REPORT OF THE CONSERVATION COMMITTEE WORKSHOP ON SOCIO-ECONOMIC VALUES OF THE CONTRIBUTION OF CETACEANS TO THE ECOSYSTEM FUNCTIONING

The Workshop was held 5th, 6th and 11th April 2022 virtually via Zoom.

1. INTRODUCTION

1.1. Welcoming remarks

The workshop was opened by Barbara Galletti, the convenor of the workshop, who welcomed all participants. A list of participants is provided as Annex A. She noted that the workshop was livestreamed on the International Whaling Commission (IWC) YouTube channel and that recordings of each session would be available on YouTube for later viewing.

The critical role whales play in nutrient cycling and carbon sequestration is increasingly relevant due to the climate emergency and has been gaining momentum since IWC, after the adoption of resolutions 2016-3 (IWC, 2016) and 2018-2 (IWC, 2018), recognised the importance of whales in the ecosystem functioning as a matter of importance.

The 2021 joint IWC-CMS Workshop on Cetaceans and Ecosystem Functioning reviewed the current state of knowledge and identified research gaps and priority for research. In addition, it was noted that the commission also endorsed a Conservation Committee (CC) workshop on socio-economic values of the contributions of cetaceans to the ecosystem functioning. The focus of this workshop is to identify methods to assess the socio-economic value of the ecosystem services provided by whales to human well-being by, for example, combating climate change and increasing fishery production, to ultimately lead to strengthened efforts to conserve and recover cetaceans stocks and populations.

Galletti noted that the workshop included presentations from ten distinguished speakers (Annex B) and she expressed thanks to the experts for their contributions and participation, the rapporteurs and the participants. She specially thanked the IWC for hosting the workshop and invited them to provide opening remarks.

Rebecca Lent, IWC Executive Secretary, welcomed participants to the workshop. She noted that the Commission recognizes the importance of this workshop and that the outcomes of the workshop will provide an important foundation for starting to understand the process of how to value the socio-economic contribution of cetaceans to ecosystem functioning. She also notes that the workshop needs to look at both market and non-market values of whales.

Galletti reminded participants that the report from the IWC-CMS Workshop on Cetaceans and Ecosystem Functioning held in 2021 provided the basis for this workshop and that the aims of the CC workshop represents a first step to identify contributions that could be addressed from a socio-economic perspective and to review existing techniques for estimating the socio-economic value of the role of cetaceans in ecosystem functioning.

1.2. Review of terms of reference and agenda

Galletti outlined the Terms of Reference for the workshop (Annex C) and the agenda (Annex D). The agenda was adopted.

1.3. Appointment of rapporteurs

James, Jimenez and Schubert were appointed as rapporteurs to assist in the preparation of the workshop report.

2. OUTCOMES OF THE IWC-CMS SCIENTIFIC COMMITTEE WORKSHOP

Toshihide Kitakado introduced the outcomes of the IWC-CMS Workshop on Cetaceans and Ecosystem Functioning. He provided an overview of nutrient circulation, ocean fertilization, whale falls and trophic cascades, among others. He highlighted the role of whale falls (sunken carcasses of whales at the seafloor) in promoting the diversity and evolution of deep sea species and to sequester carbon; the importance of whale pump and whale conveyor belt concepts for the circulation and recycling of nutrients; the role of cetaceans in the carbon cycle including storage and sequestration; as well as cetaceans as physical engineers (for example by re-suspending sediments through feeding, bubble net foraging) and their role as predators and prey that influence ecosystem functioning.

He also noted that the role of cetaceans in ecosystem functioning was largely dependent on scale, from local to global, with differences depending on species, over space and time particularly given population declines (considering pre-commercial whaling and current population numbers), and due to climate changes resulting in possible changes in ecosystem functioning.

He provided a list of cetacean traits identified at the IWC-CMS workshop that could be used to monitor the different ecosystems functions played by cetaceans (Table 1, IWC, 2021). The workshop also discussed future research needs (Table 2, IWC, 2021), identified questions/hypotheses that required additional research, and highlighted the work needing to be accomplished in preparation for a second scientific workshop (Table 3, IWC, 2021). Some of the priority needs included the development or modification of existing ecosystem models, the review of inputs needed for a robust assessment of the contribution of cetaceans, and the quantification of spatial and temporal differences in ecosystem functioning of cetaceans, with a focus on differences depending on area (e.g., Southern Ocean, North Atlantic, North Pacific, Barents Sea) and between pre-whaling and current populations.

Discussion focussed on how results of the workshop, including the research gaps identified in the workshop report, will influence policy and how the scientific analysis of the traits describing the role of cetaceans in ecosystem functioning can be translated into traits that directly or indirectly provide a benefit to humans for which a value can be determined. Galletti clarified that although the IWC-CMS workshop identified several research needs, the purpose of this CC workshop was to look at the existing scientific knowledge discussed at the IWC-CMS workshop, to examine these from a socio-economic perspective, and to try to determine if or how a socio-economic value can be assigned to specific functions of cetaceans in ecosystem to be used to promote cetacean conservation policy changes via the IWC and other national and international fora.

The outcomes of the CC workshop will also inform and guide discussions at the second SC workshop (tentatively planned for 2023) and help focus research on identified priorities. It was noted that the information from this workshop, the SC workshop, and other workshops (such as those addressing the impact of bycatch and ship strikes on cetaceans), can be packaged together and taken to inform CMS, FAO, and other bodies that work on relevant policies.

3. IDENTIFY CONTRIBUTIONS THAT COULD BE ADDRESSED FROM THE SOCIAL AND ECONOMIC PERSPECTIVES

3.1. Traits shared by marine megafauna and their relationships with ecosystem functions and services.

Tavares described a method to assess the ecosystem functions an services provided by cetaceans based on reviewing shared traits of marine megafauna, (i.e., measurable behavioural, physiological, or morphological characteristics of organisms), that can shed light on the processes influencing structure and functions of biological communities. For example, size (body length, mass) can be linked to certain traits like mortality rates and dispersal performance which can, in turn, provide information on ecological functions such as nutrient transport and ecological services such as food provision. Tavares discussed how feeding strategies and migratory traits of seabirds can affect the accumulation and type of plastic found in their nests. Furthermore, mercury concentrations in cetaceans are related to body length, trophic position, and selenium concentrations. More applications of this method are being explored and are taking advantage of the large datasets that exist for marine megafauna.

Discussions noted that when undertaking an ecosystem service valuation when there is a lack of data, a benefit transfer can be undertaken instead whereby the value taken from other published studies can be applied to a specific project as a type of proxy where such data is unavailable. If these traits can be used to assess the health of ecosystems or species to be valued, then such traits could be used as coefficient to adjust that value. For example, the value of carbon sequestration by humpback whales in Chile could be used, once adjusted based on the traits of humpback whales in Costa Rica, to determine the value of those whales by applying the relevant valuation method.

It was noted that there are a lot of papers that detail the benefit transfer methods that could be used for this type of analysis. In addition multi-metric indicators to value ecosystem health are available.

3.2. Review of IWC-CMS workshop table on traits

Over the course of the workshop, there were extensive discussions to relate the cetacean traits identified by the IWC-CMS workshop to an ecosystem service that could be assessed from a socio-economic perspective and for which a value could be assigned. It was also noted that the workshop was more oriented to dealt with the economic issues associated with cetaceans and ecosystem functioning than their social aspects and it was suggested that further discussion on its social aspects could be given in future discussions.

Different views as to the role of cetaceans in ecosystem functioning and how to value the specific traits that provide a benefit to humans have been expressed by cetacean and socio-economic specialists. This made the discussion challenging as not all participants had the same understanding over concepts and the difference between ecosystem services and ecosystem functions. It was agreed that there needed to be a common understanding of the definitions of the terms to be used and that, to assign a monetary value to a service, there must be a measurable benefit to humans. In this sense, it was also proposed that for any trait that did not provide a direct benefit to humans, its indirect benefits and/or non-market valuations could be explored in order to include other important traits and functions that could be used to monitor the health of ecosystems (e.g. the role of some species of whales in providing ecosystem functions such as nutrient cycling that could have an impact on the productivity of fisheries)..

