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WP3 - Proposal of coordinated subregional assessment, GES determination and monitoring strategy for cetacean bycatch.

Task 3.3. Common approach to GES determination and threshold values for D1C1

CetAMBICion

Coordinated Cetacean Assessment, Monitoring and Management Strategy in the Bay of Biscay and Iberian Coast subregion

Work Package 3 Task 3.3

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The CetAMBICion project, coordinated by the Spanish National Research Council (CSIC) and which includes 15 partners from Spain, France and Portugal, aims to strengthen collaboration and scientific work between the three countries to estimate and reduce cetacean bycatch in the Bay of Biscay and Iberian Coast subregion, in close collaboration with the fishing industry. Until 2023, the project will work to improve scientific knowledge on population abundance, incidental bycatch and on mitigation measures for the latter.

The project is part of the European Commission's DG ENV/MSFD 2020 (Marine Strategy Framework Directive) call and the objectives are aligned with the Habitats Directive and the Common Fisheries Policy.

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Executive summary

The objective of task 3.3 of the project CetAMBICion is to agree on both a common approach to Good Environmental Status (GES) and threshold values for D1C1 (bycatch rate), within the scope of the project. The present deliverable aims to provide the theoretical framework for the discussion and establishment of incidental bycatch thresholds and common GES assessment for the criteria, at subregional level. To this end, a review of the literature and current legislation on the subject was carried out to define the terms involved in decision-making. In addition, with the purpose of presenting real cases of the use of different thresholds to assist in the decision on the establishment of a limit for the subregion, a review of the bycatch thresholds implemented or suggested by other countries, organizations, and institutions, was made.

Firstly, the Marine Strategy Framework Directive defines the criteria D1C1 ("*The mortality rate per species from incidental bycatch is below levels which threaten the species, such that its long-term viability is ensured*"), as well as which species should be assessed and the requirement for subregional cooperation, when applicable. A clear European Union law-based definition of threshold values is also provided: when applied to bycatch, they represent the limit of anthropogenic mortality that must not be exceeded in order to reach specific conservation objectives. In turn, they must be defined in quantitative terms to be easily translated into management objectives that can be quantitatively assessed. Further definition of the conservation objectives, their purpose and recommended requirements is provided, together with some conservation objectives proposed in different regions and by different organisms, as examples.

Once the conservation objective to be achieved is defined, it is necessary to decide on the methodology to be used to set the bycatch thresholds that will lead to the achievement of the objective. Since there are several methodologies with different data requirement and different outputs and reliabilities, the main methods currently available for estimating bycatch thresholds are described together with their characteristics and data requirements.

Finally, the basis for GES assessment and determination for the criteria (D1C1) are discussed. The main conclusions of which are: (i) the main challenge is to have the necessary and accurate data to perform the assessment, which will be ultimately driven by the ongoing monitoring programmes, and (ii) the relevance of the harmonisation of the methodological standards and threshold setting process at every level to achieve consistent GES determination.

In the context of the CetAMBICion project, thanks to the workshop held in Vigo (Spain) in November 2022, an extensive discussion took place to try to reach a common approach to GES determination and threshold values for D1C1. The discussion covered all the aspects related to the establishment of conservation and management objectives, including the ambition, risk levels and the time horizon. The OMMEG (OSPAR Marine Mammal Expert Group) interpretation of the ASCOBANS conservation objective was taken as reference. So, the conservation objective considered for proposal that could be investigated in a future MSE will have an ambition level between 50 and 80% of the carrying capacity, with a low risk level (probability of 0.95) and with a reduced time horizon of 50 years. Regarding the methodology, there was an agreement in the use of the most realistic biological model in the MSE (Management Strategy Evaluation), thus forcing the methodology to be species-specific.

The need of linking conservation and management objectives was highlighted, emphasizing the key role of the organisms and entities involved in decision-making and their participation in these processes. For the GES determination, the discussion was shorter and the main idea considered was the use of the “one-out all-out rule”.

1. Introduction

In the context of the Marine Strategy Framework Directive [1], the Good Environmental Status (GES) of the marine environment is defined in relation to eleven descriptors [2], set out in the Annex I of the MSFD.

The Descriptor 1 provides a definition of GES regarding biological biodiversity (*Biological biodiversity is maintained*) and one of the **primary criterion defining GES** is the D1C1 – "*The mortality rate per species from incidental bycatch is below levels which threaten the species, such that its long-term viability is ensured*". The **criteria elements** for this criterion include species of birds, mammals, reptiles and non-commercially-exploited species of fish and cephalopods [2]. This **list of species** is to be established by the Member States (MS) considering the list of species in Table 1D of the Annex to Commission Implementing Decision (EU) 2016/1251 [3] (repealed by Commission Implementing Decision (EU) 2019/909 (until 31/12/2021) [4], later repealed by Commission Implementing Decision (EU) 2021/1168) [5]. Additionally, the Commission Decision 2017/848 [2] lists the species groups for which GES needs to be assessed. Given that most of these species are highly mobile, regional or **subregional cooperation** between MS is required for their establishment and to ensure that the assessments are coherent and coordinated. Moreover, the Article 5 of the MSFD recommends cooperation between the MS sharing a marine region or subregion, if possible, taking advantage of existing regional cooperation structures (e.g., Bern Convention (1979), Barcelona Convention (1995, Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean), OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic), ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas), ACCOBAMS (Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area)).

To **quantitatively measure the impact of incidental bycatch** (i.e., to assess D1C1) on protected, endangered and threatened species (PETS) populations or assessment units (AU), MS shall establish threshold values for the mortality rate from incidental bycatch per species, also through regional or subregional cooperation if applicable [2]. The Commission Decision 2017/848 [2] defines **threshold** as the value, or range of values, that allow for an assessment of the quality level achieved for a particular criterion, thereby contributing to the assessment of the extent to which GES is being achieved.

More specifically, the **threshold values for incidental bycatch** usually represent limits to anthropogenic mortality not to be exceeded in order to reach specific

conservation objectives (e.g., restore or maintain GES). Conservation objectives translate into short-term **management objectives** that are measurable milestones and allow to assess whether the longer-term conservation objectives are likely to be met. In fact, in most of the marine **regional assessment** methodologies and EU Directives, thresholds are defined as environmental objectives in relation to an appropriate condition [6], [7]. Thus, thresholds are precautionary and are dependent on the **quantitative conservation objectives** set, so they should be in line with them [8]. When total or estimated bycatch is measured against these threshold values or reference points, it allows to **measure the potential long-term impact** of anthropogenic removals on PETS and, therefore, to **assess** the conservation status and the long-term viability of the species [9], [10].

