Marine and Freshwater Mammal Conservation

Global evidence for the effects of interventions

Anna Berthinussen, Rebecca K. Smith & William J. Sutherland

CONSERVATION EVIDENCE SERIES SYNOPSES

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Digital material and resources associated with this synopsis are available at
https://www.conservationevidence.com/

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1. About this book

1.1 The Conservation Evidence project

The Conservation Evidence project has four main parts:

1. The **synopses** of the evidence captured for the conservation of particular species groups or habitats, such as this synopsis. Synopses bring together the evidence for each possible intervention. They are freely available online and, in some cases, available to purchase in printed book form.

2. An ever-expanding **database of summaries** of previously published scientific papers, reports, reviews or systematic reviews that document the effects of interventions. This resource comprises over 6,973 pieces of evidence, all available in a searchable database on the website www.conservationevidence.com.

3. ***What Works in Conservation,*** which is an assessment of the effectiveness of interventions by expert panels, based on the collated evidence for each intervention for each species group or habitat covered by our synopses. This is available as part of the searchable database and is published as an updated book edition each year (www.conservationevidence.com/content/page/79).

4. An online, **open access journal** *Conservation Evidence* publishes new pieces of research on the effects of conservation management interventions. All our papers are written by, or in conjunction with, those who carried out the conservation work and include some monitoring of its effects (www.conservationevidence.com/collection/view).

1.2 The purpose of Conservation Evidence synopses

Conservation Evidence synopses **do**	Conservation Evidence synopses **do not**
• Bring together scientific evidence captured by the Conservation Evidence project (over 6,973 studies so far) on the effects of interventions to conserve biodiversity	• Include evidence on the basic ecology of species or habitats, or threats to them
• List all realistic interventions for the species group or habitat in question, regardless of how much evidence for their effects is available	• Make any attempt to weight or prioritize interventions according to their importance or the size of their effects

• Describe each piece of evidence, including methods, as clearly as possible, allowing readers to assess the quality of evidence	• Weight or numerically evaluate the evidence according to its quality
• Work in partnership with conservation practitioners, policymakers and scientists to develop the list of interventions and ensure we have covered the most important literature	• Provide recommendations for conservation problems, but instead provide scientific information to help with decision-making

1.3 Who this synopsis is for

If you are reading this, we hope you are someone who has to make decisions about how best to support or conserve biodiversity. You might be a manager, a conservationist in the public or private sector, a fisher, a campaigner, an advisor or consultant, a policymaker, a researcher or someone taking action to protect your own local wildlife. Our synopses summarize scientific evidence relevant to your conservation objectives and the actions you could take to achieve them.

We do not aim to make your decisions for you, but to support your decision-making by telling you what evidence there is (or isn't) about the effects that your planned actions could have.

When decisions have to be made with particularly important consequences, we recommend carrying out a systematic review, as the latter is likely to be more comprehensive than the summary of evidence presented here. Guidance on how to carry out systematic reviews can be found from the Centre for Evidence-Based Conservation at the University of Bangor (www.cebc.bangor.ac.uk).

1.4 Background

Marine and freshwater mammals (cetaceans, pinnipeds, and sirenians for the purpose of this synopsis, see below) inhabit a diverse range of aquatic habitats such as rivers, estuaries, coastal shallows, shelf waters and deep seas. Many marine and freshwater mammal species play a vital role in maintaining the health and integrity of these ecosystems, and act as key sentinels of ecosystem change (e.g. Bonde *et al.* 2004, Wells *et al.* 2004, Roman *et al.* 2014). A recent report by the Society of Conservation Biology (Roman *et al.* 2017) highlighted the significant ecosystem services provided by cetaceans, particularly large whales. It has been postulated that these animals enhance marine primary productivity and sequester carbon on large scales thus contributing not only to the functioning of marine ecosystems, but also to the overall health of the planet (Roman *et al.* 2017). However, many species are threatened by anthropogenic impacts such as urban and industrial development, tourism, chemical and noise pollution, hunting and direct harvesting, incidental entanglement in fishing gear, interactions with marine debris, and vessel collisions (Avila *et al.* 2018). Climate change also has the potential to have serious direct and indirect effects (e.g. Evans & Bjørge 2013, Frederiksen & Haug 2015), which are challenging to predict and mitigate.

The last comprehensive International Union for the Conservation of Nature (IUCN) assessment of the conservation status of mammals in 2008 revealed that the status of marine species is of particular concern, with over a third of marine mammal species estimated to be threatened with extinction in the wild (Schipper *et al.* 2008). In addition to this, 38% of marine mammal species were classified as 'data deficient' with insufficient information available to assess the status of their populations. Freshwater cetaceans are also highly threatened and are among the world's most endangered mammals (e.g. Veron *et al.* 2008, Huang *et al*. 2017). The most recent IUCN assessment (IUCN 2019) indicates that the situation has not improved, although separate statistics are not available for marine and freshwater mammals. There is therefore a clear and pressing need for effective conservation strategies.

Conservation efforts have led to population recoveries for some species, particularly those that occupy nearshore or coastal habitats, which may be easier to protect, manage and document (Magera *et al*. 2013). A recent study found that 18 marine mammal populations (of 23 analysed) increased significantly in abundance after they became legally protected under the US Endangered Species Act (ESA) and a range of conservation measures were implemented (Valdivia *et al.* 2019).

An evidence-based framework is key for planning successful conservation strategies and for the cost-effective allocation of scarce resources for conservation programmes. Parsons *et al.* (2015) listed '*Better understanding of conservation interventions*' as a key theme of global importance for cetacean conservation. Targeted reviews may be carried out to collate evidence on the effects of a particular conservation intervention, but this approach is labour-intensive, expensive, and ill-suited for areas where the data are scarce and patchy. There is a paucity of evidence within the literature for the effectiveness of conservation interventions aimed at marine and freshwater mammals, and although targeted reviews do exist, the results can be inconclusive. For example, a recent review of technical solutions to reduce marine mammal bycatch and entanglement concluded that while several solutions showed some promise for certain species, the results were inconsistent and there was overall a lack of strong evidence for the effectiveness of most interventions, and substantial development and research is still required (Hamilton & Baker 2019). Most conservation interventions targeting marine and freshwater mammals have not yet been synthesised under a formal review and those that have would benefit from periodic updates as new research becomes available.

Here, we used a subject-wide evidence synthesis approach (Sutherland & Wordley 2018, Sutherland *et al.* 2019) to simultaneously summarize the evidence for a wide range of interventions dedicated to the conservation of marine and freshwater mammals (cetaceans, pinnipeds, and sirenians, see below). By simultaneously targeting the entire range of potential interventions for this group, we were able to review the evidence for each intervention cost-effectively, and the resulting synopsis can be updated periodically and efficiently to incorporate new research. The synopsis is freely available at www.conservationevidence.com and, alongside the *Conservation Evidence* online database (comprising all summarized information from the synopsis along with expert assessment scores), should be a valuable asset to the toolkit of practitioners and policymakers seeking sound information to support marine and freshwater mammal conservation.

1.5 Scope of the Marine and Freshwater Mammal Conservation synopsis

1.5.1 Review subject

This synthesis focuses on global evidence for the effectiveness of interventions for the conservation of marine and freshwater mammals. This subject has not yet been covered using subject-wide evidence synthesis. This is defined as a systematic method of reviewing and synthesising evidence that covers broad subjects (in this case conservation of multiple taxa) at once, including all closed review topics within that subject at a fine scale, and analysing results through study summary and expert assessment, or through meta-analysis. The term can also refer to any product arising from this process (Sutherland *et al.* 2019).

This global synthesis collates evidence for the effects of conservation interventions for marine and/or freshwater cetaceans (whales, dolphins and porpoises), pinnipeds (seals, walrus and sea lions), and sirenians (manatees and dugong). Evidence for the effectiveness of interventions targeting the conservation of other aquatic or semi-aquatic mammals (such as the polar bear, otter species, water vole etc.) are covered in separate synopses.

This synthesis covers evidence for the effects of conservation interventions for wild marine and freshwater mammals (i.e. not in captivity). We have not included evidence from the substantial literature on husbandry of marine and freshwater mammals kept in zoos or aquariums. However, where these interventions are relevant to the conservation of wild declining or threatened species, they have been included, e.g. captive breeding for the purpose of reintroductions or gene banking (for future release). For this synthesis, conservation interventions include management measures or interventions that aim to conserve wild marine or freshwater mammal populations and reduce or remove the negative effects of threats. The output of the project is an authoritative, transparent, freely accessible evidence-base of summarised studies and expert assessment scores that will support marine and freshwater mammal management decisions and help to achieve conservation outcomes.

1.5.2 Advisory board

An advisory board made up of international conservationists and academics with expertise in marine and freshwater mammal conservation has been formed. These experts inputted into the evidence synthesis at three key stages: a) reviewing the protocol including identifying key sources of evidence, b) developing a comprehensive list of conservation interventions for review and c) reviewing the draft evidence synthesis. The advisory board is listed above and online (www.conservationevidence.com/content/page/119).

1.5.3 Creating the list of interventions

At the start of the project, a comprehensive list of interventions was developed by searching the literature and in partnership with the advisory board. The list was also checked by Conservation Evidence to ensure that it followed the standard structure. The aim was to include all interventions that have been carried out or advised to support populations or communities of wild marine and freshwater mammals, whether evidence for the effectiveness of an intervention is available or not. During the synthesis process further interventions were discovered and integrated into the synopsis structure.

The list of interventions is organized into categories based on the IUCN classifications of direct threats (www.iucnredlist.org/resources/threat-classification-scheme) and conservation actions (www.iucnredlist.org/resources/conservation-actions-classification-scheme). For interventions with a large body of literature, the intervention may be split into different methods of implementation (e.g. different designs, implementation in different seasons, different methods for acclimatisation before release etc.), different species/functional groups, or broad habitats, if relevant to do so and provided that each has five or more studies testing it.

In total, we found 180 conservation and/or management interventions that could be carried out to conserve marine and freshwater mammal populations. We found evidence for the effects on marine and freshwater mammal populations for 51 of these interventions. The evidence was reported as 199 summaries from 174 relevant publications found during our searches (see Methods below).

1.6 Methods

1. Literature searches

Literature was obtained from the Conservation Evidence discipline-wide literature database, and from searches of additional subject specific literature sources (see Appendices 1–3). The Conservation Evidence discipline-wide literature database is compiled using systematic searches of journals (all titles and abstracts) and report series ('grey literature'); relevant publications describing studies of conservation interventions for all species groups and habitats were saved from each and were added to the database. Final lists of evidence sources searched for this synopsis are published in this synopsis document (see Appendices 1–3), and the full list of journals and report series is published online (www.conservationevidence.com/journalsearcher/synopsis).

a) Global evidence

Evidence from all around the world was included.

b) Languages included

Journals published in English, French, German, Japanese, Persian, Portuguese, Russian, and Spanish were searched, and relevant papers added to the Conservation Evidence discipline-wide literature database (see below).

c) Journals searched

i) From the Conservation Evidence discipline-wide literature database

All journals (and years) listed in Appendix 1b (English journals) and Appendix 2 (non-English journals) were searched, and relevant papers added to the Conservation Evidence discipline-wide literature database. An asterisk indicates the journals most relevant to this synopsis. Others are less likely to have included papers relevant to this synopsis, but if they did, they were summarised.

ii) Update searches

Additional searches up to the end of 2018 were undertaken by the synopsis authors for journals likely to yield studies for marine and freshwater mammals (see Appendix 1a).

iii) New searches

In addition to those above, new focused searches of journals relevant to the conservation of marine and freshwater mammal populations were undertaken by the synopsis authors (indicated with an asterisk in Appendix 1a). These journals were identified through expert judgement by the project researchers and the advisory board and ranked in order of relevance, to prioritise searches that were considered likely to yield higher numbers of relevant studies.

d) Reports from specialist websites searched

i) From the Conservation Evidence discipline-wide literature database

All report series (and years) in Appendix 3b were searched for the Conservation Evidence project. An asterisk indicates the report series most relevant to this synopsis. Others are less likely to have included reports relevant to this synopsis, but if they did they were summarised.

ii) Update searches

Updates to reports already searched as part of the wider Conservation Evidence project were undertaken for those most relevant to marine and freshwater mammals (indicated with an asterisk in Appendix 3b). Searches were completed to the end of 2018.

iii) New searches

New searches targeted specialist reports relevant to marine and freshwater mammal conservation as listed in Appendix 3a. These searches reviewed every report title and abstract or summary within each report series (published before the end of 2018) and added any relevant report to the project database.

The following resource has published over 9,000 reports and therefore systematic searches of every title were not possible within the time frame of this project. Instead, key word searches were carried out (see Appendix 3a).

- National Academies Press Reports (https://www.nap.edu/)

e) Other literature searches

The online database www.conservationevidence.com was searched for relevant publications that have already been summarised.

Where a systematic review was found for an intervention, if the intervention had a small body of literature (<20 papers), all publications including the systematic review were summarised individually. If the intervention had a large body of literature (≥20 papers), then only the systematic review was summarised as were any publications published since the review or not included within it. Where a non-systematic review (or editorial, synthesis, preface, introduction etc.) was found for an intervention, all relevant publications referenced within it were included, but the review itself was not summarised. However, if the review also provided new/collective data, then the review itself was also included/summarised (indicating which other summarized publications it included).

Relevant publications cited in other publications summarised for the synopsis were not included (due to time restrictions).

f) Supplementary literature identified by advisory board or relevant stakeholders

Additional journal or specialist website searches, and relevant papers or reports suggested by the advisory board or relevant stakeholders were also included, if relevant.

g) Search record database

A database was created of all relevant publications found during searches. Reasons for exclusion were recorded for all those included during screening that were not summarised for the synopsis.

2. Publication screening and inclusion criteria

A summary of the total number of evidence sources and papers/reports screened is presented in the diagram in Appendix 4.

a) Screening

To ensure consistency/accuracy when screening publications for inclusion in the literature database, an initial test using the Conservation Evidence inclusion criteria (provided below) and a consistent set of references was carried out by authors, compared with the decisions of the experienced core Conservation Evidence team. Results were analysed using Cohen's Kappa test (Cohen 1960). Where initial results did not show 'substantial' (K = 0.61–0.8) or 'almost perfect' agreement (K = 0.81–1.0), authors were given further training. A second Kappa test was used to assess the consistency/accuracy of article screening for the first two years of the first journal searched by each author. Again, where results did not show 'substantial' (K = 0.61–0.8) or 'almost perfect' agreement (K = 0.81–1.0), authors received further training before carrying out further searches.

Authors of other synopses who have searched journals and added relevant publications to the Conservation Evidence literature database since 2018, and all other searchers since 2017 have undertaken the initial paper inclusion test described above; searchers prior to that have not. Kappa tests of the first two years searched have been carried out for all new searchers who have contributed to the Conservation Evidence literature database since July 2018.

We acknowledge that the literature search and screening method used by Conservation Evidence, as with any method, will result in gaps in the evidence. The Conservation Evidence literature database currently includes relevant papers from over 300 English language journals as well as over 150 non-English journals. Additional journals are frequently added to those searched, and years searched are often updated. It is possible that searchers will have missed relevant papers from those journals searched. Publication bias was not taken into account, and it is likely that additional biases will result from the evidence that is available, for example geographic biases in study locations.

b) Inclusion criteria

The following Conservation Evidence inclusion criteria were used.

Criteria A: Conservation Evidence includes studies that measure the effect of an intervention that might be done to conserve biodiversity

1. Does this study measure the effect of an intervention that is or was under the control of humans, on wild taxa (including captives), habitats, or invasive/problematic taxa? If yes, go to 3. If no, go to 2.

2. Does this study measure the effect of an intervention that is or was under the control of humans, on human behaviour that is relevant to conserving biodiversity? If yes, go to Criteria B. If no, the study will be excluded.

3. Could the intervention be put in place by a conservationist/decision maker to protect, manage or restore wild taxa or habitats, reduce impacts of threats to wild taxa or habitats, or control or mitigate the impact of an invasive/problematic taxon on wild taxa or habitats? If yes, the study will be included. If no, the study will be excluded.

Explanation:

1.a. Study must have a measured outcome on wild taxa, habitats or invasive species: excludes studies on domestic/agricultural species, theoretical modelling or opinion pieces. See Criteria B for interventions that have a measured outcome on human behaviour only.

1.b. Intervention must be carried out by people: excludes impacts from natural processes (e.g. wave action, natural storms), impacts from background variation (e.g. sediment type, climate change), correlations with habitat types, where there is no test of a specific intervention by humans, or pure ecology (e.g. movement, distribution of species).

2. Study must test an intervention that could be put in place for conservation. This excludes assessing impacts of threats (interventions which remove threats would be included). The test may involve comparisons between sites/factors not originally put in place or modified for conservation but which could be (e.g. fished vs unfished sites,

dredged vs undredged sites – where the removal of fishing/dredging is as you would do for conservation, even if that was not the original intention in the study).

If the title and/or abstract are suggestive of fulfilling our criteria, but there is not sufficient information to judge whether the intervention was under human control, the intervention could be applied by a conservationist/decision maker or whether there are data quantifying the outcome, then the study will be included. If the article has no abstract, but the title is suggestive, then a study will be included.

We sort articles into folders by which taxon/habitat they have an outcome on. If the title/abstract does not specify which species/taxa/habitats are impacted, then the full article will be searched and then assigned to folders accordingly.

The outcome for wild taxa/habitats can be negative, neutral or positive, does not have to be statistically significant but must be quantified (if hard to judge from abstract, then it will be included). It could be any outcome that has implications for the health of individuals, populations, species, communities or habitats, including, but not limited to the following:

- Individual health, condition or behaviour, including in captivity: e.g., growth, size, weight, stress, disease levels or immune function, movement, use of natural/artificial habitat/structure, range, or predatory or nuisance behaviour that could lead to retaliatory action by humans
- Breeding: egg/sperm production, sperm motility/viability after freezing, artificial fertilization success, mating success, birth rate, litter size, calf/pup condition, 'overall recruitment'
- Genetics: genetic diversity, genetic suitability (e.g. adaptation to local conditions, use of correct routes for migratory species, etc.)
- Life history: age/size at maturity, survival, mortality
- Population measures: number, abundance, density, presence/absence, biomass, movement, cover, age-structure, species distributions (only in response to a human action), disease prevalence, sex ratio
- Community/habitat measures: species richness, diversity measures (including trait/functional diversity), community composition, community structure (e.g. trophic structure), area covered (e.g. by different habitat types), physical habitat structure (e.g. rugosity, height, basal area)

Interventions within the scope of Conservation Evidence include:

- Clear management interventions: e.g. closing an area to fishing, modifying fishing gear to reduce bycatch, controlling invasive species, creating or restoring habitats
- International or national policies
- Reintroductions or management of wild species in captivity
- Interventions that reduce human-wildlife conflict
- Interventions that change human behaviour, resulting in an impact on wild taxa or habitats

See https://www.conservationevidence.com/data/index for more examples of interventions.

Note on study types:

Literature reviews, systematic reviews, meta-analyses or short notes that review studies that fulfil these criteria will be included.

Theoretical modelling studies will be excluded, as no intervention has been taken. However, studies that use models to analyse real-world data, or compare models to real-world situations will be included (if they otherwise fulfil these criteria).

Criteria B: Conservation Evidence includes studies that measure the effect of an intervention that might be done to change human behaviour for the benefit of biodiversity

1. Does this study measure the effect of an intervention that is or was under human control on human behaviour (actual or intentional) which is likely to protect, manage or restore wild taxa or habitats, or reduce threats to wild taxa or habitats? If yes, go to 2. If no, the study will be excluded.

2. Could the intervention be put in place by a conservationist, manager or decision maker to change human behaviour? If yes, the study will be included. If no, the study will be excluded.

Explanation:

1.a. Study must have a measured outcome on actual or intentional human behaviour including self-reported behaviours: excludes outcomes on human psychology (tolerance, knowledge, awareness, attitude, perceptions or beliefs).

1.b. Change in human behaviour must be linked to outcomes for wild taxa and habitats, excludes changes in behaviour linked to outcomes for human benefit, even if these occurred under a conservation program (e.g. we would exclude a study demonstrating increased school attendance in villages under a community based conservation program).

1.c. Intervention must be under human control: excludes impacts from climatic or other natural events.

2. Study must test an intervention that could be put in place for conservation: excludes studies with no intervention, e.g. correlating human personality traits with likelihood of conservation-related behaviours.

The human behaviour outcome of the study can be negative, neutral or positive, does not have to be statistically significant but must be quantified (if hard to judge from abstract, then it will be included). It could be any behaviour that is likely to have an outcome on wild taxa and habitats (including mitigating the impact of an invasive/problematic taxon on wild taxa or habitats). Interventions include, but are not limited to the following:

- Change in adverse behaviours (which directly threaten biodiversity) e.g. unsustainable fishing (industrial, artisanal or recreational), urban encroachment, creating noise, entering sensitive areas, polluting or dumping waste, clearing or habitat destruction, introducing invasive species
- Change in positive behaviours e.g. uptake of alternative/sustainable livelihoods, number of households adopting sustainable practices, donations
- Change in policy or conservation methods e.g. designation of protected areas, protection of key habitats/species
- Change in consumer or market behaviour e.g. purchasing, consuming, buying, willingness to pay, selling, illegal trading, advertising, consumer fraud
- Behavioural intentions to do any of the above

Interventions which are particularly likely to have a behaviour change outcome include, but are not limited to the following:

- Enforcement: closed seasons, size limits, fishing gear/hunting restrictions, auditable/traceable reporting requirements, market inspections, increase number of rangers, patrols or frequency of patrols in, around or within protected areas, improved fencing/physical barriers, improved signage, improve equipment/technology used by guards

- Behaviour change: promote alternative/sustainable livelihoods, payment for ecosystem services, ecotourism, poverty reduction, debunking misinformation, altering or re-enforcing local taboos, financial incentives
- Governance: protect or reward whistle-blowers, increase government transparency, ensure independence of judiciary, provide legal aid
- Market regulation: trade bans, taxation, supply chain transparency laws
- Consumer demand reduction: fear appeals (negative association with undesirable product), benefit appeal (positive association with desirable behaviour), worldview framing, moral framing, employing decision defaults, providing decision support tools, simplifying advice to consumers, promoting desirable social norms, legislative prohibition
- Sustainable alternatives: certification schemes, captive bred or artificial alternatives, sustainable alternatives
- New policies for conservation/protection

We allocate studies to folders by their outcome. All studies under Criteria B go in the 'Behaviour change' folder. They are additionally duplicated into a taxon/habitat folder if there is a specific intended final outcome of the behaviour change (if none mentioned, they will be filed only in Behaviour change).

c) Relevant subject

Studies relevant to the synopsis subject include those focused on the conservation of wild, native, marine and freshwater mammals (cetaceans, pinnipeds, and sirenians).

d) Relevant types of intervention

An intervention has to be one that could be put in place by a manager, conservationist, policy maker, advisor or consultant to protect, manage or restore wild, native marine and freshwater mammals or reduce the impacts of threats to them. Alternatively, interventions may aim to change human behaviour (actual or intentional), which is likely to protect, manage or restore wild, native marine and freshwater mammals or reduce threats to them. See inclusion criteria above for further details.

