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Results of the work of the 'Pollution 2025' intersessional steering group

Holm, Alava, Barratclough, Barreto, Bengtson Nash, Brownlow, Desforges, Domit, Eisfeld-Pierantonio, Fernandez Rodriguez, Fossi, Garcia Garin, Genov, Kershaw, Marón, Marmontel, Noren, Pierce, Pinzone, Pirotta, Plön, Robinson, Rose, Rowles, Schwacke,

INTERNATIONAL
WHALING COMMISSION

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Abstract

In order to address the Scientific Committee's numerous recommendations related to the issue of chemical pollution and move forward with the work plan of the SG, the SG compiled information from scientific studies published in recent years (by members of the SG and others). Summaries of how this work responded to the recommendations follow and clarify the progress made in addressing each recommendation, including several made by the workshop on cumulative effects held in November 2021 (SC/68D/Rep/02). Only recommendations are listed for which answers could be provided yet. It is recommended to update this work regularly.

Results: Recommendations and Responses

SC1883

The Committee continued to work on mercury in cetaceans in response to Resolution 2016-4. It therefore: (1) encourages the continued provision of information on mercury and cetaceans; (2) encourages researchers presenting such information to report concentrations on both wet and dry weight bases; and (3) recommends that Contracting Governments support the continued monitoring of mercury in cetaceans, as this is required in order to assess the medium- and long-term impact of the Minamata Convention.

Bengtson Nash *et al.* (2021) provided the first results of mercury (Hg) accumulation in humpback whales (*Megaptera novaeangliae*), using non-lethally biopsied tissues. Large differences observed in Hg concentrations between skin and muscle tissues indicate tissue partitioning is a major factor to consider when using humpbacks for routine contaminant monitoring.

Arctic Peoples are the most exposed humans when it comes to foodborne Hg. Their knowledge is being increasingly recognised in research and decision-making. Houde *et al.* (2022) presented over 40 examples of research on Hg conducted with or by Indigenous People in the Arctic and offered insights into their key involvement. The key to successful assessment of contaminants in the Arctic is the co-production of knowledge by scientists and Indigenous People, as recognised in wider recent works across various Indigenous groups (Marsh *et al*., 2022). Sustainable funding for such activities would be beneficial, aiming at developing more research and monitoring capacity, and would promote a more holistic approach to understanding Hg in the Arctic. These activities should be well-integrated into circumpolar and international initiatives to ensure broader availability of the information and uptake in policy development (Houde *et al.,* 2022).

In 110 time series, Morris *et al.* (2022) assessed temporal trends of Hg levels in Arctic biota and found that 70% detected a 5% annual increase. Dietz *et al.* (2022) collated data on Arctic marine and terrestrial mammals as part of a predictive risk assessment. They noted that 6% of 3,500 marine mammal individuals are at high or severe risk from Hg.

Manhaes *et al.* (2022) reported bioaccumulation of trace elements, such as Hg, but also zinc (Zn), arsenic, copper and iron, in franciscanas before and after the November 2015 collapse of the Fundão dam in Mariana (Minas Gerais State). They found increasing temporal trends of Hg and Zn due to higher bioavailability. In a study on Guiana dolphins before and after an unusual mortality event (as a result of a morbillivirus outbreak), Manhaes *et al.* (2021) found signs of impaired methylmercury intoxication, probably due to an element-specific remobilization of Hg and selenium (Se). Bioaccumulation of mercury was also in found in river dolphins of the genus Inia in the Madeira river basin, Western Amazon (Barbosa *et al.*2021). The mercury contamination comes from artisanal and small-scale gold mining operations along with soil remobilization processes associated with deforestation. Concentrations were comparable to those of cetaceans in marine environments and highlight the importance of Inia river dolphins as sentinels for the ecosystem health.

Trevizani *et al.* (2021) studied the food webs in three Brazilian estuaries with respect to Hg, which occurred primarily in cetaceans, polychaetes and molluscs. Concentrations reflect the impact of anthropogenic activities in the region and, despite concentrations being generally lower than in the Northern Hemisphere, this raises concerns for public and environmental health in these highly productive coastal regions in southern latitudes.

Hauser-Davis *et al.* (2020) studied the intracellular distribution of three toxic elements—Hg, cadmium (Cd) and lead (Pb)—in stranded Guiana dolphins from southeast Brazil. Schnitzler *et al.* (2021) concluded that the high

prevalence of organic Hg compounds in the Irrawaddy dolphin, *Orcaella brevirostris,* from the Mekong River, Cambodia, was 'unusual'.