It was also noted that although ecosystem services can encompass a wide range of services, including cultural and recreational (e.g., whale watching), the ToR of the workshop and IWC resolutions focus on those specifically related to the contributions of cetaceans to ecosystem functioning. This is not to diminish those other services or values of cetaceans, which can be substantial, but the workshop was limited in its scope due to the ToR.

The workshop agreed to establish a small working group to review the IWC-CMS scientific workshop table of cetacean traits. The objective of the small working group was to clarify concepts and discuss how particular cetacean traits could be (or not) related to a socio-economic valuation.

The small working group met during and after the workshop to discuss, agree on, and complete a table format to be used for assessing the value of ecosystem services. Its first task was to agree on the definitions to be used to evaluate the ecosystem services provided by cetaceans from a socio-economic perspective in order to provide a consistent basis for defining the categories used for the analysis of the table on traits of cetaceans identified at the IWC-CMS workshop report. It reviewed different ecosystems services classifications systems used worldwide and their differences (Constanza *et al.,* 1997, 2017; MEA, 2005; TEEB, 2010; CICES, 2017). A more comprehensive review of the discussion on the definitions of Ecosystem Services used to analyse the IWC-CMS table on cetacean traits is given in Annex E.

The small working group agreed that ecosystem services include as broad categories provisioning, regulating, and cultural services that directly affect people. It also noted that it includes "supporting services" needed to maintain the other services but that these "supporting services" are considered better as functions and not services *per se.*

For the purpose of reviewing table 1from the IWC-CMS workshop report, the small working group agreed to include as broad categories: "provisioning", "regulating", "supporting" and "not ecosystem services". Cultural services were excluded from the analysis as the workshop ToR was to focus on ecosystem functioning. Furthermore, in discussing the "provisioning" service provided by cetaceans, the acquisition of meat, blubber and other products from cetaceans were excluded from the analysis as they are not related to the impact of cetaceans on ecosystem functioning. The small working group also noted that The Economics of Ecosystems and Biodiversity (TEEB) and the Common International Classification of Ecosystem Services (CICES) frameworks do not consider nutrient cycling as "supporting services" and that many cetacean contributions to the ecosystem functioning were directed towards nutrient cycling and its impact on primary productivity, and therefore should be considered here, as it is considered in other categorization frameworks such as Costanza et al. (1997) and the Millennium Ecosystem Assessment (2005)..

It was also highlighted that trying to apply an analytical framework that was created for ecosystems (e.g. the open ocean, coral reefs) to species (cetaceans in this case) can present some limitations. Perhaps the most important limitation is isolating the unit of analysis from the broader system, and therefore not capturing the many interactions between the species, the ecosystem and ultimately humans.

After agreeing to such broader categories, the small working group analysed the table on cetacean traits and proposed to divide it into three different tables: a) ecosystem functions that could be translated into ecosystem services linked to human beneficiaries (i.e. demand); b) remaining ecosystem functions that play a role as "supporting services" to ecosystem services such as the provision of food (i.e. fisheries) and; c) those ecosystem functions that are not considered to support any ecosystem services but that could function as an umbrella for the protection or restoration of supporting services.

The group also reviewed relevant literature (Lavery *et al*., 2010, 2014; Pershing *et al*., 2010; Roman *et al.,* 2014; Ratnarajah *et al.,* 2016; Chami *et al.,* 2020; Cook *et al*., 2020) that included information on the socio-economic valuation of cetacean contributions to ecosystem services to assess which parameters/traits have already been considered under a valuation framework.

A preliminary review of the IWC-CMS table on cetacean traits showed that four (mortality rates, macronutrients in whale faeces, excretion rates, and body mass) of the 26 traits identified in the IWC-CMS workshop report could be used for direct valuation of ecosystem services as they directly provide a benefit to humans, more specifically related to climate regulation (through carbon sequestration). Seventeen could be associated with ecosystems functions that can support ecosystem services that significantly contribute to the productivity of human activities. The remaining five traits could not be related to ecosystem services from a socio-economic perspective (Tables are shown in Annex F).

There were different views on the categorization of traits in the table during small working group discussions, and it was noted that this type of exercise is required as the basis of any valuation project. It was also noted that for this analysis, although cetaceans (in relation with their ecosystems) provide a wide variety of services, the traits listed under the table provided by the scientific committee focused mainly on supporting services/ecosystem functions (e.g. nutrient cycling, maintenance of genetic diversity, habitat provisioning). This scope of analysis will require a close collaboration with the IWC ecosystem modelling experts to link these functions with other ecological and economic process that directly benefit humans. For example, in the case of nutrient cycling, a line of research could be dedicated to establishing the role of cetaceans in enhancing primary production which may result in an increase in fish stocks/productions thereby benefitting the fishing industry and consumers of fish products. This benefit may differ depending on the species of cetacean.

During the workshop, it was proposed as next step to conduct an entire valuation as a pilot project. It was proposed that the pilot project should consider only one species, so that the number of functions is reduced to facilitate a simpler analysis. It was suggested that the Conservation Committee Intersessional Working Group on Cetaceans and Ecosystem Functioning could develop a proposal for a pilot project, including its terms of reference, to be presented at the Commission meeting in Portoroz, Slovenia in October 2022 for its consideration.

4. REVIEW EXISTING TECHNIQUES FOR ESTIMATING THE SOCIO-ECONOMIC VALUE OF THE ROLE OF CETACEANS IN ECOSYSTEM FUNCTIONING (MARKET AND NON-MARKET VALUES)

4.1. System of Environmental Economic Accounting (SEAA) – UN Statistics Division

Javorsek, from the United Nations Statistics Division (UNSD), presented an overview of the System of Environmental-Economic Accounting (SEEA) as the international statistical standard for Natural Capital Accounting. The SEEA provides a framework for organizing and presenting statistics on the environment and its relationship with the economy. It brings together economic and environmental information in an internationally agreed set of standard concepts, definitions, classifications, accounting rules and tables to produce internationally comparable statistics. It consists of two parts: (1) the SEEA Central Framework (SEEA CF) which looks at individual environmental assets, their use in the economy and returns back to the environment; and (2) the SEEA Ecosystem Accounting (SEEA EA) which takes the perspective of ecosystems and considers how they supply services that benefit the economy and the society. The presentation focused on the SEEA EA as the new statistical standard which was adopted in March 2021, and the efforts being made for its implementation. A further link was made to ocean accounting, and the decision of the United Nations Statistical Commission to develop an internationally agreed statistical standard on ocean accounting – SEEA Ocean. There is a growing interest of countries in development of SEEA Ocean to allow for reporting on the ocean economy concerning growth, well-being and sustainability, and a common statistical infrastructure for ocean policy, regulation, spatial management, and reporting. Participants of the workshop were invited to participate and contribute to the development of SEEA Ocean.

The work that was presented here was welcomed by the group and noted as being valuable to the workshop. Questions was raised regarding measurements being undertaken at an asset level, and not at an ecosystem level, and further clarification was requested. An example was provided of two measurement perspectives where assets are embedded in ecosystem:

- A forest is composed of trees which represent timber than can be harvested, with the timber considered the asset;
- At the ecosystem level the trees provide services to humanity and beyond through carbon sequestration, habitat, and water filtration providing value in excess of the value of timber itself as an asset.

It was asked if biodiversity was included in the system. It was clarified that biodiversity is much broader than an ecosystem trait, and many aspects of biodiversity are included in assessing the health of the ecosystem (e.g., species diversity is an indicator of forest ecosystem health; fish abundance is an indicator of ocean ecosystem health). The more species the more diverse the biodiversity of the ecosystem and the more it will be reflected in the ecosystem service analysis.

Discussion then addressed accounting for transboundary assets, due to the migrations and movements of cetaceans, and if this should be accounted via each country or via the concept of global commons for species found areas beyond nation jurisdiction (e.g., the high seas). Whilst cetaceans migrate and have impacts globally, they also provide functions to particular countries (e.g., when they occupy feeding and breeding grounds). Whilst the SEEA model is limited to the country perspective, it can be scaled to any size e.g. provinces, regional areas, ocean basins etc. There will always be a flow of assets between these areas. It can also be scaled to larger areas outside EEZ's and territories, and while these models have not yet been used in such larger geographic areas, this is being investigated.