If the following two criteria were met, a combined intervention was created within the synopsis, rather than duplicating evidence under all the separate interventions: a) there were five or more publications that used the same well-defined combination of interventions, with a clear description of what they were, without separating the effects of each individual intervention, and b) the combined set of interventions is a commonly used conservation strategy.

e) Relevant types of comparator

To determine the effectiveness of interventions, studies must include a comparison, i.e. monitoring change over time (typically before and after the intervention was implemented), or for example at treatment and control sites. Alternatively, a study could compare one specific intervention (or implementation method) against another. For example, this could be comparing the abundance of a mammal species before and after the closure of an area to fishing activities, or the reduction in mammal bycatch using different types of fishing gear. Exceptions, which may not have a control but were still included, are for example the effectiveness of captive breeding or rehabilitation programmes.

f) Relevant types of outcome

Below we provide a list of anticipated metrics; others were included if reported within relevant studies.

- Community response
    - Community composition
    - Richness/diversity
- Population response
    - Abundance: number, density, presence/absence
    - Reproductive success: egg/sperm production, artificial fertilization success, mating success, birth rate, pup/calf quality/condition, overall recruitment, age/size at maturity
    - Survival: survival rates, mortality
    - Condition: growth, size, weight, condition factors, biochemical ratios, stress, energetics, disease levels or immune function, genetic diversity
- Behaviour
    - Use of natural/artificial habitat/structure
    - Behaviour change: movement, range, timing (e.g. of migration, foraging period)
- Other
    - Reduction in entanglements/unwanted catch (‘bycatch’)
    - Change in human behaviour
    - Human wildlife conflict

g) Relevant types of study design

The table below lists the study designs included. The strongest evidence comes from randomized, replicated, controlled trials with paired sites and before-and-after monitoring.

Table 1. Study designs

Term	Meaning
Replicated	The intervention was repeated on more than one individual or site. In conservation and ecology, the number of replicates is much smaller than it would be for medical trials (when thousands of individuals are often tested). If the replicates are sites, pragmatism dictates that between five and ten replicates is a reasonable amount of replication, although more would be preferable. We provide the number of replicates wherever possible. Replicates should reflect the number of times an intervention has been independently carried out, from the perspective of the study subject. For example, 10 plots within a mown field might be independent replicates from the perspective of plants with limited dispersal, but not independent replicates for larger motile animals such as birds. In the case of translocations/release of captive bred animals, replicates should be sites, not individuals.
Randomized	The intervention was allocated randomly to individuals or sites. This means that the initial condition of those given the intervention is less likely to bias the outcome.
Paired sites	Sites are considered in pairs, within which one was treated with the intervention and the other was not. Pairs, or blocks, of sites are selected with similar environmental conditions, such as water quality or adjacent land use. This approach aims to reduce environmental variation and make it easier to detect a true effect of the intervention.
Controlled*	Individuals or sites treated with the intervention are compared with control individuals or sites not treated with the intervention. (The treatment is usually allocated by the investigators (randomly or not), such that the treatment or control groups/sites could have received the treatment).
Before-and-after	Monitoring of effects was carried out before and after the intervention was imposed.
Site comparison*	A study that considers the effects of interventions by comparing sites that historically had different interventions (e.g. intervention vs no intervention) or levels of intervention. Unlike controlled studies, it is not clear how the interventions were allocated to sites (i.e. the investigators did not allocate the treatment to some of the sites).
Review	A conventional review of literature. Generally, these have not used an agreed search protocol or quantitative assessment of the evidence.
Systematic review	A systematic review follows structured, predefined methods to comprehensively collate and synthesise existing evidence. It must weight or evaluate studies, in some way, according to the strength of evidence they offer (e.g. sample size and rigour of design). Environmental systematic reviews are available at: www.environmentalevidence.org/index.htm
Study	If none of the above apply, for example a study measuring change over time in only one site or only after an intervention. Or a study measuring use of nest boxes at one site.

* Note that "controlled" is mutually exclusive from "site comparison". A comparison cannot be both controlled and a site comparison. However, one study might contain both controlled and site comparison aspects, e.g. study of bycatch by fishers using modified nets (e.g. with a smaller mesh size) and unmodified nets (controlled), and fishers using an alternative net modification, e.g. stiffened nets (site comparison).

3. Study quality assessment & critical appraisal

We did not quantitatively assess the evidence from each publication or weight it according to quality. However, to allow interpretation of the evidence, we made the size and design of each study we reported clear.

We critically appraised each potentially relevant study and excluded those that did not provide data for a comparison to the treatment, did not statistically analyse the results (or if included this was stated in the summary paragraph) or had obvious errors in their design or analysis. A record of the reason for excluding any of the publications was included during screening and kept within the synopsis database.

4. Data extraction

Data on the effectiveness of the relevant intervention (e.g. mean species abundance inside or outside a protected area; reduction in bycatch after installation of a bycatch reduction device) was extracted from and summarised for publications that included the relevant subject, types of intervention, comparator and outcomes outlined above. A summary of the total number of evidence sources and papers/reports searched and the total number of publications included following data extraction is presented in Appendix 4.

In addition to ensuring consistency/accuracy when screening publications for inclusion in the discipline-wide literature database (see above), for a set of publications, relevant data were extracted by a member of the core Conservation Evidence team as well as the synopsis author to ensure agreement for inclusion in the synopsis. In addition, at the start of each month, authors swapped three summaries with another author to ensure that the correct type of data had been extracted and that the summary followed the Conservation Evidence standard format.

5. Evidence synthesis

a) Summary protocol

Each publication usually has just one paragraph for each intervention it tests describing the study in (usually) no more than 150 words using plain English. Each summary is in the following format:

A [TYPE OF STUDY] in [YEARS X-Y] in [HOW MANY SITES] in/of [HABITAT] in [REGION and COUNTRY] [REFERENCE] found that [INTERVENTION] [SUMMARY OF ALL KEY RESULTS] for [SPECIES/HABITAT TYPE]. [DETAILS OF KEY RESULTS, INCLUDING DATA]. In addition, [EXTRA RESULTS, IMPLEMENTATION OPTIONS, CONFLICTING RESULTS]. The [DETAILS OF EXPERIMENTAL DESIGN, INTERVENTION METHODS and KEY DETAILS OF SITE CONTEXT]. Data was collected in [DETAILS OF SAMPLING METHODS].

Type of study - use terms and order in Table 1.

Site context - for the sake of brevity, only nuances essential to the interpretation of the results are included. The reader is always encouraged to read the original source to get a full understanding of the study site (e.g. history of management, physical conditions, landscape context etc.).

For example:

A replicated, paired, site comparison study in 2002 of two coastal coral reefs in the Philippines (*1*) found that establishing a marine reserve closed to fishing resulted in higher density and biomass of species of fish taken by local fishers within the reserve compared to a fished area in one of two cases. For species taken by fishers, density and biomass inside reserve one was higher (density: 68 fish/500 m²; biomass: 89 kg) than outside (27/500 m²; 25 kg), but not significantly different inside and outside reserve two (density inside and outside: 41/500 m²; no biomass data provided). For fish species not subject to fishing, density was higher inside both reserves compared to outside; however, statistical tests showed this was mainly due to habitat variation not protection status (reserve one: 146 fish/250 m² inside, 113/250 m² outside; reserve two: 93/250 m² inside, 32/250 m² outside). No-take reserves approximately 450 m long (protected for 20 years) and 650 m long (protected for 15 years) off two islands were each compared to fished areas approximately 500 m away. Fish were surveyed in November and December 2002. Divers surveyed fish at six (reserve one) and eight (reserve two) coral reef slope sites inside and outside each reserve. Counts were along 50 x 10 m transects for fish taken by fishers and 50 x 5 m transects for fish not fished. Transects were surveyed twice.

(1) Abesamis R.A., Russ G.A., Alcala A.C. (2006) Gradients of abundance of fish across no-take marine reserve boundaries: Evidence from Philippine coral reefs. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 16, 349–371.

A replicated, randomized, controlled, before-and-after study in 1993–1999 of five harvested hardwood forests in Virginia, USA (*2*) found that harvesting trees in groups did not result in higher salamander abundances than clearcutting. Abundance was similar between treatments (group cut: 3; clearcut: 1/30 m²). Abundance was significantly lower compared to unharvested plots (6/30 m²). Species composition differed before and three years after harvest. There were five sites with 2 ha plots with each treatment: group harvesting (2–3 small area group harvests with selective harvesting between), clearcutting and an unharvested control. Salamanders were monitored on 9–15 transects (2 x 15 m)/plot at night in April–October. One or two years of pre-harvest and 1–4 years of post-harvest data were collected.

(2) Knapp S.M., Haas C.A., Harpole D.N. & Kirkpatrick R.L. (2003) Initial effects of clearcutting and alternative silvicultural practices on terrestrial salamander abundance. *Conservation Biology*, 17, 752–762.

A replicated, randomized, paired, controlled study in 1936–2009 in eight sagebrush steppe sites in Oregon, USA (*3*) found that increasing the number of livestock decreased grass and herb cover, but did not significantly alter shrub cover. Grass and herb cover in grazed areas were lower (grass: 9%, herb: 17%) than in areas that were not grazed (grass: 18%, herb: 24%). However, shrub cover was not significantly different in grazed (16%) and ungrazed (16%) areas. Eight 2 ha fenced areas excluding livestock were established in 1936. Areas adjacent to the fenced areas were grazed by cattle from 1936–2008. In summer 2009, four 20 m transects were established in each study area and vegetation cover was assessed using a line intercept method.

(3) Davies K.W., Bates J.D., Svejcar T.J. & Boyd C.S. (2010) Effects of long-term livestock grazing on fuel characteristics in rangelands: an example from the sagebrush steppe. *Rangeland Ecology & Management*, 63, 662–669.

b) Terminology used to describe the evidence

Unless specifically stated otherwise, results reflect statistical tests performed on the data, i.e. we will only state that there was a difference if it was a significant difference or will state that there was no difference if it was not significant. If there is a good reason to report differences between treatments and controls that were not tested for statistical significance, it was made clear within the summary that statistical tests were not carried out. Table 1 above defines the terms used to describe the study designs.

c) Dealing with multiple interventions within a publication

When separate results were provided for the effects of each of the different interventions tested, separate summaries were written under each intervention heading. However, when several interventions were carried out at the same time and only the combined effect reported, the result was described with a similar paragraph under all relevant interventions. The first sentence made it clear that there was a combination of interventions carried out, i.e. '... (REF) found that [x intervention], along with [y] and [z interventions] resulted in [describe effects]'. Within the results section we also added a sentence such as: 'It is not clear whether these effects were a direct result of [x], [y] or [z] interventions', or 'The study did not distinguish between the effects of [x], and other interventions carried out at the same time: [y] and [z].'

d) Dealing with multiple publications reporting the same results and reviews

If two publications described results from the same intervention implemented in the same space and at the same time, we only included the most stringently peer-reviewed publication (i.e. journal of the highest impact factor). If one included initial results (e.g. after year one) of another (e.g. after 1–3 years), we only included the publication covering the longest time span. If two publications described at least partially different results, we included both but made clear they were from the same project in the paragraph, e.g. 'A controlled study... (Gallagher et al. 1999; same experimental set-up as Oasis et al. 2001)...'.

e) Taxonomy

Taxonomy was not updated but follows that used in the original publication. Where possible, common names and Latin names were both given the first time each species was mentioned within each summary.

f) Key messages

Each intervention has a set of concise, bulleted key messages at the top, written once all the literature had been summarised. These include information such as the number, design and location of studies included.

The first bullet point describes the total number of studies that tested the intervention and the locations of the studies, followed by key information on the relevant metrics presented under the headings and sub-headings shown below (with number of relevant studies in parentheses for each).

- **X studies** examined the effects of [INTERVENTION] on [TARGET POPULATION]. Y studies were in [LOCATION 1][1,2] and Z studies were in [LOCATION 2][3,4]. *Locations will usually be countries (and water bodies/seas where relevant), ordered based on chronological order of studies rather than alphabetically, i.e. USA[1], Australia[2] not Australia[2], USA[1]. However, when more than 4-5 separate countries, they may be grouped into regions to make it clearer e.g. Europe, North America. The distribution of studies amongst habitat types may also be added here if relevant.*

COMMUNITY RESPONSE (x STUDIES)

- **Community composition (x studies):**
- **Richness/diversity (x studies):**

POPULATION RESPONSE (x STUDIES)

- **Abundance (x studies):**
- **Reproductive success (x studies):**
- **Survival (x studies):**
- **Condition (x studies):**

BEHAVIOUR (x STUDIES)

- **Use (x studies):**
- **Behaviour change (x studies):**

OTHER (x STUDIES) *(Included only for interventions/chapters where relevant)*

- **[Sub-heading(s) for the metric(s) reported will be created] (x studies):**

If no suitable studies are found for an intervention, the following text was added in place of the key messages above:

- We found no studies that evaluated the effects of [INTERVENTION] on [TARGET POPULATION].

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

g) Background information

Background information for an intervention is provided to describe the intervention and where we feel recent knowledge is required to interpret the evidence. This is presented before the key messages and relevant references included in the reference list at the end of the intervention section. In some cases, where a body of literature has strong implications for marine and freshwater mammal conservation, but does not directly test interventions for their effects, we may also refer the reader to this literature in the background sections.

6. Dissemination/communication of evidence synthesis

The information from this evidence synthesis is available in three ways:

- A synopsis pdf, downloadable from www.conservationevidence.com, contains the study summaries, key messages and background information on each intervention.
- The searchable database at www.conservationevidence.com contains all the summarized information from the synopsis, along with expert assessment scores.
- A chapter in *What Works in Conservation*, available as a pdf to download and a book from www.conservationevidence.com/content/page/79, contains the key messages from the synopsis as well as expert assessment scores on the effectiveness and certainty of the synopsis, with links to the online database.

1.7 How you can help to change conservation practice

If you know of evidence relating to marine and freshwater mammal conservation that is not included in this synopsis, we invite you to contact us via our website www.conservationevidence.com. If you have new, unpublished evidence, you can submit a paper to the Conservation Evidence journal. We particularly welcome papers submitted by conservation practitioners.

1.8 References

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2. Threat: Residential and commercial development

Background

The greatest threats from residential and commercial development tend to be destruction of habitat, pollution, and impacts from activities related to energy production and transportation. Interventions in response to these threats are described in other chapters and therefore will not be repeated here. Please refer to the following chapters: '*Habitat protection*', '*Habitat restoration and creation*', '*Threat: Pollution*', '*Threat: Energy production and mining*' and '*Threat: Transportation and service corridors*'.

Residential development can also result in an increase in recreational activities and tourism. Interventions in response to these threats are described in '*Threat: Human intrusions and disturbance – Recreational activities and tourism*'.

3. Threat: Aquaculture and agriculture

Background

Aquaculture is the farming of fish, shellfish, algae, and other organisms under controlled conditions in marine or freshwater environments. Aquaculture systems result in direct habitat loss, particularly in near-shore waters, and may also lead to pollution from biological waste, food or chemicals, and increased vessel traffic and noise disturbance (Würsig & Gailey 2002, Kemper *et al.* 2003). Mammals may also be attracted to aquaculture systems to feed on fish stocks within holding pens or excess supplementary food. This may lead to the entanglement of mammals in aquaculture gear resulting in injury or death. Marine mammal predation at fish farms can also cause significant financial losses to the aquaculture industry, which can result in human-wildlife conflict and the intentional killing or persecution of mammals (Nash *et al*. 2000).

Land-based aquaculture and agriculture can also have negative impacts on marine and freshwater mammals through the pollution of rivers and coastal habitats with run-off containing nutrients, pesticides, and other chemicals. Increases in nutrients can lead to diminished water quality and eutrophication events, including harmful algal blooms and hypoxic conditions or 'dead zones' (Breitburg *et al*. 2018).

The interventions described in this chapter focus on preventing mammal entanglements and reducing human-wildlife conflict at aquaculture systems. Interventions related to other threats from aquaculture and agriculture are described in other chapters and therefore will not be repeated here. See '*Threat: Transportation and service corridors*', '*Threat: Pollution*', '*Habitat protection*' and '*Habitat restoration and creation*'.

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Kemper C.M., Pemberton D., Cawthorn M., Heinrich S., Mann J., Würsig B., Shaughnessy P. & Gales R. (2003) Aquaculture and marine mammals: Co-existence or conflict? Pages 208–224 in: N. Gales, M. Hindell & R. Kirkwood (eds.) *Marine mammals: Fisheries, tourism and management issues*. CSIRO Publishing, Collingwood, Victoria, Australia.

Nash C.E., Iwamoto R.N. & Mahnken C.V.W. (2000) Aquaculture risk management and marine mammal interactions in the Pacific Northwest. *Aquaculture,* 183, 307–323.

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3.1. Modify aquaculture gear

- We found no studies that evaluated the effects of modifying aquaculture gear on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may be attracted to aquaculture systems to feed and can subsequently become entangled in gear. Modifications to aquaculture gear, such as using stiffened or rigid materials, may reduce the risk of entanglement. This may also reduce mammal predation on fish stocks thereby reducing human-wildlife conflict.

3.2. Modify anti-predator nets around aquaculture systems

- We found no studies that evaluated the effects of modifying anti-predator nets around aquaculture systems on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Anti-predator nets may be placed around fish pens or cages to physically exclude marine or freshwater mammals to reduce predation. However, such nets may entangle mammals, causing injury or death (e.g. Díaz López *et al.* 2007). Reducing mesh size, using stiffened or tensioned materials, and/or enclosing nets at the bottom may reduce the risk of entanglement (Kemper *et al*. 2003). These measures may also deter mammal predation more effectively thereby reducing human-wildlife conflict.

For studies that involve maintaining anti-predator nets, see '*Replace or repair damaged anti-predator nets around aquaculture systems*'.

López B.D. & Bernal Shirai J.A. (2007) Bottlenose dolphin (*Tursiops truncatus*) presence and incidental capture in a marine fish farm on the north-eastern coast of Sardinia (Italy). *Journal of the Marine Biological Association of the United Kingdom*, 87, 113–117.

Kemper C.M., Pemberton D., Cawthorn M., Heinrich S., Mann J., Würsig B., Shaughnessy P. & Gales R. (2003) Aquaculture and marine mammals: Co-existence or conflict? Pages 208–224 in: N. Gales, M. Hindell & R. Kirkwood (eds.) *Marine mammals: Fisheries, tourism and management issues*. CSIRO Publishing, Collingwood, Victoria, Australia.

3.3. Replace or repair damaged anti-predator nets around aquaculture systems

- **One study** evaluated the effects on marine mammals of replacing anti-predator nets around aquaculture systems. The study was in the North Atlantic Ocean[1] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One site comparison study in the North Atlantic Ocean[1] found that replacing anti-predator nets more frequently at salmon farms resulted in fewer salmon losses to harbour seal predation.

Background

Anti-predator nets may be placed around fish pens and cages to physically exclude marine or freshwater mammals to reduce predation and human-wildlife conflict. However, such nets may entangle mammals causing injury or death. Frequently replacing or repairing anti-predator nets may reduce the risk of mammals becoming entangled within holes or loose sections of damaged nets (Kemper *et al.* 2003). This may also prevent mammals from breaching the nets thereby reducing human-wildlife conflict.

For studies that involve modifying anti-predator nets, see '*Modify anti-predator nets around aquaculture systems*'.

Kemper C.M., Pemberton D., Cawthorn M., Heinrich S., Mann J., Würsig B., Shaughnessy P. & Gales R. (2003) Aquaculture and marine mammals: Co-existence or conflict? Pages 208–224 in: N. Gales, M. Hindell & R. Kirkwood (eds.) *Marine mammals: Fisheries, tourism and management issues*. CSIRO Publishing, Collingwood, Victoria, Australia.

A site comparison study in 2001–2003 of 26 Atlantic salmon *Salmo salar* farms in the western North Atlantic Ocean, off the coast of Maine, USA (*1*) found that farms that replaced anti-predator nets more frequently had fewer fish losses to Western Atlantic harbour seal *Phoca vitulina concolor* predation than those that replaced nets less frequently. Farms that replaced anti-predator nets more than once/year reported fewer losses of fish to seal predation than farms that replaced anti-predator nets once/year or less (data reported as statistical model results). Twenty-two farms replaced anti-predator nets more than once/year. Four farms replaced nets once/year or less. Farm managers were sent annual questionnaires in 2001–2003. Data were collected on methods used to deter predators and estimated numbers of fish lost or damaged due to seal predation.

