**ANNEX 1**

# MIGRATORY SPECIES AND MARINE POLLUTION: A BRIEF OVERVIEW OF ISSUES

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Contents

## Executive Summary

This paper provides a brief introduction to the variety of types of marine pollution affecting marine wildlife, with particular reference to marine debris, persistent organic pollutants and nutrients.

This review was requested by the 5th meeting of the CMS Sessional Committee and the document is intended to help identify potential future work on pollution by the Convention. It includes brief consideration of the main sources of pollution, work conducted to date by CMS and the role of other international bodies that seek to directly manage pollution, and how CMS might effectively complement this.

Recommendations include that the Scientific Council should hold a workshop in the intersessional period to further consider the effects of pollution, sponsor a comprehensive review of the topic as it affects marine migratory species and seek to identify hotspots where pollution and cumulative impacts may be or particular concern.

## 1. Background

Pollution, climate change, and biodiversity loss represent three planetary crises faced by society that require urgent, international action (UNEP, 2021). Of these three, the pollution threat has, arguably, the lowest profile, perhaps because many of the impacts of chemical pollutants occur out of sight and, hence, out of mind. However, its effect on the health and, by extension, the conservation of marine wildlife) should not be underestimated (Simmonds, 2017).

The development and use of petrochemical products and other synthetic chemicals are widely recognised as responsible for today's most serious pollution problems (Simmonds, 2017). Whilst, the intensive use of these chemicals allowed economic development, the broad recognition of pollution as a deeply concerning by-product is relatively recent. The first signs of problems came when it became apparent that non-target species were being killed by pesticides. Dichlorodiphenyltrichloroethane (DDT), for example, which was developed to help control insect-borne diseases in World War Two, was later found to accumulate in the adipose tissues of animals and its residues were found in their milk. Similar compounds and other chlorinated hydrocarbons in particular, had similar properties and were soon linked to bird declines. Concerns for other species followed and among the more recent developments has been recognition that some populations of marine predators at the very top of marine food chains may be being driven to extinction as a result of their pollution levels. This is the most acute level of concern for marine species but there are also issues related to chronic pollution burdens which, whilst these do not lead to the immediate death of individuals, may make the animals more susceptible to disease, compromising their health and perhaps facilitating epizootics, and also suppressing their reproduction.

Further generations of chemicals have been developed for a range of uses and concerns about the effects of some of these have emerged where they have entered the wider environment. A recent example would be the per- and polyfluorinated alkyl substances (PFAS), comprising more than 4,700 chemicals, which are a group of widely used, man-made chemicals that accumulate over time in the environment (EEA, 2023).

The story for plastics is rather similar in that their undoubted usefulness has been latterly undermined by the pollution now known to be associated with their release into the wider environment. This issue is also somewhat different to that presented by chemical pollution in that it is often highly visible leading to calls for action from the public and responses from policy makers.

In the Programme of work: Aquatic Species Conservation Issues (UNEP/CMS/ScC-SC5/Outcome 1.2) agreed at the 5th Meeting of the Sessional Committee of the CMS Scientific Council (ScC-SC5) in 2021, a document was requested detailing appropriate background information and including draft decisions for further work focused on marine debris (including fish aggregating devices, FADs), evidence of the effects of persistent organic pollutants on marine migratory species, and nutrient pollution. This paper is produced in response to this covering the types of pollution identified in the Scientific Council request and also some other categories in anticipation of a wider discussion about where CMS might best focus and how it will most effectively address these issues. The issue of FADs is addressed in UNEP/CMS/COP14/Inf.27.1.2.

## 2. Introduction

The oceans are sinks for many types of pollution including chemical wastes, plastics, pharmaceutical compounds, human-altered sediments and nutrient run-off (Willis et al., 2021). Some pollutants cause chronic toxicity and endocrine disruption in aquatic wildlife (Zandaryaa and Frank-Kamenetsky, 2021). Others, when exposures are high enough, can cause acute impacts, including mortality, for example in the case of a major oil spill. Table 1 provides a summary of the major sources of pollution in the marine environment.

**Table 1: Major sources of marine pollution (adapted from Willis et al., 2021)**

| **Pollutant Type** | **Pollutant Source** | | |
|---|---|---|---|
| | **Land-based industry** | **Municipal-based** | **Sea-based industry** |
| Sediment | Sediment from mining, agriculture, or forestry | Sediment from coastal development | Sediment disruptions (e.g. dredging and aquaculture) |
| Nutrient | Nutrients (e.g. nitrogen, phosphorous, iron) from agriculture, forestry, livestock | Nutrients (e.g. nitrogen and phosphorous) from wastewater, stormwater | Increase in nutrients (e.g. nitrogen and phosphorous) from aquaculture |
| Plastics | Plastics from packaging and transport of products | Plastics from urban stormwater, and litter escaped from waste management systems | Abandoned, lost, or discarded fishing gear from vessels. Plastics from aquaculture, shipping and offshore structures |
| Pharmaceuticals | Pharmaceuticals used in animal agriculture | Pharmaceuticals in wastewater from household waste, and medical facilities | Pharmaceuticals (e.g. anti-biotics and antiparasitic drugs) from aquaculture |
| Chemicals | POPs, heavy metals and pesticides from agriculture, mining, industrial wastewater and runoff | Petroleum and household chemicals from wastewater, and stormwater outlets | Petroleum and chemicals from shipping and offshore structures |
| Sound | | | Motor noise, seismic devices and sound propagating devices |
| Light | | Light from coastal development | Light from offshore structures and marine transport |
| Water | | Increased fresh water inputs / heated water (e.g. melted sea ice, shifts in ocean currents) | |

| **Pollutant Type** | **Pollutant Source** | | |
|---|---|---|---|
| | **Land-based industry** | **Municipal-based** | **Sea-based industry** |
| Nuclear Waste | Nuclear waste from power stations | | |

Van Dam et al. (2011) identified a difference between short-term pollution events and recurring pollution events. Short-term events have a "direct and severe impact upon multiple trophic levels of the system", including for example oil spills, which may have a localised impact, whilst recurring pollution events may have more subtle effects, for example sewage treatment effluent or herbicides runoff from land.

Certain migratory species may be particularly vulnerable to certain types of pollution depending on how they are exposed to the pollution and this may relate to location, time of year, whether or not they are migrating, and the behaviour that they are exhibiting when they are exposed. For example, a filter feeding animal may be more vulnerable to ingestion of marine debris at its seasonal feeding grounds.

Migratory and other wide-ranging marine wildlife may encounter pollution on their migratory routes and/or in breeding and feeding grounds. 'Protecting Blue Corridors, Challenges and Solutions for Migratory Whales Navigating International and National Seas', a recent report by WWF and many collaborators, illustrates this issue well (see Johnson et al., 2022). It considers the satellite tracks of over 1,000 migratory whales worldwide and outlines how whales are encountering multiple and growing threats in their critical ocean habitats – areas where they feed, mate, give birth, and nurse their young – and along their migration highways, or 'blue corridors'. Case studies in the report highlight hotspots and risks that whales navigate on their migrations, some of which can be thousands of kilometres each year.

Another recent study that may help the considerations of CMS on this topic proposed that ninety-nine species of marine mammals are threatened by pollution, with pollution hotspots located along the coasts of industrialized nations, in northwest Africa and the Philippines, and provided a map of these threats (Avila et al., 2018; Figure 1). However, the authors also warned that "risk maps based on core habitat could be misleadingly simplistic. Species core habitat maps fail to show the actual species distribution during crucial life stages and transient migration routes between summer and winter ranges."

