Annex H
Report of the Subcommittee on Ecosystem Modelling

Members: Kitakado (Chair), Banga, Barreto, Bell, Bernus, Bessega, Biuw, Brownell, Buss, Butterworth, Campbell, Canadas, Cassani, Cisternino, Cooke, Cremer, de Moor, Di Tullio, Domit, Donovan, Double, Evangelista, Ferguson, Ferreira, Freitas, Frias, Fyfe, Galletti, Germishuizen, Gilbert, Goetz, Herr, Hielscher, Hunter, Jimenez, Juscamayta, Katara, Kelly, Kema, Lang, Leal, Lee, Lundquist, Lysenko, Maldonado, Mallette, Nelson, New, Øien, Oloughlin, Palka, Passadore, Pinder, Pita, Porter, Punt, Ransijn, Reeves, Ridoux, Ritter, Robson, Romero, Rosa, Sagalés, Schubert, Seakamela, Solvang, Stachwitsch, Staniland, Thomas, Tulloch, Urrego, Virgili, Walloe, Warrie, Webster, Weinrich, Witting, Zerbini.

1. INTRODUCTORY ITEMS

1.1 Opening remarks

Kitakado welcomed the members of the Standing Subcommittee on Ecosystem Modelling (hereafter Subcommittee). He reminded Subcommittee members that EM was established in 2007 to discuss ecosystem modelling. To date, EM has advanced investigations into key inputs and methodologies for ecosystem modelling, inter alia, prey-predator relationships, habitat use and spatial-temporal distribution. Additionally, EM has progressed work on individual-based energetic models to understand the functional response of large baleen whales to variations in prey availability. Furthermore, EM is responsible for advancing work on Commission resolutions 2016-03 and 2018-02 on the role of cetaceans and their contributions to ecosystem functioning.

1.2 Election of the Chair

Kitakado was elected Chair.

1.3 Appointment of rapporteurs

Schubert was appointed rapporteur with assistance from Kelly and Biuw.

1.4 Adoption of agenda

The adopted agenda is included as Appendix 1.

1.5 Documents available

SC/69B/EM/01-03, SC/69B/REP/04, Johannessen *et al.* (2022), Biuw *et al.* (2024), Ransijn *et al.* (2021), and van den Hurk *et al.* (2023).

2. ROLE OF CETACEANS IN ECOSYSTEM FUNCTIONING: GAP ANALYSIS

2.1 Review previous Committee discussions on contribution of whales to ecosystem functioning

Cetaceans can have a broad range of functions in an ecosystem, including as predators, through nutrient transport and cycling (vertically and horizontally), carbon sequestration. In response to the Commission's adoption of Resolutions 2016-03 on the role of cetaceans in ecosystem functioning, the Committee was asked to conduct a gap analysis on the subject by examining the existing literature to identify knowledge gaps, and to develop a plan for filling those gaps through research. Resolution 2018-02 encouraged the Committee to collaborate with the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and other international organisations in this work.

The Subcommittee has been tasked with engaging in this work for the Committee. The original plan was to conduct an in-person workshop; however, due to the COVID-19 pandemic, a three-day virtual joint workshop with CMS on a gap analysis was held in 2021 (see SC/68C/REP/03). The Terms of Reference for the workshop included: review of existing scientific literature to identify ecosystem functions provided by whales; determination of functions that could be quantified reliably; identification of potential species/taxa and geographical areas on which to focus; identification of knowledge gaps; and development of a prioritized list of recommendations for scientific research to fill those gaps. The workshop included two keynote reviews of cetaceans and ecosystem functioning prepared by Drs. Roman and Wassmann, and additional presentations on specific functions (e.g., whale falls, whale pump, whale conveyor belt, role as predators) provided by other experts. The results of the workshop included the following list of questions, hypotheses, and tasks to be considered at a second workshop on the subject, scheduled for November 2023.

1. Development or modification of existing ecosystem models for the basis of subsequent items.*
2. Identify inputs needed for a robust assessment of the contribution of cetaceans in 'ocean fertilisation', 'carbon cycle and sequestration', 'delivery of nutrient and energy', and 'habitat provision' (i.e., contribution relative to species other than cetaceans, with respect to consumption, metabolism, biodiversity, and habitat, including deep sea floor).
3. Quantification of spatial difference in ecosystem functioning of cetaceans, focusing on links with environments and regional ecosystem characteristics (i.e., historical trends in different places).
4. Quantification of temporal changes in ecosystem functioning of cetaceans, with focus on the difference between pre-whaling and current populations, and identification of information and knowledge.
5. Qualitative assessment of the future roles and ecosystem functioning of cetaceans, with a focus on implications of global changes.
6. Different contributions to ecosystem functioning over different cetacean species/functional groups (i.e. small versus large, mysticetes versus odontocetes, etc.).

* The Subcommittee notes that this text is unclear in its meaning. To clarify, the "development or modification of existing ecosystem models" is intended to facilitate meeting the objectives contained in items 2-6.

In 2021, the SC agreed to focus on items 3 and 4 at the second workshop which, as an in-person event, should be better suited to engage in discussions regarding the detailed quantitative analysis of ecosystem functioning and issues related to ecosystem modelling.