(1) Nelson M.L., Gilbert J.R. & Kevin J. Boyle K.J. (2006) The influence of siting and deterrence methods on seal predation at Atlantic salmon (*Salmo salar*) farms in Maine, 2001–2003. *Canadian Journal of Fisheries and Aquatic Sciences*, 63, 1710–1721.

3.4. Minimize food waste at aquaculture systems

- We found no studies that evaluated the effects of minimizing food waste at aquaculture systems on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Supplementary feeding of fish at aquaculture systems may attract marine or freshwater mammals. Minimizing food waste may discourage mammals from foraging around anti-predator nets and becoming entangled. This may also reduce human-wildlife conflict at aquaculture facilities, as well as pollution caused by excess feed and feed additives.

3.5. Use acoustic devices at aquaculture systems

- **Six studies** evaluated the effects on marine and freshwater mammals of using acoustic devices at aquaculture systems. Four studies were in the North Atlantic Ocean[1,4,5a,5b] (USA, UK), one was in the Reloncaví fjord[2] (Chile) and one in the Mediterranean Sea[3] (Italy).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (6 STUDIES)

- **Human-wildlife conflict (6 studies):** Four of six studies (including five before-and-after and/or site comparison studies and one controlled study) in the North Atlantic Ocean[1,4,5a,5b], the Reloncaví fjord[2] and the Mediterranean Sea[3] found that using acoustic devices at salmon farms reduced predation on caged salmon by grey seals[5a,5b], harbour seals[5a,5b] and South American sea lions[2], or reduced the number of harbour seals approaching a fish cage[4]. The two other studies found that using acoustic devices did not reduce harbour seal predation at salmon farms[1], or reduce the presence, approach distances, groups sizes or time spent around fin-fish farms by common bottlenose dolphins[3].

Background

Acoustic devices may be used to deter marine or freshwater mammals from aquaculture systems. These are high power devices that operate by emitting sounds of an intensity and frequency that are aversive to the target mammal species. The primary aim has usually been to reduce mammal predation on fish stocks and damage to gear (therefore reducing human-wildlife conflict), although the risk of mammal entanglement may also be reduced. However, the high intensity sounds produced by acoustic devices have the potential to cause hearing damage to target species (Götz & Janik 2013). Negative and far-reaching effects have also been reported for non-target marine mammal species, such as killer whales and harbour porpoises (Johnston 2002, Morton & Symonds 2002, Olesiuk *et al.* 2002). The use of multiple acoustic devices within an area has the potential to cause significant noise pollution (Findlay *et al.* 2018).

Interventions that use acoustic devices in response to other threats can be found in the following chapters: '*Threat: Biological resource use – Fishing and harvesting aquatic resources*', '*Threat: Transportation and service corridors – Shipping lanes*', '*Threat: Energy production and mining – Renewable energy*', and '*Threat: Pollution – Noise pollution*'.

Findlay C.R., Ripple H.D., Coomber F., Froud K., Harries O., van Geel N.C.F., Calderan S.V., Benjamins S., Risch D. & Wilson B. (2018) Mapping widespread and increasing underwater noise pollution from acoustic deterrent devices. *Marine Pollution Bulletin,* 135, 1042–1050.

Götz T. & Janik V.M. (2013) Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series,* 492, 285–302.

Johnston D.W. (2002) The effect of acoustic harassment devices on harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. *Biological Conservation,* 108, 113–118.

Morton A.B. & Symonds H.K. (2002) Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. *ICES Journal of Marine Science,* 59, 71–80.

Olesiuk P.F., Nichol L.M., Sowden M.J. & Ford J.K.B. (2002) Effect of the sound generated by an acoustic harassment device on the relative abundance and distribution of harbor porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia. *Marine Mammal Science,* 18, 843–862.

A site comparison study in 2001–2003 of 27 Atlantic salmon *Salmo* salar farms in the North Atlantic Ocean, off the coast of Maine, USA (*1*) found that using acoustic devices did not reduce numbers of fish lost or damaged due to Western Atlantic harbour seal *Phoca vitulina concolor* predation. Estimated numbers of fish lost or damaged due to seal predation did not differ significantly between farms that did or did not use acoustic devices (data reported as statistical model results). There was also no significant difference between farms that used acoustic devices seasonally or all year round, or those that operated them for different numbers of hours/day. Eighteen farms used acoustic devices for 8–24 h/day (12 all year round; six seasonally). Nine farms did not use acoustic devices. Farm managers were sent annual questionnaires in 2001–2003. Data were collected on methods used to deter predators and estimated numbers of fish lost or damaged due to seal predation.

A before-and-after, site comparison study in 2007–2008 at two salmon farms in the Reloncaví fjord, Chile (*2*) found that installing an acoustic device reduced the amount of Atlantic salmon *Salmo salar* predated by South American sea lions *Otaria flavescens*, and fewer salmon were predated overall compared to at a farm without a device. At one farm, lower amounts of salmon were predated by sea lions in April–June 2008 after the acoustic device was installed (total 8 tons) compared to April–June 2007 before the device was installed (total 13 tons). During April–June 2008, lower amounts of salmon were also predated at the farm with the acoustic device than at a second farm without a device (total 68 tons), where amounts of predated salmon increased during this time (from 8 to 42 tons/month). The amount of predated salmon at the two farms did not differ significantly in January–March 2008 before the device was installed (8 vs 13 tons). An acoustic device (Airmar dB Plus II with eight sound projectors) was installed at one of two salmon farms in March 2008. The device emitted 1.4 ms sounds at intervals of 40 ms and a frequency of 10.3 kHz. Data on salmon predated by sea lions in 2007–2008 were taken from each of the two farms' logbooks.

A before-and-after study in 2009 at a fin-fish farm in the Mediterranean Sea, off the coast of Sardinia, Italy (*3*) found that an active acoustic device did not reduce common bottlenose dolphin *Tursiops truncatus* presence, approach distances, group size or time spent in the area compared to before or after the device was active. Bottlenose dolphin presence and minimum approach distances did not differ significantly before, during or after the acoustic device was active (data not reported). The same was true for average dolphin group sizes (before: 2 dolphins; during: 5 dolphins; after: 3 dolphins) and the average time dolphins spent in the area (before: 15 minutes; during: 19 minutes; after: 23 minutes). In February–June 2009, an acoustic device attached to a fish cage was activated (emitting 1.2–1.8 second tones at 6.2–9.8 kHz) for 40 minutes during each of 144 trials. The fish farm (12,000 m^2) consisted of 21 floating nylon mesh cages, 200 m from the shore. During each trial, dolphins were observed from a stationary boat during 40-minute periods before, during and after the device was active. Thirty periods for each of the three stages (before, during, after) were randomly selected for analysis.

A controlled study in 2007 at a fish farm in the North Atlantic Ocean, Scotland, UK (*4*) found that using an acoustic device reduced the number of harbour seals *Phoca vitulina* that approached a fish cage. Overall, fewer seals approached within 250 m of the cage when an acoustic device was used (2 seals) than when a device was not used (17 seals). No significant difference in numbers of approaches was found at distances of 250–1,500 m (with device: 8 seals; without: 11 seals) or >1,500 m from the cage (with device: 8 seals; without: 7 seals). Sixteen experimental trials (with an acoustic device) and 16 control trials (without a device) were carried out. Each trial lasted an average of 3.5 h. The device (an underwater loudspeaker emitting 200 ms pulses with a peak frequency of 950–1,000 Hz) was placed on a fish cage with the transducer at a depth of 17 m. Seals were tracked with a theodolite from the shore during each of the 32 trials in June–July 2007.

A before-and-after, site comparison study in 2010–2012 at a salmon *Salmo salar* farm in the North Atlantic Ocean, Scotland, UK (*5a*) found that deploying an acoustic device reduced predation on caged salmon by grey seals *Halichoerus grypus* and harbour seals *Phoca vitulina*. Fewer salmon were lost to seal predation while an acoustic device was deployed (0–70 fish/month) compared to before (97–104 fish/month) or after (4–9 fish/month) the device was deployed or at two control sites without acoustic devices (2–238 fish/month; 0–99 fish/month). No seal predation occurred during 10 of 12.5 months in which the acoustic device was deployed, whereas seal predation occurred during each of eight months at one control site without an acoustic device and six of seven months at the other. From January 2011 to February 2012, an acoustic device with 2–4 transducers (emitting 200 ms pulses at random intervals) was deployed at the centre of a salmon farm comprising a grid of 2 x 4 rectangular steel cages. Control sites were two salmon farms (with two rows or grids of 6–9 cages) without acoustic devices. In 2010–2012, salmon losses to seal predation (dead fish with bite wounds) were counted during 2.5 months before, 12.5 months during and 3 months after the acoustic device was deployed and during 7–8 months at the two control sites.

A before-and-after study in 2011 at a salmon *Salmo salar* farm in the North Atlantic Ocean, Scotland, UK (*5b*) found that deploying an acoustic device reduced predation on caged salmon by grey seals *Halichoerus grypus* and harbour seals *Phoca vitulina*. Fewer salmon were lost to seal predation while an acoustic device was deployed (0–10 fish/cage) compared to before the device was deployed (27–72 fish/cage). In May 2011, an acoustic device with a single transducer (emitting 200 ms pulses at random intervals) was deployed at a salmon farm (two rows of nine cages; same farm as one of the control sites in *5a*). Two cages on the farm were stocked with fish. Salmon losses (dead fish with bite wounds) were counted and removed from each of the two cages every 6–8 days during four weeks before and two weeks after the acoustic device was deployed.

(1) Nelson M.L., Gilbert J.R. & Kevin J. Boyle K.J. (2006) The influence of siting and deterrence methods on seal predation at Atlantic salmon (*Salmo salar*) farms in Maine, 2001–2003. *Canadian Journal of Fisheries and Aquatic Sciences*, 63, 1710–1721.

(2) Vilata J., Oliva D. & Sepulveda M. (2010) The predation of farmed salmon by South American sea lions (*Otaria flavescens*) in southern Chile. *ICES Journal of Marine Science*, 67, 475–482.

(3) López B.D. & Mariño F. (2011) A trial of acoustic harassment device efficacy on free-ranging bottlenose dolphins in Sardinia, Italy. *Marine and Freshwater Behaviour and Physiology*, 44, 197–208.

(4) Götz T. & Janik V.M. (2015) Target-specific acoustic predator deterrence in the marine environment. *Animal Conservation*, 18, 102–111.
(5) Götz T. & Janik V.M. (2016) Non-lethal management of carnivore predation: long-term tests with a startle reflex-based deterrence system on a fish farm. *Animal Conservation*, 19, 212–221.

3.6. Translocate mammals away from aquaculture systems to reduce human-wildlife conflict

- **Two studies** evaluated the effects of translocating mammals away from aquaculture systems to reduce human-wildlife conflict. Both studies were in the Tasman Sea[1,2] and one was also in the Southern Ocean[2] (Tasmania).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** Two studies (including one site comparison study) in the Tasman Sea[1,2] (one also in the Southern Ocean[2]) found that more than half[2] or nearly all[1] of Australian and New Zealand fur seals translocated away from salmon farms returned.

Background

Marine or freshwater mammals predating on fish stocks at aquaculture systems may be captured and translocated to other areas to reduce human-wildlife conflict. Consideration should be given to the welfare of captured mammals and the suitability of release sites.

For other interventions related to translocations, see '*Species management – Translocation* and '*Threat: Invasive or problematic species and disease – Disease – Translocate or temporarily bring marine and freshwater mammals into captivity to reduce exposure to disease*'.

A study in 2003–2005 at multiple Atlantic salmon *Salmo salar* farms in the Tasman Sea, Tasmania (*1*) found that nearly all New Zealand fur seals *Arctocephalus forsteri* and Australian fur seals *Arctocephalus pusillus doriferus* translocated away from farms returned to the farms within two weeks of release. After each of five translocations of two New Zealand fur seals, released at sites 300 km from the farms, the seals returned within an average of seven days. After 13 of 14 translocations of nine Australian fur seals, released at sites 140 and 470 km from the farms, the seals returned within an average of three and nine days respectively. The other Australian fur seal, released 140 km away, had not returned to the farms after 113 days but was recorded visiting a salmon farm in a different area. Two New Zealand fur seals and nine Australian fur seals were translocated away from farms on 19 occasions (five seals were translocated once; four seals were translocated 2–4 times). The seals were trapped at salmon farms (number of farms not reported), satellite-tagged and released at beaches 140, 300 and 470 km away in June–October 2003–2005. Each of the 11 seals was tracked for 3–147 days and recorded at an average of six locations/day after release.

A study in 1997–2005 at nine Atlantic salmon *Salmo salar* farms in the Tasman Sea and Southern Ocean, Tasmania (*2*) found that more than half of Australian fur seals *Arctocephalus pusillus doriferus* and New Zealand fur seals *Arctocephalus forsteri* translocated away from farms were recaptured at the farms and most returned after multiple translocations. Overall, 56% of relocated fur seals were recaptured at farms between 2 days and 6 years after release in other areas. Of those seals recaptured, approximately 80% returned after being translocated 2–62 times. The authors state that the actual number of seals that returned is likely to be higher as some may have evaded capture. In 1997–2005, more than 4,100 translocations of 954 microchipped seals were carried out. Seals were captured in baited traps at nine salmon farms and released at multiple locations up to 520 km away. Numbers of recaptured seals were recorded during trapping at the nine salmon farms each year in 1998–2005.

(1) Robinson S., Terauds A., Gales R. & Greenwood M. (2008) Mitigating fur seal interactions: relocation from Tasmanian aquaculture farms. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 18, 1180–1188.

(2) Robinson S., Gales R., Terauds A. & Greenwood M. (2008) Movements of fur seals following relocation from fish farms. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 18, 1189–1199.

3.7. Introduce and enforce legislation to prevent intentional killing of mammals at aquaculture systems

- We found no studies that evaluated the effects of introducing and enforcing legislation to prevent intentional killing of mammals at aquaculture systems.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may be intentionally killed (e.g. by shooting or poisoning) at aquaculture systems in attempts to reduce mammal predation on fish stocks and damage to gear. Although routine killing has been made illegal in many countries, permits or licences may be issued to allow a limited number of 'problem' individuals to be killed. Enforcement may be necessary to prevent illegal killing.

For a similar intervention, see '*Threat: Biological resource use – Introduce and enforce legislation to prevent intentional killing of mammals at wild fisheries*'.

3.8. Introduce and enforce regulations to prevent the use of harmful deterrents on mammals at aquaculture systems

- We found no studies that evaluated the effects of introducing and enforcing regulations to prevent the use of harmful deterrents on mammals at aquaculture systems.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may be harassed or subjected to harmful deterrents at aquaculture systems in attempts to reduce mammal predation on fish stocks and damage to gear. This may include using bait that is distasteful or emetic (induces vomiting), explosives and warning shots, electric fencing or chasing mammals with boats. Regulations may be introduced and enforced to prevent the use of such measures at aquaculture systems. This may also include the inappropriate use of acoustic devices, which may cause hearing damage and disturbance to both target and non-target mammals (Götz & Janik 2013).

For a similar intervention, see '*Threat: Biological resource use – Fishing and harvesting aquatic resources – Introduce and enforce regulations to prevent the use of harmful deterrents on mammals at wild fisheries*'.

Götz T. & Janik V.M. (2013) Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series,* 492, 285–302.

4. Threat: Energy production and mining

Background

Energy production (renewable and non-renewable), mining (for minerals), quarrying, and aggregate extraction, can have significant negative impacts on marine and freshwater mammals through the modification, destruction, and pollution of habitats during exploration, construction, operation, and decommissioning (e.g. Gordon *et al.* 2003, Schuster *et al.* 2015, Todd *et al.* 2015). Additional threats may arise from increased vessel traffic and shipping.

The interventions described in this chapter focus on preventing collisions, entanglements, and entrapment of marine and freshwater mammals at energy production sites. Interventions relating to other threats from energy production and mining (including offshore wind farm construction) are described in other chapters and are therefore not repeated here. See: '*Threat: Transportation and service corridors*', '*Threat: Human intrusions and disturbance – Work and other activities*', '*Threat: Natural system modifications – Dams and water management/use*', '*Threat: Pollution*', '*Habitat protection*' and '*Habitat restoration and creation*'.

Gordon J., Gillespie D., Potter J., Frantzis A., Simmonds M.P., Swift R. & Thompson D. (2003) A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal,* 37, 16–34.

Schuster E., Bulling L. & Köppel J. (2015) Consolidating the state of knowledge: a synoptical review of wind energy's wildlife effects. *Environmental Management,* 56, 300–331.

Todd V.L.G., Todd I.B., Gardiner J.C., Morrin E.C.N., MacPherson N.A., DiMarzio N.A. & Thomsen F. (2015) A review of impacts of marine dredging activities on marine mammals. *ICES Journal of Marine Science,* 72, 328–340.

Renewable energy

4.1. Modify design of underwater turbines

- We found no studies that evaluated the effects of modifying the design of underwater turbines on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

There is the potential for marine and freshwater mammals to collide with renewable energy devices, such as underwater turbines (Wilson *et al.* 2006). Turbines may be modified to reduce the risk of mammal injury or death during a collision, for example, sharp edges could be reduced, or blades shielded. Using certain colours or lighting for underwater turbines may also increase their visibility to mammals.

Wilson, B. Batty, R. S., Daunt, F. & Carter, C. (2006) *Collision risks between marine renewable energy devices and mammals, fish and diving birds*. Report to the Scottish Executive. Scottish Association for Marine Science, Oban.

4.2. Use acoustic devices at renewable energy sites

- We found no studies that evaluated the effects of using acoustic devices at renewable energy sites on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

There is the potential for marine and freshwater mammals to collide with renewable energy devices, such as underwater tidal turbines, or to become entangled in tethering lines and cables (Wilson *et al.* 2006). Acoustic devices may be used to deter marine or freshwater mammals from entering renewable energy sites. However, it should be noted that high amplitude acoustic devices may cause hearing damage to target and non-target mammal species, and may disrupt biologically important behaviour or exclude mammals from important habitats (Johnston 2002, Morton & Symonds 2002, Olesiuk *et al*. 2002, Götz & Janik 2013).

For a similar intervention, see '*Use acoustic devices at cooling water intake structures*'. For the use of acoustic devices during construction activities, such as pile driving, see '*Threat: Pollution – Noise pollution – Use acoustic devices to deter marine and freshwater mammals from an area to reduce noise exposure*'.

Interventions that use acoustic devices in response to other threats can be found in the following chapters: '*Threat: Aquaculture and agriculture*', '*Threat: Biological resource use – Fishing and harvesting aquatic resources*' and '*Threat: Transportation and service corridors – Shipping lanes*'.

Götz T. & Janik V.M. (2013) Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series,* 492, 285–302.

Johnston D.W. (2002) The effect of acoustic harassment devices on harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. *Biological Conservation,* 108, 113–118.

Morton A.B. & Symonds H.K. (2002) Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. *ICES Journal of Marine Science,* 59, 71–80.

Olesiuk P.F., Nichol L.M., Sowden M.J. & Ford J.K.B. (2002) Effect of the sound generated by an acoustic harassment device on the relative abundance and distribution of harbor porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia. *Marine Mammal Science,* 18, 843–862.

Wilson, B. Batty, R. S., Daunt, F. & Carter, C. (2006) *Collision risks between marine renewable energy devices and mammals, fish and diving birds*. Report to the Scottish Executive. Scottish Association for Marine Science, Oban.

4.3. Use real-time automated tools at renewable energy sites to detect marine and freshwater mammals and allow operations to be stopped or modified

- We found no studies that evaluated the effects of using real-time automated tools at renewable energy sites to detect marine and freshwater mammals and allow operations to be stopped or modified.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Automated detection systems, e.g. using sonar or acoustic monitoring, may be used at renewable energy sites to detect the presence of marine or freshwater mammals and allow operations to be stopped or modified. This may reduce the risk of mammal injury or death caused by collisions with moving structures, such as underwater turbines.

Power plants

4.4. Install diversion or return systems on cooling water intake structures

- We found no studies that evaluated the effects of installing diversion or return systems on cooling water intake structures on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine or freshwater mammals may enter or be drawn into the cooling water intake structures of coastal power plants, which may result in injury or death. Installing bars or screens across intake tunnels may be used as a preventative measure.

4.5. Use acoustic devices at cooling water intake structures

- We found no studies that evaluated the effects of using acoustic devices at cooling water intake structures on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine or freshwater mammals may enter or be drawn into the cooling water intake structures of power plants, which may result in injury or death. Acoustic devices may be used to deter mammals from approaching intake tunnels. However, it should be noted that high amplitude acoustic devices may cause hearing damage to target and non-target mammal species, and may disrupt biologically important behaviour or exclude mammals from important habitats (Johnston 2002, Morton & Symonds 2002, Olesiuk *et al*. 2002, Götz & Janik 2013).

For a similar intervention, see '*Use acoustic devices at renewable energy sites*'. Interventions that use acoustic devices in response to other threats can be found in the following chapters: '*Threat: Aquaculture and agriculture*', '*Threat: Biological* *resource use – Fishing and harvesting aquatic resources*', '*Threat: Transportation and service corridors – Shipping lanes*' and '*Threat: Pollution – Noise pollution*'.

Götz T. & Janik V.M. (2013) Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series,* 492, 285–302.

Johnston D.W. (2002) The effect of acoustic harassment devices on harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. *Biological Conservation,* 108, 113–118.

Morton A.B. & Symonds H.K. (2002) Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. *ICES Journal of Marine Science,* 59, 71–80.

Olesiuk P.F., Nichol L.M., Sowden M.J. & Ford J.K.B. (2002) Effect of the sound generated by an acoustic harassment device on the relative abundance and distribution of harbor porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia. *Marine Mammal Science,* 18, 843–862.

