Technical Support Information to the CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities

Module B.10.

Fin-fish

The full CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities and the stand-alone modules are online at:

cms.int/guidelines/cms-family-guidelines-EIAs-marine-noise

B. Expert Advice on Specific Species Groups

The sea is the interconnected system of all the Earth's oceanic waters, including the five named 'oceans' - the Atlantic, Pacific, Indian, Southern and Arctic Oceans - a connected body of salty water that covers over 70 percent of the Earth's surface.

This vast environment is home to a broader spectrum of higher animal taxa than exists on land. Many marine species have yet to be discovered and the number known to science is expanding annually. The sea also provides people with substantial supplies of food, mainly fish, shellfish and seaweed. It is a shared resource for us all.

Levels of anthropogenic marine noise have doubled in some areas of the world, every decade, for the past 60 years. (McDonald, Hildebrand *et al* 2006, Weilgart 2007) When considered in addition to the number other anthropogenic threats in the marine environment, noise can be a life-threatening trend for many marine species.

Marine wildlife rely on sound for its vital life functions, including communication, prey and predator detection, orientation and for sensing surroundings. (Hawkins and Popper 2014, Simmonds, Dolman *et al* 2014) While the ocean is certainly a sound-filled environment and many natural (or biological) sounds are very loud, wildlife is not adapted to anthropogenic noise.

The species groups covered in the following sub-modules are:

- Inshore Odontocetes
- Offshore Odontocetes
- Beaked Whales
- Mysticetes
- Pinnipeds
- Polar Bears
- Sirenians
- Marine and Sea Otters
- Marine Turtles
- Fin-fish
- Elasmobranchs
- Marine Invertebrates

General principles

Building on the information from module section B.1, sound waves move through a medium by transferring kinetic energy from one molecule to the next. Animals that are exposed to elevated or prolonged anthropogenic noise may experience passive resonance (particle motion) resulting in direct injury ranging from bruising to organ rupture and death (barotrauma). This damage can also include permanent or temporary auditory threshold shifts, compromising the animal's communication and ability to detect threats. Finally, noise can mask important natural sounds, such as the call of a mate, the sound made by prey or a predator.

Table 1: Potential results of sound exposure (from Hawkins and Popper 2016)

Impact	Effects on animal
Mortality	Death from damage sustained during sound exposure
Injury to tissues; disruption of physiology	Damage to body tissue, e.g internal haemorrhaging, disruption of gas-filled organs like the swim bladder, consequent damage to surrounding tissues
Damage to the auditory system	Rupture of accessory hearing organs, damage to hair cells, permanent threshold shift, temporary threshold shift
Masking	Masking of biologically important sounds including sounds from conspecifics
Behavioural changes	Interruption of normal activities including feeding, schooling, spawning, migration, and displacement from favoured areas
	These effects will vary depending on the sound level and distance

These mechanisms, as well as factors such as stress, distraction, confusion and panic, can affect reproduction, death and growth rates, in turn affecting the long-term welfare of the population. (Southall, Schusterman *et al*, 2000, Southall, Bowles *et al*, 2007, Clark,

Ellison *et al*, 2009, Popper *et al*, 2014, Hawkins and Popper 2016)

These impacts are experienced by a wide range of species including fish, crustaceans and cephalopods, pinnipeds (seals, sea lions and walrus), sirenians (dugong and manatee), sea turtles, the polar bear, marine otters and cetaceans (whales, dolphins and porpoises)–the most studied group of marine species when considering the impact of marine noise.

The current knowledge base is summarized in the following module.

This important volume of information should guide the assessment of Environmental Impact Assessment proposals.

References

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B.10. Fin-fish

Robert McCauley
Centre for Marine Science and Technology
Curtin University

Consider when assessing

- Seismic surveys
- Civil high power sonar
- Coastal and offshore construction works
- Vessel traffic greater than 100 metric tons
- Vessel traffic less than 100 metric tons

Related CMS agreements

- Agreement on the Conservation of Cetaceans of the Black Seas Mediterranean Seas and Contiguous Atlantic Area (ACCOBAMS)
- Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS)
- MOU for the Conservation of Cetaceans and their Habitats in the Pacific Islands Region (Pacific Islands Cetaceans)
- MOU Concerning the Conservation of the Manatee and Small Cetaceans of Western Africa and Macaronesia (West African Aquatic Mammals)
- Agreement on the Conservation of Seals in the Wadden Sea (Wadden Sea seals)
- MOU Concerning Conservation Measures for the Eastern Atlantic Populations of the Mediterranean Monk Seal (*Monachus monachus*) (Atlantic monk seals)
- MOU Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa (Atlantic marine turtles)
- MOU on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA)
- MOU on the Conservation of Migratory Sharks (Sharks)

