years.

Variation in the total area (trends in the number of occupied grid cells) occupied by selected species at sea during the breeding and wintering seasons. By using the Range Tool software and algorithm will provide of a standardised process that will help to ensure repeatability of the range calculation in different reporting rounds. The resulting range map will then be a combination of the automated procedure completed by expert judgement.

The trends in the number of occupied cells or area occupied is a basic and immediate parameter which signification can be statistically assessed. The assessment of the conservation status of a bird species in the Nature 2000 Directives is defined as "Unfavourable", when they undergo a large decline estimated as the "**equivalent to a loss of more than 1% per year within period specified by MS OR more than 10% below favourable reference range".**

A decreased range should not be a major concern as far as other indicators, in particular the species indicator abundance, shows an acceptable trend.

Expected outcome: Temporal trends in distributional range. Locally, and when high quality data is available, could be worth to try a density surface modelling approach such as GAM or machine learning models (UNEPMAP, 2018)

- **Marine Reptiles**

The following indicators and the way they set thresholds are evaluated for the species distributional range and pattern for marine reptiles.

**UNEPMAP: C4.5 Species distributional range (Reptiles; Common indicator 3)**

***UNEPMAP Indicators***

## C4.5 Species distributional range (Reptiles; Common indicator 3)

The European (ETRS) 10x10km² grid is used for mapping the distribution and range, accounting each known location along the Mediterranean coast. Three different maps (grids) are produced yearly for each species accounting for breeding sites, wintering sites and feeding/developmental sites of loggerheads (*Caretta caretta*) and greens (*Chelonia mydas*) (UNEPMAP, 2017; UNEPMAP, 2018).

The Range Tool software and algorithm will provide a standardised process that will help to ensure repeatability of the range calculation in different reporting rounds. After automated calculation of the range it is possible to correct the gaps to obtain a complete overview of the data following a standardised protocol. The resulting range map will then be a combination of the automated procedure completed by expert judgement (UNEPMAP, 2017; UNEPMAP, 2018).

Presence/absence information is used only, because the different methods used to detect the presence/absence of turtles range from coarse to highly accurate (within metres), along with heavy sighting/detection bias to certain key regions/sites. The trends in the number of occupied cells or area occupied is a basic and immediate parameter for which the significance may be statistically assessed. The expected assessments outputs are temporal trends in distributional range and maps showing the evolution of the distributional range for the two species at different scales.

## D1C5 Habitat for the species

According to the European Commission (2017) the D1C5 criterion is "Primary for species covered by Annexes II, IV and V to Directive 92/43/EEC and secondary for other species" and is defined as: "The habitat for the species has the necessary extent and condition to support the different stages in the life history of the species." No relevant indicators are currently assessed by the RSCs, so no sources for thresholds and their determination can be sought there. However, the HD provides relevant input.

## HD criterion assessment

The definition of favourable conservation status for a species given in Article 1 of the Habitats Directive includes "- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis" (Art. 1i).

Art 1f of the HD (European Union, 1992) defines habitat of a species as: "[…] an environment defined by specific abiotic or biotic factors, in which the species lives at any stage of its biological cycle".

Moreover, 'habitat for the species' is one of the four parameters used to assess conservation status. The reporting format requires: habitat area, habitat quality and trend together with information on the data quality and reasons for any change (ETC/BD, 2011). 'Habitat for the species' uses habitat in its original meaning of the resources (biological and physical) used by a species during its life. Although a variety of definitions have been used (see for example Mitchell, 2005 in ETC/BD, 2011), this is sometimes referred to as the ecological niche of a species. Figure 1 provides a decision tree to facilitate the assessment of the 'Habitat for the species' parameter.

**Generalists:** For some species using a wide range of habitats, often termed 'generalists', it is difficult to identify the area used with any precision. However, for these species it is less likely that the habitat is a limiting factor controlling their population size or reproduction than for a 'specialist' species dependent on one or a few habitats. For generalist species factors such as availability of prey is often more important than habitat area (ETC/BD, 2011).

**Specialists:** Some species are known to be restricted to particular habitats and have well known requirements, while some are usually found in the transitions between habitats (ETC/BD, 2011). Ideally, both the area of habitat used by the species and its trend, plus the area of suitable habitat would be available, and if they are, should be reported. In rare cases the habitat may be an Annex I habitat type or group of Annex I habitat types and information collected for the habitat assessment can provide an estimate of the habitat for the species (ETC/BD, 2011).

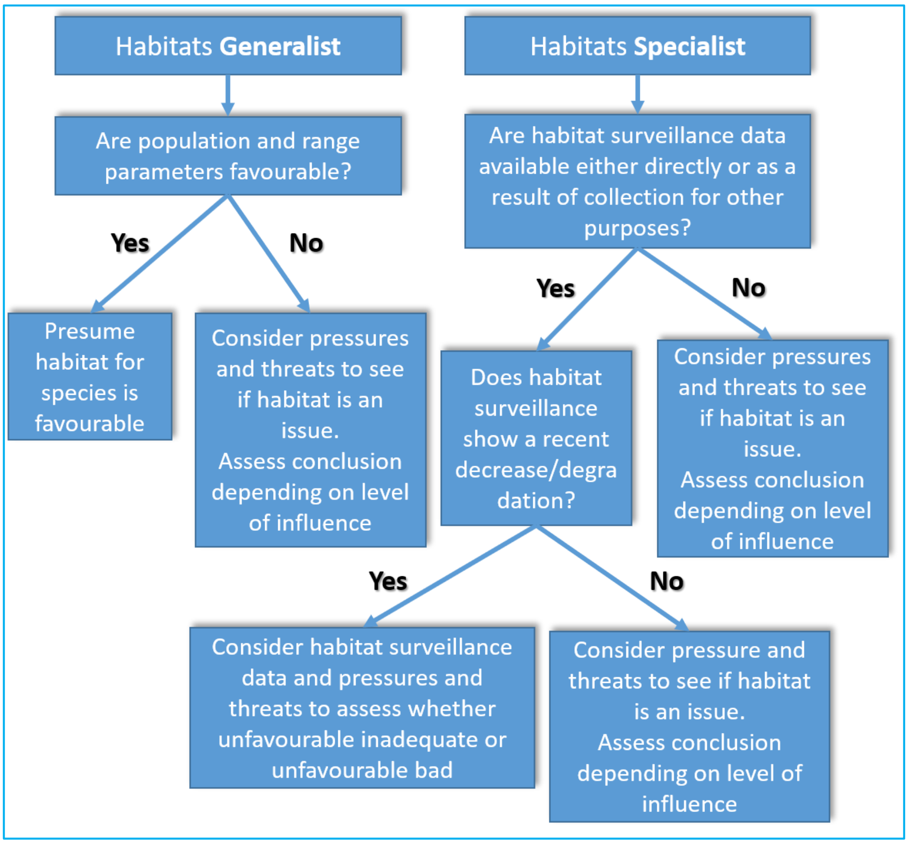



**Figure 1.** Decision tree to aid assessment of the parameter 'habitat for the species' (adjusted from the JNCC in ETC/BD, 2011).

**Area covered by habitat**

### Structures and functions (including typical species)

Article I(e) of the HD (European Union, 1992) states: "the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and the conservation status of its typical species is favourable as defined in (i)".

Structures are considered to be the physical components of a habitat type, these will often be formed by species (both living and dead), e.g. corals in some forms of reef but can also include structures such as gravel used for spawning. Functions are the ecological processes occurring at a number of temporal and spatial scales and vary greatly between habitat types. Functions are often linked to ecosystem services. Although fragmentation is not mentioned in the directive, it can disrupt habitat function and should be taken into account when assessing structure & function (ETC/BD, 2011).

For a habitat type to be considered to have a Favourable Conservation Status, HD requires its structure and functions to be favourable and its 'typical species', as well, to be at Favourable Conservation Status. Given the wide range of habitat types listed on Annex I and their inherent variability, it is not possible to give detailed guidance for each individual habitat type but clearly, the various ecological processes essential for a habitat type have to be present and functioning for the habitat type to be considered to be at FCS.