4.6. Reduce capacity of cooling water intake structures

- We found no studies that evaluated the effects of reducing capacity of cooling water intake structures on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine or freshwater mammals may enter or be drawn into the cooling water intake structures of power plants, which may result in injury or death. Reducing the capacity of intake structures may prevent mammals from entering and becoming trapped.

4.7. Use cooling towers instead of once-through cooling systems

- We found no studies that evaluated the effects of using cooling towers instead of once-through cooling systems on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Once-through cooling systems use a process that involves pulling in cold water from rivers, lakes, or the ocean to cool power plant reactors. Marine or freshwater mammals may be drawn into the intake tunnels and become trapped resulting in injury or death. An alternative approach is to use cooling towers in which water is stored in large tanks and re-used.

5. Threat: Transportation and service corridors

Background

Threats from transportation and service corridors include infrastructures such as ships and shipping lanes, ferries and bridges, communication and power cables, oil and gas pipelines, and associated threats from their activities. One of the greatest threats to marine and freshwater mammals from transportation is mortality caused by collisions with ships and other vessels. Ship-strikes affect multiple mammal species, occur worldwide, and have increased in recent decades (Laist *et al.* 2001, Van Waerebeek *et al.* 2007). Transportation and service corridors may also result in the destruction and pollution of marine and freshwater mammal habitats. Shipping is a major source of noise pollution in both the ocean and inland waterways (Wilcock *et al.* 2014), and with increased industrial access to all regions of the world, few areas remain unaffected (Hauser *et al.* 2018). Pollution may also be caused by leaching of chemicals, fuel spills, or the disposal of wastes and garbage from vessels. Non-native, invasive, or problematic species may also be spread, e.g. on the hull of ships or in ballast waters (Bax *et al.* 2003). Dredging of channels to increase the available depth for vessel traffic can also be a threat, resulting in noise and sediment-induced disturbance on marine and freshwater mammals (Todd *et al.* 2015).

Most of the interventions described in this chapter aim to reduce collision mortality from ship-strikes. Interventions related to other threats from transportation and service corridors are described in other chapters and are therefore not repeated here. See '*Threat: Pollution*', '*Threat: Invasive and other problematic species*', '*Habitat protection*' and '*Habitat restoration and creation*'.

Bax N., Williamson A., Aguero M., Gonzalez E. & Geeves W. (2003) Marine invasive alien species: a threat to global biodiversity. *Marine Policy,* 27, 313–323.

Hauser D.D.W., Laidre K.L. & Stern H.L. (2018) Vulnerability of Arctic marine mammals to vessel traffic in the increasingly ice-free Northwest Passage and Northern Sea Route. *Proceedings of the National Academy of Sciences,* 115, 7617–7622.

Laist D.W., Knowlton A.R., Mead J.G., Collet A.S. & Podestà M. (2001) Collisions between ships and whales. *Marine Mammal Science,* 17, 35–75.

Todd V.L.G., Todd I.B., Gardiner J.C., Morrin E.C.N., MacPherson N.A., DiMarzio N.A. & Thomsen F. (2015) A review of impacts of marine dredging activities on marine mammals. *ICES Journal of Marine Science,* 72, 328–340.

Van Waerebeek K., Baker A., Félix F., Gedamke J., Iñiguez M., Sanino G.P., Secchi E.R., Sutaria D., Helden A.V. & Wang Y. (2007) Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals,* 6, 43–69.

Wilcock W.S.D., Stafford K.M., Andrew R.K. & Odom R.I. (2014) Sounds in the Ocean at 1–100 Hz. *Annual Review of Marine Science,* 6, 117–140.

Shipping lanes

5.1. Divert shipping routes

- We found no studies that evaluated the effects of diverting shipping routes on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Diverting shipping routes away from important areas for marine and freshwater mammals may reduce the risk of lethal collisions (Vanderlaan *et al.* 2009, van der Hoop *et al.* 2012, Chion *et al.* 2018). Diversions may be permanent or temporary (e.g. seasonal or in response to mammal sightings), mandatory or voluntary, and may apply to all vessels or to certain vessel types or sizes. Careful planning may be required as diverting shipping routes to avoid one species could increase the collision risk for other species in new areas (Redfern *et al.* 2013). Enforcement may also be required if compliance is low.

This intervention is often combined with vessel speed restrictions, see '*Set and enforce vessel speed limits*'.

Chion C., Turgeon S., Cantin G., Michaud R., Ménard N., Lesage V., Parrott L., Beaufils P., Clermont Y. & Gravel C. (2018) A voluntary conservation agreement reduces the risks of lethal collisions between ships and whales in the St. Lawrence Estuary (Québec, Canada): From co-construction to monitoring compliance and assessing effectiveness. *PLOS ONE,* 13, e0202560.
Redfern J.V., Mckenna M.F., Moore T.J., Calambokidis J., Deangelis M.L., Becker E.A., Barlow J., Forney K.A., Fiedler P.C. & Chivers S.J. (2013) Assessing the risk of ships striking large whales in marine spatial planning. *Conservation Biology,* 27, 292–302.
van der Hoop J.M., Vanderlaan A.S.M. & Taggart C.T. (2012) Absolute probability estimates of lethal vessel strikes to North Atlantic right whales in Roseway Basin, Scotian Shelf. *Ecological Applications,* 22, 2021–2033.
Vanderlaan A.S.M. & Taggart C.T. (2009) Efficacy of a voluntary area to be avoided to reduce risk of lethal vessel strikes to endangered whales. *Conservation Biology,* 23, 1467–1474.

5.2. Set and enforce vessel speed limits

- **Two studies** evaluated the effects on marine and freshwater mammals of setting and enforcing vessel speed limits. One study was in the Indian River estuarine system[1] (USA) and the other in the North Atlantic Ocean[2] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Survival (2 studies):** One before-and-after study in the Indian River estuarine system[1] found similar numbers of manatee deaths before and after vessel speed limits were set in 'zones', but fewer deaths were recorded after speed limits were set and enforced in all areas. One before-and-after study in the North Atlantic Ocean[2] found that setting vessel speed limits during specific periods in key habitats resulted in fewer North Atlantic right whale deaths caused by collisions.

BEHAVIOUR (0 STUDIES)

Background

Introducing vessel speed limits may reduce disturbance and the risk of lethal collisions and severe injury to marine and freshwater mammals (Vanderlaan & Taggart 2007, Currie *et al.* 2017, Chion *et al.* 2018). Speed limits may be permanent, seasonal (e.g. during migration, breeding, or nursing periods) or temporary (e.g. in response to mammal sightings within an area) and may apply to all vessels or to certain vessel types or sizes. Speed limits may also be mandatory or voluntary, although greater compliance has been reported with mandatory speed limits (Lagueux *et al.* 2011). Enforcement may be required if compliance is low (Silber *et al.* 2014).

This intervention is often combined with changes to shipping routes, see '*Divert shipping routes*'.

Chion C., Turgeon S., Cantin G., Michaud R., Ménard N., Lesage V., Parrott L., Beaufils P., Clermont Y. & Gravel C. (2018) A voluntary conservation agreement reduces the risks of lethal collisions between ships and whales in the St. Lawrence Estuary (Québec, Canada): From co-construction to monitoring compliance and assessing effectiveness. *PLOS ONE,* 13, e0202560.

Currie J., Stack S. & Kaufman G. (2017) Modeling whale-vessel encounters: the role of speed in mitigating collisions with humpback whales (*Megaptera novaeangliae*). *Journal of Cetacean Research and Management,* 17, 57–64.

Lagueux K.M., Zani M.A., Knowlton A.R. & Kraus S.D. (2011) Response by vessel operators to protection measures for right whales *Eubalaena glacialis* in the southeast US calving ground. *Endangered Species Research,* 14, 69–77.

Silber G.K., Adams J.D. & Fonnesbeck C.J. (2014) Compliance with vessel speed restrictions to protect North Atlantic right whales. *PeerJ,* 2, e399.

Vanderlaan A.S.M. & Taggart C.T. (2007) Vessel collisions with whales: the probability of lethal injury based on vessel speed. *Marine Mammal Science,* 23, 144–156.

A before-and-after study in 1986–2005 at a creek and canal in the Indian River estuarine system, USA (*1*) reported that after setting vessel speed limits in 'zones', a similar number of Florida manatee *Trichechus manatus latirostris* deaths were recorded to before the speed limits, but setting and enforcing speed limits throughout all areas resulted in fewer manatee deaths. Results are not based on assessments of statistical significance. Average numbers of manatees killed by vessels were similar before (1.8 manatees/year) and after (1.8–2.1 manatees/year) vessel speed limits were introduced to specific zones. Fewer manatees were killed by vessels (average 0.3 manatees/year) after speed limits were introduced and enforced by patrols in all areas. Year-round speed limits (8–11 km/h) were set within specific zones in 1990 and 1994, although low compliance was reported (see original paper for details). In 2002, the creek and canal were designated as manatee refuges and year-round speed limits (8–11 km/h) were set throughout. Patrolling enforcement officers issued warnings and speeding tickets in 2002–2005. Manatees killed by vessels were recorded within the creek, canal and adjacent waters during five years before speed limits were set (1986–1990), 13 years after speed limits were set in zones (1990–2002) and four years after speed limits were set and enforced in all areas (2002–2005).

A before-and-after study in 1990–2013 of 10 coastal areas in the North Atlantic Ocean, USA (*2*) found that after setting vessel speed limits, fewer North Atlantic right whale *Eubalaena glacialis* deaths caused by vessel collisions were recorded than before speed limits were set. The total number of right whale deaths in the 10 areas caused by vessel collisions was lower during five years after speed limits were put in place (0 deaths) than during 18 years before (total 13 deaths). In December 2008, mandatory speed limits (≤18.5 km/h for vessels ≥19.8 m long) were put in place in 10 areas with key habitats for North Atlantic right whales (migration routes, feeding areas, calving grounds) during periods of peak whale occurrence. Numbers of whale deaths caused by vessel collisions inside (or within 83 km from) the 10 areas during 18 years before (1990–2008) and five years after (2009–2013) speed limits were set were extracted from national databases.

(1) Laist D.W. & Shaw C. (2006) Preliminary evidence that boat speed restrictions reduce deaths of Florida manatees. *Marine Mammal Science*, 22, 472–479.
(2) Laist D.W., Knowlton A.R. & Pendleton D.E. (2014) Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales. *Endangered Species Research*, 23, 133–147.

5.3. Use observers on board vessels to detect mammals and allow vessel course or speed to be altered

- We found no studies that evaluated the effects of using observers on board vessels to detect mammals and allow vessel course or speed to be altered.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Trained, dedicated observers on board vessels may be used to alert crew to the presence of marine or freshwater mammals within shipping lanes so that avoidance measures can be taken, such as slowing the vessel or changing course. Dedicated observers have been found to detect more marine mammals than standard vessel crew and often at larger distances from the vessel (Weinrich *et al*. 2010). However, the ability of observers to detect mammals will depend on the environmental conditions and speed of the vessel, among other factors, and collisions may still occur if mammals are not seen or seen too late to take avoidance measures (Wiley *et al.* 2016).

For similar interventions, see '*Use real-time automated tools on board vessels to detect mammals and allow vessel course or speed to be altered*' and '*Use remote tools to detect mammals in an area and allow vessel course or speed to be altered*'.

Weinrich M., Pekarcik C. & Tackaberry J. (2010) The effectiveness of dedicated observers in reducing risks of marine mammal collisions with ferries: A test of the technique. *Marine Mammal Science*, 26, 460–470.
Wiley D.N., Mayo C.A., Maloney E.M. & Moore M.J. (2016) Vessel strike mitigation lessons from direct observations involving two collisions between noncommercial vessels and North Atlantic right whales (*Eubalaena glacialis*). *Marine Mammal Science,* 32, 1501–1509.

5.4. Use real-time automated tools on board vessels to detect mammals and allow vessel course or speed to be altered

- We found no studies that evaluated the effects of using real-time automated tools on board vessels to detect mammals and allow vessel course or speed to be altered.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Using tools on board vessels that automatically detect marine or freshwater mammals within shipping lanes in real time and alert crew to their presence may allow collisions to be avoided. Techniques may include infra-red imaging, active sonar, Radio Detection and Ranging (RADAR), or passive acoustic monitoring (Pyć *et al.* 2016, Horton *et al.* 2017).

See also '*Use observers on board vessels to detect mammals and allow vessel course or speed to be altered*' and '*Use remote tools to detect mammals in an area and allow vessel course or speed to be altered*'.

Pyć C.D., Geoffroy M. & Knudsen F.R. (2016) An evaluation of active acoustic methods for detection of marine mammals in the Canadian Beaufort Sea. *Marine Mammal Science,* 32, 202–219.

Horton T.W., Oline A., Hauser N., Khan T.M., Laute A., Stoller A., Tison K. & Zawar-Reza P. (2017) Thermal imaging and biometrical thermography of humpback whales. *Frontiers in Marine Science,* 4.

5.5. Use remote tools to detect mammals in an area and allow vessel course or speed to be altered

- We found no studies that evaluated the effects of using remote tools to detect mammals in an area and allow vessel course or speed to be altered.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Using remote tools to alert vessel operators to marine and freshwater mammals within shipping lanes may allow avoidance measures to be taken reducing the risk of lethal collisions. Various technologies have been developed for this purpose including acoustic detection buoys (Van Parijs *et al.* 2009), software for vessels to report and receive real-time mammal sightings (e.g. 'Real Time Plotting of Cetaceans', Souffleurs d'Ecume 2012), and predictive tools (e.g. 'WhaleWatch', Hazen *et al.* 2017). Vessel operators may be alerted to mammal presence/sightings by radio (e.g. Automated Identification Systems), onboard software, or mobile phone apps (e.g. 'Whale Alert', Conserve.iO 2018).

See also '*Use observers on board vessels to detect mammals and allow vessel course or speed to be altered*' and '*Use real-time automated tools on board vessels to detect mammals and allow vessel course or speed to be altered'.*

Conserve.iO (2018) *Conserve.iO. Technology for a better planet.* Available at http://conserve.io/

Hazen E.L., Palacios D.M., Forney K.A., Howell E.A., Becker E., Hoover A.L., Irvine L., DeAngelis M., Bograd S.J., Mate B.R. & Bailey H. (2017) WhaleWatch: a dynamic management tool for predicting blue whale density in the California Current. *Journal of Applied Ecology,* 54, 1415–1428.

Souffleurs d'Ecume (2012) *REPCET Real Time Plotting of Cetaceans.* Available online at http://repcet.com

Van Parijs S.M., Clark C.W., Sousa-Lima R.S., Parks S.E., Rankin S., Risch D. & Van Opzeeland I.C. (2009) Management and research applications of real-time and archival passive acoustic sensors over varying temporal and spatial scales. *Marine Ecology Progress Series,* 395, 21–36.

5.6. Develop and implement regulations for operating vessels around mammals

- We found no studies that evaluated the effects of developing and implementing regulations for operating vessels around mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Regulations for operating vessels around marine and freshwater mammals, such as minimum approach distances, may reduce disturbance and prevent mammal reactions that could increase the risk of collisions.

For a similar intervention related to recreational tours, see '*Threat: Human intrusions and disturbance – Introduce and enforce regulations for marine and freshwater mammal watching tours*'.

5.7. Provide training to vessel operators on mammal behaviour and appropriate avoidance techniques

- We found no studies that evaluated the effects of providing training to vessel operators on mammal behaviour and appropriate avoidance techniques.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves providing training to vessel operators on marine and freshwater mammal behaviour and appropriate avoidance techniques. Mammals may not be sighted until they are in relatively close range of a vessel, such that a rapid response is required to avoid the animal, particularly when vessels are travelling at high speeds. Equipping vessel operators with appropriate knowledge and techniques to avoid mammals may reduce the risk of collisions. Training may be carried out with visual aids or simulators, as well as on board vessels.

See also '*Provide educational materials at marinas and ports to encourage vessel operators to carry out safe practices around mammals (e.g. signs, leaflets)*'.

5.8. Provide educational materials at marinas and ports to encourage vessel operators to carry out safe practices around mammals (e.g. signs, leaflets)

- We found no studies that evaluated the effects of providing educational materials at marinas and ports to encourage vessel operators to carry out safe practices around mammals.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves providing materials, such as educational signs, leaflets, and placards, at marinas and ports to encourage vessel operators to carry out safe practices around marine and freshwater mammals.

See also '*Provide training to vessel operators on mammal behaviour and appropriate avoidance techniques*'.

5.9. Use acoustic devices on moving vessels

- We found no studies that evaluated the effects of using acoustic devices on moving vessels on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

With the aim of reducing collisions, acoustic devices may be mounted on the bow of moving vessels, such as ships, to deter marine and freshwater mammals. Although large vessels emit high levels of noise, there may be a quieter area or 'acoustic shadow' directly in front of vessels due to shielding of noise by the ship's hull, and also at the water surface (Trevorrow & Vasiliev 2008). Acoustic devices may also be useful for deterring mammals from quieter vessels, such as sailing yachts. However, it should be noted that high amplitude acoustic devices may cause hearing damage to target and non-target mammal species, and may disrupt biologically important behaviour or exclude mammals from important habitats (Johnston 2002, Morton & Symonds 2002, Olesiuk *et al*. 2002, Götz & Janik 2013).

For an intervention that involves deploying acoustic devices from boats with the aim of reducing mammal entanglements and human-wildlife conflict at wild fisheries, see '*Threat: Biological resource use – Fishing and harvesting – Use acoustic devices on fishing vessels*'. For studies that involve deploying acoustic devices from boats to deter mammals prior to construction activities, see '*Threat: Pollution – Noise pollution – Use acoustic devices to deter marine and freshwater mammals from an area to reduce noise exposure*'.

Götz T. & Janik V.M. (2013) Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series,* 492, 285–302.

Johnston D.W. (2002) The effect of acoustic harassment devices on harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. *Biological Conservation,* 108, 113–118.

Morton A.B. & Symonds H.K. (2002) Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. *ICES Journal of Marine Science,* 59, 71–80.

Olesiuk P.F., Nichol L.M., Sowden M.J. & Ford J.K.B. (2002) Effect of the sound generated by an acoustic harassment device on the relative abundance and distribution of harbor porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia. *Marine Mammal Science,* 18, 843–862.

Trevorrow M.V., Vasiliev B. & Vagle S. (2008) Directionality and maneuvering effects on a surface ship underwater acoustic signature. *The Journal of the Acoustical Society of America,* 124, 767–778.

5.10. Modify vessels to reduce risk of physical injury to mammals

- We found no studies that evaluated the effects of modifying vessels to reduce risk of physical injury to mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Certain vessel modifications may reduce the severity of injuries to marine or freshwater mammals in the event of a collision. This could include installing propeller guards, such as cages, that provide a physical barrier between the propeller blades and an animal (Van Waerebeek *et al.* 2007).

Van Waerebeek K., Baker A., Félix F., Gedamke J., Iñiguez M., Sanino G.P., Secchi E.R., Sutaria D., Helden A.V. & Wang Y. (2007) Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals,* 6, 43–69.

5.11. Reduce shipping along inland waterways

- We found no studies that evaluated the effects of reducing shipping along inland waterways on freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

High levels of industrial and commercial ship traffic along inland waterways may result in disturbance and collision mortality of freshwater mammals, such as river dolphins (Van Waerebeek *et al.* 2007). This intervention involves reducing shipping along inland waterways, e.g. by using alternative modes of transport. See also '*Limit vessel traffic in shallow rivers*'.

For interventions that relate to recreational boating, see '*Threat: Human intrusions and disturbance – Recreational activities*'. For interventions that aim to reduce noise pollution caused by vessels, see '*Threat: Pollution – Excess energy*'.

Van Waerebeek K., Baker A., Félix F., Gedamke J., Iñiguez M., Sanino G.P., Secchi E.R., Sutaria D., Helden A.V. & Wang Y. (2007) Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals,* 6, 43–69.

5.12. Limit vessel traffic in shallow rivers

- We found no studies that evaluated the effects of limiting vessel traffic in shallow rivers on freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves limiting vessel traffic within shallow rivers where freshwater mammals, such as river dolphins, are likely to be particularly vulnerable to disturbance and at greater risk of being involved in collisions. See also '*Reduce shipping along inland waterways*'. For other interventions that aim to reduce noise pollution caused by vessels, see the chapter '*Threat: Pollution – Excess energy*'.

Flight paths

5.13. Introduce regulations for flying aircraft over marine and freshwater mammals

- We found no studies that evaluated the effects of introducing regulations for flying aircraft over marine and freshwater mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may be disturbed by aircraft flying overhead, such as helicopters and small airplanes (Richardson *et al.* 1997, Patenaude *et al.* 2006). Underwater noise pollution from commercial passenger airplanes is also likely to be audible to marine mammals and may be of conservation concern for species inhabiting coastal waters close to airports (Erbe *et al.* 2018). This intervention involves introducing regulations for flying aircraft over marine and freshwater mammals to reduce disturbance. This may include setting limits on minimum altitude and the duration or number of flights over individual mammal groups.

For an intervention that relates to flying drones over marine and freshwater mammals, see '*Threat: Human intrusions and disturbance – Work and other activities – Introduce regulations for flying drones over marine and freshwater mammals*'.

Erbe C., Williams R., Parsons M., Parsons S.K., Hendrawan I.G. & Dewantama I.M.I. (2018) Underwater noise from airplanes: An overlooked source of ocean noise. *Marine Pollution Bulletin*, 656–661.

Patenaude N.J., Richardson W.J., Smultea M.A., Koski W.R., Miller G.W., Würsig B. & GReene JR. C.R. (2002) Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. *Marine Mammal Science,* 18, 309–335.

Richardson W.J. & Würsig B. (1997) Influences of man-made noise and other human actions on cetacean behaviour. *Marine and Freshwater Behaviour and Physiology,* 29, 183–209.

