Migratory connectivity in the ocean

Mitigating threats from offshore activities to migratory marine species

Humpback whales in Mo'orea, French Ploynesia. Source: Toby Matthews, Ocean Image Bank.

Key Messages

- Migratory marine species play a pivotal role in the health of the ocean and the ability for people to receive benefits from marine ecosystems.
- Offshore energy production and resource extraction can pose a threat to migratory marine species through noise pollution, oil spills and leaks, collisions and habitat loss, degradation and fragmentation.
- Threats can be mitigated through application of the avoidance and minimisation steps of the mitigation hierarchy, as well as robust environmental impact assessments that take direct and indirect impacts into account.
- Threats to migratory marine species differ through the project lifecycle and so different mitigation measures are needed at different stages.
- Taking part in strategic environmental assessments is a way companies can mitigate cumulative impacts on migratory marine species.
- Many datasets exist that are related to migratory marine species and that companies can use to inform environmental impact assessments, including those containing raw tracking data, areas of importance and key habitat distribution.

Introduction

Migratory marine species include some of the last remaining megafauna of the ocean. These species help maintain healthy ecosystems and enable people to benefit from ecosystem services, such as fisheries and eco-tourism.

Migratory marine species are highly mobile species that connect disparate areas of the ocean through their movements. As such, they are a form of ecological connectivity. Ecological connectivity describes the "unimpeded movement of species and the flow of natural processes that sustain life on Earth"[1].

Migratory marine species embark on migrations to make use of resources and conditions that differ in time and space. Migrations vary in duration and distance between different species, with some taking multiple years and covering entire ocean basins. Migratory marine species include, *inter alia*, whales, sharks, tuna, turtles, and seabirds.

However, migratory marine species are threatened and some currently face extinction. They face a myriad of threats, including from offshore resource extraction and energy production. These activities can adversely impact migratory marine species and jeopardise their continued survival. Yet, these activities are needed to provide the world with a secure, affordable energy supply and natural resources for technology. Companies with offshore activities face the challenge of contributing towards a sustainable society whilst avoiding major impacts on marine biodiversity. This technical briefing explores how this can be achieved, considering offshore resource extraction and energy production.

Migratory marine species benefit the ocean and people

Migratory marine species often have outsized ecological roles[2,3]. Many are apex predators, meaning they play a vital role in maintaining healthy and productive ecosystems and maintain balance in food webs[4]. As such, many migratory marine species are considered keystone species and their presence, absence or abundance can be used to estimate the occurrence of less detectable species or to infer ecosystem health[5]. For example, presence of sharks on coral reefs can be used to infer the health of the reef[6].

Migratory marine species also contribute towards nutrient cycling as part of their migrations. Seabirds feed in the open ocean and transport nutrients to nesting sites on islands where they breed. The nutrients leach into the surrounding waters, enhancing coral reef productivity and functioning[7]. Similarly, sea turtle eggs within nests on beaches introduce nutrients to beach ecosystems[8], and sharks transfer nutrients from offshore waters to near-shore reefs[9].

Many migratory marine species also have great cultural and spiritual significance, particularly for indigenous peoples and local communities. Sea turtles have been used for ritual and subsistence purposes for millennia. For example, in Rapa Nui (Easter Island), they are considered protector beings and guides for sailors[10].

Migratory marine species also benefit local and national economies through eco-tourism. Shark eco-tourism is valued at $314 million globally per year[11]. Over the course of its lifetime, a whale is estimated to generate $2 million in economic benefits from eco-tourism, fisheries enhancement, and carbon capture[12].

Migratory marine species are threatened with extinction

Migratory marine species include some of the most threatened animals on Earth: 21% are classified as Threatened with extinction and a further 11% are classified as Near Threatened on the IUCN Red List of Threatened Species[13]. This conservation status is caused by a number of pressures, including fishing, shipping, offshore energy production and mining, pollution, habitat loss and degradation, and climate change[13].

Such pressures are not exclusive to migratory marine species and are drivers of biodiversity loss more broadly. However, these species have characteristics that make them particularly vulnerable. Their migration routes are vast, sometimes covering thousands of kilometres. This exposes them to multiple anthropogenic stressors and can lead to cumulative impacts[14]. In addition, most are large-bodied animals, meaning they are long living and slow to sexually mature. Bowhead whales (*Balaena mysticetus*) can live for up to 200 years[15] and reach maturity at approximately 20 years of age[16]. This means if a population declines it will take many years to recover. For example, the once-depleted leatherback turtle population in the Atlantic Ocean has shown a gradual recovery after decades of intrusive conservation efforts, yet recovery has taken 2-3 decades[17 18 19].