2.2 Review outcomes of the joint CMS/IWC Workshop

Schubert provided a summary of the 2nd IWC-CMS Workshop on Cetaceans and Ecosystem Functioning held in Bonn, Germany, in November 2023. He thanked the CMS and IWC for co-hosting the event and the invited experts for bringing their expertise to the event. He described the procedure used to identify and select experts, including economists, to invite to the workshop. Seventeen presentations were given at the workshop which included information on the following topics: updates to the science documenting the role of cetaceans in ecosystem functions; assessment of the pre- and post-commercial whaling abundance estimates for large whales in the Southern Ocean and Northeast Atlantic; using ecosystem models to evaluate the role of cetaceans in different oceanographic regions; applying the use of economic methodologies to assess the value of the services provided by cetaceans; and the outline of a research program to aid in addressing some of the gaps in knowledge of the ecosystem functions of cetaceans. He explained, as noted during workshop discussions, the importance of robust pre-commercial whaling and current large whale abundance estimates within different oceanographic regions to improve understanding of how the

ecosystem functions of cetaceans differ spatially and temporally. To highlight the different methodologies used to estimate pre- and post- whaling abundance, he noted three analyses prepared for or during the workshop providing such estimates for large whales in different oceanographic regions, including the Northeast Atlantic and Southern Ocean (see Annexes D, E, and F in SC/69B/REP/04). Finally, he summarized the key input provided by small Subcommittee on ecosystem modelling and socio-economic aspects created during the workshop (see Annexes G and H in SC/69B/REP/04) and the overarching workshop recommendations, which included:

- The question of how the indirect whale carbon pathways operate across vertical and horizontal spatial scales needs to be addressed, both whether the associated mechanisms are operating (nutrient cycling; carbon fixation, export and sequestration), and if so, what is the contribution of whales relative to other ecosystem components.
- Develop a framework illustrating the causal linkages between the ecosystem services to which cetaceans contribute (e.g., climate regulation, nutrient cycling contributing to primary productivity, habitat provisioning), cetacean functions in the ecosystem and the potential values to beneficiaries.
- Place the ecosystem services to which cetaceans contribute in priority order for analysis*

*The Subcommittee agreed with the establishment of an IWC SC ICG to prioritise the research needs to advance efforts to address the knowledge gaps in regard to the ecosystem functions of cetaceans (see Table 2).

In discussion, the Subcommittee thanked the Chair (Kitakado), organising convenor (Schubert), and all invited experts for their participation in the workshop and noted the value of advancing collaborative work between the IWC and CMS. The spatial and temporal difference in the ecosystem function of cetaceans was emphasized and underlies the need to develop robust pre- and post-commercial whaling abundance estimates for cetaceans. For the Southern Ocean, it was noted that two separate analyses using different methodologies (Moosa 2017 and Tulloch *et al.* (unpublished)), resulted in similar estimates (20%) of the current compared to pre-whaling biomass of large whales. In the Northeast Atlantic Ocean, models overall indicated a much higher current cetacean biomass (~80%), relative to the estimated pre- exploitation level. Models of varying complexity have been used to develop these various estimates, ranging from relatively simplistic single-species models in the case of the Northeast Atlantic, to multi-species models for the Southern Ocean. It was noted that there is a need to promote and advance the use of multi-species models to develop such estimates in different oceanographic regions while finding a balance between complexity and functionality when selecting models for such assessments. The results of such modelling work can help quantify the ecosystem functioning of cetaceans and associated uncertainties and would be useful for purposes beyond estimating the ecosystem function of cetaceans.

The Subcommittee noted the input provided by the two small Subcommittee s formed at the 2nd IWC-CMS Workshop as well as the Workshop's recommendations and encouraged those engaged in this work to incorporate this input and recommendations into current and future research endeavors. The Subcommittee would welcome future reports that provide information responsive to these matters.

2.3 Update since the IWC-CMS workshops

2.3.1 Update on additional scientific research published since 1st IWC-CMS Workshop on Cetaceans and Ecosystem Functioning

SC/69B/EM/02 summarises progress outside of the Committee on the work to understand the contribution of cetaceans to ecosystem functioning. Whale and Dolphin Conservation conducted a literature review to assess the current state of the science subsequent to the IWC-CMS expert workshop held in 2021. Results were matched against the research and development needs

identified during the workshop (SC/68C/REP/03), and areas of commonality, as well as topics in need of further consideration, were identified. The review identified over 50 scientific papers that have been published within the cetacean ecosystem functioning area of work over the last four years (2021-2024). These publications vary by focal species, subject area, and geographic location, yet collectively start to address the knowledge gaps recognised during the IWC-CMS workshop. For example, scientific understanding on whale falls, the contributions of small cetaceans to ecosystem functioning, the impact of climate change and the seasonal timing of whale migrations has progressed. However, gaps on topics such as the bioavailability of nutrients, moulting, and the impact of key nutrients and other limiting co-factors on phytoplankton growth and/or bacterial communities require further research. Many of the papers identified within the review were noted to fall within the periphery of the work area and targeted research was suggested to fully address IWC Resolutions 2016-03 and 2018-02. The authors recommend that the Scientific Committee continues to collaborate with CMS on this work stream and considers further prioritisation of topics, species, populations and ecosystems to identify priority knowledge gaps and continue to progress this area of work effectively. The authors also recommend the Scientific Committee considers the roles of small cetaceans in nutrient cycling and ecosystem functioning in note of recent publications that demonstrate the importance of their contributions in marine systems.