Related modules

- Refer also to modules B.12 when assessing impact to fish

B.10.1. Species Vulnerabilities

The use of explosives will kill fin-fish inside a certain range (Yelverton *et al* 1975), with impact zones given in Popper *et al* (2014). Intense non-explosive, impulse noise such as pile driving or seismic surveys may impact adult fin-fish by: a) creating physiological damage such as rupturing gas spaces (ie. Halverson *et al* 2012), b) damaging sensory systems (McCauley *et al* 2003), c) creating adverse behavioural responses (e.g. Pearson *et al* 1996, McCauley *et al* 2003, Slotte *et al* 2004, Fewtrell and McCauley 2012, Hawkings *et al* 2014), d) masking the reception of signals of interest, or e) disrupting prey physiology, behaviour or abundance. For fin-fish the sustained but less intense noise from vessels or offshore construction activities may commonly produce behavioural impacts or masking of communication signals as indicated above. Fin-fish exposed to lower level, man-made noise for suitable time periods may receive damage to hearing systems and so suffer a loss of fitness.

There is an enormous amount of variability in the degree of sophistication of fin-fish hearing systems and habits which may pre-dispose or protect them from impacts of man-made noise sources, thus it is difficult to generalize known impacts across all fin-fish species with a high degree of confidence. In general terms: explosives routinely cause fin-fish deaths out to some range and sub-lethal injuries beyond this, pile driving is known to produce serious physiological and organ damage to fin-fish at short range, in some cases marine seismic surveys with air guns have produced hearing damage to fin-fish while in other cases such damage has not been observed, and most man-made noise sources are capable of producing fin-fish behavioural or masking impacts to some degree. Behavioural response to an approaching noise source by fin-fish seems to be reasonably generic, pelagic fin-fish tend to move downwards to eventually lie close to the seabed or flee laterally while site-attached fish may initially seek shelter in refuges or flee. At least some species of fin-fish do habituate to continual and stationary low level noise as they readily colonize man-made offshore facilities. The longer-term implications of consistent behaviour changes or slight physiological impairment from intense signals produced by seismic surveys are not well understood.

Many fin-fish form aggregations at specific times and places to spawn and produce fertilized eggs. Such aggregations may be spaced across several months or may occur only on few occasions per season. Many fin-fish species produce communication sounds as part of such aggregations (ie. McCauley 2001). Disruptions to such fin-fish spawning aggregations by excessive noise causing physiological or behavioural changes and which overlaps a large fraction of the species' seasonal spawning period will have deleterious

impacts on the following years reproductive output.

All fin-fish are dependent on smaller prey species which may be impacted by man-made noise sources. Prey may include fin-fish or invertebrates. In general terms small, common, fin-fish prey species, such as sardines, herring or pilchards, have well developed sensory systems thus may be equally or more vulnerable to exposure to intense man-mad noise than the larger fin-fish which prey on them. The response of marine invertebrates to intense signals such as seismic survey noise, are poorly known so it is difficult to draw conclusions or comparisons on how invertebrate prey fields will be impacted by noise exposure. Any changes to prey fields induced by a man-made noise source will impact fauna, possibly negatively, higher up the food chain.

All impacts of man-made noise sources on fin-fish need to be gauged at the population level. Noise sources which produce short term impacts, localized impacts compared with a species range, or which do not overlap well with habitats or time and spatial overlap of spawning periods would be expected to be of low severity form a population perspective, and vice versa.

B.10.2. Habitat Considerations

Fin-fish occupy an enormous variety of habitats, from deep ocean depths, pelagic systems, reefs and shoals, estuarine waters to inland waterways. Some fish may utilize multiple habitats on a seasonal or life cycle basis. In general terms habitats which are enclosed, such as estuaries, bays or reefs for site attached fin-fish, may be more susceptible to exposure by intense sound sources as the fin-fish have little options to escape the source. By contrast fin-fish that occupy physically larger spaces, such as oceanic species, have more options of where to flee and may be less constrained by the implications of moving geographical regions to avoid a noise source.