The wide-ranging migrations of migratory marine species can make conservation efforts challenging. These species move between Exclusive Economic Zones (EEZs) and the High Seas as they complete their migrations. Efforts to protect them in one area can be undone by a lack of protection elsewhere. Coordinated management along the entirety of migration routes is needed but can be challenging due to the large areas and number of jurisdictions involved[20]. For example, leatherback turtles in the Pacific travel through 32 EEZs as well as the High Seas[21].

Offshore activities pose a potential threat

The ocean is highly important for energy production, resource extraction and transportation of goods. It is the world's largest generator of both renewable and non-renewable energy[22]. The ocean's role in energy production is becoming more prominent as the world aims to rapidly transition to renewable energy. Resource extraction through coastal mining provides minerals such as sand to the construction industry. It is used to build roads and buildings, and to make glass and electronics. After water, sand is the second most highly exploited resource in the world[23]. The ocean is also vital for global trade: 80% of world trade is delivered by ships[24].

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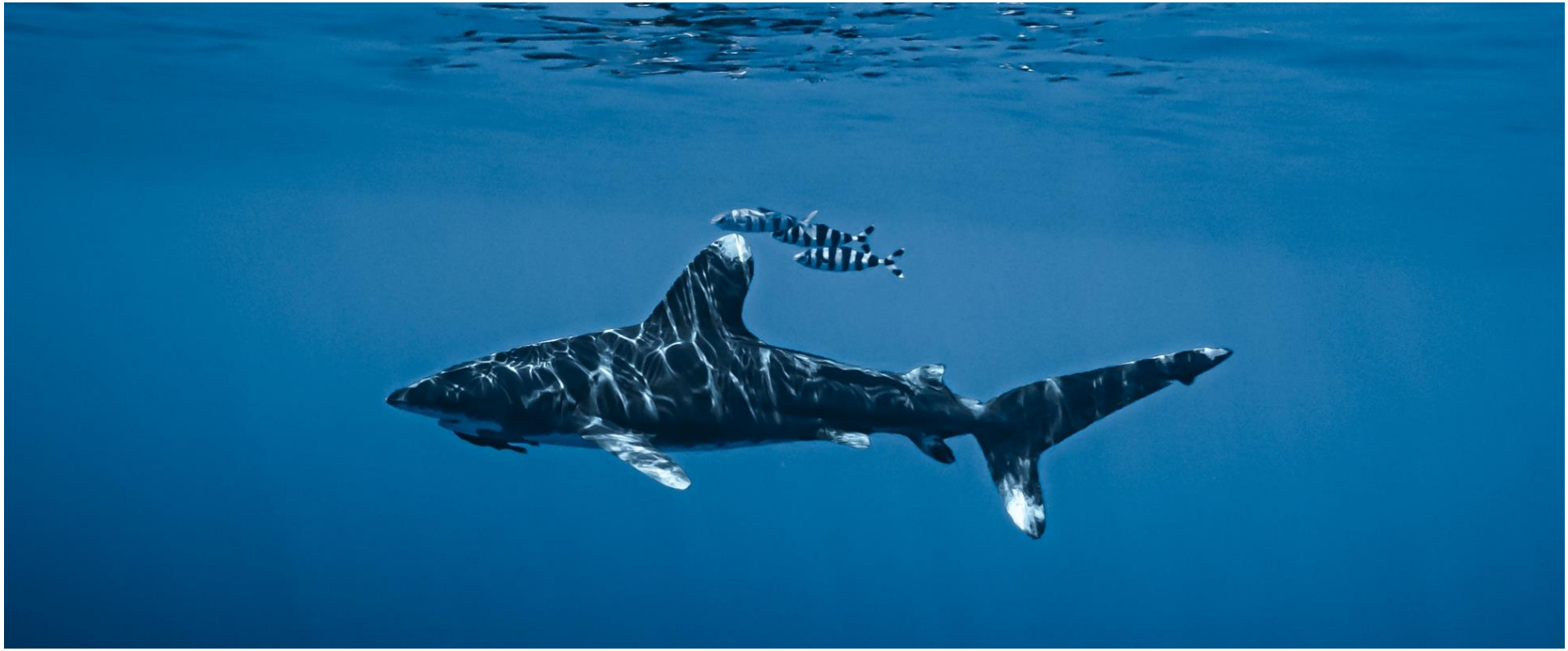
However, these offshore activities pose a threat to migratory marine species and can contribute towards population declines if those threats are not managed. Although other anthropogenic activities in the ocean represent more acute threats to certain species groups (e.g., fishing is a particularly large threat to seabirds and turtles), cumulative impacts on migratory marine species from multiple stressors means negative impacts from offshore activities can be more severe than if they occurred in isolation. Table 1 provides an overview of the types of threats from offshore activities, including some emerging threats from novel activities.