In discussion, the Subcommittee thanked the authors for the useful compilation of new studies published since 2021 that are relevant to the Subcommittee's task to examine the ecosystem functions of cetaceans. Table 1 (Annex A to SC/69B/EM/02) provides a valuable analysis of the recently published literature in relationship to the knowledge gaps identified in SC/68C/REP/03. The authors noted their interest and intent to provide regular updates on newly published literature relevant to Subcommittee's analysis of the ecosystem functions of cetaceans at future SC meetings. The Subcommittee thanked the authors for this offer and encouraged such regular updates. It was noted that the color coding used in Table 1 of SC/69B/EM/02 could be used to identify outstanding knowledge gaps with the lighter colors indicating areas of research need and it was suggested that such research needs could be prioritized based on the potential importance of the specific role of the cetaceans in the ecosystem. The Subcommittee noted this suggestion and encouraged that members approach the authors directly should they have additional input on the analysis including Table 1.

2.3.2 Estimating pre-exploitation and current abundance of large whale populations

van den Hurk *et al.* (2023) was presented addressing historical whaling in the North Atlantic. Global industrial whaling activities, often referred to as the period from c.1600 CE to modern times, have greatly impacted whale populations. Modern conservation efforts attempt to improve the protection of whale populations but lack a deep-time understanding of what pre-whaling population abundances were and how they have been affected by whaling activities. Valuable information to answer these questions is hidden in archaeological records. Taxonomic identification of whale bones found during archaeological excavations is problematic due to their typically fragmented state. This difficulty limits understanding of both the past spatio-temporal distributions of whale populations and of possible early whaling activities. To overcome this challenge, zooarchaeology were performed by mass spectrometry on an unprecedented 719 archaeological and paleontological specimens of probable whale bones from Atlantic European contexts, predominantly dating from c. 3500 BCE to the 18th Century CE. The results show high numbers of Balaenidae (probably North Atlantic right whale (*Eubalaena glacialis*) and grey whale (*Eschrichtius robustus*) specimens), two taxa that are currently no longer present, or very rare visitors, in the eastern North Atlantic. This discovery matches expectations regarding the past utilization of North Atlantic right whales, but was unanticipated for grey whales, which have hitherto rarely been identified in the European zooarchaeological record. Many of these specimens derive from contexts associated with medieval cultures frequently linked to whaling: the Basques, northern Spaniards, Normans, Flemish, Frisians, Anglo-Saxons and Scandinavians. This association raises the likelihood that early whaling impacted

these taxa, contributing to their extirpation and extinction. Much lower numbers of other large cetacean taxa were identified, suggesting that what are now the most depleted whale species were once those most frequently taken.

In discussion, the Subcommittee thanked the author for his presentation. It noted the hypothesis that historical whaling of other baleen whale species using primitive tools contributed to population decline (e.g., the Makah tribe's hunting of grey whales in the Northeast Pacific). The Subcommittee asked the author whether it is possible that environmental factors (e.g., the Little Ice Age) might have contributed to the decline and extirpation of the Atlantic grey whale. The author indicated that it is plausible that environmental factors may have contributed to the demise of the grey whale in the Atlantic Ocean.

2.3.3 Ecosystem modelling in the Southern Ocean and Northeast Atlantic Ocean

No paper was presented under this agenda item. In discussion, the Subcommittee noted that ecosystem modelling work in the Southern Ocean and North Atlantic were reviewed at the IWC-CMS 2nd Workshop on Cetaceans and Ecosystem Function in Bonn, Germany. It was noted that ecosystem modelling work in the Northeast Atlantic is ongoing with a range of ecosystem models in use and under development, including Gadget (Globally Applicable Area Disaggregated Ecosystem Toolbox) models. The Subcommittee encourages ongoing work and welcomes updates on the progress and outcomes of such initiatives at future SC meetings.

2.4 Updates from the Conservation Committee's WG

EM01 present advances made over the last year by the CC intersessional correspondence group (ICG) on cetaceans and ecosystem functioning to advance terms of reference (ToR) for a pilot project to assess the socio-economic values of the contribution of cetacean to the ecosystem functioning as requested at IWC68. An advisory group was established in 2023. A set of populations (i.e., North Pacific humpback whale; the Southern Ocean whale species assemblage (humpback, blue, fin, and minke whales); the Southwest Atlantic southern right whales; and the North Atlantic minke whale) with sufficient and accurate information, that could be targeted for such a consultancy have been identified and already discussed at SC69A. The advisory group developed ToR and a draft tender for the pilot project. Economists and ecological scientists attended the second IWC-CMS workshop in November, 2023 and revisited the pilot project ToR. The workshop experts reached agreement on the ToR priorities and noted that the pilot project consultancy should (a) center around creating a research framework to assess the economic role of cetaceans in supporting marine ecosystem services; (b) apply relevant models (with available ecological and economic data) to one or more specific populations/areas as a general case study, and; (c) provide general guidelines on how economic valuations can be used to influence whale conservation and management, either through market or policy developments. Over the next months, the draft tender should be reviewed by the ICG and the Secretariat to reflect the workshop agreements, following which a proposal will be put forward for discussion at IWC69. In addition, the Conservation Committee had requested update of the ToR of the ICG itself and a proposal has been put forward by the Secretariat and the ICG based on previous Commission decisions.

In discussion, the Subcommittee thanked the author for the presentation. The economists selected through the tender process will select the specific population/area on which they will focus, and could elect to focus on more than one population/area. Ecologists with knowledge of the population(s)/area(s) selected will collaborate with the economists on conducting the analysis. While the economic models could be applicable to small cetaceans, it was agreed by EM and the CC ICG that the pilot project will focus on population(s)/area(s) for which we have the highest quality data on pre- and post-whaling abundance/biomass estimates.