Marine mammal species are affected by **multiple pressures**: the responses to those pressures, and their cumulative impacts, are difficult to investigate and measure. Thus, biodiversity-related thresholds, such as those of incidental bycatch, cannot be set as a specific deviation from background or natural levels (e.g., as it is set for contaminants or eutrophication), but may be built based on more diverse methods [11]. The inclusion of other pressures that result in anthropogenic removals would benefit the assessments, refining bycatch-only thresholds, although it may result in lower limits for the aforementioned [12].

With the objective of a **coordinated and comparable subregional assessment** of anthropogenic cetacean removals in the ABI, there is a need to unify the methods used to set threshold values for the GES criteria [11].

The guidance of Article 8 [13] establishes the following steps: 1) Determine the elements for the assessment (list of species, e.g., marine mammals); 2) Determine the criteria to address (e.g., mortality rate from incidental bycatch); 3) Determine the scale and the area for the assessment (which should be ecologically relevant for each species group, e.g., ABI subregion for common dolphin); 4) Assign indicators; 5) Establish threshold values; 6) Assess criterion against thresholds (i.e., compare observed values with the thresholds set); 7) Determine environmental status and extent of GES achievement (or not) by species with the previous steps; and finally 8) Integrate species.

2. Conservation objectives

Introduction

Conservation objectives are the drivers of policy [14]. They can address different purposes including the definition of what is the favourable status of a species (or habitat) or the monitoring of species vulnerability and risk of extinction. Their purpose, in terms of cetacean bycatch, is to "*establish levels of anthropogenic pressure beyond which the species [...] could be negatively impacted*" [14]. The operative expression 'negatively impacted' needs further clarification and to be translated into precise quantitative terms, to define appropriate management objectives that align with the conservation objectives.

The establishment of conservation objectives is a fundamental and decisive step when setting threshold values for incidental bycatch [15] and they need to be described in specific quantitative terms, which is not always the case [16], not even in the European legislation [17].

For example, the International Council for the Exploration of the Sea (ICES) has repeatedly asked the European Commission for explicit conservation objectives to issue recommendations on the efficient management of interactions between fisheries and marine mammal populations [15]. In 2007, the ICES Working Group on Marine Mammal Ecology (WGMME) stressed how «quantitative objectives for the conservation status assessments of [marine mammals] have yet to be set by policy makers. These conservation objectives may include population size (relative to carrying capacity), minimum population size at which bycatch would be allowed and the delay in recovery of a depleted population under the management framework» [18, page 29]. In 2009, WGMME requested advice from the European Commission (DG MARE) on conservation objectives for management actions addressing both harbour porpoises and common dolphins [19, page 95][20]. In 2013, WGMME stressed that the following policy decisions were needed to properly consider the impacts of interactions between fisheries and marine mammal populations:

· "A decision is required on whether the conservation objective should be met on average or some other percentage of the time. This choice will have a significant influence on the population level as a percentage of carrying capacity achieved in the long term (if greater than % the population level achieved in the long term will exceed the specified target)" (ICES 2013; page 46)[21];

· a policy decision is required on the quantitative definition of "long term" and WGMME proposed to use 100 years [21, page 47].

The lack of decisions has been the primary reason for stopping the computation of thresholds [22, page 54]. WGMME recommended that "[the] European Commission gives serious consideration to ICES offer to host a workshop, with the objective of [...] finalising conservation objectives for a by-catch limit approach that would enable conservation aspiration to be met" [22, page 54].

Conservation objectives

Some of the most relevant conservation objectives proposed in different regions throughout the world are described below:

- **ASCOBANS** resolution on Incidental Take of Small Cetaceans [15], [23]: "*to allow populations to recover to and/or maintain 80% of carrying capacity in the long term*". Carrying capacity is the population size that would, theoretically, be reached by a population in the absence of bycatch. Importantly though, it is not necessary to know what the actual carrying capacity is to determine safe limits to bycatch. This conservation objective comes from the original ASCOBANS Incidental Take Resolution ("*to restore and/or maintain biological or management stocks of small cetaceans at the level they would reach when there is the lowest possible anthropogenic influence*") [24].

  It was developed for harbour porpoise, in 2000, within a joint International Whaling Commission (IWC)/ASCOBANS workshop [25], although it has been used for other small cetacean species. HELCOM, in 2018, considered it the most appropriate method to set anthropogenic mortality limits on harbour porpoises [6]. Also for harbour porpoise, following this conservation objective, ASCOBANS proposed (1) as "unacceptable interactions" a threshold of 1.7% of the best available estimate of abundance for total anthropogenic removals in the short term [23], [25] (i.e., all anthropogenic removals and not just mortality from bycatch) and (2) an intermediate "precautionary objective" to reduce bycatch to less than 1% of the best available abundance estimate with the general aim to minimize bycatch (i.e., to ultimately reduce it to zero). Later, in 2015, ASCOBANS [26] acknowledged that 1.7% was only appropriate for non-depleted populations, in which case a zero-bycatch approach would be more appropriate to ensure recovery. In addition, data gaps and the assumptions made on some of the input parameters for its calculation (i.e., life history parameters or abundance estimates) could produce a high uncertainty around the estimated value.

  Furthermore, these two management objectives (1 and 1.7%) may be considered simplistic/oversimplified as they were determined from simple deterministic population dynamics models created with little biological information on the species, and which do not consider the uncertainty in the population dynamics [14], [15], [27].

- **OSPAR** has a common indicator (M6) dedicated to assessing marine mammal bycatch in the OSPAR maritime area. In 2017, no assessment of the bycatch impact could be carried out in the OSPAR Intermediate Assessment because of a lack of agreed-upon thresholds and methodology to set them. The OSPAR Marine Mammal Expert Group (OMMEG) worked to address this gap for the Quality Status Report of 2023 and proposed the following conservation objective "*a population should be able to recover to or be maintained at 80% of carrying capacity, with probability 0.8, within a 100-year period*". This objective clearly states a time horizon (100 years, as recommended by ICES [28] and a given probability level (0.8, meaning a risk of 0.2 of failing to reach the conservation objective is deemed acceptable). It is a quantitative interpretation of the ASCOBANS interim objective described above, and represents a higher standard related to the carrying capacity, which will produce a lower threshold value, aggravated under conditions with bias and/or uncertainties in abundance, mortality or productivity data. The methodology to set thresholds was agreed upon at OSPAR Biodiversity Committee (BDC) in 2021, and thresholds presented at BDC in 2022. Currently, for cetacean species, OMMEG proposed to use, depending on data availability and on the species, either the modified Potential Biological Removal (mPBR) or the Removals Limit Algorithm (RLA) to set limits to anthropogenic removals in the OSPAR maritime area. These limits align with the proposed conservation objective and correspond to management objectives (i.e., threshold values), which are bycatch rates less than 1% of the best available abundance estimate for the different species. In the previous OSPAR evaluation for the North Sea (OSPAR Ecological Quality Objectives for the North Sea (EcoQ Objective adopted in the Bergen Declaration)), the management objective was that "Annual bycatch levels of harbour porpoise should be reduced to levels below 1.7% of the best population estimate" (i.e., based on the ASCOBANS short-term management objective) [29], [30].