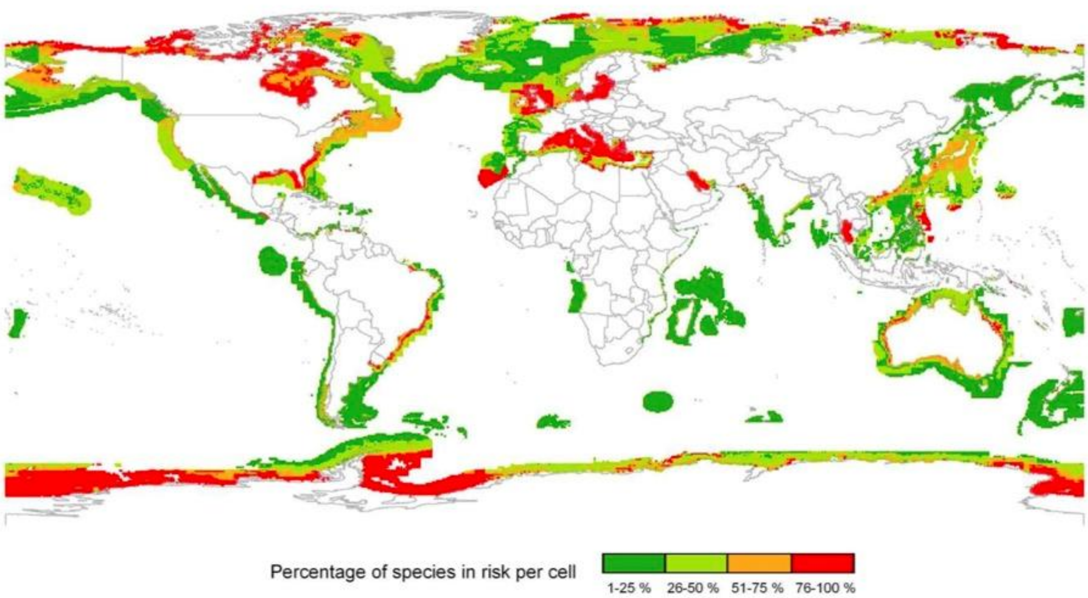

*Figure 1: Cumulative risk map showing the relative proportion of affected marine mammal species vs total marine mammal species present per cell for pollution (N species = 92). Red areas represent high-risk areas or hotspots. Source: Avila et al. (2018)*

## 3. Work to date by CMS

### 3.1 Overview

CMS has adopted various resolutions that relate to marine pollution including relating to light pollution, noise pollution, marine debris and oil pollution (see Table 2). Various Memoranda of Understanding also address pollution in their action plans (see Table 3).

**Table 2: CMS Resolutions relating to marine pollution**

| CMS Resolution | | Adopted |
|---|---|---|
| 13.5 | Light Pollution Guidelines for Wildlife | Gandhinagar, February 2020 |
| 12.20 | Management of Marine Debris | Manila, October 2017 |
| 12.14 | Adverse Impacts of Anthropogenic Noise on Cetaceans and other Migratory Species | Manila, October 2017 |
| 10.15 (Rev.COP12) | Global Programme of Work for Cetaceans | Manila, October 2017 |
| 7.3 (Rev.COP12) | Oil Pollution and Migratory Species | Manila, October 2017 |

**Table 3: CMS Memoranda of Understanding and associated Action Plans / Conservation Plans which refer to marine pollution**

| Memorandum of Understanding | Action Plan | Pollution related actions |
|---|---|---|
| Concerning the Conservation of the Manatee and Small Cetaceans of Western Africa and Macaronesia | Action Plan for the Conservation of Small Cetaceans of Western Africa and Macaronesia | Threat Reduction:<br>4.3: Promote reduction and ultimate elimination of chemical pollution or debris that affect small cetaceans.<br>4.3: Promote reduction and elimination of acoustic pollution.<br>4.7: Identify and mitigate other potential threats to small cetaceans, including ship strikes, entanglement in lost fishing gear and diseases. |
| | Action Plan for the Conservation of the West African Manatee | 3.2: Rehabilitation of West African Manatee habitats (Includes an action: “Ensure that key sites for manatees are protected from pollution.”) |
| on the Conservation of Migratory Sharks | Conservation Plan | 9.4 Promote the protection of the marine environment from land-based and maritime pollution that may adversely affect shark populations. |
| Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa | Conservation and Management Plan for Marine Turtles of the Atlantic Coast of Africa | 2.1.7 Reduce pollution in marine turtle coastal habitats, through development of appropriate legislation and best practice in collaboration with source sectors |
| on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia | Conservation and Management Plan | 2.1 Establish necessary measures to protect and conserve marine turtle habitats<br>f) Monitor and promote the protection of water quality from land-based and maritime pollution, including marine debris, that may adversely affect marine turtles |
| on the Conservation and Management of Dugongs (*Dugong dugon*) and their | Conservation and Management Plan for the MOU on the Conservation and Management of Dugongs (*Dugong dugon*) and | 3.2 Establish necessary measures to protect and conserve dugong habitats (includes an example of specific action that could be implemented: “Monitor and |

| **Memorandum of Understanding** | **Action Plan** | **Pollution related actions** |
|---|---|---|
| Habitats throughout their Range | their Habitats throughout their Range | promote the protection of water quality from land-based and maritime pollution, including marine debris, which may adversely affect dugongs and their habitats”) |
| Concerning Conservation Measures for the Eastern Atlantic Populations of the Mediterranean Monk Seal (*Monachus monachus*) | Action plan for the recovery of the Mediterranean monk seal in the Eastern Atlantic (in Spanish) | 5.2.2 Caracterización de la contaminación y parámetros físico químicos del agua (Translation: Characterization of contamination and physical-chemical parameters of water) |
| for the Conservation of Cetaceans and their Habitats in the Pacific Islands Region | Pacific Islands Regional Marine Species Programme 2022-2026. Whale and Dolphin Action Plan (pp.103-120) | No pollution related actions are included in this plan but see the Multi-species Action Plan below. |
| | Pacific Islands Regional Marine Species Programme 2022-2026. Multi-species Action Plan (pp.13-27) | Theme 4: Threat Reduction<br>Objective 2: Reduce impact of pollution and coastal and offshore development on marine species and habitats<br>4.2.1 Protect water quality by promoting sustainable land use practices (e.g. ridge-to-reef and community-based management) to protect and conserve coastal marine species habitats and foraging grounds, such as seagrass meadows.<br>4.2.2 Ensure EIA processes for coastal development take account of and avoid, reduce, or mitigate any impacts to marine species, their habitat and foraging grounds, especially coral reefs and seagrass beds, including impacts of runoff.<br>4.2.4 Enforce compliance with international and national regulations on vessel discharges containing oil and other toxic substances, including plastic, and report breaches.<br>4.2.5 Implement the Pacific Regional Action Plan: Marine Litter 2018-2025 (Pacific Marine Litter Action Plan) and the International Maritime Organization’s Action Plan to Address Marine Plastic Litter from Ships. Strengthen collaboration between relevant government agencies. Ensure proper waste disposal facilities exist at ports. |

Under the current CMS Global Programme of Work for Cetaceans, pollution and marine noise are given different levels of priority for global collaborative action in different regions. See Tables 4 and 5.