The Subcommittee engaged in a robust discussion on the need/value of understanding the relative

contribution of large whales to ecosystem functioning (e.g., nutrient cycling) compared to the contribution from lower trophic level marine species. Though the Tulloch model as at present could provide estimates of krill and baleen whale species only, modification of the model to include a wider range of species at lower trophic levels is possible, but would potentially require additional capacity and resources.

The relative contribution of large cetaceans compared to other marine species to ecosystem functions in the Southern Ocean (amongst other regions) was discussed. Some members considered that if the cetacean contribution (particularly its change from pre-whaling to the current time) lay well within the range of variability of the contribution of other species, this cetacean contribution would not be meaningful in either ecological or economic terms, so that this matter should be resolved before the pilot study was further advanced. Other members considered that, even if this is relatively small ecologically, it could still be large economically, so that further understanding of this matter was not necessary to advance the pilot project.

The Subcommittee noted that some previous attempts to place a monetary value on restoring whale populations as a nature-based climate solution (NbCS) have relied on several uncertain assumptions and estimates. These include often relatively large values for the extent by which past whaling reduced abundance. In particular, although substantial uncertainties still remain regarding estimates of some of these reduction levels for many species and the relative magnitude of carbon intake attributable to the nutrient cycling mediated by cetaceans, not all were especially large. Thus, although the biomass of the large baleen whales in the Southern Ocean is presently only some 20% of its pre- whaling level, the corresponding figure for the Northeast Atlantic may be closer to 80%. As the valuation approach is often directly related to the estimated future value of populations, many of which have now recovered to close to their pre-whaling levels, there is a risk of substantial bias in these valuations, which depends on the reliability of assumed reduction levels and consequently the magnitude of the contribution of cetaceans to the biological carbon pump through nutrient cycling.

It was also noted that there is existing momentum behind the socioeconomic aspects, with whales and cetacean restoration already being considered a marketable climate mitigation commodity. This provides further reason to continue efforts to address these knowledge gaps and uncertainties in order to inform such economic assessment and ensure that they are based on the best data available. However, some members of the WG reiterated that such an exercise remains problematic as long as substantial uncertainty remains regarding several of the key ecological processes, and that caution should be exercised when undertaking valuation analyses of cetaceans.

2.5 Current conclusions and future work

The Subcommittee has fulfilled several of the tasks directed to the Committee by the Commission (see IWC Resolution 2016-02 and 2018-03) including: (1) reviewing the ecological, environmental, management, social and economic aspects (in collaboration with the CC and its ICG on cetaceans and ecosystem functioning) related to the contributions of cetacean to ecosystem functioning; (2) completing a gap analysis regarding research needs; (3) and increasing collaboration with governmental, non-governmental, regional and international organizations, including CMS and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), in regard to research on the role of cetacean in ecosystem functions.

Despite this notable success, further work is necessary to address the identified research gaps, prioritize research needs, and to improve our knowledge of the ecosystem functions of cetaceans (large and small) so as to better inform the Commission, the scientific community, and the public on these matters using the most robust and accurate data available. To that end, the Subcommittee drew attention to the following.

***Attention**: SC, R*

*The Subcommittee **recommends** that existing models, including multi-species models, and any newly developed models continue to be used by scientists to develop more robust estimates of pre- and post-commercial whaling abundance estimates in all oceanographic regions and, particularly, in those regions where existing estimates are non-existent or based on incomplete/inadequate data.*

The Subcommittee recognised that there remains a need to use the results from the two IWC-CMS co-hosted workshops and endeavours, in collaboration with scientists and other stakeholders with relevant expertise, to develop a prioritised list of research needs for consideration at SC70.

***Attention**: S, SC, R*

*The Subcommittee **recommends** that existing and newly developed ecosystem-based models be used by the SC to improve understanding of the full suite of ecosystem functions (e.g., nutrient cycling, carbon sequestration, biodiversity (associated with whale falls), predator/prey dynamics and habitat provisioning) of cetaceans (large and small) as well as lower tropic level organisms to explore the relative contributions of a variety of marine organisms to ecosystem functions both temporally (across time) and spatially (across oceanographic regions).*

***Attention**: S, SC, R*

*The Subcommittee **recommends** that scientists, research coalitions and consortiums engaged in the study of the ecosystem functioning of cetaceans, if seeking funding from international/national funding institutions or philanthropic institutions, consider seeking a letter of endorsement from the IWC Secretariat to advance research in line with the Committee's workstreams and that will address the knowledge/data gaps previously identified by the Committee.*

***Attention**: S, CMS*

The Subcommittee recognised the progress made during previous workshops on cetacean ecosystem functioning and recommended that the Secretariat continue to liaise with the CMS Secretariat to share information that addresses the knowledge/data gaps identified and, if hosting future workshops on this subject, to consider inviting collaboration with the CMS Secretariat and other international organisations.

***Attention**: SM*

The Subcommittee recognised the growing evidence documenting the role of small cetaceans in ecosystem functioning while noting that more research/data is necessary to fully quantify the role of small cetaceans in ecosystem functioning and encourages members of the Small Cetaceans Subcommittee to join the Ecosystem Modelling Subcommittee to advance joint interests in this matter.