- **US Marine Mammal Protection Act (MMPA)** [31]**:** "*a population (or assessment unit) will remain at, or recover to, its Maximum Net Productivity Level (MNPL; typically, 50% of the populations carrying capacity), with 0.95 probability, within a 100-year period*". It aims for stocks to equilibrate within Optimum Sustainable Population (OSP; defined as being at or above the population level that will result in maximum productivity [6], [22], which is modelled as being greater than the 50% carrying capacity), at least 95% of the time, assuming reasonable levels of uncertainty when estimating the population size, the bycatch levels, and/or population growth rates. Although maintaining the populations above MNPL could be a good objective, it has been proven that base management decisions solely on assessing populations status relative to it may be inadequate [16]. In the US, this conservation objective is legally binding as it lies at the core of the US MMPA, but there is no equivalent in the European Union. The US MMPA also includes the goal of reducing incidental mortality and serious injury of marine mammals to insignificant levels approaching a zero mortality and injury rate (ZMRG). Wade and Anglis [31] described the possibility of setting it as 10% of the Potential Biological Removal (PBR), acceptable for most stocks of marine mammals (or for those with a recovery factor of at least 0.5).

- **IWC Revised Management Procedure (RMP)** [32] (firstly adopted in 1994, and later reviewed in 2000, 2003, and 2004, creating the Revised Management Scheme [33]): it [its tune aims for] "*aims for 72% of carrying capacity on average, 50% of the time*". In the first method adopted by the Commission in 1994, but never implemented, there were three commercial whaling objectives with the goal of conservation and management (i.e., conservation objectives): 1) catch limits should be as stable as possible; 2) catches should not be allowed on stocks below 54% of the estimated carrying capacity; 3) the highest possible continuing catch should be obtained from the stock. The RMP was developed to allow the orderly development of the whaling industry and the conservation of large whale species. A notable difference is that catch data on whale removals are available as all catches must be reported to the IWC. In contrast, monitoring schemes dedicated to collecting bycatch data on PETS (which are not commercial species by definition) are typically poorly developed or implemented in European marine waters [34].

- **Canadian Objective Based Fisheries Management approach** [for marine mammals]: its target is to "*maintain populations at 70% of maximum abundance recorded 80% of the times*" [35]. It was based on the Precautionary Reference Level (PRL) [36]: 70% of the historical levels [of the observed or inferred maximum population size], as recommended by Hammil and Stenson (2007) [37]).

3. Methods to set thresholds

The establishment of threshold values for bycatch in cetaceans, and other PETS, is mainly influenced by (i) data availability, that is associated with a certain methodology for monitoring and obtaining data, which implementation may not be providing data with sufficient precision; and (ii) the scientific knowledge about the pressures and their temporal and spatial variability. Following the precautionary principle used in fisheries, the absence of scientific certainty, in any of these two points, or the lack of consensus, cannot be a pretext to delay the adoption of effective measures to prevent the degradation of the populations and ecosystems [38].

In the context of D1C1, thresholds are understood to represent an upper limit to the total anthropogenic removals (including others, not restricted to bycatch) beyond which the risk of failing to achieve the conservation objectives is unacceptable for the population or species [12].

ICES reviewed the different procedures available and found that the choice of the most appropriate procedure essentially depends on the choice by managers when defining the conservation objectives, assuming that the required data can be collected from the updated monitoring programmes of the MSFD [6].

The main methods available for estimating bycatch thresholds are described below.

Trend-based

Following this methodology, thresholds are set straightforward since **data requirements** are low: (i) number of animals bycaught and (ii) fishing effort. Nonetheless, to estimate reliable limits, the bycatch monitoring data has to be consistent over the years, which can be difficult to guarantee, given the inconsistencies in monitoring programmes between years and countries [39]. Furthermore, using this approach to set thresholds may be not appropriate for D1C1 [11], provided the risk of falsely indicating GES when the limit value is reached. It should be noted that for D1C1 limits are precautionary, and should go beyond the non-deterioration principle, also aiming at restoring or maintaining populations [6]. **Misleading** judgement of GES is more likely to occur for species whose populations are depleted, in which a downward trend would not indicate an improvement in their status but rather that, since there are fewer animals, the likelihood of bycatch is lower [40]. This methodology assumes implicitly that bycatch monitoring is very accurate (and dedicated) and, in particular, that data on fishing effort for fisheries at risk of causing cetacean bycatch are readily available. In practice, this is not necessarily the case. Lastly, this methodology hinges on the detection of trends, which may be challenging with short and noisy time-series data. It is a reactive rather than a proactive methodology, which runs the risk of detecting problems in an untimely manner.

Reference-based

This methodology is based on the establishment of a reference point, as a **fixed percentage** of the best population estimate. Thus, it is tied to estimating a population size [9], an endeavour that is well understood for marine mammals, and for which robust methods are readily available [41]. It uses underlying population dynamics but ignores the uncertainty associated, and does not necessarily consider life history so, it is a simple method to use, but not robust [25]. Additionally, the conservation objective underlying this method is not always clear: the fixed percentage gives a straightforward short-term management objective but the long-term goal that will be reached is not so clear. A fixed percentage can be directly compared to the maximum net productivity rate (MNPR) if expressed as an annual percentage [22]. Thus, thresholds for removals, which are an additional source of mortality on top of natural mortality, should be a fraction of the assumed or estimated value of MNPR, to consider uncertainty. The problem is that MNPR is difficult to estimate, especially for marine mammal populations, so typically generic values are used (i.e., 4% assumed for cetacean populations or 12% for pinnipeds as in the US MMPA). Therefore, there are uncertainties regarding both values [best population estimate and MNPR] that need to be assessed, but are rarely so in practice.