## IUCN Criteria and thresholds

The IUCN Red List of Threatened Species has evolved to become the most comprehensive source of information on the global conservation status of animal, fungi and plant species. It is a critical indicator of the health of the world's biodiversity. Far more than a list of species and their status, it is a powerful tool to inform and catalyse action for biodiversity conservation and policy change. The IUCN categories (Figure 2) and criteria (Figure 3) consist the backbone for this widely endorsed action (IUCN, 2012). All RSCs have gone through similar exercises to identify and characterise threatened lists of species of their interest (European Commission, 1999; HELCOM, 2013a; OSPAR, 2008) and also European wide threat assessments of birds, marine fish and marine mammals have been published (Temple & Terry 2007; BirdLife International 2015; Nieto et al. 2015).

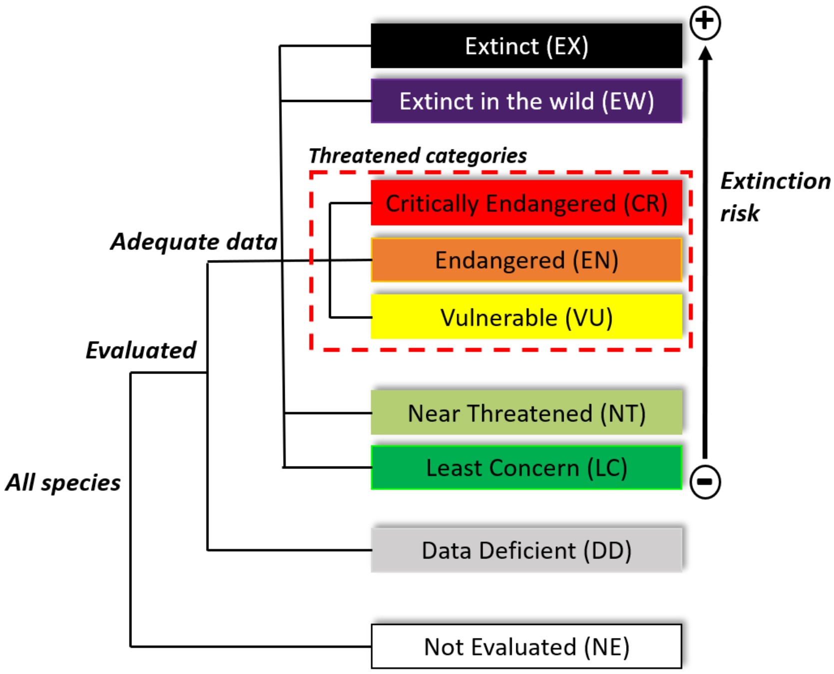



**Figure 2.** Structure of the categories (amended from IUCN, 2012).

IUCN categories and criteria (IUCN, 2012) include threshold values in relation to the classification of the extinction risk. These are comprehensively summarised in Figure 3, as some RSCs' indicators make use of these thresholds. It is however good to notice the conceptual differences between the extinction risk and the good environmental status.

**CRITERION A**

**REDUCTION IN POPULATION SIZE**
CR ≥ 90% (A1) or 80% (A2–A4)
EN ≥ 70% (A1) or 50% (A2–A4)
VU ≥ 50% (A1) or 30% (A2–A4)
NT ≥ 25% (A1) or 15% (A2–A4)

Based on any of A1–A4:
**A1. *An observed, estimated, inferred or suspected population size reduction*** over the last 10 years or three generations, where the causes of the reduction are clearly reversible AND understood AND ceased, based on any of (a) to (e) shown below

**A2. *An observed, estimated, inferred or suspected population size reduction*** over the last 10 years or three generations, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on any of (a) to (e) shown below

**A3. *A projected or suspected population size reduction in the future*** within the next 10 years or three generations, based on any of (b) to (e) shown below

**A4. *An observed, estimated, inferred, projected or suspected population size reduction*** over any 10 year or three generations period, where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on any of (a) to (e) shown below:

**a) direct observation**
**b) an index of abundance appropriate to the taxon**
**c) a decline in area of occupancy, extent of occurrence or quality of habitat**
**d) actual or potential levels of exploitation**
**e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites**

**CRITERION B**

**B1. EXTENT OF OCCURRENCE**
CR < 100 km²
EN < 5 000 km²
VU < 20 000 km²
NT < 40 000 km²
**or**

**B2. AREA OF OCCUPANCY**
CR < 10 km²
EN < 500 km²
VU < 2 000 km²
NT < 4 000 km²

**and an indication for at least two of a–c:**

**a) Severely fragmented or the number of known locations is only:**
CR: 1
EN: 2–5
VU: 6–10
NT: 11–19

**b) Continuing decline in any of the following:**
**i)** extent of occurrence
**ii)** area of occupancy
**iii)** area, extent or quality of habitat
**iv)** number of locations or subpopulations
**v)** number of mature individuals

**c) Extreme fluctuations in any of the following:**
**i)** extent of occurrence
**ii)** area of occupancy
**iii)** number of locations or subpopulations
**iv)** number of mature individuals

**Additionally category NT if:**

Extent of occurrences < 5000 km² or area of occupancy < 500 km²

**and one of the above sub-criteria a–c is met.**

**CRITERION C**

**SMALL AND CONTINUOUSLY DECLINING POPULATION**

**Number of mature individuals:**
CR < 250
EN < 2 500
VU < 10 000

**and either C1 or C2:**

**C1. An estimated continuing decline of at least:**
CR: 25% within 3 years or 1 generation
EN: 20% within 5 years or 2 generations
VU: 10% within 10 years or 3 generations

**or**

**C2. A continuing decline in numbers of mature individuals AND at least one of the following (a–b):**

**a i)** number of mature individuals in the largest subpopulation:
CR ≤ 50
EN ≤ 250
VU ≤ 1 000
or
**a ii)** proportion of the whole population in one subpopulation:
CR: 90–100%
EN: 95–100%
VU: 100%
or
**b)** extreme fluctuations in number of mature individuals (typically more than tenfold)

**Additionally category NT if:**

Number of mature individuals < 20 000 and continuing decline of at least 10% **or** Number of mature individuals < 10 000 and continuing decline of at least 5% or number of the largest population < 2 000.

**CRITERION D**

**VERY SMALL AND RESTRICTED POPULATION**

**If there is an imaginable threat** that can make the species capable of becoming CR or RE within a very short time

**and either D1 or D2:**

**D1. Number of mature individuals:**
CR < 50
EN < 250
VU < 1 000
NT < 2 000

**or**

**D2. Also VU,** if area of occupancy very restricted (typically less than 20 km²) or number of locations 1–5

**Additionally NT,** if area of occupancy restricted (typically less than 40 km²) or number of locations less than 10

**and if there is an imaginable threat** that can make the species capable of becoming VU or EN within a very short time

**CRITERION E**

**PROBABILITY OF EXTINCTION ON THE BASIS OF QUANTITATIVE ANALYSIS**

Quantitative analysis showing the **probability of extinction is at least:**

CR: 50% within 10 years or three generations, whichever is the longer (max. 100 years)

EN: 20% within 20 years or five generations, whichever is the longer (max. 100 years)

VU: 10% within 100 years

NT: 5% within 100 years

**Figure 3.** Summary of the IUCN criteria according to IUCN (2001) from HELCOM (2013a).

## Fish and Cephalopod indicators developed based on the CFP monitoring programmes

Given the lack of operational indicators for fish and cephalopods under the RSCs and the vast information coming from the CFP and the DC MAP, we explore a number of potential indicators to assess MSFD D1 criteria for fish and cephalopods. We need to mention that not all RSCs have the mandate to deal with fisheries and other organizations are responsible for these assessments. For instance, Barcelona convention is not assessing fisheries stocks, which goes under the mandate of the GFCM. There are only five fish related indicators and none for cephalopods in the list of indicators from the RSCs. These are developed for specific species based on the particular lifecycles of those species, or they are community indicators. This gap in information and methods steered to explore methods already developed in the CFP community with potential to be applied for the MSFD at species level.