***Attention**: CC, SC-CC, CG*

The Subcommittee was informed by the CC ICG on cetaceans and ecosystem functioning of the status of the pilot project to assess the socioeconomic valuation of the ecosystem functions of cetaceans consistent with the ToR and tender developed for this project and, should this project be endorsed by the CC and Commission, ***strongly encourages*** *the involvement of relevant experts in this work.*

2.6 Other

During discussion on this item, the Subcommittee expressed the need to use science to address issues of public importance including the role of cetaceans in ecosystem function. The Subcommittee also expressed the need to identify specific scientific questions and objectives to inform the public and decision-makers on issues of particular interest such as the impacts of climate change on species distributions and ecosystem functions. It was noted that prioritization of research needs could be based on existing knowledge gaps and the Subcommittee endorsed creation of an ICG to engage in this work (see Work Plan (Table 1), Intersessional email groups (Table 2), and Appendix 3). The Subcommittee noted the research proposal presented by Pearson at the IWC-CMS 2nd Workshop and its potential value in addressing some of the most important existing knowledge gaps. It was also suggested that the role of small cetaceans in ecosystem functioning is the subject of increased focus within the scientific community, and that this may be an important issue for the Small Cetaceans subcommittee to address in the future.

3. REVIEW ISSUES RELEVANT TO ECOSYSTEM MODELLING WITHIN THE COMMITTEE

3.1 Krill distribution and abundance

Kelly provided the Subcommittee with a summary of the krill data maintained by CCAMLR which include: (1) krill vessel catches; (2) observer sample data of bycatch; (3) observer data of krill length distributions; (4) observer sample data of Incidental Mortality Associated Fishing (IMAF) interactions; (5) active acoustic data (including vessel survey data and acoustic data from fishing vessels); (6) CCAMLR Ecosystem Monitoring Programme (CEMP) data for land based surveys; and (7) and non-fishery data.

In discussion, the Subcommittee thanked the author for the presentation. While data from krill surveys is always welcome, seeking all such data without first identifying the specific questions that the Committee is trying to answer or objectives it is trying to meet may not be helpful. A proposed EM ICG may be able to engage in such discussion (see Item 4 and Appendix 2).

The Subcommittee was informed about a recent paper by Skaret *et al.* (2023) that describes results from 10 years of annual acoustic-trawl surveys of krill biomass around the group of islands in the southern Scotia Sea, centred on Lat 60°44'S / Lon 45°10'W, carried out by the Norwegian Institute of Marine Research in collaboration with the krill fishing industry between 2011 and 2020. Average krill biomass within survey area ranged from 1.4 to 7.8 million tons, strongly supporting that this is among the regions in the Scotia Sea with consistently highest krill densities. While the data showed substantial spatial as well as annual variability in biomass distribution, there were no significant trends over the 10-year period. The highest krill densities were associated with the shelf edge and submarine canyons on the north side of the island group. Comparison with the CCAMLR 9.3% reference exploitation rate suggests that management of the krill fishery in the region is precautionary. Results show that industry-based surveys are cost- efficient approaches to high-quality monitoring of krill, but also highlight the high degree of spatial clustering in some years, with areas of superabundance interspersed with large areas with low biomass. Such clustering can have major influence on the results from krill surveys and highlights the need for regular high-resolution surveys in key hotspots in order to capture the dynamics. Cetacean surveys were also carried out on these surveys, and results are currently being developed for publication.

In discussion, the Subcommittee thanked the presenter for the presentation and noted that while the survey region for the annual krill surveys in the region was relatively small, there is still the potential it could help characterise the inter- annual variability in krill biomass and distribution over a broader region of the Scotia Sea. The Subcommittee also heard that the authors of Skaret *et al.* (2023) were developing automated krill data processing capability for use on krill fishing vessels. The Subcommittee looks forward to receiving new information regarding the variability in distribution and abundance of krill and cetaceans at future meetings.

3.2 Modelling of competition among whales and relationships between whales and prey

Johannessen *et al.* (2022) notes that with increased anthropogenic activity, knowledge about the spatiotemporal patterns of humpback whale foraging activity in the West Antarctic Peninsula is crucial to minimize overlap in time and space. This pilot project assessed the use of platforms of opportunity to collect fine-scale data in order to estimate abundance and predict feeding hotspots during the first half of the summer foraging season. Using density surface hurdle models, abundance was estimated to peak in late December at 19,107 individuals, and foraging hotspots were predicted to be in the Gerlache Strait and in the central Bransfield Strait. The highest concentrations of animals was predicted to be in late December, with a subsequent dispersion in mid-January. Assuming a foraging season of 120 days, this trend shows that humpback whales and the Antarctic krill fishery operate in the same time and space during April. Lastly, platforms of opportunity provided crucial infrastructure to conduct cetacean surveys and are a viable approach for future monitoring efforts.

In discussion, the Subcommittee thanked the author for the presentation. Several questions were asked about the methodology including the comparability of data between cruises given the use of cruise vessels as platforms of opportunity, the lack of standardized full line transect surveys, whether the methodology could be applied to other species, and the importance of the overlap (or lack thereof) between whales and the krill fishery. The author noted the difficulty in comparing data across cruises but explained that efforts are made to ensure proper training of students by experienced observers to reduce observer bias and variability, that the methodology works for humpback whales due to their abundance in the area, and that the lack of overlap between whales and the krill fishery at one point in time does not mean that overlap is not occurring elsewhere. As regards the krill fishery and its interactions with cetaceans, the fishery tends to focus on areas with the highest krill density resulting in increasing overlap as the krill fishery season progresses. Such overlap is only of concern to the IWC if the amount of krill being removed interferes with cetacean feeding needs; it also needs to be noted that krill in the area are not stationary but, rather, the area operates as a conveyor belt for krill from west to east. Because there is not a permanent standing stock of krill in the area, observation data represent a snapshot in time of local krill abundance, hence requiring careful consideration when evaluating such data. It was also noted that there is considerable uncertainty in the krill abundance estimates, and that other environmental factors may be influencing krill abundance which is of significant concern.