6. Threat: Biological resource use

Background

Biological resource use can have significant impacts on marine and freshwater mammal populations due to direct interactions with wild fisheries (Read *et al.* 2006, Read 2008). Mammals may be entangled, hooked, or captured in fishing gear resulting in injury or death. Mammal predation on fish catches and subsequent damage to fishing gear can also cause considerable losses to fisheries and result in human-wildlife conflict in which mammals are intentionally killed or persecuted. Fishing and harvesting of aquatic resources may also have indirect effects, such as the destruction or modification of marine and freshwater mammal habitats and the depletion of food sources (DeMaster *et al.* 2001).

Marine and freshwater mammals may also be hunted as a biological resource for their meat, oil, furs, or skins. The increased demand for aquatic wild meat (or 'bushmeat') is a significant threat to marine and freshwater mammals (Robards & Reeves 2011). Historically, hunting has occurred worldwide and has resulted in population declines of many species, and in some cases extinctions (Reeves 2009).

The interventions described in this chapter focus on reducing hunting and persecution of marine and freshwater mammals, reducing the unwanted catch of mammals in fishing gear (sometimes referred to as 'bycatch'), and improving the survival of released or escaped mammals. Interventions related to other threats from biological resource use are described in other chapters and therefore will not be repeated here. See '*Threat: Transportation and service corridors*', '*Threat: Pollution*', '*Habitat protection*' and '*Habitat restoration and creation*'.

DeMaster D.P., Fowler C.W., Perry S.L. & Richlen M.F. (2001) Predation and competition: the impact of fisheries on marine-mammal populations over the next one hundred years. *Journal of Mammalogy,* 82, 641–651.

Read A.J., Drinker P. & Northridge S. (2006) Bycatch of marine mammals in U.S. and global fisheries. *Conservation Biology,* 20, 163–169.

Read A.J. (2008) The looming crisis: interactions between marine mammals and fisheries. *Journal of Mammalogy,* 89, 541–548.

Reeves R.R. (2009) Hunting of marine mammals. Pages 585–588 in*:* Perrin W.F., Würsig B. & Thewissen J.G.M. (eds.) *Encyclopedia of marine mammals (Second Edition).* Academic Press, London.

Robards M.D. & Reeves R.R. (2011) The global extent and character of marine mammal consumption by humans: 1970–2009. *Biological Conservation,* 144, 2770–2786.

Fishing and harvesting aquatic resources

Reduce hunting and persecution

6.1. Introduce and enforce legislation to prevent intentional killing of mammals at wild fisheries

- We found no studies that evaluated the effects of introducing and enforcing legislation to prevent intentional killing of mammals at wild fisheries.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may be intentionally killed at wild fisheries to reduce predation on fish catches and damage to fishing gear (Read 2005), or for use as bait (Mintzer *et al.* 2018) or food (Clapham & Van Waerebeek 2007). Legislation may be introduced that prevents the intentional killing of mammals. Laws already exist in many countries. However, compliance can be low (e.g. Mangel *et al.* 2010) and enforcement may be required to prevent illegal killing of mammals.

For a similar intervention, see '*Threat: Aquaculture and agriculture – Introduce and enforce legislation to prevent intentional killing of mammals at aquaculture systems*'.

Mangel J.C., Alfaro-Shigueto J., Van Waerebeek K., Cáceres C., Bearhop S., Witt M.J. & Godley B.J. (2010) Small cetacean captures in Peruvian artisanal fisheries: high despite protective legislation. *Biological Conservation,* 143, 136–143.

Mintzer V.J., Diniz K. & Frazer T.K. (2018) The use of aquatic mammals for bait in global fisheries. *Frontiers in Marine Science,* 5.

Read A.J. (2005) Bycatch and depredation. Pages 5–17 in*:* Reynolds J.E., Perrin W.F., Reeves R.R., Montgomery S. & Ragen T.J. (eds.) *Marine mammal research: conservation beyond crisis.* Johns Hopkins University Press, Baltimore.

Clapham P. & Van Waerebeek K. (2007) Bushmeat and bycatch: the sum of the parts. *Molecular Ecology,* 16, 2607–2609.

6.2. Introduce and enforce regulations to prevent the use of harmful deterrents on mammals at wild fisheries

- We found no studies that evaluated the effects of introducing and enforcing regulations to prevent the use of harmful deterrents on mammals at wild fisheries.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may be harassed or subjected to harmful deterrents at wild fisheries in attempts to reduce mammal predation on fish catches and damage to gear. This may include using firecrackers and rifle shots, flashlights, banging steel poles or oars together, and chasing mammals with boats (e.g. Shaughnessy *et al.* 1981, Sepulveda *et al.* 2018). Regulations may be introduced and enforced to prevent the use of such measures.

For a similar intervention, see '*Threat: Aquaculture and agriculture – Introduce and enforce regulations to prevent the use of harmful deterrents on mammals at aquaculture systems*'.

Sepulveda M., Martinez T., Oliva D., Couve P., Pavez G., Navarro C., Stehlik M., Rene Duran L. & Luna-Jorquera G. (2018) Factors affecting the operational interaction between the South American sea lions and the artisan gillnet fishery in Chile. *Fisheries Research*, 201, 147–152.

Shaughnessy P.D., Semmelink A., Cooper J. & Frost P.G.H. (1981) Attempts to develop acoustic methods of keeping cape fur seals *Arctocephalus pusillus* from fishing nets. *Biological Conservation*, 21, 141–158.

6.3. Prohibit or restrict hunting of marine and freshwater mammal species

- **Five studies** evaluated the effects of prohibiting hunting of marine mammal species. One study was in each of the Kattegat and Skagerrak seas[1] (Denmark and Sweden), the North Atlantic Ocean, North Pacific Ocean and the Southern Hemisphere[2], the South Pacific Ocean[3] (Australia), the North Atlantic Ocean[4] (Greenland) and the Southern Ocean[5] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (5 STUDIES)

- **Abundance (5 studies):** Four of five studies (including three before-and-after studies) in the Kattegat and Skagerrak Seas[1], the South Pacific Ocean[3], the North Atlantic Ocean[4] and the Southern Ocean[5] found that after hunting was prohibited, the abundance of harbour seals[1] and humpback whales[3,4] increased over 7–30 years. The other study[5] found that numbers of mature male sperm whales did not differ significantly before or 31 years after hunting was prohibited. One review in the North Atlantic Ocean, North Pacific Ocean and the Southern Hemisphere[2] found significant increase rates for 10 of 12 baleen whale populations during 7–21 years after legislation to prohibit hunting was introduced.

BEHAVIOUR (0 STUDIES)

Background

Marine and freshwater mammals may be hunted for their meat, oil, furs, or skins. Historically, hunting of marine mammals has occurred worldwide and has resulted in population declines of many species, and in some cases extinctions (Reeves 2009). This intervention involves prohibiting or restricting hunting specifically where hunting is a major threat to a population of a species. Enforcement may also be required as illegal hunting may still occur (e.g. Consentino & Fisher 2016).

For general legal protection from a wider range of threats, see '*Species management – Species recovery – Legally protect marine and freshwater mammal species*' and '*Habitat protection – Legally protect habitat for marine and freshwater mammals*'.

Cosentino A.M. & Fisher S. (2016) The utilization of aquatic bushmeat from small cetaceans and manatees in South America and West Africa. *Frontiers in Marine Science,* 3.

Reeves R.R. (2009) Hunting of marine mammals. Pages 585–588 in*:* Perrin W.F., Würsig B. & Thewissen J.G.M. (eds.) *Encyclopedia of marine mammals (Second Edition).* Academic Press, London.

A study in 1979–1986 of a coastal area in the Kattegat and Skagerrak seas, Denmark and Sweden (*1*) reported that after hunting was prohibited, the abundance of harbour seals *Phoca vitulina* increased over seven years. Results are not based on assessments of statistical significance. The total abundance of harbour seals in the area was higher nine years after hunting was prohibited (maximum 5,608 seals) than two years after (maximum 2,345 seals). Overall, abundance was estimated to increase by 13% per year during seven years after hunting was prohibited. Hunting of harbour seals was prohibited in 1967 in Swedish waters and in 1977 in Danish waters. Aerial surveys were carried out across the area in each of seven years in 1979–1986. Each year, all haul-out sites in the area (number not reported) were photographed from the air at the end of August using the same methods, equipment, and surveyors. Seal counts were obtained from aerial photographs.

A review in 1971–1990 in the North Atlantic, North Pacific and Southern Hemisphere (*2*) found that after legislation to prohibit hunting was introduced, significant increase rates were recorded for 10 of 12 baleen whale (Mysticeti) populations of five species or species groups. Estimated increase rates during 7–21 years after hunting was prohibited were significant for four right whale *Eubalaena* spp. populations (0.07–0.13), three humpback whale *Megaptera novaeangliae* populations (0.09–0.14), one bowhead whale *Balaena mysticetus* population (0.03), one gray whale *Eschrichtius robustus* population (0.03), and one blue whale *Balaenoptera musculus* population (0.05). Increase rates for the two other monitored populations (one right whale, one humpback whale) were not significant. However, the authors note that more data may have been needed. Four legal agreements were put in place between 1935 and 1968 to protect 44 depleted baleen whale populations from exploitation. Twelve populations were monitored for 7–21 years between 1971 and 1990 using shore, aerial or shipboard counts or mark and recapture methods. The other 32 populations were not monitored.

A before-and-after study in 1962 and 1984–1992 of a pelagic area in the South Pacific Ocean, Australia (*3*) reported that after legislation to prohibit hunting was introduced, sightings of migrating humpback whales *Megaptera novaeangliae* increased over 30 years. Results are not based on assessments of statistical significance. The average number of sightings of migrating humpback whales was higher 30 years after commercial whaling was prohibited (14.4 sightings/10 h) than during the final year of whaling (8.5 sightings/10 h). Daily sightings during the peak four-week migration period were estimated to increase by an average of 12% each year from 22 to 30 years after whaling was prohibited. Legal protection from commercial whaling began in 1963. Whale sightings were collated from multiple studies (see original paper for details). Migrating whales were observed from a headland during daylight hours during at least 4 days/week in June–August in 1984–1992. Data for the final year of whaling were collected by whaling boats assisted by aircraft in 1962.

A before-and-after study in 1984–2007 in a pelagic area in the North Atlantic Ocean, Greenland (*4*) found that after legislation to prohibit hunting was introduced, the abundance of humpback whales *Megaptera novaeangliae* increased over 22 years. The estimated abundance of humpback whales in summer feeding grounds was higher 22 years after hunting was fully prohibited (1,020 whales) than before (99–271 whales). Overall, abundance was estimated to increase by 9.4% per year from 1984 to 2007. Commercial whaling of humpback whales was prohibited in 1955, although low level harvesting continued until full protection was put in place in 1985. Aerial transect surveys were conducted in July–September during one year before full legal protection (1984) and during seven years after (1985–1989, 1993, 2005 and 2007). Aircraft flew over the area at 600–750 feet and 3–4 observers recorded sightings of humpback whales along 41–103 transects/year.

A before-and-after study in 1968–1978 and 2009 of a pelagic area in the Southern Ocean, Western Australia (*5*) found that 31 years after legislation to prohibit hunting was introduced, the number of mature male sperm whales *Physeter macrocephalus* in the area did not differ significantly compared to before protection. The average number of mature male sperm whales observed in the area did not differ significantly before (6–13 whales/survey) or 31 years after hunting was prohibited (2–3 whales/survey). However, the authors state that other factors may have limited population recovery (e.g. entanglement in fishing nets, chemical and noise pollution). The sperm whale population had declined by 74% in 1955–1978 due to commercial whaling. Full legal protection was put in place after 1978 to prohibit whaling. Data for before protection were collected by aircraft used to assist in hunting whales in 1968–1978. Aircraft flew over the area at 1,500 feet and observers recorded mature male sperm whales (>11 m long) during 42–73 surveys/year. The same area was surveyed in September–December 2009 (21 surveys) using similar methods and a standard grid of 12 transects to provide comparable data 31 years after protection was put in place.

(1) Heide-Jørgensen M.P. & Harkonen T.J. (1988) Rebuilding seal stocks in the Kattegat-Skagerrak. *Marine Mammal Science*, 4, 231–246.

(2) Best P. (1993) Increase rates in severely depleted stocks of baleen whales. *ICES Journal of Marine Science*, 50, 169–186.

(3) Paterson R., Paterson P. & Cato D.H. (1994) The status of humpback whales *Megaptera novaeangliae* in east Australia thirty years after whaling. *Biological Conservation*, 70, 135–142.

(4) Heide-Jørgensen M.P., Laidre K.L., Hansen R.G., Burt M.L., Simon M., Borchers D.L., Hansen J., Harding K., Rasmussen M. & Dietz R. (2012) Rate of increase and current abundance of humpback whales in West Greenland. *Journal of Cetacean Research and Management*, 12, 1–14.

(5) Carroll G., Hedley S., Bannister J., Ensor P. & Harcourt R. (2014) No evidence for recovery in the population of sperm whale bulls off Western Australia, 30 years post-whaling. *Endangered Species Research*, 24, 33–43.

6.4. Enforce legislation to prevent the trafficking and trade of marine and freshwater mammal products

- We found no studies that evaluated the effects of enforcing legislation to prevent the trafficking and trade of marine and freshwater mammal products.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammal species threatened by trade are protected under the CITES agreement (Convention on International Trade in Endangered Species of Wild Fauna and Flora), which aims to regulate the international trade of endangered species. However, it is the responsibility of each participating country to adopt its own national legislation to ensure the regulations are implemented, and in some countries illegal trade continues (e.g. Lee & Nijman 2015).

Lee P.B. & Nijman V. (2015) Trade in dugong parts in Southern Bali. *Journal of the Marine Biological Association of the United Kingdom,* 95, 1717–1721.

6.5. Restrict capture of marine and freshwater mammals for research or aquariums and zoos

- We found no studies that evaluated the effects of restricting capture of marine and freshwater mammals for research or aquariums and zoos.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

There are both ethical and conservation concerns related to the capture of live marine and freshwater mammals for research or aquariums and zoos, and stricter regulations may be required (Rose *et al.* 2009).

Rose N.A., Parsons E.C.M. & Farinato R. (2009) *The case against marine mammals in captivity, 4th edition.* The Humane Society of the United States and the World Society for the Protection of Animals.

6.6. Introduce alternative treatments to reduce the use of marine and freshwater mammals in traditional medicine

- We found no studies that evaluated the effects of introducing alternative treatments to reduce the use of marine and freshwater mammals in traditional medicine.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may be hunted for their perceived medicinal properties (Alves *et al.* 2012). Introducing alternative treatments and dispelling myths about the health benefits of using marine and freshwater mammal products as medicine may reduce hunting pressure.

Alves R.R.N., Souto W.M.S., Oliveira R.E.M.C.C., Barboza R.R.D. & Rosa I.L. (2013) Aquatic mammals used in traditional folk medicine: a global analysis. Pages 241–261 in*:* Alves R.R.N. & Rosa I.L. (eds.) *Animals in traditional folk medicine: implications for conservation.* Springer, Berlin.

6.7. Introduce alternative food sources to replace marine and freshwater mammal meat

- We found no studies that evaluated the effects of introducing alternative food sources to replace marine and freshwater mammal meat.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

The consumption of marine and freshwater mammal meat may provide a source of protein, particularly in areas of poverty and food insecurity (Robards & Reeves 2011). Introducing other food sources to replace marine and freshwater mammal meat may reduce hunting pressure.

Robards M.D. & Reeves R.R. (2011) The global extent and character of marine mammal consumption by humans: 1970–2009. *Biological Conservation,* 144, 2770–2786.

6.8. Introduce alternative income sources to reduce marine and freshwater mammal exploitation and trade

- We found no studies that evaluated the effects of introducing alternative income sources to reduce marine and freshwater mammal exploitation and trade.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Introducing alternative income sources to replace the trade of marine and freshwater mammals may reduce hunting pressure. This could include cultivating agricultural products or rearing domestic animals. Eco-tourism may also provide an alternative source of income, although careful implementation may be required.

6.9. Introduce alternative sources of bait to replace the use of marine and freshwater mammals

- We found no studies that evaluated the effects of introducing alternative sources of bait to replace the use of marine and freshwater mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

The practice of using marine and freshwater mammals as bait is widespread and affects a range of species (Mintzer *et al.* 2018). Introducing alternative sources of bait (that do not negatively impact other species) may reduce hunting pressure. For example, fish scraps and oil and bovine viscera were found to be effective alternatives to dolphin products for attracting fish (Sinha 2002, Beltrão *et al.* 2017).

Beltrão H., Braga T. & Benzaken Z. (2017) Alternative bait usage during the piracatinga (*Calophysus macropterus*) fishery in the Manacapuru region, located at the lower Solimões-Amazonas River, Amazon basin, Brazil. *Pan-American Journal of Aquatic Sciences,* 12, 194–205.

Mintzer V.J., Diniz K. & Frazer T.K. (2018) The use of aquatic mammals for bait in global fisheries. *Frontiers in Marine Science,* 5.

Sinha R. (2002) An alternative to dolphin oil as a fish attractant in the Ganges River system: conservation of the Ganges River dolphin. *Biological Conservation,* 107, 253–257.

6.10. Inform local communities and fishers about the negative impacts of hunting to reduce the killing of marine and freshwater mammals

- We found no studies that evaluated the effects of informing local communities and fishers about the negative impacts of hunting to reduce the killing of marine and freshwater mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Education programmes that emphasize the negative impacts of killing marine and freshwater mammals may reduce hunting pressure. However, there are many factors that influence human behaviour, and it may be necessary to collaborate with social scientists to design appropriate education programs.

See also '*Educate local communities and fishers on mammal protection laws to reduce killing of marine and freshwater mammals*'.

6.11. Educate local communities and fishers on mammal protection laws to reduce killing of marine and freshwater mammals

- We found no studies that evaluated the effects of educating local communities and fishers on mammal protection laws to reduce killing of marine and freshwater mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Many countries have legislation in place to protect marine and freshwater mammals. However, a lack of public awareness of the relevant laws may contribute to illegal activities, such as hunting and killing of protected mammals. Educating local communities and fishers on mammal protection laws may help to reduce killing of marine and freshwater mammals.

See also '*Inform local communities and fishers about the negative impacts of hunting to reduce the killing of marine and freshwater mammals*'.

6.12. Introduce and enforce regulations for sustainable hunting of marine and freshwater mammals for traditional subsistence and handicrafts

- We found no studies that evaluated the effects of introducing regulations for sustainable hunting of marine and freshwater mammals for traditional subsistence and handicrafts.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves introducing regulations for the sustainable hunting of marine and freshwater mammals for traditional subsistence and handicrafts by indigenous people. This may include monitoring harvests and setting limits on the number of animals that may be removed within a given period. Enforcement may be required if compliance is low.

Reduce unwanted catch ('bycatch) of mammals and improve survival of released or escaped mammals

Spatial and temporal management

6.13. Establish 'move-on rules' for fishing vessels if mammals are encountered

- **One study** evaluated the effects on marine mammals of establishing move-on rules for fishing vessels if mammals are encountered. The study was in the Great Australian Bight[1] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** One before-and-after study in the Great Australian Bight[1] found that introducing measures to delay or relocate fishing if dolphins were encountered, along with releasing trapped dolphins, resulted in fewer short-beaked common dolphins being encircled and killed.

BEHAVIOUR (0 STUDIES)

Background

'Move-on rules' require fishing vessels to move away from an area to alternative fishing grounds if marine or freshwater mammals are encountered. The aim is to prevent injury or death resulting from the entanglement or unwanted catch ('bycatch') of mammals in fishing gear. The rules may involve moving to an alternative area located a minimum distance away. However, the efficacy of this method depends on mammals being detected, which may be difficult during the night or periods of low visibility. Passive listening devices may be used to aid detection, see '*Use passive listening devices to detect mammals and prompt fishing vessels to move away*'.

A before-and-after study in 2004–2006 of a pelagic area in the Great Australian Bight, Australia (*1*) found that introducing measures to delay or relocate fishing if dolphins were encountered, along with releasing dolphins trapped in nets, resulted in fewer short-beaked common dolphins *Delphinus delphis* being encircled and killed. The study did not distinguish between the effects of delaying/relocating fishing and releasing dolphins. Encirclement and mortality rates of dolphins in purse-seine nets were lower after the measures were put in place (0.2 dolphins encircled/net; 0.01 dolphins killed/net) than before (1.8 dolphins encircled/net; 0.4 dolphins killed/net). The measures were introduced to a sardine *Sardinops sagax* fishery in September 2005. At least one crew member/vessel was required to observe for dolphins. Fishing was delayed or relocated if dolphins were encountered. Release procedures included opening the net or a dolphin gate within the net, using weights to submerge the float line, physical removal of dolphins or stopping fishing. An independent observer recorded dolphin encirclements and deaths during 49 fishing events by eight vessels in November–June 2004/2005 (before the measures) and 89 fishing events by 12 vessels in November–June 2005/2006 (after).

(1) Hamer D.J., Ward T.M. & McGarvey R. (2008) Measurement, management and mitigation of operational interactions between the South Australian Sardine Fishery and short-beaked common dolphins (*Delphinus delphis*). *Biological Conservation*, 141, 2865–2878.

6.14. Use passive listening devices to detect mammals and prompt fishing vessels to move away

- We found no studies that evaluated the effects of using passive listening devices to detect mammals and prompt fishing vessels to move away on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Passive listening devices, such as hydrophones, may be used to detect marine and freshwater mammals and prompt fishing vessels to move away. This is likely to increase the chance of mammals being detected within an area, especially during the night or periods of low visibility.

See also '*Establish 'move-on rules' for fishing vessels if mammals are encountered*'.

6.15. Deploy fishing gear at times when mammals are less active

- We found no studies that evaluated the effects of deploying fishing gear at times when mammals are less active on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Deploying fishing gear during times when marine and freshwater mammals are less active may reduce the risk of entanglement and unwanted catch ('bycatch') of mammals. However, this intervention would not be feasible for fisheries where both mammals and the target species actively feed at the same time.