**Table 4: Priorities for global collaborative action on Pollution according to the current Global Programme of Work for Cetaceans**

| High priority | Medium priority | Lower priority |
|---|---|---|
| North East Atlantic Ocean | Central and South East Atlantic Ocean (Western Africa) | North West Atlantic Ocean, (Atlantic North America and the Caribbean) |
| Mediterranean and Black Seas | South West Atlantic Ocean (Atlantic Latin America), | South East Pacific Ocean (Pacific Latin America) |
| Central and North West Pacific Ocean (East and South East Asia) | Central and North East Pacific Ocean (Pacific North America and Eastern Tropical Pacific) | |
| Indian Ocean (including the Red Sea) | Pacific Islands Region. | |
| | Arctic Seas | |
| | Southern Ocean | |

**Table 5: Priorities for global collaborative action on Marine Noise according to the current Global Programme of Work for Cetaceans**

| High priority | Medium priority | Lower priority |
|---|---|---|
| North East Atlantic Ocean | Mediterranean and Black Seas | Caribbean Seas and North West Atlantic Ocean, |
| North West Atlantic Ocean (Atlantic North America and the Caribbean) | Central and South East Atlantic Ocean (Western Africa) | South West Atlantic Ocean (Atlantic Latin America), |
| Central and North East Pacific Ocean (Pacific North America and Eastern Tropical Pacific) | Central and North West Pacific Ocean (East and South East Asia) | South West Atlantic Ocean (Atlantic Latin America) and |
| Arctic Seas | | South East Pacific Ocean (Pacific Latin America), |
| | | Pacific Islands Region |
| | | Indian Ocean (including the Red Sea) |
| | | Southern Ocean |

### 3.2 Types of marine pollution with existing CMS work-streams/actions

Certain pollution types are already being addressed by CMS and are only touched on briefly here for completeness.

### 3.2.1 Noise pollution

Noise pollution has been considered by CMS in some detail as reflected by the decisions made at the conferences of parties.

The Conference of the Parties to CMS adopted Resolution 12.14 *Adverse Impacts of Anthropogenic Noise on Cetaceans and Other Migratory Species* at COP12, Manila, October 2017. The Resolution recognised "that anthropogenic marine noise, depending on source and intensity, is a form of pollution, composed of energy, that may degrade habitat and have adverse effects on marine life ranging from disturbance of communication or group cohesion to injury and mortality".

There are different sources of noise pollution in the marine environment. Ambient, continuous noise can come from vessel traffic and drilling in oil or gas operations or construction (Simmonds et al., 2021). Intense, impulsive noise comes from a number of sources including seismic airgun arrays used in oil and gas exploration, sonars used by the military, fisheries and research vessels, pile-driving in the construction of offshore wind farms and acoustic deterrent devices used, for example, to deter marine mammals from fisheries and aquaculture sites. Some impulsive noise can become continuous over distance and under certain conditions.

Marine noise pollution can negatively impact cetaceans by disrupting communication, reproductive and foraging behaviours, inducing chronic stress responses, causing temporary or permanent loss of hearing sensitivity, causing physical injury and, in some circumstances, causing death (Simmonds et al., 2021). Beaked whale species appear to be particularly vulnerable to some noise pollution such as mid-frequency active sonar (Simonis et al., 2020).

In Canada's Pacific regions, hotspots for ship noise and marine mammals include south coast waters (Juan de Fuca and Haro Straits) with secondary hotspots located on the central and north coasts (Johnstone Strait and the region around Prince Rupert) (Erbe et al., 2014).

Weilgart (2018) found sharks, rays and turtles to be underrepresented in noise pollution impact studies. White sharks (*Carcharodon carcharias*) have been found to exhibit a behavioural response to artificially generated sound (Chapuis et al., 2019). Loggerhead turtles (*Caretta caretta*) have been recorded diving when exposed to seismic airgun shots which could be an avoidance response (deRuiter and Doukara, 2012).

Noise pollution can impact fish development, behaviour and communication and increase stress which can, in turn, lead to increases in parasites, disease and mortality (Weilgart, 2018).

### 3.2.2 Light pollution

Light pollution is an area of active engagement by the Convention and only a brief outline is included here. At its 13$^{th}$ ordinary meeting (COP13, Gandhinagar, February 2020) the Conference of the Parties to CMS adopted Resolution 13.5 *Light Pollution Guidelines for Wildlife*. COP13 noted that artificial light is significantly increasing globally and that it is "known to adversely affect many species and ecological communities by disrupting critical behaviours in wildlife and functional processes, stalling the recovery of threatened species, and interfering with a migratory species' ability to undertake long-distance migrations integral to its life cycle, or by negatively influencing insects as a main prey of some migratory species".

Resolution 13.5 also endorsed *Light Pollution Guidelines for Wildlife*. These provide general guidelines for the management of artificial light for all wildlife and specific information for some groups of migratory wildlife including marine turtles, seabirds and migratory shorebirds. Resolution 13.5 recommends that Parties, non-Parties and other stakeholders should use the guidelines to limit and mitigate the harmful effects of artificial light on migratory species. With a view to complementing those guidelines, COP13 through Decision 13.138 requested that the Secretariat, subject to the availability of resources, prepare guidelines for adoption by COP14 on how to effectively avoid and mitigate the indirect and direct negative effects of light pollution for those taxa not yet in the focus of the guidelines endorsed by Resolution 13.5, also taking into account other existing guidance as relevant.

The effects of light pollution on marine species have been little studied to date. However, it is well known that seabirds which migrate, forage or return to their colonies at night are vulnerable to the effects of light pollution which can lead to disruption of their key behaviours, and mortality, for example through the grounding of fledglings (CMS, 2020). Migratory shorebirds are also impacted particularly whilst foraging. Flight behaviour by landbirds migrating at night can be affected by artificial light at night (Van Doren et al., 2017; Cabrera-Cruz et al., 2021).

It has long been known that turtles hatching from their eggs on beaches can be disoriented by artificial lights, and that their sea-finding ability can be disrupted (Pendoley and Kamrowski, 2016). Recent studies have started to look at how hatchlings are impacted once they have reached the water. A study in Costa Rica found that olive ridley turtles (*Lepidochelys olivacea*) were still attracted to lights when they were in the ocean (Cruz et al., 2018). This has implications for any attempts to mitigate the negative impact of artificial light in habitat used by turtles. In Western Australia, another study found that hatchling flatback turtles (*Natator depressus*) swam more slowly when there was artificial light present on a boat moored at sea (Wilson et al., 2018). The turtles also spent more time in nearshore waters when the light was on and, depending on the type of light, they could be caught by a ‘trapping effect’ meaning that they only dispersed when the light was switched off. There is some evidence that predation of hatchlings in the water increases near artificial lights (Wilson et al., 2022).

Migratory fish can also be impacted by light pollution. The critically endangered European eel (*Anguilla anguilla*) migrates down European rivers, passing through areas which are lit by artificial light, before swimming to the Sargasso Sea where they spawn (Pike et al., 2020). When eels are offered a choice of passages they favour dark passage routes over illuminated routes, are more likely to reject a route when exposed to high levels of artificial light at night and travel downstream more quickly when they do choose the illuminated route (Vowles and Kemp, 2021). As migrating eels may have to pass through a number of areas with artificial light, this could lead to a disruption of the timing of their migration.

## 4. Marine debris - plastic pollution

At its 12th meeting (COP12, October 2017) the Conference of the Parties to CMS adopted Resolution 12.20 *Management of Marine Debris*.

