The Impacts of Chemical Pollutants on Cetaceans in Europe

Tilen Genov, *Morigenos – Slovenian Marine Mammal Society, Piran, Slovenia*

“I think cetaceans are often remarkably resilient. Any single human activity may not appear as having a huge impact on them. But when you put these various threats together, their cumulative effects may become significant. Chemical pollutants, in particular, are invisible stressors that are very likely to act synergistically with other threats. We should strive to reduce all of them.”

Tilen Genov

Introduction

In modern times, human activities have introduced over 200,000 synthetic chemicals into the environment and have profoundly altered the levels of naturally occurring elements (Reijnders *et al*., 1999). Many of these chemicals are not easily degradable and have been shown to have substantial impacts on various species and ecosystems, including cetaceans. Organochlorine contaminants such as polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) are particularly worrisome, because they are persistent in the environment, highly lipophilic, bioaccumulate in individuals over time, and accumulate in top predators through trophic transfer (Green and Larson, 2016). This chapter briefly reviews the main chemical pollutants affecting cetaceans in European waters, focusing predominantly on those likely to represent the greatest threat, historically or currently. Due to space limitations, this review is not meant to be comprehensive.

Effects of chemical pollution on cetaceans

Effects of chemical pollutants can be direct or indirect, and can be manifested at the molecular, individual or community level (Reijnders *et al*., 1999). Some contaminants, particularly organochlorines, have been shown to cause a number of effects in marine mammals, including anaemia (Schwacke *et al*. 2012), immunosuppression (Tanabe *et al*., 1994) and the subsequent increased vulnerability to infectious disease (Aguilar and Borrell, 1994; Jepson *et al*., 2005; Randhawa *et al*., 2015), endocrine disruption (Tanabe *et al*., 1994; Vos *et al*., 2003; Schwacke *et al*., 2012), reproductive impairment (Schwacke *et al*., 2002) and developmental abnormalities (Tanabe *et al*. 1994; Vos *et al*., 2003). These compounds are likely directly impacting abundance via reduced reproduction or survival (Hall *et al*., 2006; Hall *et al*., 2017), with potentially dire consequences (Desforges *et al*., 2018). Some compounds may lead to cancer induction and mutagenic effects, and may even have behavioural effects (Reijnders *et al*., 1999). Indirect effects include impacts on the abundance or quality of cetacean prey. However, establishing clear relationships between concentrations of chemical pollutants in animals or their environment and their impacts on individuals or populations is extremely challenging, particularly so in cetaceans.

Cetaceans as indicators

Cetaceans and other marine mammals, typically being top predators in their ecosystems, having long life spans and carrying extensive fat stores, bioaccumulate a range of such chemicals (Vos *et al*., 2003) and are thus often regarded as ecosystem sentinels (Ross, 2000; Wells *et al*., 2004; Moore 2008). Generally speaking, toothed whales (Odontocetes) are at greater risk than baleen whales (Mysticetes), due to their diet and the associated higher position in the trophic web, as well as due to typically being present in coastal areas. Moreover, within Odontocetes, species occuring closer to the coast and/or feeding on prey found at higher trophic levels tend to be more exposed to toxicity from various chemical compounds. However, there is also substantial intra-specific variability, which can be dependent on sex, age and other factors.

In European waters, the common bottlenose dolphin (*Tursiops truncatus*) is one of the most widely distributed and commonly occurring cetaceans, particularly in coastal areas, with populations in the North Sea, Atlantic European waters, Mediterranean Sea, and Black Sea. In many parts of the world, including European waters, it is essentially “coastal” and mainly found nearshore (Bearzi *et al*., 2009). This makes it particularly susceptible to a range of anthropogenic impacts, including the exposure to organochlorine contaminants (Marsili *et al*., 2018). Due to its coastal nature, widespread distribution in European waters, and being studied in detail in many locations, it is probably a particularly good candidate species for establishing levels of chemical pollution, the impacts of pollutants on cetaceans, and for monitoring trends.

Figure 1: Common bottlenose dolphin (Tursiops truncatus) in a port in the northern Adriatic Sea. *Chemical pollutants such as polychlorinated biphenyls (PCBs) pose a serious threat to marine top predators, particularly coastal small cetaceans. © Tilen Genov, Morigenos*

Current pollutant levels in European cetaceans

A number of chemical pollutants have been analysed in tissues of several cetacean species in Europe. For several compounds and in several species, toxicological risks to these animals have been identified. Generally speaking, killer whales (*Orcinus orca*) and common bottlenose dolphins appear to have the highest levels of pollutants, with PCBs representing the main concern (Jepson *et al*., 2016).