Plön *et al*. (2023) recently assessed Hg and other major, minor and trace elements in dolphins incidentally caught in bather protection nets off KwaZulu-Natal, South Africa. Muscle tissue from four species of dolphin sampled between 2007 and 2017 had Hg concentrations that were generally higher than those reported for dolphins elsewhere, highlighting the need to reduce pollution sources affecting that coastline.

Technologies for improving the assay of Hg and Hg compounds have also been developed, such as the use of nanoscale secondary ion mass spectrometry (NanoSIMS) to characterise the spatial distribution of toxic compounds at the cellular level. Subirana *et al*. (2021) used the technology to generate fine-scale mapping of Hg compounds in the liver tissue of a sperm whale (*Physeter macrocephalus*) stranded in Scotland in 2020. This technology has future applicability for the detection of pathophysiological responses to increasing Hg accumulations in other marine mammal species.

The relationship between Hg and wider life history stages and emerging environmental contaminants of concern remains an area of uncertainty. For example, in New Zealand, Hg concentrations reported in mass stranded common dolphins (*Delphinus delphis*) revealed distinctive profiles of non-essential trace elements between sexually immature and mature individuals (Stockin *et al.*, 2021). Furthermore, significant negative correlations with trace elements, including Hg, across different reproductive states were observed in relation to some per- and polyfluoroalkyl substances (PFAS[1]). Teitelbaum et al. (2022) studied contaminant interaction in wild waterfowl, finding a possible link between mercury body burden and pathogen susceptibility. Odds of prior influenza infection increased more than fivefold across the observed range of blood mercury concentrations, while accounting for species, age, sex and date. Influenza infection prevalence was also higher in species with higher average mercury concentrations.

Kershaw has secured funding (project ID: R68D07, confirmed 17 January 2023) to update the global review of published Hg concentrations in cetaceans. A Research Assistant (University of St Andrews) will start this project in April 2023, and complete the review, update the IWC Contaminant Explorer (cf SC21222) and produce a report on key findings with Kershaw in October 2023.

SC2256

The Committee welcomes the report of the IWC Pollution 2025 Workshop (SC/68D/REP/02) and endorses its recommendations. It recognises the importance of understanding cumulative impacts of human-induced stressors on marine ecosystems.

One approach to assess the cumulative effects of stressors on cetaceans, known as PCoMS (population consequences of multiple stressors), uses individual health indicators to estimate changes in vital rates that drive population status (Tyack *et al.*, 2022). The authors proposed integrating well-established methods used in human health to assess cumulative risk to populations into ecosystem-based management. Schwacke *et al*. (2023) developed a new approach to use measures of health to estimate population survival rates, providing an additional tool to support the development of PCoMS approaches.

Pirotta *et al.* (2022) developed a conceptual framework that encompasses a diversity of approaches to analyse the combined effects of multiple stressors, ranging from data-driven to mechanistic. This paper also reaffirms the role of management needs in guiding analysis of combined effects.

Ensuring accurate age assessment to interpret biological data is an important first step in assessing population demographics and understanding the population consequences of multiple stressors (Barratclough *et al.*, 2023; Peters *et al.*, 2023). Climate change effects are among these multiple stressors (e.g. Gulland *et al*., 2022; Peters *et al.*, 2022). Bartalini *et al.* (2022) examined climate change effects and found enhanced long-range transport, re-emissions from secondary sources and shifts in migration habits, which could lead to greater exposure and accumulation of synthetic organic compounds, such as polybrominated diphenyl ethers (PBDEs[2]).

Recent studies have evaluated the population consequences of multiple stressors, including the impacts of prey limitation, noise exposure and contaminant exposure on Southern Resident killer whales (*Orcinus orca*) (Lacy *et al*., 2017), as well as the impacts of exposure to the Deepwater Horizon (DWH) oil spill and anthropogenic noise on sperm whales (Farmer *et al*., 2018).

[1] PFAS are substances that were (partly) banned due to their persistence, toxicity and bioaccumulative potential.

[2] PBDEs are synthetic organobromine compounds, used as flame retardants, listed as POPs by the Stockholm Convention in 2009.

Alava *et al.* (2018) predicted bioaccumulation and amplification of organic and metal contaminants in killer whale food webs in the northeast Pacific Ocean when modelling scenarios of climate change forcing (i.e., increase in sea surface temperature, and changes in primary production, dissolved oxygen and pH). These killer whales already face multiple stressors, including contaminants of emerging concern in the region (e.g. Lee *et al.*, 2023).

Dietz *et al.* (2021) summarised articles investigating multiple stressors acting on cetaceans in the Baltic ecosystem, in the context of the BALTHEALTH project. Exposure to anthropogenic hazardous substances and related health effects were major forces in massive population declines in Baltic Sea key species, including several marine mammals and sea birds. High trophic level key species in the Baltic are also exposed to multiple bacterial, viral and parasitic pathogens. Some of them are zoonotic, posing a potential additional risk also for human health. The authors proposed future research, including examining not-yet-considered stressors, such as overexploitation, bycatch, eutrophication and underwater noise.