Biuw *et al.* (2024) reports findings from a recent multi-vessel single-platform sightings survey carried out as part of the 2019 Area 48 Survey for Antarctic krill in the Scotia Sea, Southern Ocean. The paper was also presented to ASG/ASI for consideration of endorsement of the abundance estimate. Distance sampling analyses suggest an average fin whale density throughout the Scotia Sea of 0.0256 (CV = 0.149) whales per km^2, resulting in a design-based abundance estimate of 53,873 (CV = 0.15, 95% CI 40,233–72,138) and a model-based estimate of 50,837 (CV: 0.136, 95% CI 38,966– 66,324). These estimates are at least an order of magnitude greater than the previous estimate from the same region based on the IDCR/SOWER-2000 data, suggesting that fin whales are undergoing a substantial increase in the South Atlantic. This may have important implications CCAMLRs spatial overlap analysis process and efforts to implement a Feedback Management

system for Antarctic krill. Depending on the approach used for estimating krill consumption, this abundance estimate suggests an annual summer krill consumption by fin whales in the Antarctic Peninsula and Scotia Sea area of ~6.4 to 9.4 million tons, which would represent around 20 times the total krill catch taken by the commercial fishery in Area 48 during the same season, or about 12.7% of the 2019 summer krill standing stock estimated from data collected during the same survey. This highlights the crucial importance of including cetacean krill predators in assessment and management efforts for living marine resources in the Southern Ocean, and particularly stresses the urgent need for a re-appraisal of the abundance, distribution and ecological role of Southern Hemisphere fin whales.

In discussion, the Subcommittee thanked the author for the presentation. While the fin whales may be feeding on other species, it is assumed for the purpose of the analysis that they are primarily feeding on Antarctic krill. While there is no current isotopic analysis being conducted to confirm fin whale diets in the region, other ongoing research in the area has collected biopsy and fecal samples, and there are satellite tracking data from fin whales. The comparison between fin whale diet and krill density in the area warrants further analysis due to potential implications to the fishery. It was noted with interest that krill density is very similar in two large-scale surveys in 2000 and 2019, suggesting there has been no dramatic decrease over this period, while fin whales and other baleen whales appear to have increased considerably, and that this may warrant consideration of the role of other whales, particularly humpback and minke whales, in the area as well as consideration of the environmental conditions during the two krill survey years given the normal variability in krill numbers over time.

Ransijn *et al.* (2021) notes that quantifying marine predator consumption and prey selection is vital for understanding their impact on prey species, fisheries, and the ecosystem, and for estimating the potential impacts of ecosystem variability and fisheries on cetaceans. However, parameterizing functional responses for large predators is challenging due to limited data on predator diet and the availability of multiple prey species. Ransijn *et al.* (2021) developed a multi- species functional response (MSFR) model for harbour porpoises (*Phocoena phocoena*) in the southern North Sea, using Bayesian methods to estimate parameters and incorporate uncertainties. Prey consumption was derived from stomach content data, while prey availability was determined by the spatial overlap between prey distributions, estimated from fish survey data, and porpoise foraging ranges obtained from telemetry data. The results of the study indicated a preference for sandeels in the study area, with evidence of prey switching behaviour confirmed by the favoured type III functional response model. The integrated approach, combining data on prey consumption, predator foraging distribution, and prey availability, offers a methodological framework for modelling MSFRs for other predator species. Currently, the MSFR is being integrated into various ecosystem models to estimate likely rates of removal of fish from the system by marine mammal predators and the impacts of this on interacting fish stocks under different scenarios (e.g., different fishing catch limits, presence of man-made structures).

In discussion, the Subcommittee thanked the author for the presentation. The Subcommittee noted that the functional response is an important aspect ecosystem modelling and that MSFR has to be considered when estimating importance of various species in diet. The use of a Bayesian modelling framework has particular advantages as all uncertainty (e.g., prey availability, foraging ranges) is considered and combined into the model. Use of simple regression types of methods without considering uncertainty in prey availability does not provide such benefits and can introduce some bias into the results. The Subcommittee noted that while EM has not focused on the ecosystem modelling in the North Sea specifically, these methods could be very useful for work in other regions.

3.3 Multi-species distribution models (MSDMs)

The diversity and complexity of analytical methods used for single species distribution models (SDMs)

and multispecies distribution models (MSDMs) continue to increase. To ensure that the Committee can evaluate these types of models to determine whether the model results can be used to provide the Commission with management advice, an Intersessional Correspondence Group (ICG) was established at SC68C to advance the Committee's work on developing guidelines and possible simulation platforms for SDMs and MSDMs.