The **data requirements** for setting a reference point for bycatch are: (1) ideally a time-series of historical removals (and, at the very least, one contemporary estimate with its uncertainty), (2) a recent estimate of population abundance with its uncertainty and (3) the species conservation objectives. Intermediate targets can be applied when using this approach, for example, when the ultimate conservation objective is to reduce incidental bycatch of threatened species to zero (i.e., fixed percentage of 0%), considering the uncertainty in the estimated values [11]. By using this methodology without aiming at zero bycatch and if the population is recovering, the percentage should in fact increase over time as the population abundance increases.

A fixed percentage could support simple management approaches [11] and it is one of the most commonly used management approaches at the moment. However, this approach may be sensitive when determining the conservation status of some species, which could be negatively impacted in the long term [42]. So, it is necessary to move forward and encourage the use of more elaborated approaches.

Some examples of the previous or current use of fixed percentage [of the best population estimate] as a methodology for determining bycatch thresholds for different species are as follows (Table 1): 1.7% used by ASCOBANS and the previously used Ecological Quality Objective of OSPAR (EcoQ); 2% as proposed by the IWC.

Table 1. Examples of the use of fixed percentage, of the best population estimate, as a methodology for determining bycatch thresholds. The table shows the convention in which each fixed percentage (or threshold) was adopted together with the conservation objective motivating the selection of that value.

Convention	Conservation Objective	Management Objective (threshold)
ASCOBANS	*"to allow populations to recover to and/or maintain 80% of carrying capacity in the long term"*	1.7%
EcoQ (previously used by OSPAR)	For harbour porpoise: *"annual bycatch levels should be reduced to below 1.7% of the best population estimate"*	1.7%
IWC	*"aims for 72% of carrying capacity on average, 50% of the time"*	2%

Model-based

Potential Biological Removal (PBR) and modified PBR (mPBR)

The procedure known as Potential Biological Removal (PBR) aims to set limits to anthropogenic mortality of small cetacean populations that allow for specified conservation objectives to be met. The formula for PBR is empirically determined, using a Management Strategy Evaluation (MSE) () [43], developed in fisheries science, whereby simulations of population dynamics under different management scenarios are used to determine, on well-defined criteria, the best values for some unknown parameters to be used to achieve the conservation objective. PBR was developed in the United States (US) as a result of the revision of the US MMPA for the stock assessment of all marine mammal stocks in US waters jurisdiction [44]. The PBR may be defined as the maximum number of animals that may be removed by human activities (that is, additional mortality) from a stock while allowing it to reach or maintain its optimum sustainable population (OSP, defined as being at, or above, the population level resulting in maximum productivity) [22]. This approach is model-based as it relies on numerical simulations of marine mammal population dynamics, informed by the best available evidence (the so-called operating model).

It is a pragmatic approach: its data requirements are as minimal as possible in order to be applicable for a large panel of species, and yet is robust against several biases and uncertainties that are common in marine mammal data [16]. The PBR formula is calibrated to a given conservation objective, using simulations of population dynamics from an age-aggregated model (the operating model; [16]). Wade (1998) [16] calibrated PBR to the conservation objective of the US Marine Mammal Protection Act: "*a population will remain at, or recover to, its maximum net productivity level MNPL (typically* 50% *of the populations carrying capacity), with* 95% *probability, within a* 100-*year period*".

The formula of the PBR is:

$$PBR = N_{min} \times 0.5 \times R_{max} \times F_R \quad (1)$$

where N_{min} is the minimum population estimate (i.e., the 20[th] percentile of the best available abundance estimate, usually the most recent one, assuming a lognormal distribution), R_{max} is the maximum theoretical or estimated productivity rate of the population, and F_R is a recovery factor between 0.1 and 1.0. For small cetaceans, the maximum theoretical or estimated productivity rate, R_{max}, is very difficult to estimate in practice, but the value of 4% is consensual[1] [16]. The recovery factor F_R is most often chosen to be between 0.1 and 0.5, and allows accounting for (i) the current depletion level of the population (the more depleted, the lower F_R), and (ii) some protection against bias and uncertainties in the data. The use of $F_R < 1.0$ buffers against uncertainties that might prevent population recovery, such as biases in the estimation of N_{min} and R_{max}. Within the PBR context, the choice of $F_R = 0.5$ as a default was determined by tuning, with simulations (see below; [16]). This value is used as a default for populations that are depleted, threatened, or of unknown status, with the value allowed to be increased up to 1.0 when populations are well studied and biases in the estimation of N_{min}, and other parameters are thought to be negligible [45].

PBR is a pragmatic approach to setting limits to anthropogenic removals when a recent abundance estimate (with its associated uncertainty in the form of a coefficient of variation) is available. In that sense, its **data requirements** are few: computing PBR requires only information on species abundance in a management/assessment unit. The

[1] Rmax is difficult to estimate in practice. In the original PBR, Wade (1998) [16] reviewed the available evidence for odontocetes and found "that 4% is probably a suitable default value for odontocetes, and that 2% represents a worst-case scenario" (page 34).

actual PBR computation does not require any estimates of bycatch, and default values can be assigned to R_{max} and F_R in the absence of better evidence [16].

The **operating model** is deterministic and age-aggregated (as it is the fixed percentage approach), requiring knowledge about the demographic characteristics of the population, which can be difficult to obtain for cetacean species. Caution is required in its application, making sure that all the implicit assumptions of PBR are met [46]. ICES [15] suggested that to be more reliable, PBR should be **followed by** a more sophisticated analysis.

PBR can be considered a precautionary method, but due to the limitations in the monitoring and fisheries effort data, it is possible that for some species and populations, the current levels of bycatch exceed PBR limits [17]. Likewise, for example, given the current situation of the common dolphin assessment unit in the Bay of Biscay, if data from alternative sources such as strandings is also considered in the estimation of the anthropogenic mortality, the probability that the annual mortality exceeds the PBR is higher [17].

In the context of the US MMPA, the PBR works as a threshold that may trigger management actions if needed.

A modified PBR procedure has been developed to align with the European relevant conservation agreement, rather than with the US MMPA objectives. It was used by OMMEG to achieve its interpretation of the ASCOBANS conservation objective [27].

Some examples of the PBR applications are: a) within the US MMPA; b) in central South Australian continental shelf waters, to estimate sustainable levels of human-caused mortality for a population of common dolphins [47]; c) in several OSPAR regions, under its modified version (mPBR), as the approach to set thresholds for (i) harbour porpoise (e.g., Celtic Seas, Irish Seas, West Scotland and Ireland, Iberian Peninsula), and (ii) common dolphin in the NE Atlantic region [8].