Since many stressors are processed through a common stress-response pathway, epigenetic manifestations of stress in killer whale populations were investigated (Crossman *et al.* 2021). Large differences in the level of DNA methylation were consistent with differential stress exposure between Northern and Southern Resident killer whale populations. The applied method could be useful to assess the cumulative effects of non-lethal stressors in wildlife.

The joint exploration of nutritional and chemical links is needed to understand the ecotoxicological effects of pollutants on different life history stages (Stockin *et al.*, 2022; Stockin *et al.,* in review). Researchers carried out a combined assessment with a multidimensional niche framework. They unravelled underlying intricacies on how nutritional requirements and foraging strategies are important to predict trace metal intake (e.g. Hg, Se) and potential physiological consequences from consuming prey (Stockin *et al.*, 2022). Williams *et al.* (2020) found that juvenile harbour porpoises (*Phocoena phocoena*) in the UK had higher proportions of less chlorinated congeners than adults; nevertheless, these congeners were of higher neurotoxicity at this life stage. This pattern is of importance for other marine mammals as well. Sala *et al.* (2020) found the first evidence of fin whale mother-calf transfer of plasticisers and flame retardants and asked for investigation into the compounds' effects.

North Atlantic right whales (*Eubalaena glacialis*) have declined in body condition and are now shorter on average, a result of the cumulative effects of sub-lethal injuries from entanglements and likely also ship strikes, in combination with climate-related changes in prey and noise levels (e.g. Rolland *et al*., 2012; Christiansen *et al*., 2020; Gavrilchuk *et al*., 2021; Stewart *et al*., 2021). Wright and Kyhn (2015) concluded that, given these trends are also associated with ongoing population decline (Pettis *et al*., 2023), this case and others like it would benefit from the application of zero-sum management instead of (or at least pending completion of) cumulative impacts analyses. Of particular concern would be any activities, such as trawling, that can lead to resuspension of any contaminants within the seafloor, which can remain long after inputs from the original point source have been curtailed (e.g. Bradshaw *et al*., 2012).

SC2257

The Committee notes with concern the high levels of some flame retardants reported for several populations of dolphins in South Africa and the western Indian Ocean and encourages the relevant authorities to support systematic monitoring of pollutants and additional research to identify and mitigate the sources of pollutants.

Aznar-Alemany *et al*. (2019) monitored a number of flame retardant compounds in three dolphin species in the southwest Indian Ocean. Levels ranged from undetectable to very high. More work is needed to determine if these high levels are tied to local sources or widespread contamination of the ocean basin.

SC2164

The Committee draws the attention of the government of St Vincent and the Grenadines to the high mercury levels measured in muscle, blubber, liver and kidney in small cetaceans hunted for local consumption (McCormack et al., 2020) and recommends that:

(1) St Vincent and the Grenadines continue to monitor and assess heavy metal contamination in tissues of cetaceans taken in the local hunt and consult with the necessary experts to determine the impact of this contamination on ecosystem, cetacean and human health; and (2) research on trace element contamination in Caribbean cetaceans be prioritised, including the identification of possible sources.

Borobia *et al*. (2023) highlighted three priorities for mitigation of threats to marine mammals in the Caribbean; namely interactions between marine mammals and fisheries, pollution and acoustic disturbance. Their recommendations include "Establishment of sampling programmes for emerging contaminants (heavy

metals, micro and nanoplastics and associated chemical residues) in marine mammal resources that are harvested for human consumption".

SC21203

The Workshop identified several models with the potential to integrate data on combined effects of multiple stressors. Long-term monitoring studies, to provide base line data and investigate temporal variations, are vital to these models and the Workshop recommended that researchers/Scientific Committee: (1) Monitor vulnerable populations as much as is practical BEFORE potential stressors occur or as soon as possible after stressors become a factor; (2) Archive samples collected opportunistically from potentially vulnerable populations for future assessment (3) Monitor the most sensitive sub-lethal parameters (e.g. body condition and reproduction); and (4) Build comparable datasets across sites or even species, noting potential ecological fallacy and/or interspecies differences.

Williams *et al.* (2023) assessed the trends and status of blubber PCBs in European harbour porpoises for the period 1990-2017; they declined significantly over time in most areas. This policy-focused case study demonstrates the potential use of harbour porpoises as an indicator species for PCBs in the EU Marine Strategy Framework Directive. The authors made recommendations for improving the quality of assessments and detailed monitoring requirements to achieve the successful implementation of such an indicator.