Assessing the status of non-commercially exploited fish and cephalopods is a challenge never undertaken in such a scale in the past. Besides the protected species included in the Habitat Directive (Annex II and IV) or the IUCN red list, a sizeable amount of non-commercial species is considered priority species under various RSC's or Treaties or Organizations (Palialexis *et al*., 2018).

The source of data for conducting the assessments is to be decided at the Member State level; either a specific monitoring scheme should be set up under the MSFD umbrella or make use of the data collected under the EU data collection framework implementing the Common Fisheries Policy (European Union, 2017a; European Commission, 2016).

In the following pages we investigate how can threshold values be determined even for species that are not regularly assessed and information may come in short supply.

Based on **data availability**, methods can be classified as:

- Feasible - Data available (or Data poor methods)
- Questionable - Depending on data availability (e.g. surveys)
- Unrealistic – extremely data demanding

Based on the **approach for setting a threshold**, methods can be categorized into:

- Reference Point based
- Trend-based

Since most of these species (if not all) are not targeted species for data collection under the EU MAP (former DCF), no direct catch (by-catch) values may be available; however such estimates can be derived indirectly by extrapolating the observations of observers stationed on board fishing vessels to the total effort exerted by the fleets.

Such an approach is already in place for the Harbour porpoise bycatch estimate (OSPAR indicator), as suggested by the ICES Working Group on Bycatch of Protected Species (WGBYC) (ICES, 2015b, 2016b). More specifically:

Total bycatch (number of animals caught) = fishing effort × bycatch rate

where:

- bycatch rate (number of animals caught per day) = total number of bycaught animals observed/number of observer days,
- Fishing effort = number of days at sea (for relevant fishing gear types)

Building on the above, wherever 'catch' is mentioned in the subsequent methods, this may refer to an indirect estimate (if no direct value is available).

# D1C1 Mortality rate from incidental bycatch

**The MSY concept in the MSFD-D1 context**

MSY (maximum sustainable yield), is defined as the maximum yield (catch biomass) that can be removed from a stock in a viable way so that the stock continues to yield the maximum amount without it being in a danger of collapse (Lassen et al., 2014). In relation to MSY, FMSY is determined as the fishing mortality rate that will sustain the stock's biomass at levels (BMSY) that ensure maximum sustainable yield. Using the term 'yield' for protected, sensitive or rare species, like the ones included under D1, is out of place; the most acceptable term for yield would be 'removals' and the relevant terms for FMSY and BMSY, would be acceptable thresholds of fishing mortality (FTHR)) and biomass (BTHR); with these terms denoting levels of by-catch mortality (FTHR) that will allow the population size to remain within safe biological limits (BTHR). As a result, although many of the following methods are built around the concept of MSY, they can be straightforwardly adapted to address population status based on removals from by-catch data.

- **Data poor methods**

**Direct estimate of $F_{MSY}$**

- Zhou et al. (2012) has carried out a meta-analysis on 245 fish species worldwide investigating the relationship between fishing (F) and natural mortality (M). They concluded that in the absence of any other data, a good approximation of fishing mortality rates is given by $F_{MSY}$ = 0.87M for teleosts and $F_{MSY}$ = 0.41M for chondrichthyans.

  Pros: Easy to estimate; the least data requirements

  Cons: empirical; based on worldwide literature survey and modelling

*Setting threshold category: Reference point based ($F_{THRESHOLD} = F_{MSY}$)*

**Empirical estimates of $F_{MSY}$ from life-history traits**

- ICES WKLIFE V Report (2015) suggests that for data poor situations mortality rates can be empirically estimated from bibliographic data on maximum recorded age (Tmax) and/or maximum recorded weight (W∞). The method builds on the theory that:

  $$\mathbf{F_{MSY}=r/2}$$

  where:

  r = intrinsic growth rate which can be derived as a function of Tmax or Winf (r ~ f(Tmax or Winf))

  Pros: Easy to estimate; the least data requirements

  Cons: large prediction intervals; not tested

  *Setting threshold category: Reference point based ($F_{THRESHOLD} = F_{MSY}$)*

- McAllister *et al*. (2002) put forward the Krebs method, which (as above) builds on the hypothesis that $\mathbf{F_{MSY}=r/2}$ (according to a Schaefer production model). The method requires bibliographic data on age structured maturity, mortality and fecundity, growth parameters (e.g. von Bertalanffy), and mean generation time.

  Pros: relatively easy to estimate; relatively accurate (depending on data quality)

  Cons: no data availability for many species

  *Setting threshold category: Reference point based ($F_{THRESHOLD} = F_{MSY}$)*

**Empirical estimates of by-catch mortality from life-history traits**

- Moore *et al*. (2013), provide an approach to estimate by-catch mortality (***$F_{lim}$***) based on known population parameters such as: $R_{MAX}$ = max productivity rate, MNPL = maximum net productivity level, and M = natural mortality. ***$F_{lim}$*** is estimated in relation to $F_{CRASH}$ (highly critical level - population abundance is small but > 0) or $F_{RISK}$ (early warning level below a limit reference point such as MNPL and $F_{CRASH}$), where:

  $F_{CRASH} = R_{MAX}$; $F_{CRASH} = 2\omega M$;

  $F_{RISK} = 0.75R_{MAX}$; $F_{RISK} = 1.5\omega M$;

  $F_{MNPL} = 0.5\ R_{MAX}$; $F_{MNPL} = \omega M$;

  where $\omega$ = ratio of $F_{MNPL}$ to M

  Pros: relatively easy to estimate; relatively accurate (depending on data quality)

  Cons: Requires simulation-based performance testing

  *Setting threshold category: Reference point based ($F_{THRESHOLD} = F_{LIM}$)*

**PSA-Productivity, Susceptibility Analysis**

- Osio *et al*. (2015), have employed a method largely based on expert-knowledge to assess the status of an unprecedented number of Mediterranean stocks. Two main stock parameters have to be estimated, productivity and susceptibility, which in turn allow for an estimate of **Vulnerability = sqrt((susceptibility − 1)$^2$ + (3 − productivity)$^2$)**. This estimate can be used as a proxy of exploitation level and more specifically the ratio of fishing mortality-F over sustainable levels of mortality-$F_{MSY}$. Various life history parameters should be collected: mean age@maturity, mean size@maturity, mean max age, mean max size, fecundity, reproductive strategy, trophic level, distribution, habitat, bathymetric range, survivability.

  Pros: no specific data needs from surveys; applicable to all species

  Cons: expert knowledge needed

  *Setting threshold category: Reference point based ($F/F_{THRESHOLD} = F/F_{MSY} < 1$)*

- **Data rich methods**

**Empirical estimates of $F_{MSY}$ from survey data**

- Given that at least survey data are available, mortality rates can be estimated once again based on the assumption that **$F_{MSY}=r/2$**. Data requirements concern: time-series of survey index (relative biomass or abundance). Intrinsic growth rate *r* is estimated as the slope of log(index) against time (FISBOAT, 2007).

  Pros: surveys monitor all species

  Cons: affected by large recruitment pulses, particularly with low Nb of adults

  *Setting threshold category: Reference point based ($F_{THRESHOLD} = F_{MSY}$)*

**Survey-based methods**

- Annual length (or age) disaggregated indices from surveys allow for estimation of total mortality (Z) or fishing mortality (F). SURBA method is based on annual age disaggregated indices while LENSUR on annual length disaggregated indices (FISBOAT, 2007).

Pros: surveys monitor all species

Cons: estimates of total mortality Z rather than fishing mortality F

*Setting threshold category: Trend-based*

- Annual relative abundance indices ($CPUE_t$) from surveys allow for estimation of total mortality (Z). Knowledge of natural mortality (M) is needed to derive fishing mortality (F= Z-M) (FISBOAT, 2007). Z is estimated through the following equation:

$$Z = \frac{1}{t_2 - t_1} \times \ln \frac{CPUE(t_1)}{CPUE(t_2)}$$

Pros: survey data availability even for rare/sensitive species

Cons: uncertainty; nat. mortality M must be known/estimated

*Setting threshold category: Trend-based*

**Spawner-per-recruit model**

- Walker et al. (2019) have recently introduced a method providing proxies of fishing mortality ($F_{REALIZED}$). Data requirements concern: fishing effort by gear & area, maturity at age, weight at age, von Bertalanffy growth parameters.