Table 1. An overview of threats to migratory marine species from offshore activities.

Threat	Description	Example of direct impact	Example of indirect impact
Habitat loss, degradation fragmentation	Habitat loss, degradation fragmentation can occur from immediate physical alternation of a site for any offshore activity. This can have a pronounced impact if the site is particularly important for a species e.g., a feeding or breeding site. Many shark species depend on coastal or near-shore habitats for their early-life development, such as saltmarshes[25] or mangroves[26]. As such, loss, degradation or fragmentation can affect the availability or effectiveness of habitats that juveniles depend upon[27]. Habitat loss, degradation and fragmentation can result from offshore infrastructure construction, but also from coastal infrastructure which supports offshore activities, such as the construction of ports.	Offshore activities destroy, degrade or fragment a site used by migratory marine species to feed, displacing them from that area.	The fitness of the displaced population decreases as other feeding sites do not have the same abundance of food, or there are a lack of other feeding sites altogether.
Noise pollution and seismic activity	Noise pollution and seismic activity is most often a threat that has been associated with marine mammals[28] [29] [30], but it can affect other species including fish[31] and turtles too[32]. Noise pollution is created by, *inter alia*, ships, mining activities, offshore energy infrastructure construction. Seismic activity stems from activities such as offshore exploration for oil and gas. Noise pollution from anthropogenic activities can 'drown out' natural noises in the ocean or disturb species that are sensitive to sound. This is problematic for those that use sound to navigate or find mates and food. For instance, orcas have been found to spend less time feeding in the presence of boat noise compared to when there is none[33] [34]. In a laboratory experiment, fish that shoal were found to be less cohesive and coordinated in their movements when played noises replicating marine construction, which in the wild could make them more vulnerable to predators[35]. Background anthropogenic noise has also been shown to stress whale species, in turn reducing their fitness[36]. Seismic activity used for surveying similarly affects species sensitive to sound. It differs from other noise pollution because it produces high	Noise pollution prevents whale species from hearing mates, increases their stress and causes them to feed less.	The fitness of individuals is reduced and/or they can't locate a mate, meaning they have less offspring and the population declines.

Threat	Description	Example of direct impact	Example of indirect impact
	intensity, high decibel sounds in pulses that can directly injure or kill individuals[37] [38]. Seismic activity can alter behaviour, such as causing individuals to dive to deeper waters due to fear[39] [40]. It can also affect the ability of marine mammals to navigate and cause large-scale strandings[41]. In fish, seismic activity can rupture their swim bladders, used to control buoyancy[42].		
Collisions	Some migratory marine species are vulnerable to collisions with particular types of infrastructure used for offshore activities and shipping, causing direct mortality or serious injury. For example, offshore wind turbines are predicted to be a risk to seabirds[43]. Large-bodied species of whale and shark, as well as turtles and seabirds, are vulnerable to ship strikes[44] [45] [46].	Ship strikes within an area reduce the local populations of seabirds, turtles and marine mammals.	Eco-tourist numbers in the area decline as sightings of migratory marine species become less frequent.
Oil spills and leaks	Oil spills and leaks degrade water and have an immediate impact by smothering individuals, causing death or seriously affecting health. Offshore oil production is most associated with oil spills, but ships can also release pollutants into the water. Heavy metals can have long-lasting impacts by accumulating in migratory marine species because they are often apex predators or high up in the food chain. Persistent organic compound accumulation is virtually impossible to solve for individuals or pods that already have high levels[47]. For example, some pods of orcas have been unable to produce young in many years due to the high levels of persistent organic compounds they have accumulated in their bodies[48]. The Stockholm Convention on Persistent Organic Pollutants[49] aims to address the issues associated with persistent organic pollutants, yet this threat to marine species, and in particular marine mammals, continues[50].	Oil spills and leaks smother migratory marine species.	Persistent organic pollutants accumulate in species such as marine mammals, causing infertility and the population to decline as no offspring add to the population.
Electromagnetic fields	Electromagnetic fields are a relatively under-studied threat which is caused by submarine power cables that connect to offshore wind farms producing an electromagnetic field. Changes to migratory fish behaviour has been observed, although it is unknown whether these are temporary behaviour changes or whether there are any long-lasting impacts[51]. Some migratory marine species, such as turtles, are sensitive to the Earth's magnetic field	Electromagnetic fields from submarine power cables affect the navigation of turtle hatchlings after entering the sea.	The navigational abilities of the turtle hatchlings are affected, meaning rather than swimming out past the continental shelf to avoid predation, they remain near