Méndez-Fernandez *et al*. (2022) analysed Hg, Pb and Cd concentrations in common dolphins and harbour porpoises stranded along the French Atlantic coast from 2000 to 2017. Lead concentrations decreased in both species as a result of Pb regulations established in 2000.

For effective modelling, it is important to collect data on potential threats to vulnerable populations before crises occur. Oliveira-Ferreira *et al.* (2022) studied the bioaccumulation of organohalogen compounds in franciscanas and calculated a temporal trend with data collected before and after the Fundão dam collapse. The study showed an increase in some (e.g. pesticides, endocrine disruptors) but not all compounds.

Oliveira-Ferreira *et al.* (2021) modelled the long-term consequences of high PCB exposure and assessed the risk of severe decline for three populations of rough-toothed dolphins, *Steno bredanensis*, along the southeast and southern Brazilian coast. Remili *et al.* (2020) studied selected populations of humpback whales with respect to their concentrations of persistent organic pollutants, which showed that concentration varied with sex, geographic zones and trophic levels. Remili *et al.* (2021) revealed how a large variation in blubber PCB concentrations in Icelandic killer whales strongly depended on inter-individual variation in prey specialisation, which stresses the importance of individual ecology when forecasting how contaminants may threaten the long-term persistence of marine predators.

Ecological and ecosystem-based models, such as Ecopath with Ecosim, have been developed and applied to assess the impact of climate change on pollutant bioaccumulation in cetaceans (Alava *et al*., 2017; Alava *et al*., 2018). Climate change can increase species' sensitivity to pollutants; conversely, pollutant loads can increase sensitivity and vulnerability to climate change.

Genov *et al*. (2019) found high organochlorine levels in Mediterranean bottlenose dolphins, with males having higher levels than females, and nulliparous females having higher levels than parous females, indicating offloading of contaminants in reproductive females. Most dolphins exceeded published toxicity thresholds. Combining contaminants monitoring with information such as sex, survival and reproductive output, as well as social aspects known from long-term studies, can greatly enhance our understanding of contaminant effects and potential population-level consequences.

SC21204

The Workshop noted the importance of incorporating the level of uncertainty derived from the different steps in each section of the conceptual framework (NASEM 2017) into the estimation of population consequences, so that managers can consider both variability and uncertainty and can therefore incorporate precautionary management if needed. Interim but formal statistical methods such as expert elicitation can help to fill gaps where current information is lacking.

Schwacke *et al.* (2022) found expert elicitation to be a promising approach in assessing the DWH oil spill when refining input parameters for a multiclass structured population model.

SC21205

The workshop reiterates previous recommendations (SC19195) made by the 2019 IWC Marine Debris workshop on the development of an international treaty for the management and mitigation of marine debris

and recommends a) the report of this Pollution 2025 workshop be shared with the UN initiative (UNEA) and b) where possible workshop participants continue to provide input in the form of new research/elements to the initiative regarding mitigation of marine debris.

The 2022 UNEA Resolution 'End Plastic Pollution: Towards a legally binding instrument' established an Intergovernmental Negotiating Committee to develop specific content for the new plastic pollution treaty. The agreement is expected to address the full lifecycle of plastics, including production, design and disposal, as well as the design of reusable and recyclable products and materials.

SC21206

Recalling recommendation SC19193 the Workshop reiterated the need to identify potential indicator species in each sea (e.g., fin whale in the Mediterranean) for microplastics and marine litter in the environment.

➔ see outcome of the Marine Debris ICG

Fossi *et al.* (2020) recommended sperm whales and fin whales (*Balaenoptera physalus*) as potential indicator species for marine litter (for macro-litter at depth and micro-litter, respectively). The results from Garcia-Garin *et al.* (2021a) support the use of fin whales as indicator species for microplastics in the North Atlantic.

SC21207

The Scientific Committee is encouraged to continue investigating new omics approaches as a means of screening for new biomarkers.

Kershaw, Brownlow and Derous (University of Aberdeen, University of Glasgow) secured funding from the Leverhulme Trust to investigate novel biomarkers of cetacean health, metabolism and responses to environmental stressors, including contaminants, using proteomic and metabolomic approaches: "Characterising the impact of environmental stressors on cetacean metabolism". This work started in September 2022.

SC21208

The workshop requests the Secretariat to communicate with the Stockholm and Minamata Conventions to consider the explicit inclusion of cetacean blubber (of model species) as a core media for long-term (and retrospective) monitoring of chemicals of Arctic/Antarctic concern (CEACs) to demonstrate biomagnification potential and hereby facilitate expedited chemical regulation.

The Secretariat has sent letters to the Executive Secretaries of the Minamata and Stockholm Conventions, inviting communication regarding this matter. Any responses will be shared with the SG and wider Scientific Committee.