Population viability analysis (PVA)

PVA is another model-based approach, and more data-demanding, that requires age-specific vital parameters, such as survival and fecundities. Thus, depending on the level of knowledge of the demographic parameters of the population, the level of uncertainty will vary accordingly. Given the characteristics of the model, regarding specific demographic parameters, for each species group or assessment/management unit, ideally a unique PVA should be used. The data requirements are the following: (1) life history and demographic parameters (i.e., age structure, age of first breeding, mean fecundity for each age class, mean survival rate for each age class); (2) carrying capacity of the population; and (3) variance associated with each parameter. PVA is thus a model-based approach that relies on matrix population models to **project forward in time a population trajectory and assess how viable the population is.** Like PBR above, it relies on numerical simulation but uses an age-disaggregated model.

This type of model may allow (i) to **forecast the population consequence**s (in terms of population size or population size relative to carrying capacity) of changes in anthropogenic mortality (including bycatch), but also (ii) to **estimate the effectiveness of recovery plans for endangered species, by estimating the minimum viable population necessary to avoid extinction in a given time frame** [11].

This methodology has been used for simulating the potential effects of bycatch on a population of grey seals in Irish waters [48] or a population of bottlenose dolphins (*Tursiops truncatus*) off northern Western Australia [49].

Removal Limit Algorithm (RLA)

The procedure known as the Removals Limit Algorithm (RLA) aims to set limits to anthropogenic mortality of small cetacean populations that allow for specified conservation objectives to be met. RLA consist of a population model to simulate population dynamics, and a statistical model to estimate the mortality limit from estimates of absolute abundance and bycatch (or other incidental anthropogenic mortality) [11]. Other denominations for this procedure, when related to bycatch, are Catch Limit Algorithm (CLA) or Bycatch Limit Algorithm (BLA). It is considered a management procedure more sophisticated than PBR [11] or PVA. In fact, RLA meshes together the MSE framework underlying PBR with an age-disaggregated model similar to that used in PVA and allows for density-dependence in birth rate [50]. In doing so, RLA integrates state-of the art population modelling for marine mammals [51] and data on vital rates and bycatch rates, along with their uncertainties.

This approach uses time-series for both the population estimates and the incidental bycatch. As a result, it is possible to establish estimated population depletion and to set thresholds aligning with current depletion. If the population is heavily depleted, the threshold can be set to zero to allow for a faster recovery. If not, thresholds higher than PBR (all else being equal) can be set depending on the specific vital rates of the population. Thus, the data requirements for RLA are the following: (1) species population abundance; and (2) anthropogenic mortality, including all elements (e.g., removals).

The RLA includes an estimation step, usually carried out in a Bayesian framework. To set a threshold, it estimates two parameters from data: population growth rate (r) and depletion. The latter parameter corresponds to the depletion level at the time of the best available survey estimate. Once these two parameters have been estimated, the anthropogenic mortality limit is computed as:

$$Antropogenic\ mortality\ limit = \hat{N} \times r \times (0, depletion - IPL) \quad (2)$$

where $\hat{N}$ is the best available abundance estimate and IPL is the internal protection level set to 0.54 (*i.e.,* 54% of carrying capacity K). If the estimated depletion level of the population is below the IPL, then the bycatch limit is set to 0. The bycatch limit can be expressed as a fraction of the best available abundance estimate:

$$\frac{Anthropogenic\ mortality\ limit}{\hat{N}} = r \times (0, depletion - IPL) \quad (3)$$

This approach is used, for example, for the IWC Revised Management Procedure (RMP), OMMEG (as RLA), Small Cetaceans in the European Atlantic and North Sea (SCANS-II), and the Cetacean Offshore Distribution and Abundance in the European Atlantic (CODA) projects [52].

Management Strategy Evaluation

Management Strategy Evaluation **(MSE),** and some of the **model-based** frameworks described above (i.e., PVA or RLA), are algorithms[2] that allow to explore population dynamics under different management scenarios and estimate the limit of anthropogenic removals (i.e., thresholds), following a specific methodology linked to specific conservation objectives. MSE is the common approach to develop removal limits for the management of exploited fish species [53] and to test and select the most robust management objectives that can allow for meeting the conservation objectives despite the possible biases in the data available for managers. It is in fact the framework recognized by ICES as the most suited for the management of cetacean bycatch.

This type of management strategy evaluations are based on numerical computer simulations to compare and assess the robustness of different scenarios, or thresholds, to get consistent results compared to a specific conservation objective, under different control conditions, with a given certainty and potential uncertainties in the process (like in abundance and bycatch rate estimates) [12], [54]. In summary, an MSE consists of: (i)

[2] An algorithm is a procedure for solving a (mathematical) problem in a finite number of steps that frequently involves repetition of an operation (https://www.merriam-webster.com/dictionary/algorithm)

an **operating model** (or simulator); (ii) sources of biases to emulate uncertainty through **monitoring**; (iii) **control rule** to set removal limits (e.g., fixed percentage of abundance, PBR (Eq. 1) or RLA (Eq. 2)) and (iv) **robustness trials**, through the analysis of the simulated data, as performance metrics to assess which strategy is the best under several scenarios and policy goals. As a result, MSE allows for assessing the performance of each decision and selecting the best one, given the best data available and current uncertainties or biases (Figure 1).

Therefore, to carry out an MSE the following are of great importance: (i) the **conservation objective**, that the modelling framework should achieve; (ii) the **data input** used in the computer simulations, increased knowledge on critical data inputs will enable updates of the thresholds; (iii) the **choice of tuning** of the management procedures to achieve the conservation objective(s) defined [21], because different tunings may be specified based on different interpretations of the same conservation objective [21], which will have important consequences on the long-term outcomes. The choice of tuning includes, among others, (i) the selection of a given probability value (e.g., recover or maintain at or above 80% of the carrying capacity 50, 80 or 95% of the time); (ii) the selection of a time frame over which management scenarios are generated: generally long-term is defined as a 100-year time frame (e.g., IWC RMP, IUCN or US MMPA), or as a 200-year time frame (e.g., SCANS-II and CODA projects), but it can also be defined as the time frame of three generations of the species (e.g., also IUCN). The time frame selected should be dependent on the species characteristics such as generation times, population status (depleted or not), or the degree of certainty required (since uncertainty would increase over time) [26]; (iii) the choice of the management units to assess, that should consider the possible scenarios in terms of population structure and movement or dispersal [21].