Over 8 million tons of plastics enter the ocean each year (Häder et al., 2020). Sources of this plastic include fisheries, shipping and aquaculture sites, wastewater pipelines, shorelines and rivers (UNEP, 2016). Between 1.15 and 2.41 million tonnes of plastic waste come from rivers, with 67% of the global total coming from only 20 rivers, most of which are in Asia (Lebreton et al., 2017).

Plastic waste famously accumulates in ocean gyres and these areas have become known as garbage patches (Leal Filho et al., 2021). The debris in the garbage patches is spread across the water surface and throughout the water column from the surface to the ocean floor[1]. The debris varies in size from microplastics to large fishing nets and everything in-between. The Great Pacific Garbage Patch is located between California and Hawaii (Lebreton et al., 2018). It covers an area of 1.6 million km$^2$ and is estimated to be made up of at least 79 thousand tonnes of ocean plastic, with fishing nets accounting for at least 46% of the debris. The South Pacific Garbage Patch covers 2.6 million km$^2$ and is predominantly made up of microplastics (Leal Filho et al., 2021). The North Atlantic Garbage Patch is estimated to cover hundreds of kilometres with approximately 200,000 pieces of debris per square kilometre (Leal Filho et a., 2021). The South Atlantic Garbage Patch is relatively small, covering 0.7 million km$^2$. Further surveys are needed to determine the size of the southern Indian Ocean garbage patch and its seasonal, annual and long-term dynamics (Connan et al., 2021). The Mediterranean Sea is also recognised as an area with intense plastic pollution although it tends not to accumulate in patches (Baudena et al., 2022).

As well as the five oceanic gyres mentioned above, other microplastic hotspots include the Gulf of Mexico, Mediterranean Sea, Bay of Bengal and Coral Triangle (Germanov et al., 2018). Microplastics can adsorb and transport pollutants including pharmaceutical compounds (Santana-Viera et al., 2021). Some pharmaceuticals, e.g. the antibiotic roxithromycin, bio-accumulate more when adsorbed onto microplastics than when ingested directly (Zhang et al., 2019). See below for more details regarding pharmaceutical pollutants. There have been a number of recent papers reviewing the effects of marine debris on cetaceans and it is clear that it poses a serious threat to cetaceans when they either become entangled in it or ingest it (for example, Baulch and Perry, 2014). Injuries caused by entanglement or ingestion can be acute or chronic which can have health consequences and result in death. Issues associated with ingestion of plastic debris, for example, include starvation and gastric rupture as recorded in a sperm whale found stranded in Spain in 2012 (de Stephanis et al., 2016). Marine debris could be a conservation threat to some populations (Baulch and Perry, 2014; Eisfeld-Pierantonio et al., 2022).

Eisfeld-Pierantonio et al. (2022) found that 67.8% of cetacean species are so far known to be affected by interactions with marine debris and that different diving and feeding strategies determine how different species interact with plastic pollution. Probably all species are impacted to some extent, and a future survey of the literature will show evidence of more affected species. In 2019, the workshop on marine debris run under the auspices of the International Whaling Commission (IWC) made a number of recommendations concerning how to study and assess the impacts of plastic pollution on cetaceans (IWC, 2020). Some of these recommendations were endorsed in the resolution which was passed at the 68th IWC Commission Meeting in October 2022 (IWC, 2022) and which has identified marine debris as a priority work area for the IWC. The 2019 workshop also noted that chronic health concerns could result if plastics persisted in the gastrointestinal tract where they may negatively impact nutrition and health. Additionally, ingested plastic debris can cause inflammatory changes and act as a vector of pathogens or pollutants.

Marine debris is also impacting many birds. A review of 2,580 seabirds (from 13 species) in the North Atlantic found that great shearwaters (*Ardenna gravis*) had the highest prevalence of ingested plastic and that 71% of them had ingested at least one piece of plastic (Provencher et al., 2014). Two individuals had 36 plastic pieces in their gastro-intestinal tracts. Fifty-one per cent of northern fulmars (*Fulmarus glacialis*) had ingested plastic (individuals had between 0 and 7 pieces). According to Provencher et al. (2014), rather than the number of pieces of plastic, the mass of plastic may be more relevant. The average mass of plastics for great shearwaters was 0.11g which is 0.013% of body mass. Foraging strategy may determine how much plastic is ingested by seabirds as some species seem to be more susceptible than others.

[1] https://marinedebris.noaa.gov/info/patch.html

Microplastic pollution has been found at beaches where turtles nest. For example, at nesting sites for loggerhead (*Caretta caretta*) and green turtles (*Chelonia mydas*) in Cyprus, some of the worst pollution ever recorded was found on certain beaches (Duncan et al., 2018). As microplastics have different physical properties to natural sediments, nesting success could be affected, and sex ratios of hatchling turtles could become skewed. Duncan et al. (2018) recommended that “studies are clearly needed to evaluate the impact of plastic presence in the sand column on critical parameters such as temperature and permeability”.

Turtles can also ingest plastic debris or become entangled in it. Yaghmour et al. (2018) for example, found that 85.7% of green turtles (*Chelonia mydas*) examined had ingested marine debris. Entanglement in marine debris has been reported for all marine turtle species, in all ocean basins (Duncan et al., 2017). Most entanglement takes place in ghost gear.

Filter-feeding megafauna (mobulid rays, filter-feeding sharks, baleen whales) are at particular risk of high levels of microplastic ingestion because of the way they feed, their target prey and because their habitat overlaps with micro-plastic pollution hotspots (Germanov et al., 2018). See Figure 2. In areas with high accumulations of debris such as the garbage patches in the gyres, plastic may make up a large part of the diets of some organisms (Chen et al., 2018).