Due to competing priorities, limited progress has been made towards accomplishing the tasks set forth in the ICG's terms of reference. It was noted that guidelines were established approximately 10 years ago to conduct MSDMs, but they have not been updated since despite substantial methodological development in the intervening time period. The Subcommittee agreed that, while MSDMs remain an important topic, this work should be put on hold for now due to limited resources, but that the Subcommittee should endeavor to keep up with developments in the use of MSDMs in other fields (e.g., fisheries science). It also agreed that MSDMs should be retained as an EM agenda item but that the ICG can be closed.

3.4 Development of individual-based energetic models (IBEMs)

The Subcommittee noted the important work done by de la Mare to advance development of IBEMs. Recently, however, no papers on IBEMs have been submitted for consideration by EM and there are no funds to conduct such analyses. The Subcommittee agreed to maintain IBEMs as a standing agenda item for EM, but to close the ICG.

3.5 Effects of long-term environmental variability on whale populations

The Subcommittee noted the importance of this work and expressed support for the ongoing efforts of the E Subcommittee to evaluate the impact of climate change on whales including at a workshop conducted in 2021. The Subcommittee agreed to keep this item as a standing agenda item for future meetings.

3.6 Other

The Subcommittee did not raise and other matters for discussion.

4. COOPERATION WITH CCAMLR

4.1 CCAMLR's Ecosystem Monitoring Programme (CEMP) Report

SC/69B/EM/03 provides a description of CCAMLR's Ecosystem Monitoring Programme (CEMP), which was established in 1985 with the aim to: a) detect and record significant changes in critical components of the ecosystem, to serve as a basis for the Conservation of Antarctic Marine Living Resources; and b) to distinguish between changes due to the harvesting of commercial species and changes due to environmental variability, both physical and biological. A review of CEMP, exploring how the programme can inform CCAMLR's revised krill fishery management approach, commenced in 2023 and included discussion of cetacean science. In recognition of the importance of considering cetaceans in CCAMLR's revised krill fishery management approach, the current review of CEMP provides an opportunity for IWC and CCAMLR to further collaborate on developing advice on data, survey design, and subsequent analyses and syntheses, and to develop research networks to contribute to this work.

In discussion, the Subcommittee thanked the author for the presentation. It considered the proposal for IWC to provide advice to CCAMLR on the role that cetaceans might play in an enhanced CEMP as a good way to support collaboration between the two organisations. It was also suggested that incorporation of cetaceans into CEMP, or krill fishery management more broadly, may not be straightforward given how wide-ranging cetaceans can be in the Southern Ocean, and that any collaboration would benefit from a deeper consideration of specific management needs of both organisations. The Subcommittee endorsed the creation of an EM ICG to address data sharing with CCAMLR, facilitate IWC input into the CEMP review, and to develop, in collaboration with CCAMLR, a

high-level strategy regarding management needs for ecosystem modelling (with particular focus on whales and krill interactions, and including the influence of climate change) for both IWC and CCAMLR (see Appendix 2). It also encourages CCAMLR member states to nominate SC members with relevant expertise (e.g., Southern Ocean baleen whale abundance estimates, survey methodologies, cetacean health and consumption rates) to attend the upcoming CCAMLR WG-EMM (July 2024). The Subcommittee also recalled a plan to hold a joint IWC-CCAMLR workshop in 2019 to develop multi-species models of the Antarctic marine ecosystem, with a possible focus on the Antarctic Peninsula given it is a high-priority area for both CCAMLR and IWC (IWC, 2018, items 16.1.2-16.1.3), and that although the workshop has been delayed, the likely benefit remains.

4.2 Future work

To facilitate IWC contributing to the review of CEMP, and to consider ecosystem modelling to support management needs of both IWC and CCAMLR, an ICG was formed with Terms of Reference as in Appendix 2.

5. OTHER MATTERS

The Subcommittee did not raise any other matters for discussion.

6. BIENNIAL WORKPLAN

Summary of the biennial workplan for the Ecosystem Modelling Subcommittee.

Table 1

Workplan

Item	Topic	Intersessional 2024-26	SC70	Timeframe	Long-term aims
EM 2.5	Ecosystem functioning of small cetaceans	Update information and develop a prioritised list of research needed to advance the ecosystem functioning work	Review any new information and ICG reports	Ongoing	Review at SC70; share with relevant scientists; guide ongoing work of the Subcommittee
EM 4	Cooperation with CCAMLR	ICG activities	Review ICG reports	Ongoing	
EM 2.3	Ecosystem modelling in the Southern Ocean, Northeast Atlantic Ocean and other areas	Continue further analysis	Review results of further analyses	Ongoing	
EM 3.3	Multi-species distribution models (MSDMs)	Continue further analysis	Review results	Ongoing	
EM 3.1	Krill distribution and abundance	Conduct any data analysis	Review results	Ongoing	
EM 3.2	Modelling competition among whales and relationships between whales and prey	Continue further analysis	Review results	Ongoing	
EM 3.5	Effects of long-term environmental variability on whale populations	Continue further analysis	Review results	Ongoing	
EM 3.4	Further development of individual- based energetic models (IBEMs)	Continue further analysis	Review results	Ongoing	

Table 2

Intersessional email groups.