It is expected that biomagnification, and the associated risks, in many odontocetes would follow trends observed in other Arctic top predators, such as polar bears (e.g. Villa *et al*., 2017).

SC21209

The workshop recommended that an international database be established as well as sample archives, to analyse samples with new techniques. Furthermore, the workshop requests the Secretariat to seek formalised arrangements with the global network of Environmental Specimen Banks (ESBs) to ensure the routine collection and archiving of cetacean tissues according to standardised protocols. ESB are the time capsules of the environment and allow for retrospective analysis as new information is gained. They also limit loss of valuable archived materials through e.g. researcher movement, freezer failures, unsuitable collection or storage etc.

The Secretariat has sent a letter to the Coordinator of the Environmental Specimens Banks Group to request information on the best means to formalize arrangements for tissue collection. Information on whether a single agreement can be made for the global network or if each specimen bank requires its own arrangements was requested. If they exist, the Secretariat has requested a template or example of how such agreements are made. Responses will be shared with the SG and wider Scientific Committee.

Data collected by the EU-wide APEX study (see SC21218) are stored in a database for use by EU regulators. This supports the 'zero-pollution' policy by restricting, where necessary, the production, use or import of chemicals endangering Europe's environment (Gkotsis *et al.*, 2022).

SC21211

Given the threat to cetaceans from oil spills the Scientific Committee is encouraged to (a) study effects of multiple stressors; (b) identify areas of high risk for spills and high risk for cetaceans by establishing heat map and early warning systems; (c) follow existing guidelines and principles (e.g. NOAA guideline on oil spill response; on

assessing exposure and impacts of oil spills on MarMam) (e.g. IPIECA/IOGP key principles for the protection, care and rehabilitation of oiled wildlife; wildlife response preparedness, etc.).

Several papers assessed the impacts of oil spills on common bottlenose dolphins (*Tursiops truncatus*) in Barataria Bay, Louisiana, which was heavily affected by the DWH oil spill. Takeshita *et al.* (2021) noted consistent toxic responses in different species, and, clinically, a suite of signs and symptoms of multi-organ failure at the highest doses, whether in experiments or when exposed to high concentrations in the field. Smith *et al.* (2022) found poor pulmonary health and low reproductive success in exposed animals in the eight years following the spill. Schwacke *et al.* (2022) developed a population model, which showed that the population will take 35 years to recover and is vulnerable to emerging threats. Thomas *et al.* (2022) studied one of those emerging threats, a proposed land restoration project, which will divert freshwater from the Mississippi River into Barataria Bay.

SC21212

The workshop recalled recommendation SC1609 calling on Contracting Governments and industry to share information on exposure of, and impacts to, cetaceans; increase efforts on prevention of spills; and focus research to improve tools to detect exposure and evaluate impacts of oil spills on cetaceans. Building on this, the Workshop urged industry to establish precautionary measures to prevent oil spills., e.g. by properly maintaining their current equipment and facilities, and increase efforts to contain oil in case of oil spills rather than the use of dispersants.

Schwacke *et al.* (2022) made recommendations for managing future chemical spills that affect cetacean habitat.

SC21213

The workshop requests the: (a) IWC Secretariat (i) circulate the report of this workshop to appropriate entities to communicate the workshop discussions. (ii) draw the attention of the Commissioners to the report of the workshop and, in particular, the finding that oil exposure can lead to significant adverse acute and chronic pathologies (i.e. respiratory diseases, immunological disorders, endocrine disruption, reproductive disorders) threating cetacean life with population effects (b) Commissioners bring this information to the attention of their relevant national authorities.

A Circular was distributed to all IWC members and observers with the Pollution 2025 Workshop Report (Circular IWC.ALL.418) in March 2022. The IWC webpage for Chemical Pollution was updated with details of the Pollution 2025 programme and includes a link to the workshop report. The report was endorsed as SC/68D/REP/02 and subsequently endorsed by the Commissioners at IWC68.

SC21215 and SC21216

The Workshop requests the Secretariat and members of the Sub-Committee on Environmental Concerns and the marine debris ICG to continue international engagement on debris tracing and prevention (e.g. via monitoring of cetacean microplastic ingestion, Extended Producer Responsibility polycyclic aromatic hydrocarbon (PAH) fingerprinting), to pursue solutions on marine debris and to suggest mitigation strategies.

➔ see outcome of the Marine Debris ICG

The Secretariat will be participating in the upcoming marine debris workshop prior to ECS April 2023. There will be ongoing discussion with GGGI on in-kind activities to be conducted once signing the Statement of Support is complete. Details of other engagement on marine debris will be included in the Secretariat document to the Scientific Committee under the agenda item Cooperation with Other Organizations.