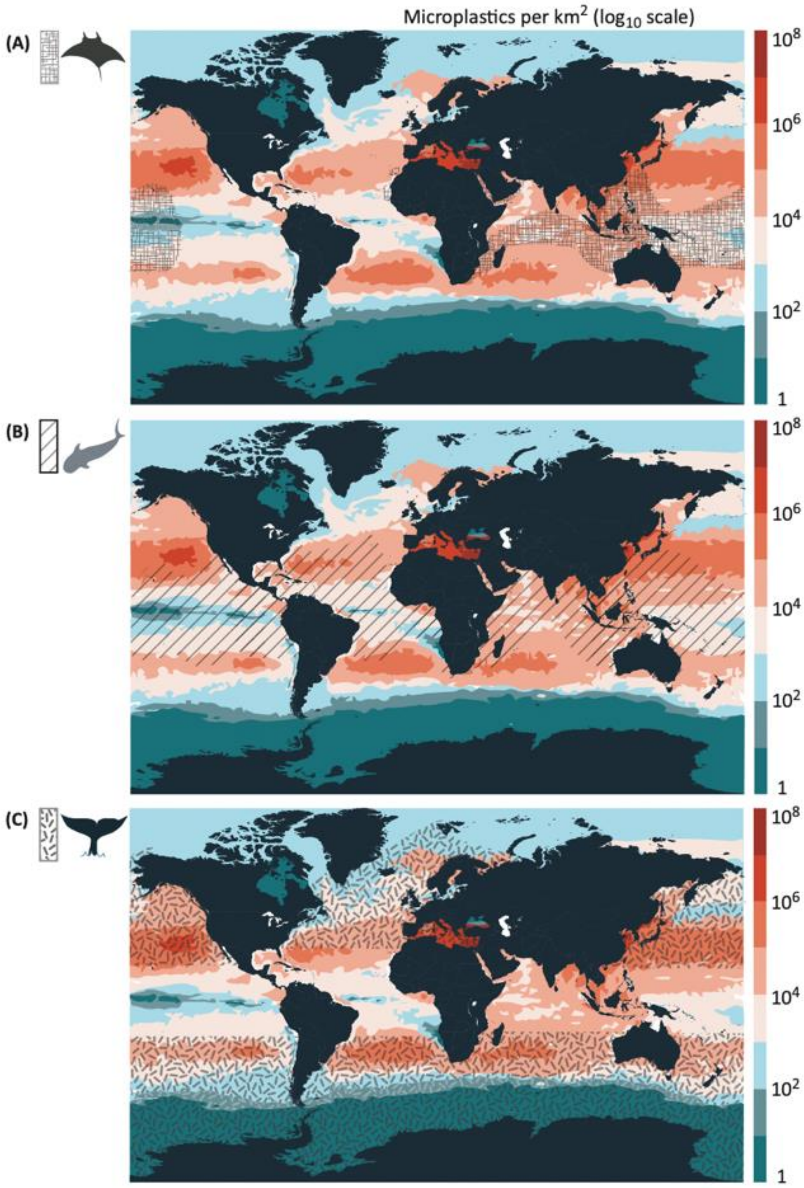


*Figure 2. Key buoyant microplastic hotspots overlap with habitat ranges of filter-feeding marine megafauna. Habitats of 3 species are overlapped with regions with high levels of buoyant microplastic pollution. (A) Reef manta ray (*Mobula alfredi*) (B) Whale shark (*Rhincodon typus*) (C) fin whale (*Balaenoptera physalus*). Source: Germanov et al. (2018)*

The significance of microplastics in terms of related health effects is still being evaluated but it has long been known that certain pollutants associate with microdebris and so their ingestion may provide a significant route for these plastics to enter the bodies of animals. Similarly, plastic pieces may contain substances, for example plasticisers, that can leach from the material once it has been ingested. This role of microdebris in particular in the transference of substances is currently of growing concern (Eisfeld-Pierantonio et al., 2022; IWC, 2020). Baleen whales, because of the vast quantities of water that they filter, may be especially at risk of ingestion of small particles of plastic of the same size range as their prey. There may also be an overlap between baleen whale feeding locations and marine debris hot spots, as shown for the Mediterranean Sea (Fossi et al., 2020).

## 5. Chemical pollutants

By the end of World War II, a variety of new, synthetic compounds were available for pest control and private companies were set up to manufacture and market them meaning that by 1950, 15 insecticides and fungicides were in common use (Peterle, 1991). Decades later this number has increased by orders of magnitude and nowadays far more is known about the environmental consequences of such compounds.

Persistent organic pollutants (POPs) pose a significant threat to marine wildlife (Simmonds, 2017). DDT and polychlorinated biphenyls (PCBs) are of particular concern as they persist in the environment and accumulate in marine animals at the top of the food web. POPs disrupt the endocrine system, thereby impacting hormonal functions including reproduction and development for fish and other wildlife (Johnson et al., 2013). Organochlorine pesticides also disrupt reproduction in fish. The environmental consequences of PCBs have been well described (Jepson and Law, 2016), although it is only in recent years that it has become clear how significant this threat is to marine top predators in particular.

Many compounds bioaccumulate and can have physiological effects but here we will focus on the polychlorinated biphenyls, both as an example and because there is evidence of their particular impact on apex predators. There is a considerable literature now about PCB contamination. Bans on these compounds, mean that they are now largely a legacy problem and this makes addressing them all the more challenging.

Stuart-Smith and Jepson (2017) commented that whilst cetacean blubber PCB concentrations initially declined following the mid-1980s European Union (EU) ban on PCB use and manufacture, “they have since stabilised in most European biota (including cetaceans) with PCB levels in multiple dolphin species markedly exceeding all known marine mammal PCB toxicity thresholds”. Hence, Stuart-Smith and Jepson (2017) concluded that population declines in these species are likely the result of reproductive failure, driven by high PCB concentrations in adult females. In the most industrialised regions of Europe, the few remaining coastal killer whale (*Orcinus orca*) populations are close to extinction and PCBs are generally high in Europe. Orcas have been described as ‘among the most highly PCB-contaminated mammalian species in the world’, reflecting their long lives, the fact that they are apex predators and extremely high movement of PCBs through the milk of mothers to their offspring.

Desforges et al. (2018) using an individual-based model framework, showed that PCB-mediated effects on reproduction and immune function threatened the long-term viability of >50% of the world’s killer whale populations. Killer whale populations near industrialised regions, and those feeding at high trophic levels regardless of location, are at high risk of population collapse.

Other marine top predators, such as some shark species may also be at significant PCB risk although there has been insufficient research in most species to assess this properly (Stuart-Smith and Jepson, 2017).

The Mediterranean Sea has been identified as a marine pollution hotspot due to the high levels of PCBs present (Handoh and Kawai, 2014) and many species of cetaceans there are highly contaminated (Jepson and Law, 2016). Jepson et al. (2016) highlighted the western and central Mediterranean and south-west Iberia, the Gulf of Cadiz and the Strait of Gibraltar in particular as being ‘PCB hotspots’. Other areas with high levels of PCBs include the North Sea, the Baltic Sea, Atlantic Coast of North America, Hudson Bay, the Bering Sea, East Asia and the Eurasian edge of the Arctic Ocean (Handoh and Kawai, 2014).

Desforges et al. (2016) concluded that “marine mammals worldwide are exposed to the highest levels of environmental contaminants of all wildlife.” Persistent organic pollutants and heavy metals (mainly PCBs and mercury, Hg) suppress marine mammals’ immune function and can, therefore, lead to infectious disease outbreaks (Desforges et al., 2016). Indeed, it is important to consider how pollution impacts marine mammals by looking at how pollutants can prevent them from dealing with stresses from other environmental factors such as disease (Reijnders et al., 2009).

Migrating fish such as salmon, their habitat and food webs are exposed to pesticides but there is a lack of information regarding how these pesticides impact food webs, for example (Macneale et al., 2010). “Pesticide degradates (breakdown products) and metabolites…can be more toxic than the parent compound (e.g. organophosphate insecticides)…[and]…the fate, persistence, and toxicity of so-called “inert” ingredients in pesticide formulations remain poorly understood” (Macneale et al., 2010). Pollution, particularly PCBs and dioxins, is one of the reasons for a decline in the population of Baltic salmon (*Salmo salar L.*) (Kulmala et al., 2013).

A full review of the pollution issues related to heavy metals would need to consider a very large significant literature, but an example of concern is the accumulation of such substances in the tissues of fish, which may have effects on their health and that of their predators (see for example, Jezierska and Witeska, 2006). It is well established that fish living in polluted waters tend to accumulate heavy metals in their tissues and accumulation of metals in various organs of fish may cause structural lesions and functional disturbances.

## 6. Nutrients

Excessive nutrients can have devastating effects on coastal marine ecosystems. Increases of nutrient input to coastal areas is mainly from agricultural sources but also from atmospheric deposition from fossil fuel combustion (Howarth, 2008). The resulting process, known as ‘eutrophication’, leads to hypoxia, anoxia, habitat degradation, loss of biodiversity, changes in food-webs, increased harmful algal blooms and ‘dead zones’. Mortalities of seagrass, algae and fish may result.