Item	Type	Name	Terms of reference	Members
2.5	ICG	Ecosystem modelling research prioritisation	Develop prioritised list of research needs to address knowledge gaps in our understanding of the role of cetaceans in ecosystem functioning.	Schubert (Convenor), Biuw, Butterworth, Freitas, Gilbert, Hunter, Kelly, Kitakado, Li, Ransijn, Tulloch
4	ICG	Cetacean science advice for CCAMLR krill management	Provide advice on cetacean science to CCAMLR's revised krill management approach, CEMP, and ecosystem modelling.	Kelly (Convenor), Bell, Biuw, Butterworth, CCAMLR scientists, Dalla Rosa, Double, Fisher, Harris, Herr, Johnson, Kitakado, Langerock, Robson, Seyboth, Staniland, Vermeulen

7. ADOPTION OF REPORT

The report was adopted on 28 April 2024 at 09:22. The Chair expressed his sincere appreciation to the rapporteurs, Schubert, Kelly, Ferguson and Biuw for their excellent and hard work and thanked the participants for their valuable contributions. The participants thanked the Chair for his leadership of the Subcommittee and for his skill in chairing the meetings.

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Appendix 1

Agenda

1. Introductory items

1.1 Opening remarks

1.2 Election of the Chair

1.3 Appointment of rapporteurs

1.4 Adoption of agenda

1.5 Documents available

2. Role of cetaceans in ecosystem functioning: gap analysis

2.1 Review previous Committee discussions on contribution of whales to ecosystem functioning

2.2 Review outcomes of the joint CMS/IWC workshop

2.3 Update since the workshop

2.3.1 Update on additional scientific research published since 1st IWC-CMS Workshop on Cetaceans and Ecosystem Functioning

2.3.2 Estimating pre-exploitation and current abundance of large whale populations

2.3.3 Ecosystem modelling in the Antarctic Ocean and northeast Atlantic Ocean

2.4 Updates from the Conservation Committee's WG

2.5 Current conclusions and future

work 2.6Other

3 Review issues relevant to ecosystem modelling within the Committee

3.3 Krill distribution and abundance

3.4 Modelling of competition among whales and relationships between whales and prey

3.5Multi-species distribution models (MSDMs)

3.6 Development of individual-based energetic models (IBEMs)

3.7 Effects of long-term environmental variability on whale populations

3.8Other

4 Cooperation with CCAMLR

4.3 CAMLR's Ecosystem Monitoring Programme (CEMP) Report

4.4 Future work

5 Other matters

6 Biennial workplan

7 Adoption of Report

Appendix 2

Terms of Reference for Intersessional Correspondence Group (to work between SC69B and SC70) on provision of advice on cetacean science to CCAMLR's revised krill management approach and CEMP and ecosystem modelling

Preamble:

The IWC-SC has an opportunity to contribute to the enhancement of CCAMLR's Ecosystem Monitoring Programme (CEMP) so as to provide data and advice needed to inform the krill fishery management approach (which needs to take account of the potential impact of krill catches on whale populations), as well as to inform the ecosystem roles of cetaceans in the Southern Ocean.

1. Expertise from IWC-SC to provide to the ongoing CEMP review:

- Identification of knowledge gaps in terms of cetacean data in application to an enhanced CEMP and the revised krill management approach
- Advice on population status and trends of baleen whale species which are found in the CCAMLR Convention Area, particularly humpback, fin, blue and Antarctic minke whales.
- Methods and technology to support monitoring for abundance, distribution and smaller-scale behaviour.
- Methods of monitoring and undertaking health-checks for cetacean populations (i.e., contaminants, body condition, pregnancy rates and population changes).
- Methods and technology to support estimation of krill consumption rates by whales
- Advice on existing research programmes or collaborations studying cetaceans in the Southern Ocean.

2. In collaboration with CCAMLR, develop a high-level strategy regarding management needs for ecosystem modelling (with particular focus on whales and krill interactions, and including the influence of climate change) for both IWC and CCAMLR. This is to pursue the requirements of CCAMLR Article II which have consequences for the IWC as well as for CCAMLR. This would include liaising with CCAMLR Secretariat regarding types, availability and suitability of krill data. The collaboration would also include a review of current and recent ecosystem modelling undertaken by CCAMLR.

Appendix 3

Terms of Reference for Intersessional Correspondence Group (to work between SC69B and SC70) to develop a prioritised list or research to address the knowledge gaps related to understanding the role of cetaceans in ecosystem functioning

Preamble:

In the Terms of Reference developed by the Ecosystem Modelling Subcommittee and endorsed by the IWC-SC and the Commission, the Subcommittee agreed to "develop a prioritized list of recommendations for scientific research to fill identified knowledge gaps, including studies on methodological approaches to study how cetaceans affect ecosystem functioning." While the two IWC-CMS workshops on cetaceans and ecosystem functioning have made great progress on identifying key research topics and compiling lists of these, additional work is needed to prioritize these to identify key research needs, satisfy the directives contained in IWC Resolutions 2016-03 and 2018-02. This ICG will endeavor to prepare such a list as follows:

1. Solicit the expertise of scientists, including IWC-Scientific Committee members, to review the outcomes of the 1st and 2nd IWC-CMS workshops on cetaceans and ecosystem functioning as well as other sources of information, including the published literature and ongoing research projects, to:
    a. On the basis of research topics identified during previous workshops develop a prioritized list of recommendations for scientific research to fill identified knowledge gaps, including studies on methodological approaches to study how cetaceans affect ecosystem functioning;
    b. Identify the species and oceanographic regions where such research may be of particular importance to expeditiously fill such knowledge gaps;
    c. Assess how ongoing research projects may fill such knowledge gaps;
    d. Identify potential funding sources for such prioritized research needs.
2. Prepare a report documenting the results of this initiative for submission to IWC SC70 for review by the Ecosystem Modelling Subcommittee and the IWC-SC.