6.16. Deploy fishing gear at different depths

- **One study** evaluated the effects on marine mammals of deploying fishing gear at different depths. The study was in the Arafura Sea[1] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Reduction in entanglements/unwanted catch (1 study):** One controlled study in the Arafura Sea[1] found that fishing nets deployed 4.5 m below the water surface had fewer entanglements of dolphins than surface nets.

Background

Deploying fishing gear at different depths may reduce interactions with marine and freshwater mammals, and subsequent entanglements and unwanted catch ('bycatch') of mammals. However, the feasibility of this intervention will depend on the type of fishery and the ecology of the target species.

A controlled study in 1986 of pelagic sites in the Arafura Sea, northern Australia (*1*) found that fishing nets deployed 4.5 m below the water surface had fewer entanglements of dolphins than surface nets. Entanglement rates of dolphins (including common bottlenose dolphins *Tursiops truncatus* and spinner dolphins *Stenella longirostris*) were lower in nets deployed 4.5 m below the water surface (0.2 dolphins/deployment) than in nets deployed at the water surface (0.4 dolphins/deployment). For target species, average catch rates were lower for mackerel in nets deployed 4.5 m below the surface (0.9 fish/deployment) than in surface nets (4 fish/deployment), but did not differ significantly for sharks, tuna or billfish (see original paper for data). A commercial vessel carried out 37 deployments of two fishing nets: one deployed at a depth of 4.5 m; one deployed at the water surface. Both nets were 4.9 km long x 15 m deep with a mesh size of 140–150 mm.

Dolphin entanglements and target fish catches were recorded for each of the 37 deployments in February–March 1986.

(1) Hembree D. & Harwood M.B. (1987) *Pelagic gillnet modification trials in northern Australian seas*. Reports of the International Whaling Commission 37, 369–373.

Catch, effort and capacity reduction

6.17. Limit the number of fishing vessels or fishing days in an area

- We found no studies that evaluated the effects of limiting the number of fishing vessels or fishing days in an area on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Limiting the number of fishing vessels or days in which an area can be fished may reduce the risk of entanglements and unwanted catch ('bycatch') of marine and freshwater mammals. This may involve the rotation of fishing areas. Careful planning may be required to ensure that fishing effort is not redirected to other areas with a high mammal density.

6.18. Limit the length of fishing gear in an area

- We found no studies that evaluated the effects of limiting the length of fishing gear in an area on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Limiting the length of fishing gear, such as ropes, lines, or nets, in an area may reduce the risk of entanglements and unwanted catch ('bycatch') of marine and freshwater mammals. This could involve using shorter ropes or lines, or using multiple pots, traps or nets on each line.

6.19. Reduce duration of time fishing gear is in the water

- We found no studies that evaluated the effects of reducing the duration of time fishing gear is in the water on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Reducing the duration of time that fishing gear is in the water ('soak time') may reduce the risk of entanglements and unwanted catch ('bycatch') of marine and freshwater mammals. This may include reducing the amount of time that gear is used for active fishing, as well as avoiding leaving static gear in place when not being fished, e.g. to store gear or reserve a fishing patch.

Modifications to fishing gear and practices

6.20. Use weakened fishing gear

- We found no studies that evaluated the effects of using weakened fishing gear on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Using weakened fishing gear may allow entangled or hooked marine and freshwater mammals to release themselves more easily. This may involve using nets and ropes with a reduced breaking strength (e.g. Knowlton *et al.* 2016), or weak links between fishing lines, buoys, or net panels. The bending strength of hooks may be decreased to a level that retains the target catch but allows caught mammals to release themselves by straightening the hook (sometimes referred to as 'weak hooks'; Bayse & Kerstetter 2010, Bigelow *et al.* 2012). However, mammals may still be injured by weakened gear, and it is important to assess the survival of released animals (McLellan *et al.* 2014). This intervention may also increase the amount of debris and derelict fishing gear in marine and freshwater environments.

Bayse S.M. & Kerstetter D.W. (2010) Assessing bycatch reduction potential of variable strength hooks for pilot whales in a western North Atlantic pelagic longline fishery. *Journal of the North Carolina Academy of Science,* 126, 6–14.

Bigelow K.A., Kerstetter D.W., Dancho M.G. & Marchetti J.A. (2012) Catch rates with variable strength circle hooks in the Hawaii-based tuna longline fishery. *Bulletin of Marine Science,* 88, 425–447.

Knowlton A.R., Robbins J., Landry S., McKenna H.A., Kraus S.D. & Werner T.B. (2016) Effects of fishing rope strength on the severity of large whale entanglements. *Conservation Biology,* 30, 318–328.

McLellan W.A., Arthur L.H., Mallette S.D., Thornton S.W., McAlarney R.J., Read A.J. & Pabst D.A. (2014) Longline hook testing in the mouths of pelagic odontocetes. *ICES Journal of Marine Science,* 72, 1706–1713.

6.21. Retain buoys and lines at the sea floor or river bed when not hauling

- We found no studies that evaluated the effects of retaining buoys and lines at the sea floor or river bed when not hauling on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Retaining buoys and lines at the sea floor or river bed when not hauling may reduce the risk of marine and freshwater mammals becoming entangled in vertical lines within the water column. Buoy lines may be kept coiled on the fishing pot or trap until they are remotely released to the surface by fishers for hauling (e.g. Partan & Ball 2016). Automatic or timed-release systems may also be used.

Partan J. & Ball K. (2016) *Rope-less fishing technology development*. Project 5 Final Report, Consortium for Wildlife Bycatch Reduction.

6.22. Use sinking lines instead of floating lines

- We found no studies that evaluated the effects of using sinking lines instead of floating lines on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Using sinking or negatively buoyant lines (e.g. between pots or traps) that lie closer to the sea floor or river bed instead of floating in the water column may reduce the risk of marine and freshwater mammals becoming entangled.

6.23. Use bindings to keep trawl nets closed until they have sunk below the water surface

- We found no studies that evaluated the effects of using bindings to keep trawl nets closed until they have sunk below the water surface on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Bindings may be used to keep trawl nets closed until they have sunk below the water surface. This may reduce the risk of marine and freshwater mammals becoming entangled.

6.24. Use stiffened materials or increase tension of fishing gear

- **One study** evaluated the effects on marine mammals of using stiffened materials in fishing nets. The study was in the South Atlantic Ocean[1] (Argentina).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Reduction in entanglements/unwanted catch (1 study):** One controlled study in the South Atlantic Ocean[1] found that using stiffened fishing nets did not reduce the number of Franciscana dolphin entanglements.

Background

Using stiffened materials or increasing the tension of fishing nets, ropes or lines may reduce the risk of marine and freshwater mammals becoming entangled. However, tensioned vertical ropes may cause injuries to mammals that come into contact with them (Baldwin *et al.* 2012).

For another intervention that may involve stiffened gear, see '*Use acoustically reflective fishing gear materials*'.

Baldwin K., Byrne J. & Brickett B. (2012) *Taut vertical line and North Atlantic right whale flipper interaction: experimental observations*. University of New Hampshire and Blue Water Concepts.

A controlled study in 2009–2010 of a pelagic area in the South Atlantic Ocean, off the coast of Buenos Aires, Argentina (*1*) found that using stiffened fishing nets did not reduce the number of Franciscana dolphin *Pontoporia blainvillei* entanglements compared to conventional nets. Entanglement rates of Franciscana dolphins did not differ between stiffened and conventional nets (both 0.08 dolphins/haul). Catch rates of the three main target fish species also did not differ between net types (whitemouth croaker *Micropogonias furnieri*, striped weakfish *Cynoscion guatucupa*, king weakfish *Macrodon ancylodon*; see original paper for data). Monofilament nylon gill nets of two types (nets made from a stiff grade of nylon and conventional nets; number of each not reported) were deployed in 150 locations by a fishery. The nets were sampled 1–19 times resulting in 273 hauls of stiffened nets and 279 hauls of conventional nets. An observer on board each of three fishing vessels retrieving the nets recorded the number of entangled dolphins within each of 552 hauls between October 2009 and March 2010.

(1) Bordino P., Mackay A.I., Werner T.B., Northridge S.P. & Read A.J. (2013) Franciscana bycatch is not reduced by acoustically reflective or physically stiffened gillnets. *Endangered Species Research*, 21, 1–12.

6.25. Use a smaller mesh size for fishing nets

- We found no studies that evaluated the effects of using a smaller mesh size for fishing nets on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Using a smaller mesh size for fishing nets may reduce the risk of marine and freshwater mammals becoming entangled (Northridge *et al.* 2017). However, the feasibility of this intervention will depend on the size of the target catch species. There may also be issues with implementation where minimum mesh size regulations are in place to reduce unwanted catch of juvenile animals and/or smaller species.

Northridge S., Coram A., Kingston A. & Crawford R. (2017) Disentangling the causes of protected-species bycatch in gillnet fisheries. *Conservation Biology,* 31, 686–695.

6.26. Use a larger mesh size for fishing trap-nets

- **One study** evaluated the effects on freshwater mammals of using a larger mesh size for fishing trap-nets. The study was in the River Indal[1] (Sweden).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One controlled study in the River Indal[1] found that a fishing trap-net with a larger mesh size in the first two sections had fewer grey seals feeding around it and less damage caused by seals.

Background

Trap-nets are stationary nets that have a series of net chambers, which fish can enter but not easily escape from. It has been suggested that using a larger mesh size for trap-nets may discourage marine and freshwater mammals, such as seals, from feeding on trapped fish, which may reduce the risk of entanglement as well as human-wildlife conflict. Fish chased by mammals could escape through a larger mesh and would be less likely to become entangled in the side panels of the trap-net. This may make trap-nets less attractive to feeding mammals.

A controlled study in 2000–2001 at the mouth of the River Indal, northern Sweden (*1*) found that a fishing trap-net with a larger mesh size in the first two sections had fewer grey seals *Halichoerus grypus* feeding around it and less damage by seals than a conventional trap-net. Fewer seals were observed surfacing (average 0.2 seals/h) and feeding on fish (0 seals) around the modified trap-net than a conventional trap-net (surfacing: average 1.6–4.1 seals/h, feeding: 0.1–0.3 seals/h). The modified trap-net had fewer holes caused by seals (total 6) than the conventional trap-net (total 269), although statistical significance was not assessed. Catches of target salmon *Salmo salar* and trout *Salmo trutta* were higher in the modified trap-net during one trial, and similar in modified and conventional trap-nets during two trials (see original paper for data). A modified and conventional trap-net were alternated between two fishing sites on opposite sides of a river mouth during three trials (each lasting 15–25 days). Both had a 100-m leader net with 3–4 funnel-shaped sections leading to a 'seal-safe' fish chamber. The first two sections had mesh sizes of 400 mm (modified trap-net) or 200 mm (conventional trap-net). Target fish catches and holes were recorded every other day during each of the three trials in June–August 2000. Seals were observed daily from the shore and with a video camera above each trap-net during two of the three trials in July–August 2001.

(1) Lunneryd S.G., Fjälling A. & Westerberg H. (2003) A large-mesh salmon trap: a way of mitigating seal impact on a coastal fishery. *ICES Journal of Marine Science*, 60, 1194–1199.

6.27. Limit size of trawl net openings

- We found no studies that evaluated the effects of limiting the size of trawl net openings on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Limiting the size of trawl net openings may reduce the risk of marine and freshwater mammals entering the net and becoming trapped or entangled. However, any mammals that do enter the net may be less likely to find their way out through a smaller opening.

6.28. Increase visual detectability of fishing gear for mammals

- **Two studies** evaluated the effects on marine mammals of increasing the visual detectability of fishing gear for mammals. One study was in the Gulf of St. Lawrence[1] (Canada) and one was in Cape Cod Bay[2] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (2 STUDIES)

- **Behaviour change (2 studies):** One study in the Gulf of St. Lawrence[1] found that minke whales approached white ropes more slowly and changed their bearing more when approaching black ropes compared to ropes of other colours. One study in Cape Cod Bay[2] found that simulated ropes painted red or orange were detected by North Atlantic right whales at greater distances than green but not black ropes, and more whales collided with green ropes than the other three rope colours.

Background

Increasing the visual detectability of fishing gear to marine and freshwater mammals may allow mammals to detect and avoid gear reducing the risk of entanglements. This intervention may involve changing the colour, pattern, or luminosity of gear materials, or attaching markers or LED lights to gear.

A study in 2010 of a pelagic area in the Gulf of St. Lawrence, Canada (*1*) reported that white ropes were approached more slowly by minke whales *Balaenoptera acutorostrata* than ropes of other colours, and whales changed their bearing more when approaching black ropes. Results are not based on assessments of statistical significance. Minke whales had greater reductions in swimming speed when approaching white ropes (average -1 m/s) than black, yellow, orange, green or blue ropes (combined average -0.5 m/s). Minke whales changed their bearing more when approaching black ropes (average 91°) than white, yellow, orange, green or blue ropes (combined average 55°). In June–August 2010, experimental trials were carried out with white, black, yellow, orange, green and blue polypropylene ropes (1.5 cm diameter) suspended in water 8–14 m deep. During each trial, 5–10 ropes of the same colour were spaced 15 m apart perpendicular to the shore. Ropes were attached to a buoy and moored to the sea floor. Observers in a boat anchored 100 m away recorded the speed and bearing of 7–12 individual whales passing the ropes of each colour.

A study in 2013 at a pelagic site in Cape Cod Bay, USA (*2*) found that simulated ropes painted red or orange were detected by North Atlantic right whales *Eubalaena glacialis* at greater distances than ropes painted green but not black, and more whales collided with green ropes than the other three rope colours. Changes in the behaviour of right whales approaching the ropes occurred at greater average distances from red ropes (3.9 m) and orange ropes (4.1 m) than green ropes (1.9 m). The difference was not significant between black ropes (3 m) and the other three rope colours. More whales collided with green ropes (total seven whales) than the other three rope colours (total 2–3 whales), although the difference was not tested for statistical significance. A row of four simulated vertical ropes (spaced 25 m apart) were placed 75–100 m in front of whales travelling near the water surface. Ropes consisted of 10-foot sections of rigid PVC pipe (1-inch diameter) painted red, orange, green or black and suspended between a weight and a buoy. Whales were observed from a stationary boat. Changes in the behaviour of whales (including respiration, mouth closures, submergence times, and turning angles) within 10 m of the ropes were recorded by video 52 times during nine days in 2013. Distances were measured with a laser range finder.

(1) Kot B.W., Sears R., Anis A., Nowacek D.P., Gedamke J. & Marshall C.D. (2012) Behavioral responses of minke whales (*Balaenoptera acutorostrata*) to experimental fishing gear in a coastal environment. *Journal of Experimental Marine Biology and Ecology*, 413, 13-20.
(2) Kraus S., Fasick J., Werner T. & McCarron P. (2014) *Enhancing the visibility of fishing ropes to reduce right whale entanglements*. Report to the Bycatch Reduction Engineering Program (BREP), National Marine Fisheries Service, Office of Sustainable Fisheries, 67–75.

6.29. Attach acoustically reflective objects to fishing gear

- **Two studies** evaluated the effects on marine mammals of attaching acoustically reflective objects to fishing gear. One study was in the Timor Sea and Arafura Sea[1] (Australia) and one was in the Gulf of Alaska[2] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Reduction in entanglements/unwanted catch (1 study):** One controlled study in the Timor Sea and Arafura Sea[1] found that attaching metallic bead chains to fishing nets did not reduce the number of dolphin entanglements.
- **Human-wildlife conflict (1 study):** One controlled study in the Gulf of Alaska[2] found that attaching acrylic beads next to fishing hooks did not reduce predation on fish catches by sperm whales.

Background

Acoustically reflective objects, such as chains or beads (sometimes referred to as 'passive acoustic deterrents'), may be attached to fishing gear to deter marine and freshwater mammals that use echolocation. This may reduce the risk of entanglement or hooking of mammals, as well as human-wildlife conflict resulting from mammal predation on fish catches.

A replicated, controlled study in 1984–1985 of two pelagic areas in the Timor Sea and Arafura Sea, Australia (*1*) found that attaching metallic bead chains to fishing nets did not reduce dolphin entanglements. In both years of the study, dolphin entanglement rates did not differ significantly between nets with bead chains (rates not reported; total entanglements: 1984 = 3 dolphins, 1985 = 29 dolphins) and conventional nets (total entanglements: 1984 = 21 dolphins, 1985 = 17 dolphins). Three dolphin species were entangled: common bottlenose *Tursiops truncatus*, spinner *Stenella longirostris* and pantropical spotted dolphins *Stenella attenuata* (see original paper for data). In 1984, a commercial vessel fished two types of gill net: one with 4-mm bead chains (8 or 16-m vertical chains attached at 8 m intervals; fished for 450 h); and one conventional net (fished for 354 h). Both net types (approximately 5 km long x 16 m deep, mesh size 150 mm) were deployed 3 m below the water surface. In 1985, a commercial vessel fished gill nets (10.5 km long; 39 deployments in total) with alternating 1-km sections with and without 4-mm bead chains (woven into the net in diagonal rows). Nets (15 m deep, mesh size 140–150 mm) were deployed at the water surface. Fishers recorded dolphins entangled in the nets in September–October 1984 and September–November 1985.

A controlled study in 2012 in a pelagic area in the Gulf of Alaska, USA (*2*) found that attaching acrylic beads next to fishing hooks did not reduce sperm whale *Physeter macrocephalus* predation on catches of target sablefish *Anoplopoma fimbria*. Catch rates of sablefish when sperm whales were present did not differ significantly between fishing gear with and without beads attached next to hooks (data not reported). The number of whale vocalizations associated with predation events (rapid clicks followed by a pause) also did not differ significantly between fishing gear with and without beads (data not reported). In March–August 2012, four commercial fishing vessels deployed 24 'long line' fishing lines each divided into five experimental units. Each unit (comprising 4 x 183 m sections of gear with 168 hooks on each) was randomly assigned as a treatment (25 mm acrylic sphere 'beads' attached next to hooks) or control (no beads). An observer on board the fishing vessels recorded sablefish catches during hauls of 32 units of fishing gear in which whales were present.

Acoustic recorders attached to each of the 24 fishing lines recorded sperm whale vocalizations.

(1) Hembree D. & Harwood M.B. (1987) *Pelagic gillnet modification trials in northern Australian seas*. Reports of the International Whaling Commission 37, 369–373.
(2) O'Connell V., Straley J., Liddle J., Wild L., Behnken L., Falvey D. & Thode A. (2015) Testing a passive deterrent on longlines to reduce sperm whale depredation in the Gulf of Alaska. *ICES Journal of Marine Science*, 72, 1667–1672.

6.30. Use acoustically reflective fishing gear materials

- **Five studies** evaluated the effects on marine mammals of using acoustically reflective fishing gear materials. Two studies were in the Bay of Fundy[1,4] (Canada) and one study was in each of the Fortune Channel[2] (Canada), the North Sea[3] (Denmark) and the South Atlantic Ocean[5] (Argentina).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (2 STUDIES)

- **Behaviour change (2 studies):** One controlled study in the Fortune Channel[2] found that harbour porpoises approached nets made from acoustically reflective material (barium sulfate) and conventional nets to similar distances and for similar durations, but porpoises used fewer echolocation clicks at barium sulfate nets. One controlled study in the Bay of Fundy[1] found that harbour porpoise echolocation activity was similar at barium sulfate and conventional nets.

OTHER (3 STUDIES)

- **Reduction in entanglements/unwanted catch (3 studies):** Two of three controlled studies (including two replicated studies) in the North Sea[3], the Bay of Fundy[4] and the South Atlantic Ocean[5] found that fishing nets made from acoustically reflective materials (iron-oxide[3] or barium sulfate[4]) had fewer entanglements of harbour porpoises than conventional fishing nets. The other study found that nets made from barium sulfate[5] did not reduce the number of dolphin entanglements.

Background

Using acoustically reflective fishing gear materials, such as nylon infused with chemicals or metal oxides, may increase the detectability of gear for marine and freshwater mammals that use echolocation. This may allow mammals to avoid fishing gear reducing the risk of entanglements. However, it should be noted that using gear materials that are acoustically reflective can also change the density, stiffness and/or colour of the gear, making it difficult to determine which mechanism is causing a deterrent effect (Larsen *et al.* 2007, Mooney *et al.* 2007).

Larsen F., Eigaard O.R. & Tougaard J. (2007) Reduction of harbour porpoise (*Phocoena phocoena*) bycatch by iron-oxide gillnets. *Fisheries Research,* 85, 270–278.
Mooney T.A., Au W.W.L., Nachtigall P.E. & Trippel E.A. (2007) Acoustic and stiffness properties of gillnets as they relate to small cetacean bycatch. *ICES Journal of Marine Science,* 64, 1324–1332.

A controlled study in 2000 of a pelagic area in the Bay of Fundy, Canada (*1*) found that fishing nets made from acoustically reflective materials (barium sulfate) had similar harbour porpoise *Phocoena phocoena* echolocation activity around them compared to conventional nets. The average occurrence and rate of porpoise echolocation clicks were similar at barium sulfate nets (18–54 intervals with clicks/h; 32–52 clicks/h) and conventional nets (17–57 intervals with clicks/h; 18–54 clicks/h). Average catches of target groundfish species did not differ significantly between barium sulfate nets (0.41 fish/h) and conventional nets (0.38 fish/h). In July–August 2000, nine barium sulfate and 14 conventional gill net strings were deployed across a fishing area (same study site and nets as *4*). All strings (comprising 3 x 100 m nets, 15 cm stretched monofilament mesh) were deployed on the ocean bottom at depths of 100–130 m for 24–72 h. Four acoustic detectors attached to each of the 23 net strings continuously recorded porpoise echolocation activity at 10 second intervals for a total of 225 h on barium sulfate nets and 366 h on conventional nets.