The ways in which enhanced algal blooms can negatively affect other species include that they block light to underwater plants, making it difficult or impossible for them to grow (Smithsonian Environmental Research Center, 2023). Without these plants some animals, such as larval crabs and fish, are deprived of food and habitat. The ‘dead zones’ created by algal blooms are areas of hypoxia (very low oxygen). Some low-oxygen zones are transient lasting just a few hours overnight, because algal photosynthesis boosts oxygen during the day, whereas respiration sucks up oxygen at night in the absence of photosynthesis. Enhanced algal blooms make the day-night swings, which naturally occur, far more extreme. Oxygen depleted zones can last for months, years or longer.

Sewage discharges can also affect nutrient loadings. Wear et al. (2021) reported that sewage pollution hotspots occur globally in terrestrial, aquatic and marine systems and that “untreated and poorly treated sewage elevates concentrations of nutrients, pathogens, endocrine disruptors, heavy metals, and pharmaceuticals in natural ecosystems”. The same authors also comment on impacts on coral reefs and salt marshes, habitats which may be important for the various life stages of migratory species.

Human-induced coastal eutrophication has been described as one of the greatest threats to the health of coastal estuarine and marine ecosystems globally (Malone and Newton, 2020). Nitrogen is generally understood to be the primary cause of eutrophication in most coastal ecosystems, although this does not mean that phosphorus does not also play a role. In the second half of the twentieth century, the global supply of dissolved inorganic nitrogen doubled as a result of human activities and anthropogenic inputs (160 Tg N yr-1) now exceed all natural N-fixation in the oceans (140 Tg N yr-1). Figure 3 provides a schematic of nutrient pathways and consequences.

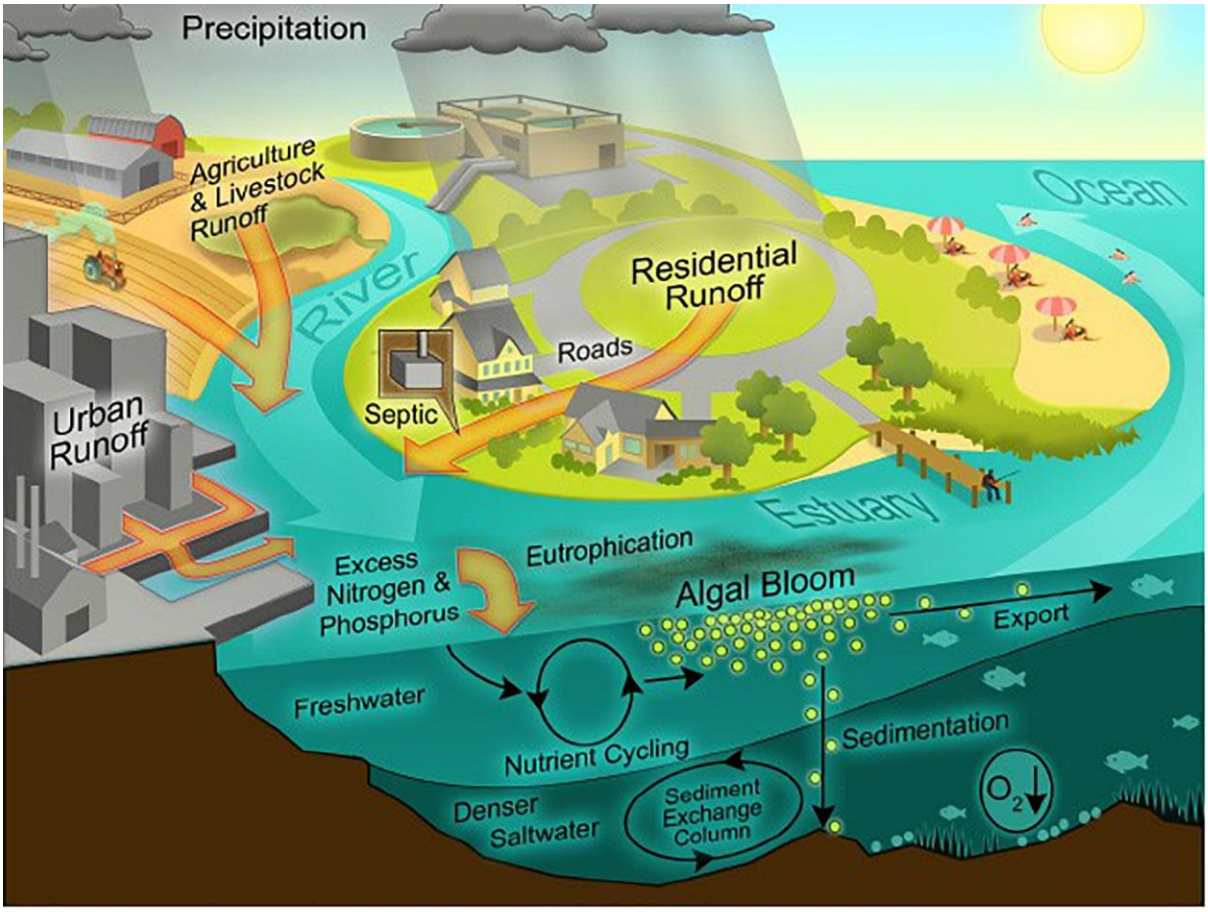


*Figure 3. Nutrient enrichment pathways and consequences (Source: Malone and Newton, 2020).*

## 7. Sediments

Increases in terrigenous material[2]l as particulate (organic and inorganic) and dissolved organic matter "affect the physical properties of the water column, enhancing turbidity and reducing penetration of solar radiation available for photosynthesis… they also alter the chemical properties of the water body" (Häder et al., 2020). These increases may be caused by factors such as mining activities and extreme rain events. Van Dam et al. (2011) noted that the "association of pollutants with particulate matter may increase environmental persistence. Because of the rapid sorption of many contaminants to sediments, it is not surprising the largest reservoirs of chemical stressors will be found in estuaries, wetlands or nearby urban centres. Nevertheless, suspended sediments transported in monsoonal flood-plumes have the potential of contaminating sites further offshore".

High sediment loads can have physiological and behavioural effects on fish (Kjelland et al., 2015). Increased concentration and exposure time to suspended sediment increases the

[2] Terrigenous materials refers to sediments including rock debris, mineral grains and clay particles

severity of fish response although different species have different tolerance levels (Wenger et al., 2017). Fish may avoid turbid water and their foraging and habitat choices may be impacted by the presence of suspended sediment. Physiological changes include damage to gills which "impairs respiratory ability, nitrogenous excretion and ion exchange" (Wenger et al., 2017). Sediment which is contaminated has an even greater impact on fish (Wenger et al., 2017).

## 8. Transient large-scale pollution events

Migratory birds are threatened by short-term pollution events, for example the northern gannet (*Morus bassanus*) is a long-distance migrant which was impacted by the Deepwater Horizon explosion in the Gulf of Mexico (Montevecchi et al., 2012) See case study box below.

Oil pollution is one of the recognised causes of mortality for migrating Magellanic penguins (*Spheniscus magellanicus*) (Stokes et al., 2014). These birds migrate from breeding grounds in southern Argentina northwards to wintering areas in northern Argentina, Uruguay and southern Brazil following a corridor within 250 km of the coast. An average one-way migration is 2,000 km, with some penguins travelling over 3,000 km.