Pros: works for data limited cases

Cons: designed for bottom trawl fisheries; effort by gear should be available

*Setting threshold category: Reference point based ($F_{THRESHOLD}$= $F_{REALIZED}$)*

**Catch based methods**

- Whenever catch data are available, more traditional stock assessment methods can be employed: surplus production models (Punt and Hilborn, 1996) or CMSY method (Froese *et al.*, 2017). Data needs include annual catches (both for surplus production models & CMSY), prior for *r* (intrinsic growth rate) and biomass estimate at beginning and end of period (CMSY).

Pros: catch estimates available from on-board observers for all species

Cons: less well suited for lightly exploited stocks where the catches have very little impact on biomass, and for species with very low resilience.

*Setting threshold category: Reference point based ($F_{THRESHOLD}$= $F_{MSY}$)*

- Quinn and Deriso (1999) in their classical textbook 'Quantitative fish dynamics' provide a series of methods to estimate total mortality (Z) through relative catch indices (CPUE) or annual catches ($C_t$) or various length metrics ($L_{inf}$, mean length of catch, Length at first capture). Required data include annual CPUEs or Number of individuals captured or mean Length caught-$\bar{L}$, min length caught, L∞, k growth parameter. Some of the equations for estimating Z are:

$$Z = \frac{1}{t_2 - t_1} * \ln \frac{CPUE(t_1)}{CPUE(t_2)} \qquad Z = k\frac{L_\infty - \bar{L}}{\bar{L} - L'} \qquad \ln C(L, L_\infty) = a + \frac{Z}{K}\ln(L_\infty - L)$$

Pros: catch estimates available from onboard observers for all species

Cons: rare species may not be recorded due to limited observer effort

*Setting threshold category: Trend-based*

**Analytical stock assessments**

- In the case that data are in abundance (catch & survey data available) one can apply analytical stock assessment methods, which are considered the most accurate approaches (Quinn and Deriso, 1999; Pedersen & Berg, 2017). Input required: catch - age disaggregated age/length data, survey - age disaggregated age/length data indices, L-W relationships, growth parameters.

  Pros: accuracy

  Cons: rich data dependent

  *Setting threshold category: Reference point based ($F_{THRESHOLD} = F_{MSY}$)*

# D1C2 Population abundance

- **Data poor methods**

No data poor methods to cite.

- **Data rich methods**

**Relative index of abundance - survey or catch based**

- The most simple and straightforward approach is to study abundance indices derived either from experimental surveys or commercial fisheries. Input: annual indices of abundance (CPUE).

  Pros: surveys monitor all species

  Cons: no absolute estimate of population size

  *Setting threshold category: Trend-based*

**Survey-based methods**

- Trenkel (2007) has estimated relative biomass using only survey data by applying the BREM method (biomass random effects model). The approach requires two separate biomass indices, one for the total stock and one for the recruits only.

  Pros: surveys monitor all species

  Cons: very sensitive to starting values

  *Setting threshold category: Reference point based ($B_{THRESHOLD} = B_{MSY}$)*

- Population density (relative abundance) can be inferred through visual census surveys. Thanopoulou et al (2018) compare strip vs line transects in underwater visual surveys as a method to estimate abundance. Input needed: n, number of individuals; 2w, total width of the transect; L, length of the transect; Ac, total covered (sampled) area. Population density is calculated as:

$$\hat{D} = \frac{n}{2wL} = \frac{n}{A_c}$$

Pros:

- all species monitored in situ, it yields the most complete species list of all possible methods;

- if rebreathers are used by the scientific divers it detects rare species, species with cryptic behaviour and species that normally avoid capture by other methods (Pyle 1996, 1998, 2000);

- may be coupled with fishery-independent capture by the observer when more data on size / age/ maturity are needed for certain species (Samoilys and Gribble, 1997; Seaman, 2000);

- the only method applicable for non-commercial species that cannot be captured with fishery-dependent methods

Cons:

- imperfect detectability but still much better species richness than any other method;

- experience of observer important and must be calibrated prior of the survey.

*Setting threshold category: Trend-based*

**Catch based methods**

- CMSY method introduced by Martell & Froese (2013) has been applied to estimate reference points from catch data by Froese et al. (2017). CMSY allows for calculation of maximum intrinsic rate of population increase *r*, unexploited stock size *K* and maximum sustainable yield MSY. It can furthermore provide reasonable predictions of relative biomass levels. According to the Schaefer production model MSY occurs at rK/4 and $B_{MSY}$=K/2 (Punt & Hilborn, 1996). Data requirements: annual catches, prior for *r* (intrinsic growth rate); prior for biomass estimate at beginning and end of period.

  Pros: catch estimates available from on-board observers for all species

  Cons: less well suited for lightly exploited stocks where the catches have very little impact on biomass, and for species with very low resilience

*Setting threshold category: Reference point based ($B_{THRESHOLD}$= $B_{MSY}$)*

- Edwards (2015) suggests that in the absence of proper stock assessments, MCY (maximum constant yield) can be used as a proxy of MSY. MCY=$c*Y_{bar}$, where: $Y_{bar}$=average yield over an historical period when the stock was considered to be in good condition; 0.6<=*c*<=1 (c expresses natural variability))

  Input required: time series of historical catches (yields)

  Pros: catch estimates available from on-board observers for all species

  Cons: rare/sensitive species are not always recorded by on-board observers; based on the presumption that the reference catch is a suitable proxy for MSY; need for a proper selection of *c; $B_{MSY}$ has to be derived by other methods*

*Setting threshold category: Reference point based ($B_{THRESHOLD}$= $B_{MSY}$)*

**Analytical stock assessments**

- In the case of catch & survey data availability, analytical stock assessment methods, can provide accurate estimates of population abundance (Quinn and Deriso, 1999; Pedersen & Berg, 2017). Input required: catch - age disaggregated age/length data, survey - age disaggregated age/length data indices, L-W relationships, growth parameters.

Pros: accuracy

Cons: rich data situations only

*Setting threshold category: Reference point based ($B_{THRESHOLD} = B_{MSY}$)*

**eDNA metabarcoding**

- A novel cost-effective sampling method to derive population size is eDNA metabarcoding (Taberlet, 2012; Evans et al., 2016; Lacoursiere-Roussel et al., 2016; Baker et al., 2018). Data needs concern only sea water samples and further processing in the lab.

  Pros: non-invasive and cost-efficient method; works even for species with very low abundance and can be applied at areas where conventional sampling is forbidden (e.g. MPAs) or are difficult to reach given their great depths or the type of substratum.

  Cons: eDNA metabarcoding protocols may need standardization by optimizing and implementing novel analytical techniques in different environmental conditions.

  *Setting threshold category: Trend-based*

**IUCN Red List Categories and Criteria**

These criteria were analysed earlier as a potential source of assessments. For fish species their relevance is captured in the following points and can be applied to D1C4, as well:

- Based on IUCN Red List criteria A, C, D (population size) and E (generation, population dynamics) a population trend can be estimated.
- The threshold is crossed if the analysis results in conditions being met for categories from Near Threatened to Critically Endangered.
- Various information sources may be used to derive population trends

Pros:

- already in place, widely used;

- makes use of all available information types and sources

- flexible and complex multi criteria analysis.

Cons:

- natural variability of species ranges, especially under climate change

- reliability dependent on quality of info available for the assessment.

# D1C3 Demographic characteristics

- **Data poor methods**

  No data door methods to cite.

- **Data rich methods**

**Survey-based methods**

- Intrinsic population growth rate *r* can be calculated from a series of annual biomass or abundance indices (FISBOAT, 2007). Input required: time series of survey index (either biomass or abundance). *r* can be estimated as the slope of log total abundance against time, by fitting a mixed model as follows:

$logN_t = b_0+r*t+w(t)+e(t)$, where:

w(t) ~ Normal(0,s^2 ) (year to year variance)

e(t) ~Normal(0,se^2) (random error))

Pros: surveys monitor all species

Cons: affected by large recruitment pulses, particularly if numbers of adults are low

*Setting threshold category: Reference point based (r > removal rate)*

- $L_{50}$, length at maturity or length at which at least 50% of the population is sexually mature, is widely used as a population metric (FISBOAT, 2007). Easy to measure, it requires length distribution data and maturity estimates by length class.