Threat	Description	Example of direct impact	Example of indirect impact
	and use it for navigation. Although not yet studied, there is a potential for electromagnetic fields produced by submarine cables to impact this navigational ability, particularly for turtle hatchlings. They can distinguish small differences in the Earth's magnetic field and could be more likely to be in close proximity to submarine cables after hatching on beaches and moving into coastal waters[52].		to the coast and are at risk from predation.



An Oceanic Whitetip Shark in Hawaii. Source: Carlos Diaz, Ocean Imagine Bank.

Direct and indirect impacts

includes examples of both direct and indirect impacts from different threats posed by offshore activities on migratory marine species. Whereas direct impacts are more obvious and easier to study, indirect impacts are more nuanced and harder to monitor[53]. Direct impacts on migratory marine species can lead to indirect impacts on the wider ecosystem[54 55 56] and people[57 58 59], in addition to migratory marine species themselves.

Indirect impacts include displacement as key habitats are removed, degraded, or fragmented, or as species seek to avoid sites due to proximity of anthropogenic activities[37 60]. This means they are not able to access key sites for feeding or breeding and expend extra energy taking longer routes to other sites[61]. In turn, this can result in reduced health and fitness amongst individuals and populations, making them more susceptible to predators and disease. Offshore activities can also cause prey disturbance, displacing prey that migratory marine species rely on.

Potential positive impacts

In some cases, offshore activities can result in positive impacts for migratory marine species too. Certain offshore infrastructure can support new feeding sites for migratory marine species through creating new habitats which marine species have colonised, such as wind farms acting as artificial reefs[62 63]. In addition, offshore sites such as wind farms can offer shelter for migratory marine species (amongst other marine life) from threats such as fishing or shipping[62].

Threats from offshore activities can be avoided and minimised

The mitigation hierarchy can be used to mitigate threats to migratory marine species from offshore activities (Table 2). It is particularly important to prioritise the avoidance and minimisation steps, because these are typically vulnerable species.

Restoration of populations of migratory marine species is highly challenging due to their longevity[15 64]. For example, certain whale populations are only now just recovering from hunting in the 19th and 20th centuries[65], highlighting the time needed for population recovery of these long-lived, slow-to-mature species. These features are common characteristics of many migratory marine species[16 64]. Due to these challenges, restoration of marine habitats that migratory marine species depend on, and that have been lost, degraded or fragmented as a result of offshore activities, can be used as a proxy means of migratory marine species restoration. This may be possible in some cases, although not all. Restoration may not be appropriate if the site has an outsized role in supporting migratory marine species and its removal would jeopardise their continued survival. Table 2 outlines how restoration could be undertaken in the context of migratory marine species populations and the habitats they rely on.

Offsetting impacts on migratory marine species populations is rarely likely to be legitimate or effective due to the inherent challenges of restoring migratory marine species populations, as outlined under the restoration step[66]. Offsetting impacts to marine habitats as a proxy may be possible if there was strong evidence migratory marine species would benefit and if the offsetting met key criteria (outlined in Table 2). However, offsetting is still highly challenging in the context of migratory marine species and further research is needed as to how to ensure it would be legitimate in the context of these species.

Table 2. Examples of how the mitigation hierarchy can be applied in the context of migratory marine species.