SC21218

The Workshop recommended that in order to inform mechanisms and trends in legacy chemicals and exposure and effects to emerging contaminants of concern, future research should focus on multiple sampling opportunities of the same individual and species.

Multiple sampling and resampling of concentrations of legacy persistent organic pollutants, measured at different times from 2000 to 2016 in the blubber of Sarasota Bay common bottlenose dolphins, showed declining concentrations; however, the concentrations also differed depending on the compounds, sex and age class (Kucklick *et al.*, 2022).

Alava *et al.* (2020) conducted the first assessment of legacy contaminants (POPs and Hg) in free-ranging common bottlenose dolphins in the Gulf of Guayaquil in Ecuador. Concentrations were lower than or similar to those found in dolphins from other regions, such as the southeast United States, and some were above the threshold for immunotoxic and endocrine disruptive effects.

A systematic biomonitoring study of thousands of chemicals of concern (legacy and emerging contaminants) in 67 apex predator and prey species followed a different approach, demonstrating that exposure to a diverse 'cocktail' of contaminants of different categories is widespread (Androulakakis *et al.*, 2022; Gkotsis *et al.*, 2022).

A global review on PBDE contamination in cetaceans paid special attention to the species with the highest reported levels (Bartalini *et al.*, 2022). Non-declining levels are alarming, including in cetaceans from the northeast Pacific Ocean, which may be linked to the increased import of electronics waste. High levels in some endangered species, such as beluga whales in the St Lawrence Estuary and Southern Resident killer whales in the Salish Sea, are influenced by the discharge of contaminated waters deriving from wastewater treatment plants.

To investigate temporal trends in contaminants, Montone *et al.* (2023) analysed persistent organic pollutants in the blubber of franciscanas from 2000-2018. They observed downward temporal trends for most POPs; however, increased proximity to highly urbanised regions resulted in higher PCB levels.

The exploration of 'new' chemicals, such as PFAs and brominated flame retardants, has been of interest in the past few years, in polar wildlife (e.g. Herzke *et al.*, 2022; Lippold *et al.*, 2022) and also in marine mammals of the north, west and southwest Atlantic Ocean (Oliveira-Ferreira *et al.*, 2023; Combi *et al.*, 2022, Sala *et al.*, 2022), Indian Ocean (Aznar-Alemany *et al*., 2019) and south Pacific Ocean (Stockin *et al*., 2021).

Dziobak *et al.* (2021, 2022a, 2022b) measured phthalates in common bottlenose dolphins in Sarasota Bay. Urinary concentrations varied across spatial scales, which led to the suggestion that researchers and management agencies should consider a population's ranging pattern, geographic habitat characteristics and sample timing when assessing small cetacean health in relation to contaminant exposure (Dziobak *et al.*, 2022a). Hart *et al.* (2022) compared levels of urinary phthalate metabolite concentrations among bottlenose dolphins to levels reported in human samples. The authors used the One Health approach to develop hypotheses for phthalate-associated health effects for exposed bottlenose dolphins. Lee *et al.* (2023) investigated emerging contaminants and new POPs (PFAS and HBCDD) in Southern Resident and Bigg's killer whales. They found *in utero* maternal transfer, with very high transfer rates, raising concerns regarding pathological implications and potential impacts on foetal development and production of a viable neonate.

Garcia-Garin *et al.* (2022) performed multiple sampling and analysis on phthalate concentrations over a 29-year period in North Atlantic fin whales, demonstrating neither a statistically significant relationship with biological variables examined nor a time trend.

Schnitzler *et al.* (2021) also measured compounds of organochlorines, polybrominated flame retardants as well as tributyltin and its derivatives, in Irrawaddy dolphins from the Mekong River, Cambodia.

Baini *et al.* (2016) analysed seven phthalate esters (PAEs[3]) in open surface water samples, as well as skin biopsy samples from four cetacean species, in the northwest Mediterranean Sea. These PAEs were detected in 42% to 79% of the water samples. All the sampled water had microplastic debris, confirming the widespread distribution of microplastics on the seawater surface in the Mediterranean. Appreciable levels of these compounds were found in all four cetacean species sampled, meaning water sampling can be a non-invasive method to evaluate PAEs ingested by marine wildlife.

Andvik *et al.* (2023) reported on POPs, including brominated flame retardants, PFAS and metals, in the blubber, liver and muscle of adult common minke whales (*Balaenoptera acutorostrata*) from the Barents Sea. Several of these contaminants were transferred at high levels to the foetus via the placenta. Legacy POPs were the dominant compound group in every tissue, although generally lower levels were seen compared to 20-30 years ago and were under thresholds for risk of health effects. This was the first study to report occurrence and placental transfer of emerging contaminants in common minke whales from this region.