  Pros: surveys monitor all species

  Cons: influenced by the smallest, youngest year classes

  *Setting threshold category: Trend-based*

- $L_{95}$, proportion of large fish or the 95th percentile of length-frequency distribution. This index has been proposed as a more robust index of population status than average length; the concept behind this population metric is that size-selective fishing, targeting the larger fish may result in a change in size-structure of the community. The typical K-selected species that grow slowly to large sizes (e.g. chondrichthyans), will be stronger affected by fisheries than the r-selected species that show the opposite growth rate. Length distribution data is required.

  Pros: surveys monitor all species

  Cons: very sensitive to selective removals (e.g. fishing usually targets mature specimens)

  *Setting threshold category: Trend-based*

- Optimal conservation lengths ($L_{max5\%}$ or $L_{25\%}$) are considered indicators of population health status (ICES WKLIFE V Report, 2015). Provided that a set of data is available (Lmat (Length@maturity), Linf, Lc (length at first capture), L-W relationships, catch@length) the following formulas allows for estimation of conservation thresholds:
  for large individuals:
  Lc/Lmat >0.8 and $L_{MAX5\%}$/Linf >0.8
  for immature individuals
  Lc/Lmat > 1 and $L_{25\%}$/Lmat >0.8
  where: $L_{MAX5\%}$ = Mean length of largest 5%, $L_{25\%}$ = 25th percentile of length distribution

  Pros: surveys monitor all species

  Cons: Relative catchability of survey may not directly reflect stock status

  *Setting threshold category: Reference point based (Optimal conservation length)*

- Gonadosomatic index (GSI) is a metric allowing for assessing the reproductive potential of the population (FISBOAT, 2007). It is easily calculated as the ratio of gonad weight over the total weight of the specimen. Data needs include body weight and gonad weight.

Pros: surveys monitor all species

Cons: very sensitive to the maturity stage and the timing of the spawning cycle

*Setting threshold category: Trend-based*

- Large Fish Indicator (LFI) has been developed to respond to fishing pressure on the proportion of large fish (Greenstreet et al., 2012). Estimates of fish biomass density-at-length is required. LFI is then calculated as:

$$LFI = \frac{B_{L>L_{LF}}}{B_{L>L_{LF}} + B_{L\leq L_{LF}}}$$

where L is length (in cm) and B is biomass density (as $kg/km^2$).

Pros: surveys monitor all species

Cons: species growth differs by environment; what is the effect of climate change on this indicator? How do we set reliably the optimal length defining 'large fish'?

*Setting threshold category: Trend-based*

## D1C4 Distributional Range and pattern

- **Data poor methods**

No data door methods to cite.

- **Data rich methods**

**Survey-based or Catch based methods**

- Spatial expansion/occurrence of a species can be assessed based on occurrence observations (UNEP, 2018). Presence/absence data on a standardized gridded map is required. These data can be either from experimental surveys or commercial fisheries footprint.

Pros: surveys monitor all species

Cons: imperfect detectability for rare species

*Setting threshold category: Trend-based*

**Species distribution models**

- A wide series of models named 'SDMs-Species distribution models' have been employed for long to study species ecology (Guisan & Zimmermann, 2000). Data needs may be limited to just a set of geolocated presence/absence or abundance values of each species to a series of auxiliary datasets, such as environmental indices. Under the category SDM one can assign: GLMs, Neural Networks, ordination and classification methods, Bayesian models, GAMs, environmental envelopes Ecological Niche Models (ENM), MaxEnt or combinations of the above.

Pros: allows for predicting probability of occurrence in areas where no data are available

Cons: imperfect detectability for rare species; historical data may not be available

*Setting threshold category: Trend-based*

## Data availability – gaps

Reviewing the aforementioned methods, it becomes obvious that **monitoring is key** to achieving meaningful results. Most methods require information that may not be readily available or not available at all. Ongoing monitoring schemes, such as the EU Fisheries Data Collection Framework (currently EU MAP), are designed to assess the viability of commercial fisheries targeting specific species/stock. MSFD needs go beyond the 'specific' and embrace the whole ecosystem, expecting the species evaluation with ecological relevance to all anthropogenic pressures. Herein we tried to provide methods for assessing the species falling under D1 through datasets that should be available for all EU member states. In some cases, no data are actually needed to come to a conclusion; however, the accuracy accompanying these methods may be far from the aspired.

### Data access

As a first step all EU member states will have to conduct a data mining exercise and investigate what kind of data are available; where are these data stored and who is hosting them may be an issue. According to the most recent opinion of the STECF (Review of DC MAP – Part 1 (STECF-13-06) - page 20[1]), 'end-users' of scientific data include the European Commission, national governments, RFMOs, ICES, STECF, Advisory Councils, NGOs and universities. Therefore, access should be provided effortlessly.

### Pilot studies

As a second step, and upon identifying gaps and/or inconsistencies in the datasets, a series of pilot studies may have to be launched so that to formulate a sampling scheme tailored to monitor D1 species lacking desired information. Although these approaches may be species and region specific, they must share compatible sampling techniques allowing for comparisons of results among areas.

[1] https://stecf.jrc.ec.europa.eu/documents/43805/506417/STECF+13-06+-+DC-MAP+review+part+1.pdf

## Conclusions

This inventory of indicators, which focuses on the methods to set thresholds or assessment values, is the first step to harmonise these methods at the highest possible level. In addition, the list of indicators provides good practices, some well tested, with potential to be applied to any of the three levels of harmonisation (Figure 4). This process denotes that the indicators and their methods to set threshold values should go through a detailed evaluation and testing, considering the challenges and objectives derived from the Commission Decision 2017/848/EU (European Commission, 2017).

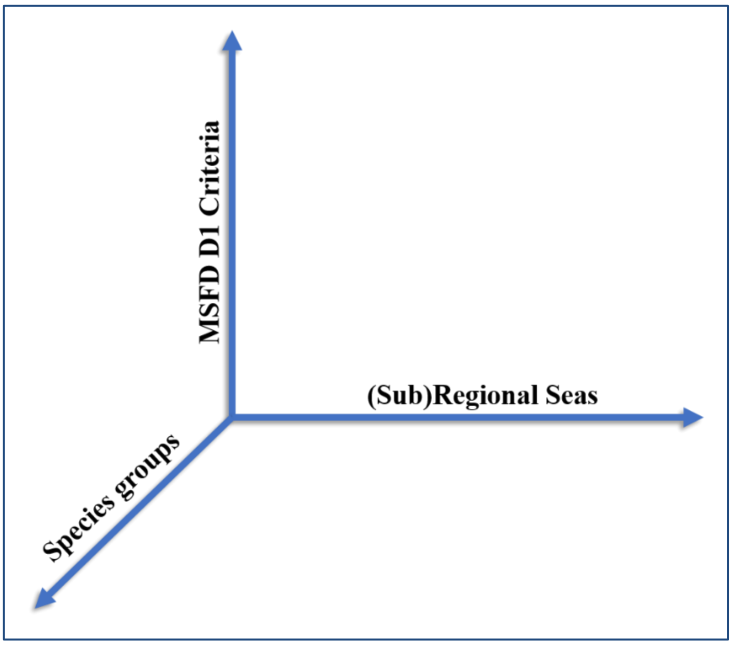



**Figure 4.** The three levels at which the methodological standards and the threshold setting processes need to be harmonised, to achieve consistent GES determination for the species assessed under the MSFD.

At the species group level, there are several indicators for some marine mammals, especially for seals and less for whales, in all relevant regions. Most of them developed for the specific group, including agreed ecological objectives or specific population characteristics (e.g. targeted growth rate). The challenge in this case is to agree on a single method with the potential to be applied to the regions that have similar species and populations, given the wide distributional range of these species. As all marine mammals are in the HD annexes (European Union, 1992), the methods developed for the HD should be considered for the MSFD methods' harmonisation process.