Step of mitigation hierarchy	Application of step in the context of different threats, using examples.
Avoidance	Threat: Placement of offshore activities on key sites e.g., feeding, breeding or nursery grounds (*habitat loss, degradation and fragmentation*). Action: **Avoid** placing offshore activities over those key sites that are essential to the continued survival of a species.
Minimisation	Threat: Seismic surveys for oil and gas during the exploration stage (*noise pollution and seismic surveys*). Action: Halt surveys during the portion of the year when migratory marine species are using/passing through the area to **minimise** impact (e.g., when turtles are gathering offshore to breed and nest). Threat: Shipping to support offshore energy production and resource extraction (*collisions*). Action: Re-route shipping lanes to **minimise** overlap with known migratory pathways and/or where there is overlapping, reducing ship speeds.
Restoration	Threat: Oil spills and leaks from offshore oil extraction *(oil spills and leaks).* Action: (Restoring migratory marine species populations) Provide additional protection to local seabird nesting sites to **increase/restore** the population. (Restoring habitats migratory marine species rely on) Oil spill clean-up and active **restoration** of degraded habitats migratory marine species use e.g., planting seagrass seeds.
Offsetting	Jacob et al. (2020)[67] outline the following criteria that marine offsets need to meet in order to be legitimate: • Comparable (a true exchange for the biodiversity lost) • Additional (over and above what would have happened without the offset) • Lasting (in place for at least as long as the impacts) • Within limits (some impacts are not offsetable) Further research is needed to establish what offsets mean in the context of migratory marine species and if they are possible.

The mitigation hierarchy can be applied as part of a robust environmental impact assessment (EIA)[68]. It should be applied iteratively and at each stage of the operation or project lifecycle, including exploration, development, operation, and decommissioning[69]. Different stages of an operation or project lifecycle can pose different threats to migratory marine species. This means different steps of the mitigation hierarchy may need to be applied at each stage and different actions are needed to mitigate threats. For example, noise pollution is a threat from offshore oil and gas during the exploratory phase when seismic surveys are carried out. During the operational phase, oil spills and leaks pose a larger threat.

EIAs and biodiversity action plans should reflect the dynamic nature of migratory marine species in space and time. In addition to different actions to mitigate threats being needed at different stages of the project lifecycle, different actions may be needed within the same stage and in different months or seasons to account for migratory marine species presence or absence during different parts of the year.

Because migratory marine species are a form of connectivity, it means negative impacts on their populations can be far-reaching and felt in disparate locations to where the stressor occurs[70]. EIAs should take this into account when defining the area of influence, as much as they are able to. For example, if a whale shark population declines on one side of an ocean, those individuals never complete their onward journey to other locations, where they are not present to feed on plankton. The absence of whale sharks could result in increased plankton blooms, reducing productivity of fisheries in the area. Although incorporating such indirect impacts into an EIA is challenging, it is a step towards ensuring all potential threats are truly mitigated.

To address the issue of cumulative impacts on migratory marine species from multiple sectors, companies that operate offshore activities could become involved in a strategic environmental assessment (SEA). They assess the potential effects of all proposed activities within a given area at the planning stage and are often used in marine spatial planning processes. SEAs can use cumulative impact assessments to calculate cumulative impacts within a given area[71]. Involvement in a SEA process could help companies that operate offshore understand their impact on migratory marine species in relation to other ocean activities. In addition, the information provided would be specific to the geographic area and its context, rather than having to rely on generalisations.

Companies may also find that certain actions, such as participating in a SEA, become an emerging requirement in the coming decade in light of the adoption of the Kunming-Montreal Global Biodiversity Framework[72] under the Convention on Global Biodiversity.

Data and knowledge

Mitigating the threats to migratory marine species from offshore activities requires data and knowledge. Tracking data has increased over the past two decades[73], and more recently, so have tools which synthesise this data to inform decision making.

Migratory marine species datasets that consist of raw tracking data include the Seabird Tracking Database, which contains the world's largest collection of seabird tracking data. Others include the Global distribution of Sei whales and the Global distribution of Sperm whales. Some datasets are based on important feeding or breeding sites, such as the Global Distribution of Sea Turtle Nesting Sites. The Migratory Connectivity in the Ocean (MiCO)[74] system aggregates tracking data of migratory marine species, so can be used to consider multiple species. Datasets such as these can be used to determine whether offshore activities overlap with migratory marine species.