Gui *et al.* (2016) surveyed six dolphin species incidentally caught in shark net installations or stranded off the South African east and south coast from 2005 to 2009 to study POP exposure. Concentrations of DDTs in two species were among the highest levels reported in delphinids globally. The concentrations of Mirex and Dieldrin in South African delphinids were higher than those found in species from other regions of the Southern Hemisphere.

Data on environmental PCB and PBDE contamination in common bottlenose dolphins and Atlantic spotted dolphins (*Stenella frontalis*) from the Brazilian coast will assist in the establishment of dolphin population conservation strategies (Lavandier *et al.*, 2019).

[3] Phthalate esters are found in a wide variety of consumer and food packaging products. Some of the phthalate esters are known to be toxic to the developing male reproductive system.

SC21219

The Workshop highlighted the need for: (1) interdisciplinary research on Baltic Sea harbour porpoise populations at the national and international level (Baltic Range states, ASCOBANS, HELCOM), (2) the continuation of long-term datasets (and the creation of new datasets) to investigate temporal variations; and (3) systematic health investigations and interpretations by trained experts. The workshop suggested that funding for Baltic Sea projects should be secured for marine mammal species which may be transboundary rather than for national areas, which may only hold part of a species population.

In the context of the BALTHEALTH project, Dietz *et al.* (2021) found that the combined effects of bycatch, even at the lowest estimated rate of 7 indiv/yr, and reduced fecundity (due to endocrine disruptive contaminants) are causing a population collapse in Baltic Sea harbour porpoises, with a high probability over the next century of declining to ≤ 50 animals. Kesselring *et al.* (2017) concluded that a shortened lifespan of Baltic Sea harbour porpoises is linked to an anthropogenically influenced environment with rising bycatch mortalities due to local gillnet fisheries. Siebert *et al.* (2022) found severe lesions in harbour porpoises in the Baltic Sea, due to blast trauma after abandoned World War II munitions were detonated. This once again highlights the importance of acute and chronic effects of blast and acoustic trauma in this highly endangered population.

SC21220

To assess the impacts of cumulative stressors the workshop proposed that at least five different health indicators be monitored (lung and ear status are the best early indicators of overall animal health).

Based on the finding that testes weights of harbour porpoises were negatively associated with PCB concentrations and body condition, Williams *et al.* (2021) suggested including indicators of impacts on male fertility, such as testes weight, in population health assessments.

SC21222

The workshop recommended that Kershaw assess the funding requirements to facilitate the update and maintenance of the Contaminant Explorer tool and submit an application to the SC Research fund.

(related to SC2169: The Committee: (1) draws attention to two important tools: the "IWC Effects of Pollutants on Cetacean Populations (SPoC) Model (http://www.smru.st-andrews.ac.uk/IWC_PCB_Cet_Pop_Model)" and the "IWC Contaminant Mapping Tool http://www.smru.st-andrews.ac.uk/IWC_Contaminant_Explorer/), (2) recommends that both the SPoC and the IWC Contaminant Mapping Tool continue to be maintained, and the Contaminant Mapping Tool updated; and (3) requests Kershaw to provide an update at SC68D, as new data are included in the Contaminant Mapping Tool.

Kershaw has secured funding (project ID: R68D07, confirmed on 17 January 2023) to update the global review of published Hg, PCB and DDT concentrations in cetaceans. See entry under *SC1883*.

SC21223

The workshop recommended further development of a broad toolbox (including in vitro and in silico methods, and other sensitive bioindicators) to study the effects of chemical and other stressors, as well as integrative modelling (such as dynamic energy budget) to incorporate multiple stressors into a common research framework.

In this context, the importance of epigenetics was discussed at the workshop and its use is reflected in, amongst others, Barratclough *et al.* (2021). Pinzone *et al.* (2022) worked to develop a general framework for indicators of persistent chemicals, using marine mammals from the OSPAR region. This study will be featured in the upcoming OSPAR QSR2023; its preliminary results highlight large data heterogeneity and extensive knowledge gaps at spatial and temporal scales.

Mancia *et al*. (2021) extracted genomic DNA from the skin of fin whales in the northern Mediterranean Sea and, using the levels of contaminants measured in the blubber of the same individuals, conducted DNAm profiling[4]. One aim of this study was to identify potential contaminant exposure-related genes. Results indicated that DNAm-affected genes function in cutaneous, vascular and nervous systems. The identification of cellular response pathways allows for the development of sensitive tools based on predicted responses.