Well-developed and tested methods have been applied for the marine birds, achieving a remarkable level of harmonisation in the Baltic and the Northeast Atlantic regions. The next step will be to explore the potential to apply them to the Mediterranean and the Black Sea. However, the short time-series and the very few marine birds with adequate information to apply such methods might hinder a direct testing. Nevertheless, this exercise is an opportunity for the Member States and the RSCs to identify data gaps and cover them through updates of their monitoring programmes with targeted parameters, considering the emerging requirements.

Very few indicators, species specific, have been developed for fish and cephalopods. This was expected because not all RSCs have the mandate to deal with fisheries (e.g. Barcelona Convention), which in this case is covered by other organisations (GFCM in the Mediterranean). In addition, in the first MSFD cycle, it was not clear which fish and cephalopods species are assessed for the MSFD Descriptor 1 and which under Descriptor 3. On the other hand, the CFP collects data for all fish and cephalopod species and has well developed and tested methods, which were not yet applied to the MSFD. Thus, we performed a thorough scan of such methods and their data requirements, believing that the CFP was not considered at its full capacity. The proposed methods can complement the assessment of species that do not have developed indicators.

At the level of the MSFD criteria the operational or developing indicators cover well the population abundance (D1C2) and the distributional range (D1C4) and less the other criteria. This was expected, because of the overlap of the two criteria with the Habitat Directive (European Union, 1992). For the birds' group the demographic characteristics are well covered, more adequately compared to other groups. This indicates that depending on the life cycle of the species-specific criteria some can be more informative for population characteristics rather than for distributional range. For instance, the breeding success for a bird species can be more informative for the status of the population compared with the distributional range. Of course, these causal links should always be interpreted according to the prevailing pressures.

The evaluation of the threshold setting approaches should be in-line with the concepts and requirements described in Art. 4 of the Decision 2017/848/EU (European Commission, 2017) in relation to the Good Environmental Status (GES) determination. Common agreed methods for setting thresholds will secure the harmonisation in the GES determination for the MSFD species. Eventually, the GES determination for species with distributional range beyond the national waters, or at regional scale will have a unique classification status, facilitating the decision to apply measures to particular pressures.

# References


ASCOBANS, 2015. Report of the ASCOBANS Workshop on the Further Development of Management Procedures for Defining the Threshold of 'Unacceptable Interactions' Part I: Developing a Shared Understanding on the Use of Thresholds/Environmental Limits. London, United Kingdom, 10 July 2015.

Baker, C. S., Steel, D., Nieukirk, S., & Klinck, H., 2018. Environmental DNA (eDNA) From the Wake of the Whales: Droplet Digital PCR for Detection and Species Identification. Frontiers in Marine Science, 5, 133.

BirdLife International, 2015. European Red List of Birds. Luxembourg: Office for Official Publications of the European Communities

Barcelona Convention, 2017. Mediterranean Quality Status Report; https://www.medqsr.org/biodiversity-and-ecosystems.

BSC, 2017. Black Sea integrated monitoring and assessment program for years 2017-2022. [http://ec.europa.eu/environment/marine/international-cooperation/regional-sea-conventions/bucharest/pdf/BSIMAP_2017_to_2022_en.pdf].

Buckland S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L., 2001. *Introduction to Distance Sampling: estimating abundance of biological populations.* Oxford University Press.

CODA, 2009. *Cetacean Offshore Distribution and Abundance in the European Atlantic* (CODA), 43pp.

Cook, A.S.C.P., Calbrade, N.A., Austin, G.E. and Burton, N.H.K., 2011. Determining foraging use of the Dee estuary by common terns from the recent declining colony at the Shotton Lagoons and Reedbeds SSSI. BTO report to CCW, Thetford.

Cook, A.S.C.P., Robinson, R.A. and Ross-Smith, V.H., 2014. Development of MSFD Indicators, Baselines and Target for Seabird Breeding Failure Occurrence in the UK (2012), JNCC Report 539, ISSN 0963 8901.

Cook A.S.C.P., Dadam, D., Mitchell, I., Ross-Smith, V.H. and Robinson, R.A., 2014a. Indicators of seabird reproductive performance demonstrate the impact of commercial fisheries on seabird populations in the North Sea. Ecological Indicators 38: 1–11.

Cury, P.M., Boyd, I.L., Bonhommeau, S., Anker-Nilssen, T., Crawford, R.J.M., Furness, R.W., Mills, J.A., Murphy, E.J., Österblom H., Paleczny, M., Piatt, P.F., Roux, J.-P., Shannon, L. and Sydeman, W.J., 2011. Global seabird response to forage fish depletion – one-third for the birds. Science 334: 1703–1706.

DG Environment, 2017. *Reporting under Article 17 of the Habitats Directive: Explanatory notes and guidelines for the period 2013-2018*. Brussels. Pp 188.

DG Environment, 2017a*. Reporting on species and habitats under MSFD and HBD. Habitats and Birds Directives*. Expert Group on Reporting, MSFD CIS 2017. https://circabc.europa.eu/w/browse/73c25322-7ed8-4739-8c6e-5b66c9d30171.

DG Environment, 2017b. *Reporting under Article 12 of the Birds Directive: Explanatory notes and guidelines for the period 2013-2018*. Brussels. Pp 63.

Edwards, Charles TT, 2015. *Review of data-poor assessment methods for New Zealand fisheries*. Ministry for Primary Industries.

Englund, A., Ingram, S. and Rogan, E., 2007. Population status report for bottlenose dolphins using the Lower River Shannon SAC, 2006–2007. Final report to the National Parks and Wildlife Service.

Epstein, Y., López-Bao, J. V., & Chapron, G., 2016. A Legal-Ecological Understanding of Favorable Conservation Status for Species in Europe. Conservation Letters, 9(2), 81–88. https://doi.org/10.1111/conl.12200.

ETC/BD, 2011. *Assessment and reporting under Article 17 of the Habitats Directive: Explanatory Notes & Guidelines for the period 2007-2012.* Brussels. Pp123.

ETC/BD, 2014. *Article 17 Reporting – Assessments of conservation status at the EU biogeographical level - Public consultation*. ETC/BD Technical paper 3/2014, Paris.

European Commission, 1999. *Protocol Concerning Specially Protected Areas And Biological Diversity In The Mediterranean*, Annex II. L 322.

European Commission, 2008*, Directive 2008/56/EC of the European Parliament and the Council establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)*. L 164/19-40.

European Commission, 2008, *Commission Implementing Decision (EU) 2016/1251 of 12 July 2016 adopting a multiannual Union programme for the collection, management and use of data in the fisheries and aquaculture sectors for the period 2017-2019.* L 207/113.

European Commission, 2017, *Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU*. L 125/43.

European Union, 1992, *Council Directive 92 /43 /EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.* L. 206/7.

European Union, 2004, *COUNCIL REGULATION (EC) No 812/2004 of 26.4.2004 laying down measures concerning incidental catches of cetaceans in fisheries and amending Regulation (EC) No 88/98.* L 150/12.

European Union, 2009, *Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds*. L 20/7.

European Union, 2017a, Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008. L 157/1.

Evans, N. T., Olds, B. P., Renshaw, M. A., Turner, C. R., Li, Y., Jerde, C. L., ... & Lodge, D. M., 2016. Quantification of mesocosm fish and amphibian species diversity via environmental DNA metabarcoding. Molecular ecology resources, 16(1), 29-41.

FISBOAT, 2007. FISBOAT - Fisheries Independent Survey-Based Operational Assessment Tools, Final Activity Report. Available at: http://www.ices.dk/explore-us/projects/EU-RFP/Pages/FP6-FISBOAT.aspx

Fortin, M., Keitt, T., Maurer, B., Taper, M., Kaufman, D., Blackburn, T., 2005. Species' geographic ranges and distributional limits: pattern analysis and statistical issues. Oikos 108, 7-17.

Froese, R., Demirel, N., Coro, G., Kleisner, K. M., & Winker, H., 2017. Estimating fisheries reference points from catch and resilience. Fish and Fisheries, 18(3), 506-526.