It was noted that SEEA is intended to be a national level of accounting, so it's built for countries to assess their ecosystem services and assets, based on existing statistics. Currently, approximately 90 countries have conducted SEEA accounting of their ecosystem services and assets. To see examples of this accounting system being used, go to https://seea.un.org/

4.2. Assessing Economic and Socio-Cultural Value of whale Ecosystem Services

Cook on behalf of Davidsdottir provided a synthesis of some of the interdisciplinary work from the ARCPATH (https://ncoe-arcpath.org/) project that focused on the effects of climate change on arctic social-ecological systems. It does so through looking at impacts to the ecosystem service of eco-tourism (whale watching). Whales present a group of species that are vulnerable to climate change and, at the same time, are central to the economies, cultures, and identities of many arctic coastal communities. One such community is the town of Húsavík in Skjálfandi Bay, Iceland.

The presentation outlined the main findings from an initial literature review to examine the effects of climate change on whales, globally, before using these findings and site-specific data from climate change modelling, whale observations from whale watching boats and whale watching trip records to investigate possible future impacts on whale watching in Skjálfandi Bay. The literature review identified three categories of impacts on whales due to climate change; changing distributions and migration, prey availability, and sea-ice extent/ocean temperature.

Linear regression models identified statistically significant relationships between sea-surface temperatures (SST) and cetacean sightings for minke whales, blue whales and white-beaked-dolphins over the period 1995 to 2017. These species appear to have changed their usual feeding areas, and the results implied that further increases in SST are likely to further affect whale distributions. Future climate scenarios indicate that at least 2°C of SST warming in Skjálfandi Bay up to 2050 might be inevitable regardless of the future emissions scenario. The reliance of the local tourism sector on whale watching makes Húsavík vulnerable to the effects of climate change on whales. This calls for adaptation planning and conservation measures that could enhance the protection of whales beyond the scope of the current whale sanctuary in Skjálfandi Bay.

Galletti noted the importance of considering the impacts of climate change and other threats affecting the variability of cetacean's ecosystem functions and to consider difference scenarios and impacts of such threats when modelling potential socio-economic values (through time).

4.3. Estimating Use and Non-use Values for Ecosystem Impacts of Aquatic Species: Design and Application of Stated Preference Methods

Johnston provided an overview of different market and non-market valuation techniques. He stressed the need for clear and rigorous definition of the values to be measured; what values are valued directly by the beneficiaries (humans); who are the beneficiaries of the values; how do the values affect the beneficiaries welfare; and what methodological approaches are best applied to estimate the value. Market valuation methods are used to estimate total economic value for ecosystem services providing “use values” both direct (e.g., food supply) and indirect (e.g., reducing flood risk). However, Sated Preference Methods (SPM) are the only economic valuation tools that can be used to estimate total economic value of ecosystem services that provide both “use” and “non-use” or passive values which includes “existence values”, “bequest values”, and “altruistic values.” While market valuation methods are often easier to apply due to the availability of market data, there are many values associated with ecosystem function change that can only be estimated using SPM. This method relies on responses to survey questions to determine how people would behave under hypothetical but feasible scenarios to estimate economic value. Both methods (market valuation and SPM) rely on “willingness to pay” (WTP) or “willingness to accept” concepts that provide theoretical measures of value. Johnston also provided a clear example of SPM for a project involving the restoration of a migratory fish passage in Rhode Island.

Whilst this presentation focussed on ecosystem services, and not the products that can be derived or extracted from whales, it was noted during the discussion that there still is not a clear understanding of the full set of ecosystem services provided by whales (e.g., increased fish yields that result from increased nutrients from whales). It was agreed that it is fairly easy to assess the market values of whales based on their recreational value linked to whale watching. It was also noted that our understanding of the ecosystem services provided by cetaceans is in its infancy.

As reported during the discussion, if the services provide by whales does not directly benefit people, then the market value is zero. However, the Rhode Island case study regarding a project to restore migratory fish passage demonstrated that the social value of fish passage restoration was due to effects on ecosystem function and not based on the value of the fish. Therefore, it was noted that it is possible to value these benefits based on their indirect impacts using the stated preference methods, as it studies the inherent value that people place on such services which may be influenced by a person’s opinion as to the importance of the asset.

4.4. Past, Present and Future of the Ecosystem Services Provided by Cetacean Carcasses

Quaggiotto provided an overview of the ecosystem services associated with cetacean strandings. She showed that ecosystem services have been altered by humans through exploitation of wild populations during the whaling era and more recently by regulations on carcass management and disposal to abide by environmental health requirements. She conducted in a systematic review of the scientific literature and gathered data on cetacean strandings worldwide to: 1) identify the ecosystem services provided by stranded cetacean carcasses in the past and present; 2) estimate the density of cetacean strandings currently occurring in selected coastal areas around the globe, and analyse its association with human population density and regulations; and 3) identify and discuss the regulations and methods concerned with whale carcass disposal in specific regions of the world.

The literature review revealed that stranded cetacean carcasses have provided a rich and varied array of provisioning, regulating, cultural, and supporting ecosystem services to ancient and modern civilisations worldwide. Also, they found that the current density of stranded carcasses (mean: 0.090 strandings • $year^{-1}$ • km^{-1}; range: 0.001–0.978) and the disposal methods widely varied across the studied regions and countries. In addition, neither human population density or the existence of regulations were good predictors of stranding densities.

Finally, Quaggiotto provided recommendations for the future management of stranded cetacean carcasses, by identifying those disposal methods that minimize costs and maximize ecosystem functions and services. In particular, natural decomposition in situ was encouraged whenever possible; otherwise, the present coastal management strategies could be improved by including zoning, seasonal use limitation and educational outreach depending upon the local scenario.

Overall, further socio-ecological research is strongly needed to guide stranded cetacean carcass management towards enhancing the net benefits that humans and ecosystems gain from carcasses. This is particularly important as cetacean populations are recovering – likely increasing the frequency of strandings, and considering that as human population increase in coastal areas, new disposal regulations are approved.

It was noted during the discussion that the presentation provided very useful information. It was suggested that differences between the stranding rates of species such as odontocetes, that strand more frequently, could also be monitored. Concerns were expressed as to whether it was appropriate to evaluate a species as an ecosystem service but, it was noted that a carcass itself provides an ecosystem service when it becomes stranded, to avian, terrestrial, and marine scavenger species which consume the carcass overtime thereby removing any disease or health risk associated with the deteriorating carcass. It was also noted that the ecosystem services provided by a carcass was a very good example of what we are trying to accomplish at the workshop, as the services linked to nutrient circulation via the whale pump and conveyor belt are harder to define and quantify. Questions on the release of carbon into the atmosphere from stranded carcasses versus carbon being stored for decades in whale falls to the deep sea, will necessitate a different assessment approach to compare the nutrients provided to terrestrial ecosystem and the carbon released as the carcass degrades versus the carbon and emissions released via carcass incineration or if the carcass is towed out to sea. Assessing the latter option would require consideration of the emissions associated with carcass transport. It was suggested that burying stranded carcasses (instead of allowing natural decomposition on the beach) could be the preferred method for disposal that reduces health risks and minimizes costs recognizing that burial limits the services the carcass can provide to only a subset of scavenging species. Alternatively, buried carcasses may attract sharks, which would not be acceptable to beach users.