B.10.3. Impact of Exposure Levels

Known impacts of intense impulse noise exposure on fin-fish include consistencies in fish behavioural response to sound, but many anomalies. For high-energy impulse signals, such as seismic survey signals, the following can be said:

Fish behaviour most often changes at some range near to an approaching seismic vessel and generalized changes include diving, lateral spread or fleeing an area (e.g. Pearson *et al* 1996, McCauley *et al* 2003, Slotte *et al* 2004, Fewtrell and McCauley 2012, Hawkings *et al* 2014).

Fish behaviour is strongly impacted by an approaching seismic source above received levels of 145–150 dB re 1 $\mu Pa^2.s$ (SEL) (McCauley *et al* 2003), which equates to around 2–10 km using measured air gun arrays > 2000 cui.

Avoidance to an approaching seismic vessel by fish may be partly driven by the fish behavioural state, with feeding fishes appearing to be more tolerant and in one instance not showing avoidance to an approaching seismic survey vessel (Penä *et al* 2013).

Catch rates in some fisheries are altered during and after seismic operations, prolonged seismic can cause large-scale displacement of fish resulting in decreased fish abundance in and near a seismic operations area and increased fish abundance at long range (tens of km) from the seismic operations area (Engås *et al* 1996, Slotte *et al* 2004),

Long-term monitoring of reef fish community structure before and after a seismic survey programme showed no large-scale change in community structure (Miller and Cripps 2013) and fish sound production behaviour (chorusing) continued after a seismic programme with no apparent long-term change (McCauley 2011),

Exposure to accurately emulated repeated pile driving signals suggest physical injury (organ damage) arises at levels equivalent to 1920 strikes at 179 dB re 1 $\mu Pa^2.s$ or 960 strikes at 182 dB re 1 $\mu Pa^2.s$, or an equivalent single strike SEL of 210–211 dB re 1 $\mu Pa^2.s$ (Halvorsen *et al* 2012).

In a review of experimental findings of sound on fishes Popper *et al* (2014) present sound exposure guidelines for fin-fish in the form of estimated levels at which the following occur: 1) mortality and potential mortal injury, 2) impairment – recoverable injury, 3) impairment – TTS, 4) impairment – masking, and 5) behavioural changes. They present these impacts for three categories of fin-fish, 1) no swim bladder, 2) swim bladder present but no links to otolith system, or 3) swim bladder present with links to otolith system, plus sea turtles and eggs/larvae. Popper *et al* (2014) present this data for sources of explosives, pile driving, air gun arrays, sonar and shipping. Given the lack of experimental evidence for most of these categories they were forced to: 1) either extrapolate from another exposure type, animal group or both, and 2) rather than presenting threshold levels often present the subjectively evaluated likelihood of an impact type occurring at 'near' (tens of m),

'intermediate' (hundreds of m) and 'far' (thousands of m) ranges. The thresholds listed for physical injury (mortality and impairment-recoverable injury) for pile driving and seismic air gun signals are the same, being primarily based on the pile driving work of Halverson *et al* (2012). Readers are referred to Popper *et al* (2014) for the particular thresholds for a fin-fish and sound exposure type as the reader should see their text for the reasoning and caveats behind the values presented.

B.10.4. Assessment Criteria

In assessing impacts of a noise source on fin-fish any EIA document should consider species which:

- are important for commercial fisheries,
- are listed as threatened, vulnerable or are endemic to an area,
- can be considered as important 'bait fish' or are important as prey species for higher order fauna,
- have limited ability to flee an intense noise source,
- utilize a noise impacted area for specific purposes such as feeding or spawning events.

In considering impacts of underwater noise on a species of fin-fish, factors which must be taken into account include:

- hearing capabilities of the species in question including knowledge of morphological adaptations to increase hearing capability, noting fin-fish primarily respond to motion of the water particles and less to measures of sound pressure. Fin-fish have a diverse range of morphological adaptations to improve hearing capability,
- studies of known impacts on this species,
- studies of known impacts on related species either taxonomically, morphologically or in general terms if no other comparison is available (ie. pelagic fishes, benthic fishes etc),
- particular spatial and temporal features which are critical to that fin-fish population's survival (ie. specific feeding areas or prey types, spawning locations and periods).

For migratory fin-fish impact assessment must consider if a noise producing action may cause a species to leave an area and if so, the consequences of this to the species in question, for other fauna and for commercial fisheries which target that species.

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