Gilles, A., Viquerat, S., Becker, E.A., Forney, K.A., Geelhoed, S.C.V., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U., Sveegaard, S., van Beest, F.M., van Bemmelen, R. and Aarts, G., 2016. Seasonal habitat-based density models for a marine top predator, the harbor porpoise, in a dynamic environment. Ecosphere7 (6): e01367. 10.1002/ecs2.1367.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F. & Øien, N., 2002. Abundance of harbour porpoises and other cetaceans in the North Sea andadjacent waters. Journal of Applied Ecology 39: 361-376.

Greenstreet, S.P.R., Rossberg, A.G., Fox, C.J., Le Quesne, W.J.F., Blasdale, T., Boulcott, P., Mitchell, I., Millar, C., and Moffat, C.F., 2012. Demersal fish biodiversity: species-level indicators and trends based targets for the Marine Strategy Framework Directive. ICES Journal of Marine Science, 69, 1789–1801.

Guisan, A., & Zimmermann, N. E., 2000. Predictive habitat distribution models in ecology. Ecological modelling, 135(2-3), 147-186.

Hammond, P.S. et al., 2013. Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation, 164, 107–122.

HELCOM, 2013a. *HELCOM Red List of Baltic Sea species in danger of becoming extinct*. Balt. Sea Environ. Proc. No. 140.

HELCOM, 2018. Number of drowned mammals and waterbirds in fishing gear. HELCOM core indicator report. Online. [5/7/2018], [http://www.helcom.fi/Core%20Indicators/Number%20of%20drowned%20mammals%20and%20waterbirds%20HELCOM%20core%20indicator%202018.pdf]. ISSN 2343-2543

HELCOM, 2018a. Abundance of waterbirds in the wintering season. HELCOM core indicator report. Online. [5/7/2018], [http://www.helcom.fi/baltic-sea-trends/indicators/abundance-of-waterbirds-in-the-wintering-season/]. ISSN 2343-2543.

HELCOM, 2018b. Population trends and abundance of seals. HELCOM core indicator report. Online. [16/7/2018], [http://www.helcom.fi/baltic-sea-trends/indicators/population-trends-and-abundance-of-seals/]. ISSN 2343-2543.

HELCOM, 2018c. Abundance of salmon spawners and smolt. HELCOM core indicator report. Online. [16/7/2018], [http://www.helcom.fi/baltic-sea-trends/indicators/abundance-of-salmon-spawners-and-smolt/]. ISSN 2343-2543.

HELCOM, 2018d. Abundance of sea trout spawners and parr. HELCOM core indicator report. Online. [16/7/2018], [http://www.helcom.fi/baltic-sea-trends/indicators/abundance-of-sea-trout-spawners-and-parr/]. ISSN 2343-2543.

HELCOM, 2018e. Abundance of coastal fish key species. HELCOM core indicator report. Online. [16/7/2018], [http://www.helcom.fi/baltic-sea-trends/indicators/abundance-of-key-coastal-fish-species]. ISSN 2343-2543.

HELCOM, 2018f. Reproductive status of marine mammals. HELCOM core indicator report. Online. [16/7/2018], [http://www.helcom.fi/Core%20Indicators/Reproductive%20status%20of%20seals%20HELCOM%20core%20indicator%202018.pdf]. ISSN 2343-2543.

HELCOM, 2018g. Distribution of Baltic seals. HELCOM core indicator report. Online. [16/7/2018], [http://www.helcom.fi/baltic-sea-trends/indicators/distribution-of-baltic-seals/]. ISSN 2343-2543.

Holt, D.W., 1994. Effects of short-eared owls on common tern colony desertion, reproduction, and mortality. Colonial Waterbirds 17: 1-6.

ICES, 2008. *Report of the Workshop on Seabird Ecological Quality Indicator*, 8–9 March 2008, Lisbon, Portugal. ICES CM 2008/LRC:06. 60 pp.

ICES, 2010. EC request on cetacean bycatch Regulation 812/2004, Item 3. ICES Advice 2010, Book 1, 1.5.1.5. Special Request Advice October 2010.

ICES, 2011. Report of the Working Group on Seabird Ecology (WGSE). 1–4 November 2011, Madeira, Portugal. ICES CM 2011/SSGEF:07. 77 pp.

ICES, 2013. Report of the Working Group on Marine Mammal Ecology (WGMME), February 4-7, Paris, France. ICES CM 2013/ACOM:26. 117 pp.

ICES, 2015. Report on the Working Group on Ecosystem Effects of Fishing (WGECO). 8 – 15 April 2015. ICES CM 2015/ACOM:24.

ICES, 2015b. Report of the Working Group on Bycatch of Protected Species (WGBYC), 2–6 February 2015, Copenhagen, Denmark. ICES CM 2015/ACOM:26. 77 pp.

ICES. 2015c. Report of the Joint ICES/OSPAR/HELCOM Working Group on Seabirds (JWGBIRD), 9–13 November 2015, Copenhagen, Denmark. u117234. 42 pp.

ICES, 2016. Report on the Working Group on Ecosystem Effects of Fishing (WGECO). 6 – 13 April 2016. ICES CM 2016/ACOM:25.

ICES 2016a. Bycatch of small cetaceans and other marine animals – Review of national reports under Council Regulation (EC) No. 812/2004 and other published documents. ICES Advice 2016, Book 1, 1.6.1.1; Advice Northeast Atlantic and adjacent seas. Published 15 April 2016.

ICES, 2016b. Working Group on Bycatch of Protected Species (WGBYC), 1–5 February 2016, ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM:27. 82 pp.

ICES, 2017. Report of the OSPAR/HELCOM/ICES Working Group on Marine Birds (JWGBIRD), 6-10 November 2017, Riga, Latvia. ICES CM 2017/ACOM:49. 98 pp.

IUCN, 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission Gland, Switzerland and Cambridge, UK. 32pp

IUCN, 2012. IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp. ISBN: 978-2-8317-1435-6.

IWC, 2000. Report of the IWC-ASCOBANS Working Group on harbour porpoises. Journal of Cetacean Research and Management 2 (supplement): 297-305. IWC (2004). Report of the Scientific Committee. Journal of Cetacean Research and Management (supplement) 6: pp12-13; 88-89; 171-183.

Jones, E., McConnell, B., Sparling, C., Mattiopoulos, J., 2013. Grey and harbour seal usage maps. Marine Mammal Scientific Support Research Programme MMSS/001/11. Currently available from: http://www.scotland.gov.uk/Topics/marine/science/MSInteractive/Themes.

Jüssi, M., Härkönen, T., Jüssi, I., Helle, E., 2008. Decreasing ice coverage will reduce the reproductive success of Baltic grey seal (Halichoerus grypus) females. Ambio 37: 80–85.

Lacoursière-Roussel, A., Côté, G., Leclerc, V., & Bernatchez, L., 2016. Quantifying relative fish abundance with eDNA: a promising tool for fisheries management. Journal of Applied Ecology, 53(4), 1148-1157.

Lassen, H., Kelly, C., and Sissenwine, M., 2014. ICES advisory framework 1977–2012: from MSY to precautionary approach and back. ICES Journal of Marine Science, 71: 166–172.

McAllister, M.K., Pikitch, E.K. and E.A. Babcock, 2001. Using demographic methods to construct Bayesian priors for the intrinsic rate of increase in the Schaefer model and implications for stock Rebuilding, Can. J. Fish. Aquat. Sci., 58, 1871–1890.

Martell, S. and Froese, R., 2013. A simple method for estimating MSY from catch and resilience. Fish and Fisheries 14, 504–514.

Mitchell Sean C., 2005. How useful is the concept of habitat? - a critique. Oikos 110, no. 3 (9): 634-638.

Moore, J. E., Curtis, K. A., Lewison, R. L., Dillingham, P. W., Cope, J. M., Fordham, S. V., ... & Zhou, S., 2013. Evaluating sustainability of fisheries bycatch mortality for marine megafauna: a review of conservation reference points for data-limited populations. Environmental Conservation, 40(4), 329-344.