SC21224

The workshop agreed that the use of cell and tissue culture and other in-vitro approaches showed strong promise for allowing effect assessment and can be used to collect physiological data by looking at, inter alia,

[4] DNA methylation, an epigenetic modification of DNA which regulates DNA expression, thus influencing development and cell lineage differentiation

oxygen use rates from the blubber tissue in culture. The Workshop therefore encouraged the continued development and application of these (in vitro and in silico) techniques.

Regarding new approach methodologies (so called 'NAMs'), Langan *et al.* (2023) reviewed several papers that assessed the use of non-animal testing methods to understand complex chemical stressors, risks and hazards. Noyes *et al.* (2019) described an adverse outcome pathway network for thyroid disruption, using in vitro techniques to identify potential harmful compounds, integrate a chemical's toxicity mechanism and assess apical effects.

NAMs developed for tissue culture of blubber collected from seal species (Bennett *et al*., 2017; Robinson *et al*., 2018; Robinson *et al*., 2021) indicate these are viable approaches for experimentally investigating tissue level responses to various pollutants encountered by wild marine mammal populations, including cetaceans. Thus far these approaches have been used to explore changes in blubber physiology in response to legacy (e.g. PCBs; Robinson *et al*., 2018) and emerging (phthalates; Tranganida *et al*., 2023) pollutants and enable studies that investigate the whole organism impacts of chronic pollutant levels affecting blubber function (Bennett *et al*., 2021). These methods have great potential to be applied to cetaceans and have been designed to enable researchers to conduct such studies in locations away from traditional laboratory settings, previously a limitation to conducting tissue culture work on wild marine mammal populations.

SC21225

Scientists across disciplines are encouraged to find a shared language and methodology to assess the combined effects of multiple stressors as it is a cross-disciplinary problem.

With respect to this recommendation, approaches such as the ones presented in Alava *et al.* (2018), Tyack *et al.* (2022) and Pirotta *et al.* (2022) are helpful steps forward.

SC21226

The workshop encouraged the SC and wider Research Community to continue the investigation, and improve the understanding, of the cumulative impacts of human activity induced stressors on marine ecosystems. These include, inter alia, climate change, ocean acidification, marine litter, noise, eutrophication, biomass overharvesting.

➔ See response to *SC2256*

SC21227

The workshop emphasised the value of an interface between science and policy to consider multiple sources of morbidity and mortality when developing conservation and management plans and address the geopolitical importance. The Workshop therefore recommends: (1) the Secretariat and the wider Commission continue communication and cooperation with range states and appropriate bodies e.g. NOAA, ASCOBANS; ACCOBAMS, etc. which develop management plans (2) Improve, synthesise, and respond to emerging knowledge across all disciplines and sectors to include government, academic and industry information, and traditional and local knowledge.

➔ Re traditional and local knowledge, see response to *SC1883*.

A review on the impacts of chemical pollutants on cetaceans in Europe (Genov, 2021) provides several recommended actions related to policy makers, private sector and the public.

SC21228

The workshop reiterates previous recommendations for IWC to continue collaboration with the Arctic Council (SC1403), CCAMLR (CO1833) and other policy bodies to effectively communicate their expertise and the relevant parts of its annual SC report. The Secretariat is requested to establish observer status at these and other relevant organisations to expand the IWC's reach with policy makers. Further, the Workshop encourages the IWC to work with these bodies and funding organisations (e.g. National Science Foundation (NSF)) in their aim to strengthen scientific cooperation and joint monitoring among the Arctic states, and with other states, organisations and stakeholders involved in Arctic research or traditional and local knowledge, with a focus on (a) prioritising research issues, filling knowledge gaps, and developing mechanisms to share and exchange observational data (b) real-time identification of arctic stressors and impact characterisation to develop actionable transboundary mitigation strategies and (c) devise realistic management strategies for a multi-user/multi-cetacean species Arctic seascape.

Houde *et al*. (2022) provide a good example for an enhanced collaboration and an important step forward in filling knowledge gaps.

SC1909

Reiterates the threat that chemical pollutants pose to cetaceans.

Several papers confirmed this threat and added new knowledge (cf responses to SC1883, SC2256, SC21203, SC21211, SC21218, and others). Pyrethroid insecticides belong to the category of emerging contaminants; although they can be metabolised, Vidal *et al.* (2020) measured them in the livers of stranded or bycaught Guiana dolphins from eight locations on the Brazilian coast. Baini *et al*. (2020) evaluated PCBs and PBDEs in Cuvier's beaked whales (*Ziphius cavirostris*) in the Mediterranean Sea for the first time and found that 80% of the individuals assessed had levels above the toxicity threshold for marine mammals. Garcia-Garin *et al*. (2021b) found a decline in the concentration of Pb in the bones of franciscanas in the Rio de la Plata estuary (Uruguay), likely the result of a prohibition against Pb additives in fuel since the 1990s.

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