When birds get oil on their feathers they can die from hypothermia as the feathers are no longer waterproof or insulating (Henkel et al., 2012). They can also suffer from dehydration, starvation, arthritis, gastrointestinal problems, infections, pneumonias, cloacal impaction and eye irritation. Birds may ingest oil when they attempt to preen their feathers but, in the case of shorebirds, oil ingestion also occurs as the birds forage in contaminated areas. Ingested oil can have toxic effects on the kidney, liver and gastrointestinal tract. The potential effects of an oil spill on migratory shorebirds is shown in Figure 4.

Migration is energetically and physiologically demanding and the sublethal effects of oil may have severe consequences that lead to population-level effects (Henkel et al., 2012). Migration also provides a mechanism whereby the effects of the spill may be transported to ecosystems far removed from those in the immediate vicinity of the contamination."

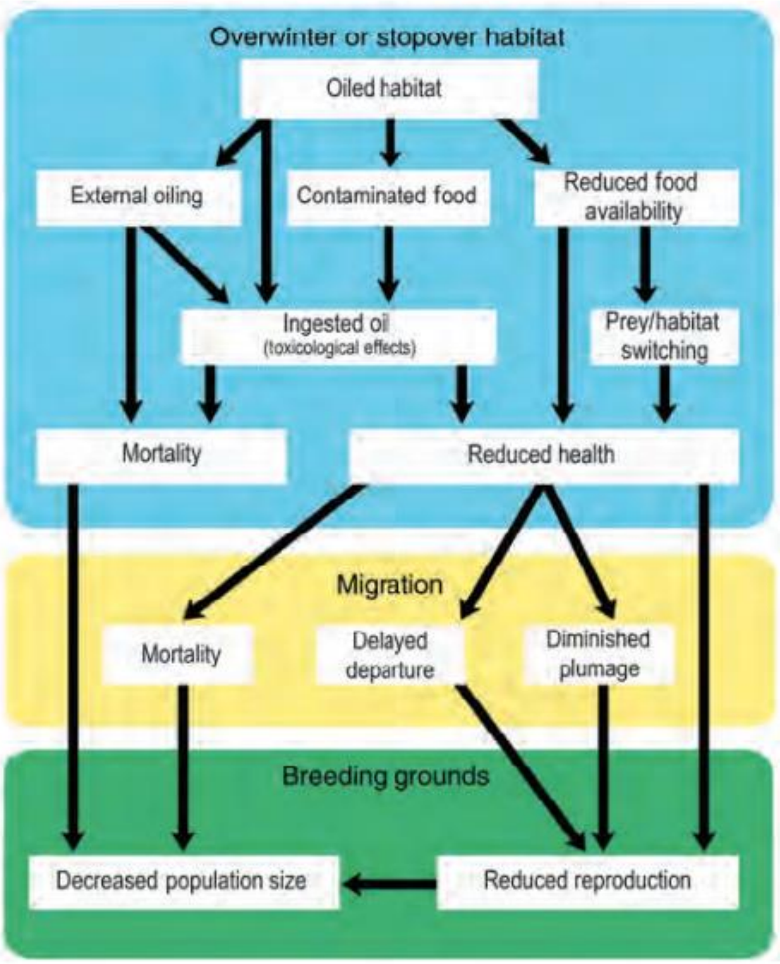


*Figure 4: Oil contamination pathways and potential carryover effects at each stage of the annual cycle (overwintering or stopover habitat, migration, and breeding) for migratory shorebirds. Source: Henkel et al. (2012)*

**Case study: Deepwater Horizon**

In April 2010, there was an explosion on the Deepwater Horizon drilling unit which led to at least 5 million barrels of oil and at least 250,000 metric tons of natural gas being released into the Gulf of Mexico (Joye, 2015). The release lasted 87 days. Chemical dispersants were applied at the sea surface and underwater at the discharging wellhead to increase the dissolution of the oil in offshore waters, and to reduce its arrival on shorelines. However, the dispersants used were highly toxic and the combination of dispersant with crude oil increased the toxicity of the oil to microzooplankton (Almeda et al., 2014). According to Joye (2015) “the hydrocarbon infusion…negatively affected multiple levels of the Gulf’s food web, from the microscopic plankton at the base to pelagic fish and top predators, such as dolphins.”

Biological effects were found in sharks exposed to polycyclic aromatic hydrocarbons (PAHs) following the Deepwater Horizon oil spill (Walker, 2011). Henkel et al. (2012) estimated that “as many as 86,000 shorebirds were potentially affected by trace or light oiling of their feathers.” Shorebirds would also have ingested oil tarballs whilst foraging.

Other transient but large-scale events could include other chemical spills from pipelines and shipping or the loss of plastics, such as the exceptional spill of plastic pellets that occurred in Sri Lanka in May 2021 (see for example, de Vos et al., 2022).

## 9. Pharmaceuticals

Pharmaceuticals and personal care products are increasingly being found in the environment including in fish tissue (Ramirez et al., 2009). Sources of pharmaceuticals entering the marine environment include sewage, aquaculture, animal husbandry, horticultural crops and waste disposal (Gaw et al., 2014). "Once discharged into aquatic environments, pharmaceuticals and their metabolites can undergo biotic and abiotic transformation (degradation) and sorb to suspended particulate matter (SPM) and sediments and, in some cases, accumulate in the tissues of aquatic organisms," (Gaw et al., 2014). The processes by which this takes place may differ between fresh and saltwater environments (Gaw et al., 2014).

Pharmaceutical compounds have been found in coastal areas worldwide (Fabbri and Franzellitti, 2016). Areas with dense populations and intensive industrial and agricultural activities can be considered hotspots.

A large number of pharmaceuticals enter the Baltic Sea marine environment mainly those from therapeutic groups of anti-inflammatory and analgesics, cardiovascular and central nervous system agents (Zandaryaa and Frank-Kamenetsky, 2021). In the Mediterranean, 13 pharmaceuticals were highlighted as being a cause for concern including 8 antibiotics, 3 analgesics/anti-inflammatories, metoprolol and 17 $\alpha$-ethinylestradiol (Desbiolles et al., 2018).

## 10. Freshwater runoff

Increases in freshwater runoff in coastal areas e.g. in the northern Baltic Sea, could have an impact on species distribution (Vuorinen et al., 2015). "In the Baltic Sea freshening of the water has caused both qualitative and quantitative changes in fish fauna," according to Vuorinen et al. (2015).

Prolonged exposure to freshwater or low salinity can have serious health consequences for some marine cetaceans. For example, common bottlenose dolphins (*Tursiops truncatus*) have been recorded with skin lesions, corneal oedema and electrolyte abnormalities following exposure to water with low salinity (Deming et al., 2020). Ninety-six per cent of dolphins exposed to low salinity during Hurricane Harvey, which struck the southeast USA in 2017, were recorded as having at least one skin lesion, with 65% of these dolphins exhibiting lesions of medium or high extent (Fazioli and Mintzer, 2020). In scenarios where there is an acute salinity change, dolphins may experience energetic costs due to a reduction of available prey and increased energy expenditure. This may be due to effects on buoyancy and reduced foraging efficiency (Booth and Thomas, 2021). Although dolphins can tolerate some exposure to low salinity, animals that are in poor health, or which are very young or very old, may die from exposure. Once an animal's skin barrier has been significantly degraded due to prolonged exposure, there is an increased risk of infection, "decompensation of adrenal and renal systems in addition to other chronic illnesses, and subsequent malnutrition," (Booth and Thomas, 2021).