5. INSTITUTIONAL FRAMEWORKS TO UNDERSTAND THE SOCIAL AND ECONOMIC VALUES OF THE CONTRIBUTION OF CETACEANS TO ECOSYSTEM FUNCTIONING

5.1. Toward a Nature-Positive Economy: The Case of Oceans and Cetaceans

Chami introduced a concept that uses nature-based solutions to bring a new economic paradigm for nature conservation that includes market players in the conservation strategy. By recognizing that humanity is facing two risks: climate change and loss of biodiversity (natural capital) that are interconnected and both related to human activities, a new economic paradigm is needed that considers nature as our home and that living nature is valuable. Examples of the contributions to ecosystems services provided by elephants, whales, seagrass, mangroves and saltmarshes were provided. They included *inter alia* capturing CO_2, fertilizing the ocean, providing defence from floods, increasing fish stocks, etc. He provided estimates that ecosystem services from one whale could be worth 2 million dollars, one elephant 1.7 million dollars, or global seagrass communities more than one trillion dollars. Chami emphasized the need for a legal framework that could define property rights and a system to assess and submit claims for damages, as natural capital will become protected if it is valued. In the specific case of cetaceans, Chami highlighted the key contribution they play by promoting phytoplankton growth, enhancing primary production thereby benefiting global fisheries, and sequestering carbon. In this sense, it is essential to convert science knowledge into monetary valuation. It is a win win-win model as once the values of the services can be determined, financial interests can convert this value into money if a legal framework ensures the protection of the natural service assets and invites the marketplace to be a partner in the process. Technology could be used to monitor the natural capital and value of, for example, potential carbon credits or any other type of credit, and a transparent, traceable, and trustful means of buying and selling needs to be set. The nature-based solution chain would then be set up with suppliers, buyers, regulations, and marketplaces.

During the discussion, a question was asked about developing a financial mechanism for transboundary assets/species to share the benefits and losses of these assets across different countries. Such a mechanism would likely be dependent on where a whale lives. For example, if a whale lives 80 percent of its life in the waters of one country, and 20 percent in another, then the benefit of that asset may be split accordingly. It was emphasised that technology or some mechanism, perhaps involving a collaboration between the IWC and CMS, is needed to determine where whale populations spend their time so that countries can prove that a whale/population is 'theirs'. If this approach is taken, offsets cannot be claimed from more than one country otherwise there will be double accounting of such benefits.

This assessment becomes more difficult for cetacean species that are found on the high seas. It was suggested that a solution could be similar to a global pot of money that countries pay into, with the funds allocated to countries to advance protections for those species/ populations in their waters.

It was also reiterated that currently the economic value of cetaceans is 100 percent anthropogenic. In other words, if an asset does not have a value to humans, it has no economic value. The need to move to an eco-centric value chain of benefits, as a replacement for the traditional consideration of only anthropogenic value, was stressed. A market system is required that takes into account that even if a whale is not seen (e.g., if it is an offshore or deepwater species) it is still providing a service and 'working on behalf of humanity'. Since we know these services exist, it was noted that we should 'pay the whale for its services', stop discussions about extracting the whale (the asset), and focus our conservation strategies on promoting living, thriving, and abundant whale stocks/populations that will perform ecosystem services throughout their lives.

Discussions occurred in regard to the potential of a weighting system (e.g., where carbon markets should be weighted in favor of coastal states containing cetacean breeding grounds). In addition, participants discussed a carbon markets system where local communities and organisations who protect the breeding, feeding, and other habitat for whales receive the benefits and that such benefits are not solely directed to government agencies or private enterprises. It was noted that this is precisely where block chain technology comes into play.

It was noted that, to date, CMS has not delved into carbon market deliberations in the context of its work to conserve migratory species given the complexities of developing such a market for migratory species which will take some time to resolve. It was suggested that this topic should be considered by CMS as soon as possible given the need to focus on the ongoing development of such carbon markets.

5.2. Common Asset Trusts for Marine Stewardship: The Case of Whales

Constanza and Hernandez-Blanco introduced the Common Asset Trust concept and expanded it into its potential use for marine stewardship. Coastal and marine ecosystems, as well as the benefits they provide to human well-being, are common resources, which require new governance systems for their sustainable use. To address this management challenge at multiple scales, the creation of Common Asset Trusts (CAT) for the ocean based on Elinor Ostrom's governance principles is proposed. In the case of whales, CAT were evaluated to determine if they can be created to provide an institutional arrangement based on the collaboration of different actors from society, as well as the financial mechanism that would provide the funding needed to implement the stewardship activities for the protection and restoration of the population of these migratory animals.

It was noted during the discussion that the CAT concept is tackling the key issue of the transboundary aspect of migratory species as a common good and their relations to property rights/ownership that are not necessarily similar to private property. Subsequent interventions focused on private investment and how to motivate such investment. In this regard, it was noted that tour operators would benefit directly by investing in conserving whale populations. An example is if dive operators invested in conserving coral reefs, this would provide a direct private return for their business while, at the same time, benefits associated with increased coral abundance, diversity and improved reef health. However, it was also noted that the dive operator could let the government invest in coral reef protection and still reap the benefits, but then the private investors would not get the publicity and status that investing directly in reef conservation would bring.

5.3. Co-Developing Good Governance to Integrate Socio-Economic Data in Marine Science Policy

Stead introduced a model of co-developing good governance to integrate socio-economic data in marine science and management policies. She highlighted the importance of collecting empirical social data (Krause *et al.*, 2020) such as perceptions towards management of cetaceans that is linked with economic (e.g. jobs/income; Mikkelsen *et al*., 2020) and environmental data (population dynamics of cetaceans) to improve understanding about the relationship between policy efficacy and management effectiveness. Many marine policies prioritise environmental and economic data yet many acknowledge you can only manage people. For example, perceptions influence attitudes which influence human behaviour such as compliance with regulations or rule-breaking. The Bycatch Assessment and Mitigation in the Western Indian Ocean (BYCAM) project was used as an example to show the benefits of co-developing good governance based on empirical socio-economic data (Salmin *et al.*, 2019; Temple *et al*., 2019; 2020). Bayesian Belief Networks were recommended as an analytical approach to visualising the importance of collecting social and economic data (Slater *et al*., 2013).

Systems thinking was highlighted as important to understanding science policy needs for supporting cetacean management (Stead, 2018; 2019). The paper also explained how policy review workshops were useful for mapping which organisations are involved in science, policy and management to assess where gaps and overlaps are. Recognising the importance of linking local with national, regional and international governance processes demonstrates the benefits of developing coherent and integrated strategies to support sustainable cetacean management.

6. WORKPLAN AND RECOMMENDATIONS

During discussions of the revised tables (prepared from the table contained in the IWC-CMS workshop report), it became clear that efforts to identify those cetacean traits that could be valued from a socio-economic perspective would be a challenge. As the ecosystems functions that could be so valued had to provide a benefit to humans given current valuation concepts, most of the traits could not be directly linked to a human benefit (or demand). Therefore, it was proposed to consider stated methods or any other non-market valuation methods to include the valuation of the services that cetaceans provide that benefit both humans and the health of ecosystems.

In addition, it was suggested that this would require a close collaboration with the IWC specialists to link these functions with other ecological and economic processes that directly benefit humans. In particular, the role of cetaceans in nutrient cycling has been highlighted as very important but there remains a need to quantify the link between cetaceans, nutrient cycling, the benefit to primary production, an increase in fish stocks, and, ultimately to the fishing industry. Quantifying such links will demonstrate the importance of cetaceans to the economics of the industry.

In the short term, the workshop proposed the development of a pilot project to assess the socio-economic values of a single species to simplify the number of services to be valued. It was suggested that the Conservation Committee Intersessional Working Group on Cetaceans and Ecosystem Functioning could develop a proposal, including terms of reference, for a pilot project to be presented at the Commission meeting in Portoroz, Slovenia in October 2022 for consideration.

The workshop also proposed the following medium-to-long term actions:

- Associate valuation methods to specific ecosystem services and assess socio-economic potential (starting with the pilot project).

- Consider the impacts of climate change and any other threat that may affect the role that cetacean play in ecosystem functioning and model potential socio-economic impacts on different scenarios (through time).
- Start a discussion on the development of financial and institutional frameworks (e.g. Common Asset Trusts) to integrate socio-economic valuation into the cetacean decision-making process and advance proposals to create conservation funding sources that benefit from the ecosystem services provided by cetaceans.

7. ADOPTION OF THE REPORT

The workshop report was adopted by correspondence.

8. LITERATURE CITED

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ANNEX A - LIST OF PARTICIPANTS

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Charlotte Nithart	Robin des Bois
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Yolanda Alaniz	Comarino Mexico
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ANNEX B – SPEAKER'S AFFILIATIONS AND AREAS OF STUDY

Ralph Chami, Assistant Director at the International Monetary Fund. Author of "Nature's Solution to Climate Change: A strategy to protect whales can limit greenhouse gases and global warming" published by IMF, 2019.