PCBs and DDTs

In most of Europe, the use of PCBs and OCPs such as dichlorodiphenyltrichloroethane (DDT) was prohibited in the 1970s-1980s, due to concerns about their toxicity to humans and other organisms, and their environmental persistence. Following the ban, these compounds declined in several European cetaceans (Law *et al*., 2012), including in the Mediterranean Sea (Aguilar and Borrell, 2005; Borrell and Aguilar, 2007). However, they remain far from phased out, as they continue to be found at high levels in several cetaceans species in Europe (Jepson *et al*., 2016). PCBs in particular, have declined at a slower pace than DDTs (Aguilar and Borrell, 2005) and have subsequently reached a plateau in harbour porpoises (*Phocoena phocoena*) around the United Kingdom (Law *et al*., 2012) and in striped dolphins (*Stenella coeruleoalba*) in the western Mediterranean Sea (Jepson *et al*., 2016).

Among chemical pollutants, PCBs currently represent the main source of concern, as high concentrations have been found in several species, often exceeding known toxicological thresholds at which physiological effects or even reproductive impairment are known to occur (Jepson *et al*., 2016; Desforges *et al*., 2018; Genov *et al*., 2019). High PCB levels have been linked to small populations, range contraction, or population declines in some striped dolphin, common bottlenose dolphin and killer whale populations (Jepson *et al*., 2016). Killer whales, particularly populations feeding on high trophic level prey such as marine mammals or the Atlantic bluefin tuna (*Thunnus thynnus*), are especially at risk, with the highest PCB levels ever recorded, and strong evidence of population suppression across multiple populations (Jepson *et al*., 2016; Desforges *et al*., 2018). Levels are also very high in European common bottlenose dolphins (Jepson *et al*., 2016). Within the Mediterranean Sea, concentrations found in these animals generally tend to decline from west to east, and from north to south (Genov *et al*., 2019), while in the European Atlantic and North Sea waters, they are particularly high in animals living around the Iberian peninsula and around the United Kingdom (Jepson *et al*., 2016).

DDT levels in the western Mediterranean Sea and around the United Kingdom (Aguilar and Borrell, 2005; Borrell and Aguilar, 2007; Law *et al*., 2012) are much lower than those of PCBs, while in the Eastern Mediterranean Sea, they are higher than those of PCBs (Shoham-Frider *et al*., 2009; Gonzalvo *et al*., 2016).

Hexachlorobenzene (HCB)

HCB levels are generally extremely low in European waters (Law *et al*., 2012; Gonzalvo *et al*., 2016; Genov *et al*., 2019) and the current environmental input of this compound is likely negligible (Borrell and Aguilar, 2007).

Polybrominated diphenyl ethers (PBDEs)

PBDEs have been widely used as flame retardants, but were largely banned in Europe in the 2000s. Concentrations in UK harbour porpoises reached a peak in 1998, with a subsequent 67.6% reduction by 2008 (Law *et al*., 2010).

Hexabromocyclododecane (HBCD)

HBCD is a flame retardant, with levels in harbour porpoises around the UK significantly increasing after 2001, but then significantly decreasing after 2003 (Law *et al*., 2012)

Polycyclic aromatic hydrocarbons (PAHs)

PAHs are petroleum-derivate compounds. Few studies have addressed these compounds in cetaceans. A study from the Canary Islands showed that these compounds are present in common bottlenose dolphins, but their impact on populations remains poorly known (García-Álvarez *et al*., 2014). PAHs have been associated with severe lung disease in common bottlenose dolphins in the Gulf of Mexico, following the Deepwater Horizon oil spill (Schwacke *et al*., 2014), showing that chemical pollution related to oil spills has the capacity to drastically impact cetacean health.

Heavy metals

Among metals, mercury (Hg) is one of the pollutants of most concern due to its persistence, high toxicity and accumulation in top predators (Vos *et al*., 2003). Small cetaceans have the highest recorded levels of mercury among any organisms (Bowles, 1999). Among European seas, the Mediterranean Sea may be especially vulnerable, due to its semi-enclosed nature, as well as the relatively high presence of this metal, from both natural and anthropogenic sources (Andre *et al*., 1991). However, following concerns about the toxic effects of mercury on biota and human health, levels have decreased substantially since the 1980s and 1990s, due to efforts to reduce emissions from industries, power plants and mining (a useful summary can be found in Borrell *et al*., 2014).