Other datasets can be used that identify priority sites for migratory marine species. The Important Marine Mammal Area (IMMA) database identifies areas of importance to the conservation of marine mammal species, including migratory species. A similar Important Marine Turtle Area database is currently being developed to identify, areas of particular significance for the conservation of marine turtles and their contributions to local people, including habitats used for migration. The Key Biodiversity Areas (KBA) dataset can be filtered by the species that triggered the KBA, enabling filtering of KBAs triggered by migratory marine species.

Other tools of relevance to offshore energy production include the Avian Sensitivity Tool for Energy Planning (AVISTEP), which shows the sensitivity of birds to energy infrastructure and includes offshore wind as well as seabirds.

Other non-migratory marine species spatial datasets can be used in EIAs to help manage impacts on these species, such as spatial data on the habitats they rely on. Ocean+ Habitats and Ocean+ Data Viewer contain data on the distribution of critical marine and coastal

habitats, and broader marine biodiversity spatial datasets, respectively. UN Biodiversity Lab contains global biodiversity spatial data, including marine-specific datasets.

As well global datasets, local, national or regional datasets of both species and habitats are important to include in EIAs, where available. They will likely provide higher levels of detail for specific sites, complementing global datasets which reflect the vast ranges migratory species encompass.

Knowledge gardened by indigenous peoples (IPs) and local communities (LCs) is also a useful and powerful resource. The cultural significance of migratory marine species to IPs and LCs mean they have a wealth of knowledge and understanding of these species that has been built up over many generations. As well as complementing existing datasets, IPs and LCs knowledge can be used in areas where there is limited or gaps in data. Further still, IPs and LCs knowledge can be used as a source of the values of migratory marine species and as such, a measure of the impacts of offshore activities that need to be taken into account within EIAs. Data and knowledge on migratory marine species can be used to inform project screening and EIAs when projects are in the planning stage. However, they can also be applied to operational projects during ongoing or future phases of the project lifecycle. Field surveys, as well as consultation with migratory marine species and regional experts, can be used to complement datasets and inform decision-making.

Policy relevance

Companies will often be operating in countries that are a Party to international conventions aiming to conserve and sustainably use biodiversity, including the Convention on Biological Diversity[75] and the Convention on the International Trade in Endangered Species of Wild Fauna and Flora[76]. Of particular pertinence to migratory marine species is the Convention on the Conservation of Migratory Species of Wild Animals (CMS)[77]. Parties to the CMS have agreed to conserve and restore habitats that migratory species rely on, as well as to "prevent, remove, compensate for or minimize…activities or obstacles that seriously impede or prevent the migration of…species"[78]. By operating within a country that is Party to the CMS, companies have an obligation and important role to ensure this commitment is met.

The CMS operates as an umbrella agreement, under which specific taxonomic and/or regional agreements and memoranda of understanding exist. Those relating to migratory marine species include, *inter alia*, the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area[79] and the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas[80]. In addition, single species action plans exist under the CMS as well as its daughter agreements, such the Conservation Plan for Migratory Sharks[81] and the Single Species Action Plan for the Angel Shark in the Mediterranean Sea[82].

The CMS produces guidelines to support its Parties, some of which may be useful for companies wishing to mitigate their impacts on migratory marine species. For example, guidelines on marine noise-generating activities within environmental impact assessments[83].

Conclusion

Migratory marine species are keystones of ocean health. They help maintain healthy, balanced ecosystems and, in turn, the ability for people to benefit from the ocean. But they are also highly

threatened. Whilst their migratory behaviour allows them to access resources that change in time and space, it also exposes them to numerous stressors that has been described as 'death by a thousand cuts'.

All ocean-users have a role to play in mitigating these threats. There are actions that organisations with offshore activities can take to mitigate potential threats. Data to inform these mitigation actions is also increasing, including rapid increases in availability of species tracking data, and these can be used to inform measures to mitigate harm.

With the adoption of the Kunming-Montreal Global Biodiversity Framework (GBF), countries will be working to revise and update their national biodiversity strategies and action plans and take action to meet the Kunming-Montreal 2030 Global Targets. Efforts by the private sector to protect biodiversity will be key to the GBF's success. With migratory marine species including some of the most threatened species of Earth, efforts to protect them can provide a fundamental contribution towards the success of the GBF.

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