Nieto, A., Ralph, G.M., Comeros-Raynal, M.T., Kemp, J., García Criado, M., Allen, D.J., et al., 2015. European Red List of marine fishes. Luxembourg: Publications Office of the European Union.

Osio, G. C., Orio, A., & Millar, C. P., 2015. Assessing the vulnerability of Mediterranean demersal stocks and predicting exploitation status of un-assessed stocks. Fisheries Research, (171), 110-121.

OSPAR, 2008. OSPAR list of Threatened and/or Declining Species and Habitats. OSPAR Commission (Reference number 2008-6).

OSPAR, 2012. MSFD Advice Manual and Background Document on Biodiversity; Version 3.2 of 5 March 2012. Approaches to determining good environmental status, setting of environmental targets and selecting indicators for Marine Strategy Framework Directive descriptors 1, 2, 4 and 6. ISBN 978-1-909159-14-3. Publication Number: 581/2012 [https://www.ospar.org/work-areas/cross-cutting-issues/msfd/msfd-advice-manuals].

OSPAR, 2016. Proposed assessment values for common and candidate indicator. Meeting of the OSPAR Commission. OSPAR 16/3/3 Rev.1. Tenerife: 20–24 June 2016.

OSPAR, 2018. Harbour Porpoise Bycatch. Intermediate Assessment 20167. Online. [5/7/2018], [https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-mammals/harbour-porpoise-bycatch].

OSPAR, 2018b. Seal abundance and distribution. IA 2017. Online [5/7/2018], in: [https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-mammals/seal-abundance-and-distribution/].

OSPAR, 2018c. Abundance and Distribution of Coastal Bottlenose Dolphins. Online. [5/7/2018], [https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-mammals/abundance-distribution-cetaceans/abundance-and-distribution-coastal-bottlenose-dolphins/].

OSPAR, 2018d. Grey Seal Pup Production. Online. [5/7/2018], [https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-mammals/grey-seal-pup/].

OSPAR, 2018f. Marine Bird Abundance. Online. [7/1/2018], [https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-birds/bird-abundance/].

Palialexis, A., V. Tornero, E. Barbone, D. Gonzalez, G. Hanke, A. C. Cardoso, N. Hoepffner, S. Katsanevakis, F. Somma and N. Zampoukas, 2014. *In-depth assessment of the EU Member States' submissions for the Marine Strategy Framework Directive under Articles 8, 9 and 10*, Publications Office of the European Union, Luxembourg. doi:10.2760/794186.

Palialexis A., A.C. Cardoso, F. Somma, 2018. *JRC's reference lists of MSFD species and habitats,* EUR 29125 EN, doi:10.2760/794186.

Pedersen, M. W. and Berg, C. W., 2017, A stochastic surplus production model in continuous time. Fish Fish, 18: 226-243. doi:10.1111/faf.12174.

Punt A.E., Hilborn R., 1996. Biomass dynamic models. User's manual. FAO Computerized Information Series (Fisheries) No.10. Rome, FAO:62pp

Pyle R.L., 1996. How much coral reef biodiversity are we missing? Global Biodiversity 6(1), 3-7.

Pyle R.L., 1998. Use of advanced mixed-gas diving technology to explore the coral reef "twilight zone" pp. 71-88. In: Tanacredi J.T. & Loret J. (eds.) Ocean Pulse: A Critical Diagnosis. Plenum Press, New York.

Pyle R.L., 2000. Assessing undiscovered fish biodiversity on deep coral reefs using advanced closed-circuit rebreather diving technology. Marine Technology Society Journal 34(4), 82-91.

Quinn, T., Deriso R.B., 1999. Quantitative fish dynamics. Oxford Univ. Press: 542pp

Samoilys M.A. and Gribble N., 1997. Introduction, pages 1-6. In: Samoilys M.A. (ed.) Manual for Assessing Fish Stocks on Pacific Coral Reefs. Department of Primary Industries, Townsville, Australia.

SCOS, 2014. Scientific advice on matters related to the management of seal populations, 2014. Scientific Committee on Seals (SCOS). [http://www.smru.st-and.ac.uk/documents/2259.pdf].

Seaman W., 2000. Artificial Reef Evaluation, with application to natural marine habitats. CRC Press LLC, ISBN 0-8493-9061-3.

Shealer, D.A. and Kress, S.W, 1991. Nocturnal abandonment response to black-crowned night-heron disturbance in a common tern colony. Colonial Waterbirds, 14, 51-56.

Svensson, C.J., Hansson, A., Harkonen, T., Harding, K., 2011. Detecting density dependence in growing seal populations. Ambio. 40: 52–59. DOI 10.1007/s13280-010-0091-7.

Taberlet, P., Coissac, E., Hajibabaei, M. and Rieseberg, L. H., 2012, Environmental DNA. Molecular Ecology, 21: 1789-1793. doi:10.1111/j.1365-294X.2012.05542.x.

Taylor, B., Chivers, S. J., Larese, J. and Perrin, B., 2007. Generation length and percent mature estimates for IUCN assessments of cetaceans. Southwest Fisheries Science Center. Administrative report LJ-07-01, 18 pp.

Temple, H.J. and Terry, A. (Compilers), 2007. *The Status and Distribution of European Mammals*. Luxembourg: Office for Official Publications of the European Communities.

Thanopoulou Z, Sini M, Vatikiotis K, Katsoupis C, Dimitrakopoulos PG, Katsanevakis S., 2018. How many fish? Comparison of two underwater visual sampling methods for monitoring fish communities. PeerJ 6: e5066, [https://doi.org/10.7717/peerj.5066].

Thompson, P. M., Lusseau, D., Corkrey, R. and Hammond, P. S., 2004. Moray Firth bottlenose dolphin monitoring strategy options. Scottish Natural Heritage Commissioned Report No. 079 (ROAME No. F02AA409).

Trenkel, V.M., 2007. A biomass random effects model (BREM) for stock assessment using only survey data: application to Bay of Biscay anchovy. ICES CM 2007/O:03.

UNEPMAP, 2017. IMAP Common Indicator Guidance Facts Sheets (Biodiversity and Fisheries). UNEP(DEPI)/MED WG.444/6/Rev.1. Athens, 11 July 2017.

UNEPMAP, 2018. Progress Report on the implementation of Decision IG.22/7 on the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP). Regional Meeting on IMAP Implementation: Best Practices, Gaps and Common Challenges. Rome, Italy, 10-12 July 2018. UNEP/MED WG.450/3.

Vanhatalo, J., Vetemaa, M., Herrero, A., Aho, T., Tiilikainen, R., 2014. By-catch of grey seals (Halichoerus grypus) in Baltic fisheries – a Bayesian analysis of interview survey. Plos One. doi:10.1371/journal.pone.0113836.

Walker, N. D., García-Carreras, B., Maxwell, D. L., Le Quesne, W. J. F. and Jennings, S., 2019. A data-limited approach for estimating fishing mortality rates and exploitation status of diverse target 15 and non-target fish species impacted by mixed multispecies fisheries. ICES Journal of Marine 16 Science, DOI: 10.1093/icesjms/fsy205.

Winship, A.J., 2009. Estimating the impact of bycatch and calculating bycatch limits to achieve conservation objectives as applied to harbour porpoise in the North Sea. PhD thesis, University of St Andrews, UK. Available from: http://research-repository.st-andrews.ac.uk/handle/10023/715.

Zhou, S., Yin, S., Thorson, J.T., Smith, A.D.M. & Fuller, M., 2012. Linking fishing mortality reference points to life history traits: an empirical study. Canadian Journal of Fisheries and Aquatic Sciences 69, 1292–1301.

**GETTING IN TOUCH WITH THE EU**

**In person**

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

**On the phone or by email**

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

- at the following standard number: +32 22999696, or

- by electronic mail via: https://europa.eu/european-union/contact_en

**FINDING INFORMATION ABOUT THE EU**

**Online**

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

**EU publications**
You can download or order free and priced EU publications from EU Bookshop at: https://publications.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

KJ-NA-29820-EN-N

## The European Commission's science and knowledge service

Joint Research Centre

### JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

**EU Science Hub**
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2760/282667
ISBN 978-92-76-09156-1