## 11. Nuclear waste

Low-level radioactive materials are sometimes deliberately disposed of in the marine environment (Kolar and Gugleta, 2019). For example, low-level radioactive waste $^{14}C$ is discharged into the Irish Sea from the Sellafield Ltd. facility in the UK and enriched $^{14}C$ activities have been found in all marine mammal samples from the west coast of the British Isles (Tierney et al., 2017).

Kolar and Gugleta (2019) found that "accumulation of radionuclides can lead not only to increased mortality and morbidity rates [for marine and freshwater fish], but also to changes in reproductive and developmental patterns as well as alterations in the genetic makeup." The migratory patterns of some fish species mean that trace radiation can end up being introduced into food webs in areas where there was none present before.

As well as deliberate disposal of radioactive material into the marine environment, sometimes accidental discharge takes place which can have more extreme impacts on wildlife. After the Fukushima Daiichi nuclear accident in Japan in 2011 radiocesium ($^{134}Cs$ and $^{137}Cs$) levels in Pacific bluefin tuna (*Thunnus orientalis*) were 10 times greater than before the accident (Madigan et al., 2012). The tuna were also found to have carried the Fukushima-derived radionuclides from Japan to California.

## 12. Emerging issues

As described above, it is reasonable to assume that new threats will emerge in the context of human-made chemicals entering the environment and this means that vigilance is needed to try to identify such emerging threats.

New pollution sources may also emerge related to the increasing number of industrial activities moving into the oceans. One such is deep-sea mining. Concerns about this as a source of noise, and potentially other sources of pollution, have recently been raised (for example Thompson et al., 2023). Deep-sea mining is considered in a separate document but, in brief, this relates to the exploitation of certain minerals in the deep seas. The Clarion-Clipperton Zone (CCZ) in the North Pacific, for example, has been highlighted as of particular interest to mining companies aiming to exploit polymetallic nodules. This has an average depth of 5,500 m and is an area of approximately 11,650,000 km$^2$. If permitted, commercial-scale mining may operate 24-hours a day, at varying depths. The sounds produced from mining operations, including from remotely operated vehicles on the seafloor, overlap with the frequencies at which cetaceans communicate, which can cause auditory masking and behaviour change in marine mammals.

## 13. Work by other international bodies on marine pollution

### 13.1 Marine Debris

To date the International Whaling Commission (IWC) has held three international workshops on cetaceans and marine litter (IWC., 2020). The most recent workshop reviewed the latest evidence on interactions with cetaceans and identified best practice for gross pathology, including for micro-debris. Based on its review of both published and unpublished sources, the workshop agreed that "the scale of the actual and projected increase in plastics" was "alarming," noting that cetaceans can be killed by ingestion because of gastric impaction/occlusion and perforation or as a result of the associated lesions.

The 2019 IWC workshop also considered entanglement, noting that ~640,000 tons of Abandoned, Lost and otherwise Discarded Fishing Gear (ALDFG) arrives in the oceans annually. Among its recommendations, the workshop highlighted how important long-term studies are and the need for uniformity in post-mortem studies. At the present time, the most universally used method to examine effects and occurrence in cetaceans is the examination during necropsy of the gastrointestinal tract of stranded individuals. This can demonstrate the type of exposure of the species but has limitations in terms of identifying all the adverse effects on both the individual and at the population level. Problems with this approach include that:

i) few bodies are retrieved;
ii) of these, even fewer are in good enough condition to be examined; and
iii) an apparently low associated rate of reporting.

It should also be noted that Heads of State, Ministers of environment and other representatives from UN Member States endorsed a historic resolution at the UN Environment Assembly (UNEA-5) on March 2nd 2022 in Nairobi to End Plastic Pollution and forge an international legally binding agreement by 2024. The new legally binding instrument ill address the full lifecycle of plastic, including its production, design and disposal.

### 13.2. Persistent pollutants

Hazardous chemicals related agreements include the Rotterdam Convention on the Prior Informed Consent Procedure for certain Hazardous Chemicals and Pesticides in International Trade, the Stockholm Convention on Persistent Organic Pollutants (POPs), the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Minamata Convention on Mercury. In addition, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal focuses specifically on waste-related issues.

## 14. Conclusions

As described here, marine environments and, hence, migratory marine wildlife may be affected by a range of different types of pollution. In recent years the issue of plastic pollution has developed a significantly high profile and international action is now following to control it. Other forms of pollution are far less well understood by the public and policy makers.

The evidence base for impacts of pollutants also appears to be highly variable in terms of making conclusions about their significance for migratory marine wildlife, although this report only constitutes an initial review and further research would be appropriate. Persistent organic pollutants, as exemplified by (but not limited to) PCBs are well established as a significant threat to some apex marine predators. The chronic effects of pollutants on health, including reproduction (and therefore the ability of populations to maintain themselves and/or recover), are less well described and rarely included in conservation plans. Similarly, an analysis that helps to determine hot spots where pollution is known or likely to be significant would help to focus efforts by CMS and its Parties.

Of course, pollution in all its forms does not act in isolation from other environmental stressors. Increased climate change-driven precipitation, for example, may lead to increased freshwater inundation of coastal habitats with accompanying enhanced sediment and nutrient inputs. Additionally, where, for example, coastal dump sites are flooded (perhaps also as a result of sea level rise), pollution may increase in adjacent waters. The interacting and potentially cumulative nature of stressors affecting marine wildlife needs to be recognised.

## 15. Recommendations

As CMS is a biodiversity-facing convention, its primary role in addressing marine pollution will be to complement the actions by other international bodies that deal directly with source reduction or otherwise direct control of the release of pollution.
The response from CMS and its Parties to marine pollution issues affecting migratory marine wildlife could be broadly three-fold:

1. Take action to integrate addressing the pollution threat into conservation plans for the taxa concerned, and in practice, this could mean three discrete things:

    - firstly, taking into account pollution-induced threats to the survival, health and welfare of the taxa concerned, including effects on reproduction (which should clearly be allowed for in assessing the ability of the populations and species to maintain themselves or recover);
    - secondly, helping to describe and publicise the threats from pollution to the affected populations, species and their habitats (thereby increasing knowledge and appropriate actions to address and mitigate pollution, including at source); and
    - thirdly, developing science-based actions to address pollution threats to migratory species and their habitats, taking into account feeding, breeding and migratory grounds.

2. Where there is a chronic pollution threat, for example from legacy pollutants, encouraging appropriate action to mitigate this, recognising its, often, transboundary nature and thus the requirement for close collaboration among member states and with other international bodies; and

3. Where there is an acute pollution problem, such as a chemical, oil or plastic pellet spill, encouraging swift and appropriate emergency action to address this.

The Scientific Council should now consider how best to prioritise its work on pollution and the following actions are recommended:

i. Run an intersessional workshop of experts to further assess the threats from all forms of pollution to migratory marine species and to help identify hotspots of pollution impact, including cumulative impacts;
ii. In support of the above and in advance of the workshop, sponsor the production of a comprehensive review of this topic;
iii. Seek to identify localities where marine pollution and migratory marine species significantly intersect and make recommendations based on this for future action; and
iv. Seek enhanced cooperation and coordination with other UN institutions and MEAs, including bodies that will be set up under the jurisdiction of the Biodiversity Beyond National Jurisdiction Agreement (BBNJ) and the new international plastics treaty when they come into force.

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