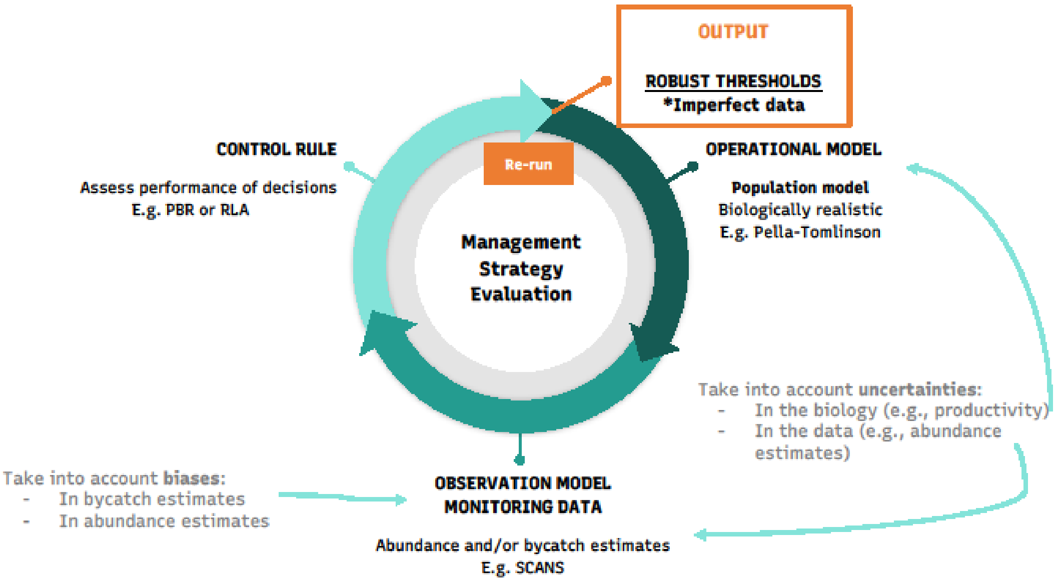

Figure 1. Diagram explaining the Management Strategy Evaluation (MSE) and each of its components.

Example of three different tunings using the same conservation objective (ASCOBANS objective), carried out by SCANS-II and CODA projects [21]:

1) Tuning 1: the management procedure should reach or exceed the conservation objective 50% of the time ("*recovering to and/or maintaining 80% of carrying capacity*"), which should be reached on average.
2) Tuning 2: the management procedure should reach or exceed the conservation objective 95% of the time (*"recovering to and/or maintaining <u>at or above</u> 80% of carrying capacity"*), which is stricter and therefore a more conservative procedure.
3) Tuning 3: a modification of tuning 2, for a worst-case scenario (a.k.a., a robustness trial). It further assumes that the bycatch data used by the procedure is underestimated by 50%, i.e., real bycatch would be twice the estimated value.

Illustration 2: The fixed percentage rule was used in an MSE, using an age-disaggregated population model calibrated on the life-history of North Sea harbour porpoises [49, 54]. A base case scenario (accurate bycatch estimates and abundance estimates) and a robustness trial, wherein bycatch is underestimated by a factor, were tested by running 500 simulations (Figure 2). The fixed percentage rule, set to the ASCOBANS 1.7%, reaches the ASCOBANS conservation objective when information on abundance and bycatch are accurate (Figure 2A), but it is not robust to biased information on bycatch (Figure 2B).

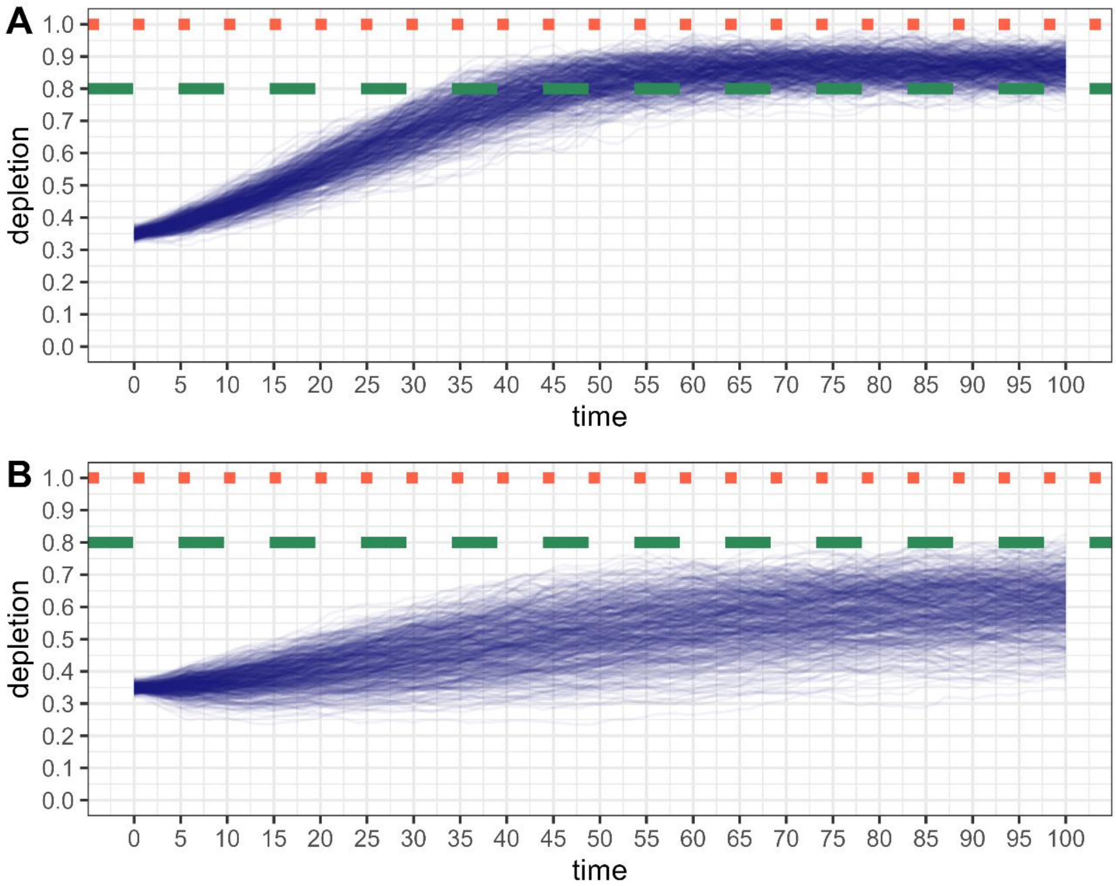

Figure 2. All 500 simulations showing the population dynamics of a hypothetical harbour porpoise population that is initially depleted, and then managed over 100 years with the fixed percentage rule of a bycatch limit set to 1.7% of the best available abundance estimate. (A) Base case scenario assuming accurate information on bycatch and abundance. (B) Robustness trial assuming accurate information on abundance and biased estimates of bycatch. The dashed line shows the 80% of carrying capacity. Depletion is abundance relative to carrying capacity.