Unlike compounds such as PCBs and DDTs, which are man-made substances and therefore an "evolutionary novelty" to which cetaceans have no adaptation, heavy metals have been present in the marine environment for millenia. As a consequence, a number of storage and detoxifying mechanisms that may alleviate the effects of high concentrations have evolved in many cetacean species (Bowles, 1999). Cetaceans are able to metabolize the toxic organic methylmercury into a less toxic inorganic mercury (Palmisano *et al*., 1995; Nigro and Leonzio, 1996). Therefore, while metals may represent a toxicological risk to cetaceans, high concentrations alone do not necessarily imply toxicity (Bowles, 1999). However, this does not mean that metals do not pose a threat. Once levels exceed the storage and binding capacity, toxicological risk increases. Contamination by mercury still persists, with levels in Mediterranean striped dolphins reaching threshold levels of tolerance for mammalian hepatic tissue, above which hepatic damage can occur (Borrell *et al*., 2014). In addition, synergistic effects with environmental factors such as deficiency in levels of iron and zinc, as well as water temperature and salinity (Bowles, 1999), or with concentrations of organochlorine pollutants (Lahaye *et al*., 2007) may elevate the toxicological risk of certain metals. In common bottlenose dolphins, animals from the Mediterranean Sea have substantially higher concentrations of mercury than those found in the Atlantic and the North Sea (García-Alvarez *et al*., 2015).

Novel emerging compounds

Following bans of certain compounds, new ones have appeared on the market, with their effects on biodiversity still poorly understood, but several have already been detected in marine mammals (Covaci *et al*., 2011). Recently, pyrethroid pesticides were analysed in the livers of striped dolphins from the Spanish Mediterranean Sea (Aznar-Alemany *et al*., 2017). These compounds are used for household, commercial, farming and medical applications. They became popular as a substitute for other banned pesticides, because they were presumed not to be persistent in the environment, and were believed not to accumulate in mammals, but they may nevertheless represent a health risk to European cetaceans (Aznar-Alemany *et al*., 2017).

Even more recently, a study showed the first evidence of the accumulation of organophosphorus flame retardants (OPFRs, a class of flame retardants, which are also used as plasticizers, antifoaming agents and as performance additives in consumer products) in marine mammals, in common dolphins (*Delphinus delphis*) from Spanish Mediterranean waters (Sala *et al*., 2019). It is possible that new chemicals will be added to the list of pollutants likely to impact cetaceans in the future.

Conclusion

Studies have shown that different chemical pollutants impact different cetacean species (as well as age and sex classes within species) in different ways. While some pollutants in Europe have significantly declined or are declining, PCB levels are high in several species and remain a cause of concern. Their effects should not only be considered on their own, but especially in relation to other impacts and stressors. Even in cases when population declines may be linked to other causes, the influence of PCBs on reproductive ability may supress population recovery following potential catastrophic events related to other causes. The risk of chemical pollutants should therefore be integrated in cumulative risk assessments.

Recommended actions

Policy

- The presence of pollutants in tissues of marine biota is already included as Descriptor 8 of the Marine Strategy Framework Directive (MSFD), while marine mammals are one of the indicators of "Good Environmental Status" under Descriptor 1 of MSFD.
- At the European policy level, PCB levels in relation to established toxicity thresholds should be used to assess "Favourable Conservation Status" of marine mammals under the EU Habitats Directive (Jepson and Law, 2016).
- Consideration of chemical pollutants should be included in risk analyses and impact assessments of other activities likely to impact cetaceans, due to cumulative and synergistic effects.

Management measures

- In Europe, greater compliance with the Stockholm Convention is needed by EU member states in order to significantly reduce PCB contamination of the marine and terrestrial environment by 2028 (Jepson *et al*., 2016; Jepson and Law, 2016; Stuart-Smith and Jepson, 2017).
- Measures include the safe disposal or destruction of large stocks of PCBs and PCB-containing equipment, limiting the dredging of PCB-laden rivers and estuaries, reducing PCB leakage from old landfills, limiting PCB mobilization in marine sediments, and regulating the demolition of PCB-containing precast buildings such as tower blocks built in the 1950s–1980s (Jepson *et al*., 2016; Jepson and Law, 2016; Stuart-Smith and Jepson, 2017).

Private sector

- See “management measures” above.
- The private sector should work closely with governmental bodies to comply with the provisions of the Stockholm Convention.

Science

- Cetaceans are long-lived predators that integrate contaminant concentrations over time and are, therefore, useful model species to monitor contaminant concentrations and their trends. Being highly mobile, they are likely good regional (rather than local) indicators (Genov *et al*., 2019) and, as top predators, they are likely representative of the ecosystem as a whole (Borrell and Aguilar, 2007).

Public

- Generally, greater awareness is needed of the risks posed by chemical pollutants to wildlife and, in particular, to cetaceans at the top of marine food webs. This will, hopefully, lead to more responsible consumer habits and individual behaviour related to life choices.

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