A controlled study in 2003 in a fjord in the Fortune Channel, Vancouver Island, Canada (*2*) found that fishing nets made from an acoustically reflective material (barium sulfate) were approached to similar distances and for similar durations by harbour porpoises *Phocoena phocoena* compared to conventional nets, but porpoises used fewer echolocation clicks at barium sulfate nets. Harbour porpoises approached to similar distances and spent similar amounts of time within 50 m of barium sulfate nets (average 18 m; 24 seconds) and conventional nets (average 18 m; 20 seconds). At barium sulfate nets, echolocating porpoises used fewer clicks (average 23 clicks/interaction) and had longer click intervals (average 51 ms) than at conventional nets (average 56 clicks/interaction; click interval: 45 ms). Two surface gill nets (one barium sulfate, one conventional; both 45 x 9 m, 0.62 mm diameter mesh) were deployed in August 2003. Barium sulfate nets were a mix of high-density barium sulfate and nylon dyed green. Conventional nets were semi-transparent blue nylon. A theodolite was used to track porpoises during six deployments (14 h over four days) with the barium sulfate net and nine deployments (26.5 h over eight days) with the conventional net. A click detector suspended in the middle of each net at a depth of 4.5 m recorded echolocation activity.

A replicated, controlled study in 2000 of six pelagic sites in the North Sea, Denmark (*3*) found that fishing nets made from an acoustically reflective material (iron-oxide) had fewer entanglements of harbour porpoises *Phocoena phocoena* than conventional nets. No porpoises were found in entangled in iron-oxide nets, whereas a total of eight porpoises (average 0.1 porpoises/km/day) were entangled in conventional nets. Average catch rates of target cod *Gadus morhua* were lower in iron-oxide nets (6–15 fish/km/day) than conventional nets (8–32 fish/km/day). Each of six sites was fished for three days with 4–8 strings (50 x 60 m gill nets) of each of two net types: high-density iron-oxide nets and conventional nylon nets. The authors did not find a significant difference in acoustic target strengths between the two net types (see original paper for details) and suggest that other factors (e.g. net colour, stiffness, mechanics) may have reduced porpoise entanglements. An observer on board a chartered commercial fishing vessel recorded the number of entangled porpoises and fish catches as the nets were hauled in September–October 2000.

A controlled study in 1998 and 2000–2001 of a pelagic area in the Bay of Fundy, Canada (*4*) found that fishing nets made from an acoustically reflective material (barium sulfate) had fewer harbour porpoise *Phocoena phocoena* entanglements than conventional nets. Entanglement rates of harbour porpoises were lower in barium sulfate nets than in conventional nets (data reported as statistical model results). For target fish species, catch rates of haddock *Melanogrammus aeglefinus* were lower in barium sulphate nets than conventional nets, but catches of Atlantic cod *Gadus morhua*, pollock *Pollachius virens* and spiny dog fish *Squalus acanthias* were similar (see original paper for data). In July–September 1998, 2000 and 2001, gill net fishery vessels deployed a total of 590 strings of barium sulfate nets and 815 strings of conventional nets. Barium sulfate nets were made from nylon containing particles of barium sulfate (3% volume, 10% weight) and dyed pale blue. Conventional nets were transparent nylon. All nets (300 m long, 4 m deep, stretched mesh size of 15 cm) were deployed at depths of 60 m for 24 h (same study site and nets as *1*). Onboard observers or fishers recorded porpoise entanglements and fish catches as the nets were hauled.

A controlled study in 2009–2010 of two pelagic areas in the South Atlantic Ocean, off the coast of Buenos Aires, Argentina (*5*) found that fishing nets made from an acoustically reflective material (barium sulfate) had a similar number of Franciscana dolphin *Pontoporia blainvillei* entanglements to conventional nets. Entanglement rates of Franciscana dolphins did not differ significantly between barium sulfate nets (0.1 dolphins/haul) and conventional nets (0.08 dolphins/haul). Catch rates of the three main target fish species also did not differ (whitemouth croaker *Micropogonias furnieri*, striped weakfish *Cynoscion guatucupa*, king weakfish *Macrodon ancylodon*also; see original paper for data). Monofilament nylon gill nets of two types (nets infused with barium sulfate and conventional nets; number of each not reported) were deployed in 150 locations across two fishing areas. The nets were sampled 1–19 times resulting in 255 hauls of barium sulfate nets and 279 hauls of conventional nets. An observer on board each of three fishing vessels retrieving the nets recorded the number of entangled dolphins within each of 534 hauls between October 2009 and March 2010.

(1) Cox T.M. & Read A.J. (2004) Echolocation behavior of harbor porpoises *Phocoena phocoena* around chemically enhanced gill nets. *Marine Ecology Progress Series*, 279, 275–282.
(2) Koschinski S., Culik B.M., Trippel E.A. & Ginzkey L. (2006) Behavioral reactions of free-ranging harbor porpoises *Phocoena phocoena* encountering standard nylon and BaSO4 mesh gillnets and warning sound. *Marine Ecology Progress Series*, 313, 285–294.
(3) Larsen F., Eigaard O.R. & Tougaard J. (2007) Reduction of harbour porpoise (*Phocoena phocoena*) bycatch by iron-oxide gillnets. *Fisheries Research*, 85, 270–278.
(4) Trippel E.A., Holy N.L. & Shepherd T.D. (2009) Barium sulphate modified fishing gear as a mitigative measure for cetacean incidental mortalities. *Journal of Cetacean Research and Management*, 10, 235–246.
(5) Bordino P., Mackay A.I., Werner T.B., Northridge S.P. & Read A.J. (2013) Franciscana bycatch is not reduced by acoustically reflective or physically stiffened gillnets. *Endangered Species Research*, 21, 1–12.

6.31. Use acoustic devices on fishing gear

- **Thirty-three studies** evaluated the effects on marine mammals of using acoustic devices on fishing gear. Eight studies were in the North Atlantic Ocean[1,2,7,15,17,20,22,26] (Canada, USA, UK), four studies were in each of the North Pacific Ocean[3,6,13,19] (USA) and the North Sea[23,28,30,31] (Germany, Denmark, UK), three studies were in the Mediterranean Sea[12,14,16] (Spain, Italy), two studies were in each of the Fortune Channel[4,10] (Canada), the South Atlantic Ocean[5,8] (Argentina, Brazil) and the Baltic Sea[9,30] (Denmark, Germany, Sweden), and one study was in each of Moreton Bay[11] (Australia), the Black Sea[18] (Turkey), the Celtic Sea[21] (UK), the South Pacific Ocean[24] (Peru), the Rainbow Channel[25] (Australia), the UK[27] (water body not stated), the Great Belt[29] (Denmark), Omura Bay[32] (Japan), and the Indian Ocean[33] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (16 STUDIES)

- **Behaviour change (16 studies):** Twelve of 16 controlled studies (including three replicated studies) in the North Atlantic Ocean[17,22,26], the Fortune Channel[4,10], the South Atlantic Ocean[8], Moreton Bay[11], the Mediterranean Sea[12], the Celtic Sea[21], the Rainbow Channel[25], a coastal site in the UK[27], the Great Belt[29], the North Sea[31], Omura Bay[32] and the Indian Ocean[33] found that using acoustic devices on fishing nets[7,12,21,22,26,27,31,32], float lines[4,8] or simulated fishing nets[17,29] resulted in harbour porpoises[4,17,21,22,29], common bottlenose dolphins[7,12,26], tuxuci dolphins[8], finless porpoises[32] and seals[27,31] approaching nets or lines less closely[4,7,17,26], having fewer encounters or interactions with nets[12,26,32], or activity[21,22,29] and sightings[8,27,31] were reduced in the surrounding area. The other four studies found that using acoustic devices on trawl nets[33], float lines[10] or simulated fishing nets[11,25] did not have a significant effect on the behaviour of common bottlenose dolphins[33], harbour porpoises[10], Indo-Pacific humpback dolphins[25] or dugongs[11].

OTHER (19 STUDIES)

- **Reduction in entanglements/unwanted catch (14 studies):** Nine studies (including seven controlled studies and two before-and after studies) in the North Atlantic Ocean[1,2,20], the North Sea[23,28], the South Atlantic Ocean[5], the North Pacific Ocean[13], the Black Sea[18], and the South Pacific Ocean[24] found that using acoustic devices on cod traps[1] or fishing nets[2,5,13,18,20,23,24,28] resulted in fewer collisions of humpback whales[1] or entanglements of harbour porpoises[2,18,20,23,28], Franciscana dolphins[5], beaked whales[13] and small cetaceans[24]. Three studies (including two controlled studies and one before-and-after study) in the North Pacific Ocean[3,6,19] found that using acoustic devices on fishing nets resulted in fewer entanglements of some species but not others. One controlled study in the North Atlantic Ocean[15] found that fishing nets with a 'complete' set of acoustic devices had fewer entanglements of harbour porpoises, but those with an 'incomplete' set did not. One replicated, controlled study in the North Sea and Baltic Sea[30] found that using acoustic devices on fishing nets reduced harbour porpoise entanglements in one fishing area but not the other.
- **Human-wildlife conflict (6 studies):** Five of six studies (including six controlled studies, one of which was replicated) in the Baltic Sea[9], the Mediterranean Sea[14,16], the North Pacific Ocean[19], a coastal site in the UK[27] and the North Sea[31] found that using acoustic devices reduced damage to fish catches and/or fishing nets caused by common bottlenose dolphins[14,16] and seals[9,27,31]. The other study[19] found that acoustic devices did not reduce damage to swordfish catches by California sea lions.

Background

Acoustic devices (sometimes referred to 'pingers') may be deployed on fishing gear to deter marine or freshwater mammals. This may reduce the risk of mammals becoming entangled or captured in fishing gear. Mammal predation on fish catches may also decrease, which may reduce human-wildlife conflict at wild fisheries. However, acoustic devices should be used with caution as the effects can span large distances and mammals may be deterred from important habitats or migration routes (Carlström *et al.* 2009). The use of multiple acoustic devices in an area may also have cumulative effects (Findlay *et al.* 2018).

Studies have been included that tested acoustic devices on both active and simulated fishing gear. For similar interventions, see '*Use acoustic devices on fishing vessels*' and '*Use acoustic devices on moorings*'.

Interventions that use acoustic devices in response to other threats can be found in the following chapters: '*Threat: Aquaculture and agriculture*', '*Threat: Transportation and service corridors – Shipping lanes*', '*Threat: Energy production and mining – Renewable energy*', and '*Threat: Pollution – Noise pollution*'.

Carlström J., Berggren P. & Tregenza N.J.C. (2009) Spatial and temporal impact of pingers on porpoises. *Canadian Journal of Fisheries and Aquatic Sciences*, 66, 72–82.

Findlay C.R., Ripple H.D., Coomber F., Froud K., Harries O., van Geel N.C.F., Calderan S.V., Benjamins S., Risch D. & Wilson B. (2018) Mapping widespread and increasing underwater noise pollution from acoustic deterrent devices. *Marine Pollution Bulletin,* 135, 1042–1050.

A controlled, before-and-after study (year not stated) in eight pelagic areas in the North Atlantic Ocean, off the coast of Canada (*1*) found that cod *Gadus morhua* traps with acoustic devices attached had fewer humpback whale *Megaptera novaeangliae* collisions than traps without acoustic devices. The average number of humpback whale collisions was lower at traps after acoustic devices were installed (0.02 collisions/day) compared to before (0.4 collisions/day) or at control traps without acoustic devices (0.04 collisions/day). Average fish catches (including target species) were greater in traps with acoustic devices (686 kg/day) than those without (30–235 kg/day). In spring and summer, fishers deployed cod traps for 169 days before and 1,762 days after acoustic devices were installed. Control traps without acoustic devices were deployed for 2,223 days. Six or seven acoustic devices were attached to each trap (one at each corner, 2–3 on the leader section), 2 m below the water surface. Devices emitted sound pulses centred at 4 kHz every 3–6 seconds. Fishers recorded whale collisions and fish catches for each trap deployment.

A randomized, controlled study in 1994 of a pelagic site in the North Atlantic Ocean, off the coast of New Hampshire, USA (*2*) found that using active acoustic devices on fishing nets resulted in fewer harbour porpoise *Phocoena phocoena* entanglements compared with using inactive acoustic devices. The probability of at least one porpoise being entangled was lower in nets with active acoustic devices (0.0027) than in nets with inactive acoustic devices (0.025). Two harbour porpoises were entangled in nets with active devices, whereas 25 were entangled in nets with inactive devices. Catches of target cod *Gadus morhuai* and pollock *Pollachius virens* were similar in nets with active and inactive devices (data not reported). Commercial gill net fishers deployed a total of 844 net strings (each comprising 12 nets, 92 m long x 4 m deep, stretched mesh size 15 cm) with acoustic devices attached at 92 m intervals. The acoustic devices on each net string were randomly assigned as active (emitting 300 ms sounds every 4 seconds at 10 kHz; total 421 net strings) or inactive (silent; total 423 net strings). Net strings were submerged for 24 h. Onboard observers and fishers recorded porpoise entanglements and fish catches during daily hauls in October–December 1994.

A controlled study in 1995–1997 of a pelagic area in the North Pacific Ocean, off the coast of Washington, USA (*3*) found that fishing nets with acoustic devices attached had fewer entanglements of harbour porpoises *Phocoena phocoena* than nets without acoustic devices, but the number of harbour seal *Phoca vitulina* entanglements did not differ. In 1995 and 1996, harbour porpoise entanglement rates were lower in fishing nets with acoustic devices attached (0.02 porpoises/net/day) than without (0.4–0.5 porpoises/net/day). Harbour seal entanglement rates did not differ with or without acoustic devices (both 0.05 seals/net/day). In 1997, with acoustic devices on all nets, entanglement rates were 0.07 porpoises/net/day and 0.07 seals/net/day. Catches of target chinook salmon *Oncorhynchus tshawytscha* and sturgeon *Acipenser* spp. did not differ significantly with or without acoustic devices (see original paper for data). In 1995 and 1996, two pairs of gill nets (183 m long, 50–80 meshes deep) were deployed on the ocean bottom at depths of 8–12 m, spaced >300 m apart. One net in each pair had 11 acoustic devices ('piezo buzzers') attached at 17 m intervals 4–7 m below the surface; the other had no devices. The devices (emitting pulses every 4 seconds with peak frequencies at 3 and 20 kHz) were rotated between nets. In 1997, all four nets had acoustic devices attached. Nets were checked every 24 h on 51–61 days in July–August 1995 and 1996 and 180 days in June–August 1997.

A controlled study in 1999 in a fjord in the Fortune Channel, Vancouver Island, Canada (*4*) found that using an acoustic device on a float line resulted in harbour porpoise *Phocoena phocoena* groups approaching less closely. The average distance of porpoise groups from the centre of the float line was greater during trials with an active acoustic device attached (530 m) compared to trials before (150 m) or after (152 m). In June–July 1999, a float line was deployed during six days before an acoustic device was attached (total 26.5 h), five days with an acoustic device attached (emitting 300 ms pulses every 5–30 seconds at frequencies of 20–160 kHz; total 21 h), and two days after the device was removed (total 7 h). The float line (65 m long) had 10-m long weighted lines attached every 0.5 m. The acoustic device was attached to the centre of the float line, 30 cm below the water surface. Porpoises were tracked from the shore using a theodolite before (172 groups), during (44 groups) and after (22 groups) the acoustic device was attached. An acoustic detector deployed 1 m below the centre of the float line recorded porpoise echolocation clicks.

A replicated, randomized, controlled study in 1999–2000 of multiple pelagic sites in the South Atlantic Ocean, off the coast of Buenos Aires, Argentina (*5*) found that fishing nets with active acoustic devices attached had fewer entanglements of Franciscana dolphins *Pontoporia blainvillei* than nets with inactive acoustic devices. Entanglement rates of Franciscana dolphins were lower in fishing nets with active acoustic devices attached (0.002 dolphins/m^2/hour) than in nets with inactive acoustic devices (0.01 dolphins/m^2/hour). However, South American sea lions *Otaria fivescens* damaged fish more in nets with active than inactive devices (see original paper for data). Catch rates of target fish did not differ between nets (active devices: 2.2 kg/m^2/hour; inactive devices: 2.3 kg/m^2/hour). Between October 1999 and February 2000, a total of 604 gill nets with acoustic devices attached (Dukane NetMark 1000, spaced 50 m apart) were deployed on the ocean bottom at multiple sites (number not reported). Each of 604 nets was randomly assigned as a treatment (active acoustic devices emitting pulses every 4 seconds with a peak frequency of 10 kHz; 309 nets) or control (inactive silent acoustic devices; 295 nets). Observers on board the fishing vessels recorded fish catches, entangled dolphins and sea lion damage as each of the 604 nets was retrieved.

A replicated, randomized, controlled study in 1996–1997 of multiple pelagic sites in the North Pacific Ocean, off the coasts of California and Oregon, USA (*6*; same fishery as *13* and *19*) found that fishing nets with acoustic devices attached had fewer entanglements of short-beaked common dolphins *Delphinus delphis* and California sea lions *Zalophus californianus* than nets without acoustic devices, but no difference was found for eight other marine mammal species. Entanglement rates were lower for short-beaked common dolphins and California sea lions in fishing nets with acoustic devices attached (both 0.01 entanglements/net) than in nets without acoustic devices (short-beaked common dolphins: 0.07 entanglements/net; California sea lions: 0.05 entanglements/net). Numbers of entanglements did not differ for eight other dolphin, porpoise, whale and seal species (see original paper for data), although sample sizes were small. Between April 1996 and October 1997, 'drift' gill nets were deployed at multiple sites (number not reported) and randomly assigned as treatment nets (Dukane NetMark 1000 acoustic devices; 295 nets) or control nets (no acoustic devices; 314 nets). Acoustic devices were spaced 91 m apart and emitted 300 ms pulses with a peak frequency of 10–12 kHz. Observers on board the fishing vessels recorded entangled marine mammals as each of the 609 nets was retrieved.

A randomized, controlled study in 2001 at a coastal site in the North Atlantic Ocean, off the coast of North Carolina, USA (*7*) found that fishing nets with active acoustic devices were approached within 100 m by fewer common bottlenose dolphin *Tursiops truncatus* groups than nets with inactive devices, although the number of dolphin groups observed within 300 m of the nets and average closest approach distances were similar. Fewer dolphin groups approached within 100 m of nets with active acoustic devices (2 of 25 groups, 8%) than inactive devices (7 of 15 groups, 47%). The average number of dolphin groups observed within 300 m of the nets and average closest approach distances did not differ significantly with active (0.4 groups/h; 47 m) or inactive (0.6 groups/h; 38 m) acoustic devices. A gill net was deployed on random days with three active acoustic devices attached (Dukane NetMark 1000, emitting regular interval pulses at 10 kHz; total 13 days) or three inactive (silent) acoustic devices (total nine days). The net (200 m long, stretched mesh size 76 mm) was deployed 300 m from a beach perpendicular to the shore in water 3–6 m deep. Two observers tracked 40 dolphin groups from the shore using a theodolite over 22 days in April–May 2001.

A controlled study in 1996–1998 at a coastal site in the South Atlantic Ocean, near Fortaleza, Brazil (*8*) found that float lines with active acoustic devices attached had fewer tucuxi dolphin sightings *Sotalia fluviatilis* around them than float lines with inactive acoustic devices or no devices. On average, fewer tucuxi dolphins were sighted in two quadrats on either side of a float line with active acoustic devices attached compared to float lines with inactive acoustic devices or no devices attached (data reported as statistical model results). The average number of dolphin sightings did not differ significantly between trials within seven other quadrats that were not immediately adjacent to the float line (see original paper for data). A float line (100 m long) was deployed with active acoustic devices attached (30 trials), inactive (silent) acoustic devices attached (20 trials) and with no devices (55 trials). Each trial lasted 1–7 h. Five acoustic devices (Dukane NetMark 1000) were evenly spaced along the float line. Two observers on the shore recorded dolphin sightings within nine quadrats (0.5–0.9 km^2) in a 6-km^2 area surrounding the float line during each of the 105 trials between November 1996 and August 1998.

A replicated, controlled study in 1998–2000 at 19 pelagic sites in the northern Baltic Sea, Sweden (*9*) found that using acoustic devices at salmon trap-nets resulted in an increase in intact fish catches and a decrease in damaged fish and fishing gear, likely due to reduced grey seal *Halichoerus grypus* predation. Trap-nets with acoustic devices had higher intact fish catches (26 kg/day), lower average quantities of fish damaged by seals and birds (4 kg/day) and fewer new holes in fishing gear (result reported from text, which does not match data in table) than those without acoustic devices (fish catches: 12 kg/day; damaged fish: 7 kg/day). Salmon trap-nets were deployed at each of 19 sites (3–9/year) with acoustic devices (total 600 fishing days, 755 trap-net lifts) and without acoustic devices (total 493 fishing days, 668 trap-net lifts). Trap-nets consisted of a leader net starting close to the shore and ending in a funnel-shaped net and fish chamber (10 x 5 x 5 m). An acoustic device (Lofitech Fishguard) was deployed on a raft next to the fish chamber with the transducer at a 5 m depth (emitting 250–500 ms pulses at 15 kHz). Eight commercial fishers recorded catch weight, numbers of fish damaged by seals and birds, and damage to fishing gear during a total of 1,423 trap-net lifts across three fishing seasons in 1998–2000.

A controlled study in 2003 in a fjord in the Fortune Channel, Vancouver Island, Canada (*10*) found that using an acoustic device at a float line did not reduce the approach distances or time spent near the line by harbour porpoises *Phocoena phocoena*. Closest approach distances of harbour porpoises and time spent within 50 m of float lines did not differ significantly between lines with an acoustic device (average 25 m; 32 seconds) or without (average 28 m; 17 seconds). In August 2010, a float line was deployed on one occasion (total 2.8 h) without an acoustic device and on three occasions (total 12.5 h) with an acoustic device. The acoustic device (a CD player with an underwater transducer at a depth of 4.5 m) emitted 0.3 second pulses at 2.5 kHz. Porpoises within 50 m of the float line were tracked with a theodolite during each of the four deployments.