Illustration 3: PBR was used in an MSE, using an age-disaggregated population model calibrated on the life-history of North Sea harbour porpoises [49, 54]. A base case scenario (accurate bycatch estimates and abundance estimates) and a robustness trial, wherein bycatch is underestimated by a factor, were tested by running 500 simulations (Figure 3). PBR with the recovery factor set to 0.3 reaches the ASCOBANS conservation objective when information on abundance and bycatch are accurate (Figure 3A), and also to some extent with biased information on bycatch (Figure 3B). It can be observed that is more robust than the fixed percentage rule (Figure 2B). Extensive testing would allow to tune the recovery factor so that the ASCOBANS objective is met with a probability set by policy makers.

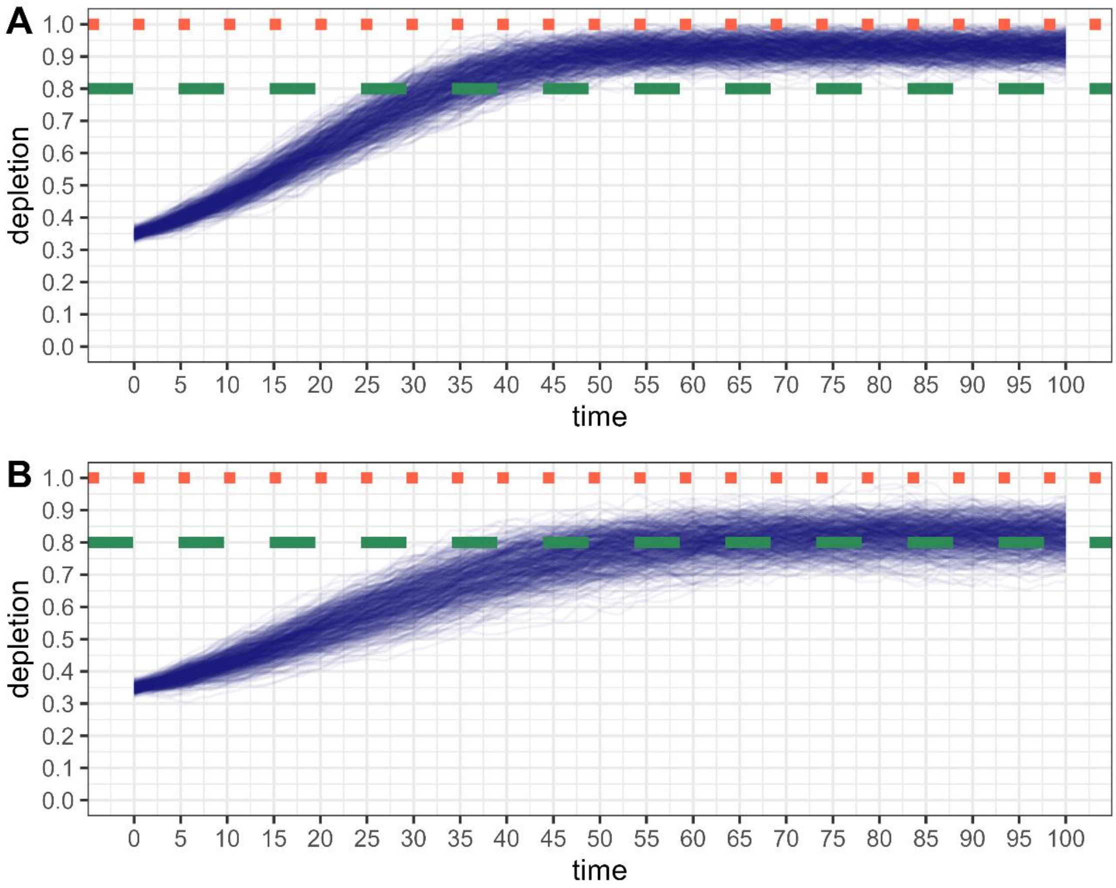

Figure 3. All 500 simulations showing the population dynamics of a hypothetical harbour porpoise population that is initially depleted, and then managed over 100 years with PBR and a recovery factor set to 0.3. (A) Base case scenario assuming accurate information on bycatch and abundance. (B) Robustness trial assuming accurate information on abundance and biased estimates of bycatch. The dashed line shows the 80% of carrying capacity. Depletion is abundance relative to carrying capacity.

A published example of the use of MSE on cetaceans: Genu and colleagues (2021) [54] tuned PBR to the OMMEG quantitative interpretation of ASCOBANS interim objective ("*to restore and/or maintain populations to 80% or more of the carrying capacity*"). The results were reviewed by OMMEG and presented to the OSPAR BioDiversity Committee in 2021, which agreed on the methods to set limits to anthropogenic removals of marine mammals in the OSPAR Maritime Area [55].

4. GES Assessment

The methods described in section 3 (e.g., PBR or RLA) are control rules, that is to say, what is needed to set a threshold for incidental removals, but are not what is needed to carry out an **assessment**.

Once tuning has been carried out (i.e., after running thousands of simulations: e.g., Genu et al. (2021) [56] carried out 200 000 simulations to tune mPBR), the removal limit (i.e., threshold) needs to be set using the most recent data on the population of interest. An abundance estimate of the population (and/or abundance trends) and an estimate of the bycatch rates (and/or its trend) are then necessary for the assessment, as to evaluate them against the threshold calculated (Point 6 of the Guidance of Article 8 MSFD Assessment [13]). Usually, an estimate of abundance is the most limiting factor for the application of these methods to set a threshold [53]. In fact, there is data deficiency for most of the cetacean species, impeding their assessment or the implementation of robust methods (e.g., the fixed percentage or PBR requires at the very least a recent abundance estimate), and estimates may not have enough temporal or spatial precision. Also, estimates of bycaught animals may be biased due to insufficient/inadequate coverage, and to the methodology used on the onboard observer programmes in the fishing fleet, for example [34]. Thereupon, although a threshold or conservation objective may have been accorded or established, the main challenge is to have available the necessary and accurate data to carry out the assessment. The confidence in setting thresholds and in the assessments will be improved when regular monitoring programmes include all the required parameters and all the species listed, as in need of assessment.