Robert Constanza, Australian National University. Founder of Ecological Economics journal. Areas of expertise include: ecological economics, ecosystem services, landscape ecology, integrated ecological and socioeconomic modelling

Brynhildur Davidsdottir, University of Iceland. Professor of environment and natural resources and recently appointed to the Scottish Council of Economic Advisers. Specializes in biology, economics, system dynamics and evaluation of ecosystem services.

Marcello Hernandez-Blanco, PhD in Ecological Economics from the Australian National University and Master of Science in Biodiversity, Wildlife and Ecosystem Health from the University of Edinburgh. His areas of study include natural capital valuation, green and blue economy, financial mechanisms for conservation, environmental policy design, climate change, and environmental management, among others.

Marko Javorsek, Environmental-Economic Accounts Section Statistician at the United Nations Statistics Division. He has closely worked on the UN System of Environmental Economic Accounting.

Robert Johnston, Professor of Economics, Clark University. Research interests include economic valuation, benefit transfer and ecosystem services, with an emphasis on aquatic, riparian and coastal systems.

Toshihide Kitakado, Department of Marine Biosciences, Tokyo University. Convenor of IWC Scientific Committee Ecosystem Modelling sub-committee and co-chair of the IWC-CMS workshop on cetaceans and ecosystem functioning.

Martina Quaggiotto, Lecturer in Ecology in Biological and Environmental Sciences at the University of Stirling. Research interests include the ecological impact of carrion (mostly marine) on scavengers and soil and the ecosystem services associated with it.

Selina Stead, Marine Biologist and Tropical Scientist, Professor at School of Earth and Environment, University of Leeds. Specialises in environmental governance and has expertise in coral reef ecosystems, fisheries, aquaculture and marine protected areas.

Davi Tavares, Leibniz Centre for Tropical Marine Research. Research interests include understanding how biological diversity respond to both natural and human-induced changes in tropical coastal environments.

ANNEX C – WORKSHOP TERMS OF REFERENCE

Resolution 2016-3 on Cetaceans and their Contributions to Ecosystem Functioning resolves to review the ecological, management, environmental, social and economic aspects related to the contributions of cetaceans to ecosystem functioning to people and natural systems, as a matter of importance and directs the Conservation Committee to undertake this review.

At IWC67, the Commission endorsed a proposal to hold a workshop on the socio-economic values of the contribution of cetaceans to ecosystem functioning. The workshop aims to address the economic and social value of the contribution of cetaceans to ecosystem functioning.

The workshop should:

- *Review the findings of the IWC Scientific Committee regarding the outcomes of the SC workshop "Cetaceans & Ecosystem Functioning: A Gap Analysis Workshop".*
- *Identify any potential ecosystem services provided by cetaceans that could be addressed from social, conservation/management and economic perspectives.*
- *Review existing techniques of economic and social valuation of the ecosystem services provided by cetaceans and identify potential new methods that could be applied to assess the contributions of cetaceans.*
- *Identify knowledge gaps and data needed to better assist in the review.*
- *Develop a prioritized list of recommendations to fill these knowledge gaps and advance this research.*
- *Suggest potential approaches to integrate the contribution made by cetaceans to marine ecosystem functioning into the decision-making processes of the IWC and other fora, mainly focused on improvements*.

ANNEX D - WORKSHOP AGENDA

Day 1 Identify contributions that could be addressed from the social and economic perspectives.

- Nutrient circulation: carbon sequestration; nutrient flux, etc.
- Ocean fertilization (vertical: "whale pump" and horizontal: "whale conveyor belt") and impacts on fisheries
- Whale falls
- Cetaceans as predators (trophic cascades, sublethal effects)
- Other socio-economic dimension of contributions to ecosystem functioning not previously identified.

15:00-15:10	• Welcome and introductions, Barbara Galletti
15:10-15:40	• Presentation of the outcomes of the IWC-CMS Scientific Committee workshop, Toshihide Kitakado
15:40-16:00	• Questions SC report
16:00-16:20	**BREAK**
16:20-16:40	**Presentation:** Traits Shared by Marine Megafauna and Their Relationships with Ecosystem Functions and Services. Davi Tavares. Q&A
16:40-17:00	**Presentation:** The System of Environmental Economic Accounting. Marko Javorsek. Q&A
17:00-18:00	Discussion and start to complete Table 1

Day 2 Review existing techniques for estimating the socio-economic value of the role of cetaceans in ecosystem functioning

- Estimates of market values; this could include carbon sequestration based on global carbon market prices
- Estimates of the non-market values; techniques may include hedonic pricing, contingent valuation methods (e.g. willingness to pay), travel cost models and damage assessment model (see https://www.oceaneconomics.org/nonmarket/methodologies.asp)
- Identify methods to be applied to assess the contribution of cetaceans and potential for the development of 'best practice guidelines'.

15:00-15:10	Welcome, summary of previous discussions and topics for Day 2
15:10-15:35	**Presentation:** Toward a Nature-Positive Economy: The Case of Oceans and Cetaceans, Ralph Chami Q&A
15:35-16:00	**Presentation:** Assessing economic and socio-cultural value of whale ecosystem services, Brynhildur Davidsdottir/David Cook. Q&A
16:00-16:20	**BREAK**
16:20-16:40	**Presentation:** "Estimating Use and Nonuse Values for Ecosystem Impacts of Aquatic Species: Design and Application of Stated Preference Methods", Robert Johnston Q&A
16:40-17:00	**Presentation:** "Common Asset Trusts for marine stewardship", Robert Costanza
17:00-17:20	**Presentation:** "Common Asset Trusts for marine stewardship: the case of whales", Marcello Hernandez-Blanco, Q&A
17:20-18:00	Round table, open discussion: • Identify methods to be applied to assess the contribution of cetaceans and potential for the development of 'best practice guidelines'.

Day 3 Review existing techniques for estimating the socio-economic value of the role of cetaceans in ecosystem functioning *(continuation)*

- Estimates of market values; this could include carbon sequestration based on global carbon market prices

Identify knowledge gaps and data needed to better assist in understanding the social and economic values of the contribution of cetaceans to ecosystem functioning.

Develop a prioritized list of recommendations to fill these knowledge gaps and advance on this topic.

Suggest potential approaches to include this topic into local, national, regional, and international decision-making processes.

15:00-15:10	Welcome, summary of previous discussions and topics for Day 3
15:10-15:35	**Presentation:** Co-developing good governance to integrate socio-economic data in marine science policy- Selina Stead Q&A
15:35-16:00	**Presentation:** Past, present and future of the ecosystem services provided by cetacean carcasses, Martina Quaggiotto Q&A
16:00-16:20	**BREAK**
16:20-18:00	Round table, open discussion: • Identify knowledge gaps and data needed to better assist in understanding the social and economic values of the contribution of cetaceans to ecosystem functioning. • Develop a prioritized list of recommendations to fill these knowledge gaps and advance on this topic. • Suggest potential approaches to include this topic into local, national, regional, and international decision-making processes.

ANNEX E - DEFINITIONS OF ECOSYSTEMS SERVICES USED UNDER THE SOCIO-ECONOMIC PERSPECTIVE OF THE CONTRIBUTIONS OF CETACEANS TO ECOSYSTEM FUNCTIONING

The definitions of ecosystems services used here are related specifically to the socio-economic perspective of the contribution of cetaceans to ecosystem functioning. The objective is to have a consistent use of these categories for the analysis of the table on traits of cetaceans identified by the IWC-CMS workshop on Cetaceans and Ecosystem Functioning.

To better understand the concept of ecosystem services, the concept of capital and natural capital should first be described. Capital can be defined as a "stock of materials or information that exists at a point in time" (Costanza *et al*. 1997), or moreover as "a stock of something that yields a flow of useful goods or services" (Costanza *et al*. 2014, p. 119). Following the definition of capital, natural capital can be defined as "a stock of natural resources (i.e., ecosystems) that yield a flow of goods and services (i.e., ecosystem services)," such as the case of a mangrove forest that provides food and water filtration to communities. Costanza and Daly explain the flow of goods and services as the "natural income" and the stock that yields the flow as the "natural capital" (Costanza & Daly 1992, p. 38). Sustainability is therefore centered in the wise use of income; depleting the stocks is called capital consumption (T. Prugh *et al*. 1995, p. 51) and is the reason for ecosystems' loss and degradation.

Generally speaking, ecosystem services are the benefits that people obtain from ecosystems (Millennium Ecosystem Assessment, 2005; IPBES, 2019; TEEB, 2010; Hernández-Blanco & Costanza, 2019). A more complete definition of ecosystem services is "the benefits people derive from functioning ecosystems, the ecological characteristics, functions, or processes that directly or indirectly contribute to human well-being" (Costanza *et al*. 2011). Ecosystem services include as broad categories provisioning, regulating, and cultural services that directly affect people. It also includes supporting services needed to maintain the other services (see figure 1). In the more recent literature, "supporting services" are considered as functions and not services *per se*. The following is a brief description of these categories:

- **Provisioning services**, such as timber, water, fiber, and food. A clear example of how these services interact with the other three types of capital is fishing activity, where fish provided to people as food requires fishing boats (built capital), fishermen (human capital), and fishing communities (social capital).
- **Regulating services**, such as pollination, flood control, water regulation, pest control, climate control, water purification, and air quality maintenance. For example, storm protection provided by wetlands (natural capital) to infrastructure such as hotels and houses on the coast (built capital), protecting its residents and other members of the community. Contrary to provisioning services, these services are not marketed.
- **Cultural services** that provide spiritual, recreational, and aesthetic benefits. A recreational benefit requires natural capital such as a waterfall, built capital like a trail and a road, human capital that appreciate the waterfall, and social capital, such as friends and family and the institutions that make the waterfall accessible.
- **Supporting services**, such as photosynthesis, nutrient cycling, and soil formation. These types of services do not require the interaction with human, social, and built capital; they affect human well-being indirectly by maintaining key processes that are necessary for the other three types of services. Using this description of supporting services, some scholars have argued that instead of ecosystem services they are ecosystem functions. Although this is true, supporting services can be used as a proxy to evaluate services in the other categories if more direct measures are not available (Costanza *et al.* 2011; MEA 2005)

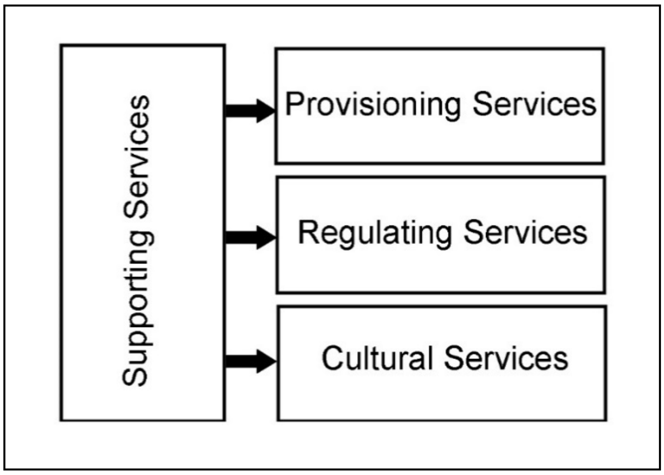

Figure 1 – Ecosystems Services Categories and relations

Table 1 from Costanza *et al.* (2017) presents a list of ecosystem services under the most common categorization frameworks.

Table 1. Comparison of four of the main ecosystem services classification systems used worldwide and their differences and similarities. Source: Costanza *et al.* (2017)

	Costanza et al., 1997 (a)	Millennium Ecosystem Assessment, 2005	TEEB, 2010	CICES 4.3 (v. 2013) (b)
Provisioning	Food production (13)	Food	Food	Biomass - nutrition
	Water supply (5)	Fresh water	Water	Water
	Raw materials (14)	Fibre etc.	Raw materials	Biomass – Fibre, energy & other materials
		Ornamental resources	Ornamental resources	
	Genetic resources (15)	Genetic resources	Genetic resources	
		Biochemicals and natural medicines	Medicinal resources	
	X	X	X	Biomass - Mechanical energy
Regulating & Habitat	Gas regulation (1)	Air quality regulation	Air purification	Mediation of gas- & air flows
	Climate regulation (2)	Climate regulation	Climate regulation	Atmospheric Comp. & climate regulation
	Disturbance regulation (storm protection & flood control) (3)	Natural hazard regulation	Disturbance prevention or moderation	Mediation of air and liquid flows
	Water regulation (4) (e.g. natural irrigation & drought prevention)	Water regulation	Regulation of water flows	Mediation of liquid flows
	Waste treatment (9)	Water purification and waste treatment	Waste treatment (esp. water purification)	Mediation of waste, toxics and other nuisances
	Erosion control & sediment retention (8)	Erosion regulation	Erosion prevention	Mediation of mass-flows
	Soil formation (7)	Soil formation *[supporting service]*	Maintaining soil fertility	Maintenance of soil formation and composition
	Pollination (10)	Pollination	Pollination	Life cycle maintenance (incl. pollination)
	Biological control (11)	Regulation of pests & human diseases	Biological control	Maintenance of pest- and disease control
Supporting & Habitat	Nutrient cycling (8)	Nutrient cycling & photosynthesis, primary production,	X	X
	Refugia (12) (nursery, migration habitat)	'Biodiversity'	Lifecycle maintenance (esp. nursery)	Life cycle maintenance, habitat and Gene pool protection
			Gene pool protection	
Cultural	Recreation (16), incl. eco-tourism & outdoor activities	Recreation & eco-tourism	Recreation & eco-tourism	Physical and experiential interactions
	Cultural (17) (incl. aesthetic, artistic, spiritual, education & science)	Aesthetic values	Aesthetic information	
		Cultural diversity	Inspiration for culture, art & design	
		Spirit. & religious val.	Spiritual experience	Spiritual and/or emblematic interactions
		Knowledge systems Educational values	Information for cognitive development	Intellectual and representative interactions

a) Costanza *et al* (1997) did not make a division into main categories; numbers (1-17) refer to Table 1
b) CICES is still in development. The list included here is v. 4.3 downloaded on 7 May 2017 from https://cices.eu/cices-structure/

It is key to distinguish between ecosystem processes and functions, on the one hand, and ecosystem services on the other. Ecosystem processes and functions refer to biophysical relationships that exist regardless of whether or not humans benefit. The opposite is the case with ecosystem services, which only exist if they contribute to human wellbeing (Braat 2013).

A second key point to highlight is that trying to apply an analytical framework that was created for ecosystems (e.g. the open ocean, coral reefs) to species (cetaceans in this case) can present some limitations. Perhaps the most important limitation is isolating the unit of analysis from the broader system, and therefore not capturing the many interactions between the species and the ecosystem (including humans). Although some ecosystem services such as pollination and pest control are evaluated based on a target species (e.g. common bee), these analyses also consider as equally important the habitat of these species (see for example Ricketts *et al*., 2004).

Some recent research has tried to apply the ecosystem services model to species of whales. For example, Cook *et al*. (2020) classified ecosystem services provided by whales using the Common International Classification Ecosystem Services (CICES) framework (Table 2).