5. GES Determination

The determination of the GES is a central concept in the MSFD implementation [1], [2], [13], given that most of the operational provisions of the MSFD are linked to it.

To achieve **consistent GES determination** of the species assessed under the MSFD (Point 7 of the Guidance of Article 8 MSFD Assessment [13]), the methodological standards and the threshold setting processes need to be harmonised at three different levels: (i) the MSFD criteria to be evaluated, e.g., D1C1; (ii) the species groups, determined by international subregional cooperation of the MS, e.g., small toothed cetaceans; and (iii) the spatial scale, e.g., subregional in the framework of the CetAMBICion project [11].

The Regulation 2017/848 [2] establishes that the **extent to which GES** has been achieved should be expressed for each area assessed as the "*mortality rate per species and whether this has achieved the threshold values set*".

Some examples of indicators and status assessments for bycatch of marine mammals are the following [40]:

- Indicator "Number of drowned mammals and waterbirds in fishing gear" of HELCOM [6], in the Baltic Sea area. This indicator defines GES as "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". But there is no quantitative threshold value agreed upon for this indicator, so the assessment is done qualitatively.

- Indicator M6 of OSPAR, which is referred to marine mammal bycatch, and for which the last evaluation was focused on the establishment of assessment units of harbour porpoise (Kattegat and Belt Seas, North Sea and Celtic and Irish Seas). It uses the ICES WGBYC advice for the assessment.

Finally, Article 9 of the Directive establishes that, concerning the initial assessment made under Article 8, Member States shall determine a set of characteristics for GES based on the qualitative descriptors listed in Annex I, and taking into account the pressures or impacts of human activities (Table 2, Annex III).

6. Proposal of common approach

GES assessment for cetaceans requires an agreed-upon quantitative conservation objective. Discussions on an appropriate **conservation objective** for cetacean species in the ABI subregion were initiated at the CetAMBICion workshop held in Vigo (Spain), in November 2022. Participants discussed the **ambition level** (which level of depletion is appropriate to mean 'long-term viability'?), the **risk level** (what is an acceptable probability of failing to reach the conservation objective?) and the **time horizon** over which to carry out MSE (should this horizon be shorten to 50 years?).

It was determined/agreed/discussed that the current ambition of the ASCOBANS **conservation objective** of 80% of carrying capacity is very demanding, and if associated with a small risk of failing (e.g., 5%), results in a bycatch limit of zero. The OMMEG (OSPAR Marine Mammal Expert Group) interpretation of the ASCOBANS **conservation target** is an interpretation that may be very conservative, leading to bycatch limits that are very low and difficult to meet in practice, even assuming perfect management as soon as the limit is known. The OSPAR conservation objective was proposed and discussed between the partners of the project as a ready-to-use protocol (involving both the conservation objective and the methodology), since the countries involved in the project already agreed on them in the framework of the Convention. Nonetheless, most of the participants agreed **shortening the time period**.

The most common **time horizon** for the conservation objectives reviewed is 100 years, which was considered to be possibly too long to detect threats in the context of the MSFD. The time range most often considered in the discussions was 50 years. This was supported by the results of the simulations carried out in the OSPAR context, where the results for 50, 100 and 200 years were found to be similar.

Increasing the **risk of failure** (risk level) did not seem appear appropriate, as it would mean a lowering of ambition with respect to the overall GES. Therefore, discussions centred around keeping a **small risk** (5%, as in the US MMPA, for example), **shortening the time horizon** to 50 years, and lowering the target to less than 80% of the carrying capacity.

An appropriate target of **ambition level** is needed, and a lower figure such as 70% or 60% of the carrying capacity, corresponding in that later case to the best available knowledge on the likely level of maximum net productivity of cetacean species, are worth considering. Traditionally, in Europe, ASCOBANS/ICES wanted to be ambitious so they set 80% instead of the 50% set by the US (in the US MMPA), a value that comes from the fisheries management and that will determine a population as depleted. The determination and choices of the levels of ambition and risk will highly influence the results.

Regarding the **methodology** to use, it was agreed that, when possible, the most realistic biological model will be used. So, the methodology should be always species-specific. Accordingly, the methodology will be data rewarding: the most information or data available, the higher the thresholds could be.

Finally, in the framework of the MSE, there is a need for (i) linking conservation and management objectives, and (ii) coordinating monitoring programmes and programmes of measures. At present, there are differences among the countries participating in the project in terms of the level of integration and linkages between the programmes. For example, in Spain, the organism in charge of both programmes (monitoring and measures programmes) is the same, so communication and integration should be optimal. In Portugal, the integration between both programmes has been carried out only for those aspects related to bycatch. Lastly, in France the organisms in charge of the programmes are different and there is no communication between them.

What became clear from this last part of the discussion, related to the organisms and entities involved in decision-making, is that there is a need for the authorities, as well as scientists and experts, to be involved in the process of setting the conservation objectives, specially from France and Spain. In Portugal for example, from the manager perspective they ask for clear conservation objectives with certainty, that may be provided by scientists. Therefore, there is a need for a common understanding, keeping in mind that scientists also need some guidance to know what to test in the models.

Several scenarios of different conservation objectives could be investigated in a future MSE, within the following ranges and with the following premises:

"*a population should be able to recover to or be maintained at [50-70] % of carrying capacity, with probability [0.9-0.95], within a [25-50-75] year period*",

where [] are placeholders for agreed-upon figures. A clear and quantitative conservation objective is required for any GES assessment with respect to bycatch.

The **implementation** of new conservation objectives was also discussed. Is there time to implement them? The use OSPAR approach, is almost agreed by all the parties and ready to use, but there is no real agreement on it yet. Using a modified version of OSPAR's for the assessment under the MSFD (reducing the conservation objective in terms of % of ambition, or selecting another different), should not be a problem for the compromise with OSPAR, since both objectives can be assessed. In fact, it can be also an improvement for the next cycle of assessment of the MSFD. Using RLA will not be realistic at this stage, because of the computational requirements of RLA. Nonetheless, it can be an improvement for the next cycle of assessment of the MSFD. There is also an intermediate approach in between fisheries management and PETS protection, e.g., IWC contemplated stable levels for whaling industry. It is something that can be tested and selected inside the control rule and then reach the final goal of eliminating bycatch by stable limits of removal.

Regarding the GES determination, there were not many discrepancies is this and the decision was to use the "one-out all-out" rule.

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