Table 2. CICES classification of whale ecosystem services. Source: Cook *et al.* (2020)

Section	Division	Group	Class	Class type	Service
Provisioning (biotic)	Biomass	Animals for nutrition, materials or energy	Wild animals	By amount of product	Food products (meat, blubber, skin and intestines)
Provisioning (biotic)	Biomass	Animals for nutrition, materials or energy	Wild animals	By amount of product	Whale bones, teeth and baleen
Provisioning (biotic)	Biomass	Animals for nutrition, materials or energy	Wild animals	By amount of product	Oil-based products deriving from blubber
Regulation and maintenance (biotic)	Regulation of physical, chemical and biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (including gene pool protection)	By amount and source	Enhanced biodiversity and evolutionary potential
Regulation and maintenance (biotic)	Regulation of physical, chemical and biological conditions	Water conditions	Regulation of chemical composition of atmosphere and oceans	By type of living system	Climate regulation (carbon sequestration)
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	By type of living system or environmental setting	Tourism (whale watching)
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems used for entertainment or representation	By type of living system or environmental setting	Music and arts (entertainment)
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems used for entertainment or representation	By type of living system or environmental setting	Sacred and/or religious
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable education and training	By type of living system or environmental setting	Educational
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable aesthetic experiences	By type of living system or environmental setting	Aesthetics
Cultural (biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that are resonant in terms of culture or heritage	By type of living system or environmental setting	Community cohesiveness and cultural identity
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value	By type of living system or environmental setting	Existence
Cultural (biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value	By type of living system or environmental setting	Bequest

For the current analysis, although cetaceans (in relation with their ecosystems) provide a wide variety of services, as requested by the Scientific Committee we focus mainly[1] on supporting services/ecosystem functions (e.g. nutrient cycling, maintenance of genetic diversity, habitat provision). This scope of analysis will require a close collaboration with the IWC ecosystem modellers to link these functions with other ecological and economic process that directly benefit humans. For example, in the case of nutrient cycling, a line of research could be

[1] Other service that has been identified as a potential priority of research at IWC is climate regulation (through carbon sequestration).

dedicated to establishing the role of cetaceans in enhancing primary productions that increases fish stocks/production ultimately benefitting the fishing industry and consumers of fish products. This benefit may differ depending on the species of cetacean.

Establishing the dependence of humans with cetaceans should be the ultimate goal of the analysis, not only to be able to value (not price) the role that these species have in socio-ecological systems, but to be able to create the institutional (i.e. governance) and financial mechanisms that can protect and restore the population of cetaceans worldwide.

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ANNEX F – SUMMARY ANALYSIS OF IWC-CMS WORKSHOP TABLE ON CETACEAN TRAITS

The following three tables represents the proposed sub-division and analyses provided by the small working group that reviewed the IWC-CMS workshop table on cetacean traits.

Colour code and first six columns are what the IWC-CMS workshop table on cetacean traits considered. The new columns have been added and completed by the small working group to reflect their relations to socio-economic valuations.

Colour code: RED = nutrient transfer and circulation, GREEN = feeding-related traits, BLUE = provision of habitat, contribution to biodiversity, and blue carbon

Table a) - Ecosystem functions that could be translated into ecosystem services due to the existence of human beneficiaries[2]

Trait	Description	Functions	Services	Example	Reference(s)	Ecosystem Service Category1 (as determined by Socio-Economic workshop participants)	Ecosystem Service subdivision1 (as determined by Socio-Economic workshop participants)	Ecosystem Service Category2 (as determined by Socio-Economic workshop participants)	Ecosystem Service subdivision2 (as determined by Socio-Economic workshop participants)	Have already been considered in previous socio-economic models?
Mortality rate	Number of deaths per unit of time in a particular area	Nutrient transport, carcass succession and decomposition in deep sea, coast lines, and breeding areas	Biodiversity promotion in the deep sea, maintenance of gene flow and genetic diversity,	Whale fall communities throughout the deep sea; ecological and evolutionary stepping stones for hydrothermal vent and cold seep animals; nutrient supply for condors, polar bears, sharks and gulls	Smith et al., 2014; 2015, 2017, 2019; Taylor et al. 2007; Marón et al. 2015	Provisioning	*Genetic resources*	Regulating	*Carbon sequestration and climate regulation*	YES
Macronutrients in whale feces	Amount of nitrogen (NH4+) and phosphorous (PO43-) in whale feces	Stimulation of phytoplankton growth	The growth rate of phytoplankton from areas of whale populations	North Atlantic right whales stimulate the growth of phytoplankton species	Roman and McCarthy 2010; Roman et al. 2016,	Regulating	*Carbon sequestration and climate regulation*	Supporting	*Nutrient cycling*	YES
Excretion rate	Amount of excreted material per unit of time (g/day)	Nutrient storage, vertical nutrient subsidies, and community shaping by	Nutrient cycling, enhanced primary productivity, carbon storage and sequestration	Iron in sperm whale feces in Southern Hemisphere, nitrogen in baleen whales in	Lavery et al. 2010; Roman and McCarthy 2010	Regulating	*Carbon sequestration and climate regulation*	Supporting	*Nutrient cycling*	YES
Body Mass	"Size matters", with high metabolic efficiency, larger animals store more carbon compared to smaller ones	Storing carbon, preventing it from being released into the atmosphere	Contribution to blue carbon as a "nature based solution" (NBS)	Same food (krill) that supports one 92-ton blue whale also supports • 7 minke whales • 1800 penguins but, the total biomass would be less (1/2 or 1/10), extra carbon would go to atmosphere	Pershing & Stamieszkin 2020; Pershing et al.. 2010; Roman et al. 2014	Regulating	*Carbon sequestration and climate regulation*			YES

[2] Note that two columns are considered as Ecosystem Services Category as well as Ecosystem Services subdivision (1 and 2) due to the identification and listing of more than one ecosystem services related to a specific traits.

Table b) - Ecosystems functions that play a role as "supporting services"

Trait	Description	Functions	Services	Example	Reference(s)	Ecosystem Service Category1 (as determined by Socio-Economic workshop participants)	Ecosystem Service subdivision1 (as determined by Socio-Economic workshop participants)	Have already been considered in previous socio-economic models?	Additional Comments
Body size and latitude	Cetaceans in tropical systems are dominated odontocetes (mostly smaller species: beaked whales, blackfish, delphinids), which largely replace mysticetes	Energy conversion by feeding on individual prey in a more oligotrophic environment vs engulfing swarms.	Vertical transport of nutrients - either by relatively shallow divers that feed nocturnally on diel migrating prey or deep divers. Smaller but more numerous whale falls	Small cetaceans nearly absent from Antarctic waters	Baird et al. 2001, 2008; Shaff and Baird 2021; Doughty et al. 2016?	Supporting	*Nutrient cycling*		Increase marine food web productivity; increase in number and productivity of marine species;
Capital breeding	Stored energy used for reproduction and survival	Long-distance migration, winter calving and fasting	Transport of nutrients from highly productive foraging grounds to nutrient poor, low latitude feeding grounds, in the form of carcasses, placentas, skin sloughing, feces, and urine	Coastal species such as gray whales, humpbacks, and rights, best exhibit these traditional baleen migrations	Roman et al. 2014; Acevedo et al. 2017	Supporting	*Nutrient cycling*		
Epidermal molt	Killer whales and other migratory species travel thousands of kilometers each year for skin molt migration. Also some behaviors such as breaching (e.g. humpback whales) remove skin but also	Routine skin maintenance, feeding/molting hypothesis	Nutrient transport, microbial connectivity, food for scavengers and detritivores	Southern Hemisphere killer whales and other whales that migrate from polar latitudes to tropical waters	Pitman et al. 2019; Whitehead 1985	Supporting	*Nutrient cycling*		
Life span	Time in years	Nutrient storage	Nutrient cycling and maintenance of trophic interactions and ecosystem resilience and stability	Baleen whales are among the longest living mammals; foraging, migration, and whale fall communities are all affected by this trait	Keane et al. 2015; Taylor et al. 2007; Jones et al. 2009	Supporting	*Nutrient cycling*	YES	It has been used on valuation methods rather to estimate carbon sequestration trough lifetime.
Migration	Distance traveled per day,	Nutrient transport,	Resource subsidies from high nutrient	Nutrient dispersion,	Doughty et al. 2016;	Supporting	*Nutrient cycling*		
Prey for predators	Cetaceans as prey to killer whales and sharks, including 50 cm cookiecutter sharks	Providing prey for a range of predators	Killer whales and large sharks are a source of carcasses for scavengers and detritivores. For small sharks: a source of nutrient movement from surface layers to mid-water communities	Killer whale predation on large and small cetaceans; nearly all cetaceans in low latitudes have cookiecutter shark bite wounds.	Jefferson et al. 1991; Pitman et al. 2001, Barrett-Lennard et al. 2011, Wenzel and López Suárez 2012, Pitman et al. 2015	Supporting	*Nutrient cycling*		
Whale pump	Nutrients moved from aphotic zone to the surface	Similar to that of the biological pump, nutrient transfer from depth to surface and across migration routes	Nutrient cycling and promotion of biological diversity, particularly nitrogen, phosphorus and iron	Field studies and models have been conducted in the Southern Ocean, North Atlantic, and North Pacific Focus on iron, nitrogen, and phosphorus.	Nicol et al. 2010, Roman & McCarthy 2010, Roman et al. (2016)	Supporting	*Nutrient cycling*		
Body size and soft tissue lipid content	Mass, percent weight	Organic and inorganic nutrient storage and transport through growth, migration, mortality, and sinking	Transport of organic matter and inorganic nutrients from productive upper ocean to food-poor deep sea, provision of food to deep- sea, shallow-water and terrestrial scavengers, formation of reducing habitats at seafloor, nutrient cycling, carbon	Whale-fall communities at deep-sea floor in multiple stages of succession	Smith and Baco 2003; Smith et al. 2014, 2015, 2017, 2019; Pershing et al. 2010	Supporting	*Nutrient cycling*		

Table b) - Ecosystems functions that play a role as “supporting services” (continuation)

Trait	Description	Functions	Services	Example	Reference(s)	Ecosystem Service Category1 (as determined by Socio-Economic workshop participants)	Ecosystem Service subdivision1 (as determined by Socio-Economic workshop participants)	Have already been considered in previous socio-economic models?	Additional Comments
Bone lipid content	Percent and total mass of lipids in skeleton	Provision of persistent organic and sulfide- rich habitat at seafloor	Promotion of habitat heterogeneity (including organic-rich and chemoautotrophic habitats) and biodiversity at the deep- sea floor, evolution of novel whale-fall species, ecological and evolutionary stepping	Whale-fall communities at deep-sea floor in organic-enrichment and sulphophilic stages	Smith and Baco 2003; Higgs et al. 2010; Smith et al., 2015	Supporting	*Habitat provisioning*		Increase in benthic biodiversity, discovery of potential microbes/enzymes with value to humans
Iron content in feces	Percent of iron content in whale feces, stimulation of primary and secondary productivity (krill) in feeding grounds	Provision of iron-rich sources to support and enhance phytoplankton and zooplankton growth	Nutrient enrichment of feeding grounds, stimulation of productivity throughout the wider marine ecosystem	Blue, fin, humpback, and sperm whales in Southern Ocean	Lavery et al 2014; Roman et al. 2014; Nicol et al 2010;	Supporting	*Nutrient cycling*	YES	
Social and reproductive behavior	Group size	Nutrient provision	Concentration of nutrients via hot spots and hot moments	Fecal plumes from right whale breeding aggregations concentrate nutrients in surface waters	Roman et al. 2016, Roman et al. in review	Supporting	*Nutrient cycling*		
Consumption rate	Amount of prey or milk ingested per unit of time	Trophic dynamics and cascades, nutrient storage and transfer	Ecosystem resilience and stability	Baleen whales on foraging grounds, deep-diving species in the aphotic zone	Savoca et al. in review; Pauly et al. 1998; Goldbogen et al. 2019; Costa & Maresh 2017	Supporting	*Nutrient cycling*	YES	Improve ecosystem function. It has been used to determine nutrient cycling associated with excration rate and nutrient content.
Diel feeding patterns	Most feeding occurs at night and tracks deep scattering layer - mostly in the tropics	Allows animals to feed on vertically migrating midwater prey.	Vertical transport of nutrients from midwater to the surface	E.g., pantropical spotted dolphin, beaked whales (Ziphius Mesoplodon), rough-toothed dolphins,	Baird et al. 2001; Baird et al. 2008; Shaff and Baird 2021;	Supporting	*Nutrient cycling*		
Feeding distance	Distance between the breeding location and foraging area	Nutrient storage, movement of nutrients from areas of high productivity to areas that	Nutrient cycling and promotion of biological diversity	Whales have the longest migration of any mammals, traditional migration of baleen whales	Corkeron and Connor 1999; Geijer et al. 2016; Acevedo et al. 2017;	Supporting	*Nutrient cycling*		
Diving behaviour	(Maximum) dive depths	Diving for foraging	Displacements more deeply, more movement of nutrients in the water column	Beaked whales and sperm whales dive deeper than any other animal	Würsig et al. 2018; Encyclopedia of marine mammals	Supporting	*Nutrient cycling*		
Skeleton size and	Mass and surface	Provision of persistent	Promotion of habitat heterogeneity	Whale-fall communities at	Smith and Baco 2003;	Supporting	*Habitat provisioning*		
Carcass sinking to deep-sea floor	Nutrient food source for deep ocean fauna	Food source for many specialised deep-sea species, not found elsewhere. Many different stages, and last for decades on the sea-floor.	Physically modify and create new habitats. A number of stages supporting different species including 102 species ‘whale fall specialists’ that are not found elsewhere and need a whale fall to complete life cycles.	Whale-fall communities at deep-sea floor in multiple stages of succession	Schuller et al. 2004; Smith and Baco 2003; Smith et al. 2014, 2015, 2017, 2019	Supporting	*Habitat provisioning*	YES	It has been used on valuation methods not as habitat provision but as climate regulation & carbon sequestration, associated to body mass and mortality rate rather than "carcass sinking to deep-sea floor"

Table c) – Ecosystem functions that are not considered to directly support any ecosystem services

Trait	Description	Functions	Services	Example	Reference(s)	Ecosystem Service Category1 (as determined by Socio-Economic workshop participants)	Have already been considered in previous socio-economic models?	Additional Comments
Trophic Level	Trophic level of species in relation to prey consumption	Diet composition and trophic level ranges	Some nutrients are bio- accumulated in the food web. Cetaceans also exert top down controls on food webs	Predators, including smaller species, often have higher micronutrient concentrations in faeces	Pauly et al. 1998	Not ecosystem service		Strenthen marine food webs contributing to increased marine productivity
Surplus killing	Killing either more or much larger prey than can be consumed	Food source for deep and shallow water organisms and terrestrial scavengers	Can provide large amounts food (tons) for benthic scavengers and detritivores	Killer whales feeding on gray whales in Alaska, minke whales in Antarctica, and blue whales in Western Australia.	Barrett-Lennard et al. 2011, Pitman et al. 2015, Pitman et al. in review	Not ecosystem service		Enhance health of benthic scavengers, detritivores, and other animals in water column as well as for avian and terrestrial wildlife species
Cetaceans as 'beaters' of live prey for seabirds	Feeding/traveling whales and dolphins opportunistically providing live prey for seabirds	Seabirds catch prey that would not normally be available to them	The prey is dispersed as guano at sea and at colonies	Seabirds feeding with bubble-net feeding humpbacks and in association with dolphin schools	Au and Pitman 1986,Obst & Hunt 1990; Anderson & Lovvorn 2008, Veit and Harrison 2017	Not ecosystem service		Increase food availability for sea birds potentially increasing survival and production with nutrient benefits to terrestrial ecosystems (e.g., forests, wetlands, aquatic). (Note that the feeding behavior of some cetaceans recirculates prey and nutrients in the water column to the benefit of seabirds as well as marine creatures occupying different layers of the water column)
Cetaceans providing carrion for scavenging seabirds	Large, predatory odontocetes break up large prey and scraps are scavenged by seabirds	Seabirds feeding on prey normally too large for them	The prey is dispersed as guano at sea and at colonies	Seabirds picking up scraps from feeding mammal- eating killer whales, or other odontocetes	Pitman and Ballance 1992, Ridoux 1987	Not ecosystem service		Increase food availability for sea birds potentially increasing survival and production with nutrient benefits to terrestrial ecosystems (e.g., forests, wetlands, aquatic)
Reproduction rate	Number of calves per year	Reproduction	More offspring more biomass for the ecosystem	In general, small cetaceans have more calves per year than large ones	De Magalhaes & Costa 2009	Not ecosystem service	YES	Enhances ecosystem health with potentially additive benefits to nutrient cycling, climate regulation, and other identified services. It has been used on valuation methods associated to population abundance estimates and increase in trends.