A controlled study in 2002 and 2005 at a pelagic site in Moreton Bay, Queensland, Australia (*11*) found that active acoustic devices of two types deployed to simulate a fishing net had similar numbers of dugongs *Dugong dugon* passing between them compared to inactive acoustic devices, and dugong orientation and feeding behaviour were also similar. The number of dugongs passing between two acoustic devices was similar when the devices were active or inactive (data reported as statistical model results). The proportion of dugongs oriented towards the acoustic devices and the number of dugongs feeding within 100 m of them also did not differ significantly when the devices were active or inactive. Two acoustic devices (either 4 kHz or 10 kHz 'BASA' devices) were deployed 50–55 m apart at depths of 1 m below the water surface to simulate a fishing net. The devices were attached to a research vessel and an anchored floating tube close to dugong herds. Each trial comprised three 10-minute sequential treatments with both devices inactive (silent), active (emitting pulses at 4-second intervals), and inactive (silent). Ten trials were carried out in

August 2002 with 10 kHz devices. Sixteen trials were carried out in July 2005 with 4 kHz devices. Dugong behaviour and feeding plumes (disturbed sediment) were recorded with a video camera attached to a balloon during each of the 26 trials.

A replicated, randomized, controlled study in 2005 of multiple pelagic sites in the Mediterranean Sea, off the Balearic Islands, Spain (*12*) found that one of three types of acoustic device attached to fishing nets reduced common bottlenose dolphin *Tursiops truncatus* interactions with the nets. The average interaction rate of bottlenose dolphins with nets was 70% lower when active Aquatec AQUAmark 210 devices were attached to nets than when inactive devices or no devices were attached (data reported as statistical model results). The difference in interaction rates was not significant for two other types of acoustic device: Dukane NetMark 1000 and SaveWave Dolphinsaver High-impact. Target fish yields (measured as profit) did not differ significantly between treatments (see original paper for details). A total of 1,193 gill nets were deployed on the ocean bottom at multiple sites (number not reported). One of seven treatments was randomly assigned to each net: one of three types of active acoustic device attached (Aquatec: 260 nets; Dukane: 272 nets; SaveWave: 211 nets), one of three types of inactive (silent) acoustic device attached (Aquatec: 118 nets; Dukane: 74 nets; SaveWave: 114 nets) or no device attached (144 nets). Observers on board each of 59 fishing vessels recorded dolphin interactions (sightings of dolphins around the nets or dolphin-damaged fish) in July–December 2005.

A before-and-after study in 1990–2006 of multiple pelagic sites in the North Pacific Ocean, off the coasts of California and Oregon, USA (*13*; same fishery as *6* and *19*) found that using acoustic devices on fishing nets reduced the number of beaked whale (Ziphiidae) entanglements. No beaked whales were found entangled in fishing nets during the 11 years in which acoustic devices were used, whereas 33 whales of at least six species were entangled during the six years before the devices were used (see original paper for details). In 1990–1995, a total of 3,303 nets were deployed without acoustic devices. In 1996–2006, a total of 4,381 nets were deployed with acoustic devices attached at 91 m intervals (average 40 devices/net). The devices emitted 300 ms pulses at 10–12 kHz. Each of the 7,684 'drift' gill nets (1,800 m long x 65 m deep) was deployed from dusk until dawn at depths of 11–90 m to catch swordfish and sharks. Observations of entangled whales were made by biologists on board fishing vessels in 1990–2006.

A controlled study in 2001 of a pelagic area in the Mediterranean Sea, off the Balearic Islands, Spain (*14*) found that using acoustic devices on fishing nets reduced damage to nets and fish caused by common bottlenose dolphins *Tursiops truncatus*. Fishing nets with active acoustic devices had significantly fewer holes (average 1 hole/net) than nets with inactive acoustic devices (average 8 holes/net) or no devices (average 6 holes/net). The percentage of caught fish bitten by dolphins was also lower in nets with active devices (7%) compared to inactive devices (13%) or no devices (17%), although statistical significance was not assessed. Catch rates of target red mullet *Mullus surmuletus* did not differ significantly between nets with active devices (0.6 kg/net), inactive devices (0.7 kg/net) and no devices (0.9 kg/net). A total of 55 trammel net deployments (each with multiple nets, 50 m long x 2 m high, tied together) were deployed across a fishing area (340 km^2). One of three treatments was rotated between deployments: active acoustic devices attached (27 deployments), inactive (silent) acoustic devices attached (16 deployments) or no devices (12 deployments). Acoustic devices (Aquatec AQUAmark 100; emitting eight different signals of 5–30 second duration at 20–160 kHz) were attached at 150 m intervals. An observer on board each of three fishing vessels recorded fish catches, dolphin-damaged fish and new holes in the nets during each of the 55 hauls in September–October 2001.

A controlled study in 1999–2007 of a pelagic area in the Northwest Atlantic Ocean, USA (*15*) found that fishing nets with a 'complete' set of acoustic devices attached had fewer harbour porpoise *Phocoena phocoena* entanglements than nets without acoustic devices, but nets with an 'incomplete' set of acoustic devices had the highest number of entanglements. Harbour porpoise entanglement rates were lower in nets with a 'complete' set of acoustic devices attached (0.02 porpoises/metric tons landed) than in nets with no acoustic devices (0.05 porpoises/metric tons landed). Entanglement rates were highest in nets with an 'incomplete' set of acoustic devices attached (0.12 porpoises/metric tons landed). In 1999–2007, acoustic devices were attached to gill nets during commercial fishing operations. Gill net strings were deployed with either a 'complete' set of acoustic devices attached (11 devices on each string of 10 x 92 m long nets; total 2,407 hauls), an 'incomplete' set of acoustic devices (<11 devices/string; total 1,065 hauls), or no devices (total 3,157 hauls). Acoustic devices emitted 300 ms pulses every 4 seconds at 10 kHz. Observers on board the fishing vessels recorded porpoise entanglements, fish catches and numbers of acoustic devices used during each of the 6,629 hauls in 1999–2007.

A controlled study in 2006 of a pelagic area in the Mediterranean Sea, off the coast of southern Italy (*16*) found that using acoustic devices on a fishing net resulted in higher fish catches and less net damage, likely due to reduced predation by common bottlenose dolphins *Tursiops truncatus*. A fishing net with acoustic devices attached had higher average fish catches (5.2 kg/h) and fewer small holes (0.8 holes/50 m) than a net without acoustic devices (4.1 kg/h; 1.2 holes/50 m). Two identical gill nets (900 m long x 2.2 m deep) were deployed on the ocean bottom; one with four evenly spaced acoustic devices attached and one without. Acoustic devices (STM and SEAMed model DDD02) emitted 6-second signals at random intervals with a frequency range of 0.1–150 kHz. Researchers on board the fishing vessel recorded the presence of dolphins and fish catches in each net during 29 hauls in spring 2006. Small holes (<20 cm) were counted in both nets at the end of the experiment.

A controlled study in 2001 at a pelagic site in the North Atlantic Ocean, off the coast of Scotland, UK (*17*) found that using acoustic devices on a simulated fishing net reduced the approach distances and echolocation activity of harbour porpoises *Phocoena phocoena*. The average approach distance of porpoise groups from the 'net' was greater when acoustic devices were active (961 m) than inactive (653 m). The average number of echolocation encounters within 0–500 m of the 'net' was lower when devices were active (0.1–0.3 encounters/h) than inactive (0.3–0.7 encounters/h). The difference in the number of echolocation encounters was not significant at 750 m (active: 0.36 encounters/h; inactive: 0.42 encounters/h). In April–June 2001, a simulated fishing net (a 700-m lead line) was deployed on the ocean bottom with eight acoustic devices (Dukane NetMark 1000) attached at 100 m intervals. Six devices were active (emitting 300 ms pulse at 10–12 kHz every four seconds) or inactive (silent) for alternating 4-h periods. Two devices at the centre of the 'net' were inactive throughout. Acoustic loggers deployed at 0, 250, 500 and 750 m from the 'net' recorded porpoise echolocation clicks while acoustic devices were active (total 1,472 h) and inactive (total 1,352 h). Observers on the shore tracked porpoise groups with a theodolite while acoustic devices were active (11 groups during 30 h) and inactive (39 groups during 49 h).

A controlled study in 2006 of a pelagic area in the Black Sea, Turkey (*18*) found that fishing nets with acoustic devices attached had fewer entanglements of harbour porpoises *Phocoena phocoena* than nets without acoustic devices. Harbour porpoise entanglement rates were lower in nets with acoustic devices (0.01 porpoises/day) than in those without acoustic devices (0.47 porpoises/day). Catch rates of target Black Sea turbot *Schophthalmus maeoticus* were higher in nets with active acoustic devices (1.1 fish/day) than in those without (0.5 fish/day). During each of 20 fishing trips, one gill net string was deployed with acoustic devices attached (Dukane NetMark 1000 emitting 300 ms signals every 4 seconds at 10–12 kHz, spaced 200 m apart) and one was deployed without acoustic devices. Each string comprised 16 nets tied together (total length 1.1 km, 160 mm mesh size). Nets were deployed at depths of 17–183 m for 168–288 h. Entangled porpoises and fish catches were recorded during each of the 20 fishing trips in March–April 2006.

A before-and-after study in 1990–2009 of multiple pelagic sites in the North Pacific Ocean, off the coasts of California and Oregon, USA (*19*; same fishery as *6* and *13*) found that using acoustic devices on fishing nets reduced entanglements of two of five marine mammal species, but did not reduce damage to target broadbill swordfish *Xiphias gladius* catches by California sea lions *Zalophus californianus*. The proportion of fishing net deployments with at least one entanglement was lower for nets with acoustic devices than those without for short-beaked common dolphins *Delphinus delphis* (with devices: 3.2%; without: 5.7%) and northern elephant seals *Mirounga angustirostris* (with devices: 0.5%; without: 2.4%). The difference was not significant for northern right whale dolphins *Lissodelphis borealis* (with devices: 0.003%; without: 0.005%), Pacific white-sided dolphins *Lagenorhynchus obliquidens* (with devices: 0.005%; without: 0.003%) or California sea lions (with devices: 2.6%; without: 1.6%). In one year, the proportion of deployments with swordfish catches damaged by California sea lions did not differ significantly with (19 of 69 deployments; 28%) and without acoustic devices (38 of 124 deployments; 31%). In 1990–1998, fishing nets (1,281 in total) were deployed without acoustic devices. In 1996–2009, fishing nets (2,792 in total) were deployed with acoustic devices (≥30 devices/net at 91 m intervals, emitting 300 ms pulses every 4 seconds at 10–12 kHz). Nets (each 1.5–1.8 km long, 65 m deep, 40–60 cm mesh size) were deployed for 8–20 h between dusk and dawn by a 'drift' gill net fishery targeting swordfish and sharks. Onboard observers recorded mammal entanglements in 1990–2009. Sea lion damage to swordfish catches (shredding of the body) was recorded in 1997.

A controlled study in 2008–2011 of a pelagic area in the North Atlantic Ocean, off the coast of southwest England, UK (*20*) found that fishing nets with acoustic devices attached had fewer entanglements of harbour porpoises *Phocoena phocoena* than nets without acoustic devices. Porpoise entanglement rates were lower in fishing nets with acoustic devices attached (0.007 porpoises/haul) than in those without acoustic devices (0.02 porpoises/haul). Fishing vessels (>12 m) deployed fleets of gill nets (up to 8 km in length) with acoustic devices attached (total 999 hauls) and without acoustic devices (total 907 hauls). Dolphin Dissuasive Devices (model DDD-02, STM Products) were either attached to the middle of each section of 20 net panels (in 2008) or to the end ropes and 10 m above the anchor (in 2009–2011). Between August 2008 and April 2011, entangled porpoises were recorded during each haul by independent observers (1,709 hauls) or fishers (197 hauls).

A replicated, controlled study in 2009–2010 of three pelagic sites in the Celtic Sea, off the coast of Cornwall, UK (*21*) found that fishing nets with acoustic devices had lower echolocation activity of harbour porpoises *Phocoena phocoena* around them than nets without acoustic devices. Overall, 35–51% fewer harbour porpoise clicks were recorded at nets with acoustic devices (total 800–20,000 clicks/site) than at nets without acoustic devices (total 2,000–40,000 clicks/site). Only one entangled porpoise was found during the study, in a net without an acoustic device. Three commercial fishing vessels deployed pairs of 'tangle' nets (267 mm mesh; number not reported) between April 2009 and April 2010. Each pair had an experimental net with acoustic devices attached (Aquatec AQUAmark 100, spaced 200 m apart) and a control net with no devices. Acoustic devices emitted 400 ms pulses at 20–140 kHz. Each pair of nets was deployed for approximately five days at depths of 20–100 m to target benthic fish species. Acoustic detectors attached to the nets recorded porpoise echolocation clicks during a total of 640 days in 2009–2010.

A controlled study in 2012–2013 of a pelagic area in the North Atlantic Ocean, off the coast of Cornwall, UK (*22*) reported that fishing nets with acoustic devices had lower echolocation activity of harbour porpoises *Phocoena phocoena* around them than nets without acoustic devices. Results are not based on assessments of statistical significance. Overall, the number of porpoise echolocation clicks recorded was 6,321 clicks at nets with acoustic devices, compared to 34,600 clicks at nets without acoustic devices. In October 2012–March 2013, four fishing vessels (<12 m long) deployed pairs of inshore 'tangle' nets (22–35 cm monofilament mesh deployed flat on the seabed) with and without acoustic devices during a total of 161 days of fishing. Acoustic devices (Fishtek Banana Pingers, spaced 2 m apart) emitted 300 ms sounds at random intervals of 4–12 seconds with random frequencies between 50–120 kHz. Nets were deployed for five days at depths of 20–100 m. An acoustic logger attached to each net recorded porpoise echolocation clicks.

A controlled study in 2006 of multiple pelagic sites in the North Sea, Denmark (*23*) found that fishing nets with acoustic devices attached at two different spacings had fewer entanglements of harbour porpoises *Phocoena phocoena* than nets without acoustic devices. Overall, entangled porpoises were recorded in fewer hauls of fishing nets with acoustic devices attached at 455 m spacings (0 hauls) and 585 m spacings (5 hauls) than nets with no acoustic devices attached (22 hauls). Numbers of entanglements did not differ significantly between the two device spacings. Average catch rates of target hake *Merluccius* spp. did not differ significantly between nets with acoustic devices at 455 m spacings (29 fish/km/day) and nets without acoustic devices (30 fish/km/day; data not reported for nets with devices at 585 m spacings). Strings of 45–135 gill nets were deployed during five commercial fishing trips in July–September 2006. The nets had acoustic devices (Aquatec AQUAmark 100) attached at spacings of 455 m (24 hauls) or 585 m (43 hauls) or had no devices attached (41 hauls). Observers on board the fishing vessels recorded porpoise entanglements and hake catches within each of the 108 hauls.

A replicated, controlled study in 2009–2011 of multiple pelagic sites in the South Pacific Ocean, northern Peru (*24*) found that fishing nets with acoustic devices attached had fewer entanglements of small whale, dolphin and porpoise species than nets without acoustic devices. Average entanglement rates were lower in fishing nets with acoustic devices (0.5 cetaceans/km/h) than in nets without acoustic devices (0.8 cetaceans/km/h). Five species or species groups were entangled including dolphins, porpoises, and pilot whales *Globicephala* spp. (see original paper for details). Catch rates of target sharks and eagle rays *Myliobatis* spp. did not differ significantly with acoustic devices (26 sharks/km/h; 0.002 rays/km/h) or without (19 sharks/km/h; 0.001 rays/km/h). Six small-scale 'drift' net vessels carried out 43 experimental fishing trips (total 156 nets with acoustic devices) and 47 control trips (total 195 nets without acoustic devices) during 29 months in April 2009–August 2011. Acoustic devices (Dukane NetMark 1000, emitting 300 ms pulses at 10–12 kHz) were attached to the lead line of experimental nets spaced 200 m apart at a depth of 14 m. Onboard observers recorded entanglements and target fish catches during each of the 90 fishing trips.

A randomized, controlled study in 2007–2008 at a pelagic site in the Rainbow Channel, Queensland, Australia (*25*) found that when a row of three active acoustic devices was deployed to simulate a fishing net, the number of Indo-Pacific humpback dolphin *Sousa chinensis* groups observed, the minimum surfacing distance of dolphins to a device and the number of days in which dolphins did not cross devices was similar to when three inactive devices were deployed. The number of dolphin groups observed did not differ significantly with active acoustic devices (average 4 groups/day) or inactive acoustic devices (5 groups/day). The same was true for the minimum distance between a surfacing dolphin and an acoustic device (active devices: average 41 m; inactive: 33 m) and the number of days in which dolphins did not cross the row of acoustic devices (active devices: 7 days; inactive: 3 days). A row of three acoustic devices (Fumunda acoustic alarms) was deployed across a channel to simulate a gill net. On randomly selected days, all three devices were either active (emitting 300 ms pulses every 4 seconds at 10 kHz; total 10 days) or inactive (silent; total 10 days). Devices were attached to buoys anchored to the seafloor and submerged at a depth of 5 m in water 10–15 m deep. A total of 84 dolphin groups were observed from the shore during 20 days using a video camera attached to a theodolite in September 2007–April 2008.

A randomized, controlled study in 2004–2005 across two coastal areas in the North Atlantic Ocean, off the coast of North Carolina, USA (*26*) found that when active acoustic devices were used on fishing nets, common bottlenose dolphins *Tursiops truncatus* interacted with the nets less and echolocated more compared to when inactive devices were used. Fewer dolphins approached within 500 m and interacted with nets with active acoustic devices than nets with inactive acoustic devices (data reported as statistical model results). Dolphins spent more time echolocating near to nets with active acoustic devices than nets with inactive or no devices. In 2004–2005, commercial fishers deployed 83 gill nets with active acoustic devices (SaveWave devices attached to the float line, 100 m apart, emitting sounds at frequencies of 5–90 kHz and 30–160 kHz) and 68 gill nets with inactive (silent) devices. Gill nets (300 m long) were deployed perpendicular to the shore. An onboard observer recorded dolphin behaviour around each of the 151 nets. In 2004, a research vessel towing a hydrophone recorded the echolocation clicks of seven dolphins within 500 m of four nets with active acoustic devices, two nets with inactive devices and one net without devices deployed by another fishery.

A randomized, controlled study in 2009–2010 at a coastal site (water body not stated) in Scotland, UK (*27*) found that using an acoustic device at a bag-net reduced the number of grey seals *Halichoerus grypus* and harbour seals *Phoca vitulina* around the net and the amount of seal-damaged salmon (Salmonidae). The number of grey and harbour seal sightings/survey within 80 m of the net was lower when the acoustic device was active than when it was inactive (data reported as statistical model results). No seal-damaged salmon were found in the nets when the acoustic device was turned on, whereas 5–7% of salmon catches were damaged when the device was off. An acoustic device (Lofitech Seal Scarer) was deployed alongside a salmon double bag-net deployed 90 m offshore. In July–August 2009 and 2010, the acoustic device was randomly set as active (emitting 500 ms pulses at 15 kHz) or inactive (silent) for 12 h (2009) or 24 h periods (2010). An observer recorded seals from the shore during surveys (each lasting an average of 1.4 h) with the device turned on (34 surveys) and off (41 surveys). Fishers recorded seal-damaged catches during hauls with the device turned on (78 hauls) and off (104 hauls).

A replicated, controlled study in 1997 at a wreck and an area of seabed in the North Sea, Denmark (*28*) found that using active acoustic devices on fishing nets resulted in fewer harbour porpoise *Phocoena phocoena* entanglements compared with using inactive acoustic devices or no devices. At both sites, harbour porpoises were found entangled in fewer nets with active acoustic devices attached (wreck: 0 nets; seabed: 1 net) than in nets with inactive or no acoustic devices attached (wreck: 8 nets; seabed: 15 nets). Catches of target cod *Gadus morhua* did not differ significantly with active, inactive, or no acoustic devices (data reported as statistical model results). Gill nets were deployed on the ocean bottom at depths of 20–80 m at two sites (a wreck and a flat/stony seabed). Nets had active acoustic devices attached (wreck: 1,052 nets; seabed: 5,596 nets), inactive (silent) acoustic devices attached (wreck: 1,056 nets; seabed: 5,210 nets) or no devices (wreck: 74 nets; seabed: 2,973 nets). Acoustic devices (prototype LU-1, Loughborough University, UK) were attached to nets at 70 m intervals and emitted 300 ms pulses at 40–120 kHz. Observers on board each of 14 fishing vessels recorded porpoise entanglements for a total of 592 hauls during 168 fishing days in August–October 1997.

A controlled study in 2005 in a pelagic area of the Great Belt, Denmark (*29*) found that using active acoustic devices of two types on simulated fishing nets resulted in fewer detections of harbour porpoises *Phocoena phocoena* compared to when devices were inactive. Harbour porpoise detection rates within each of two 0.6 km^2 areas were lower when two types of acoustic device were active ('Airmar' devices: 40% lower; 'SaveWave' devices: 65% lower) compared to when devices were inactive (data reported as statistical model results). Detection rates at three control sites without acoustic devices located 2.5, 3 and 5 km away did not change significantly over the same period. Acoustic devices were deployed across two areas (each 0.6 km^2). Fifty-five 'Airmar' devices (emitting 300 ms pulses every 4 seconds at 10 kHz) were deployed 100 m apart in one area. Fifteen 'SaveWave Black Save' devices (emitting pulses of 200–900 ms every 4–16 seconds with frequency sweeps of 30–60 kHz) were deployed 200 m apart in the other. In May–June 2005, the acoustic devices were alternately activated and deactivated for six repeating cycles of 2–9 days to simulate gill net fishery deployments. Seven acoustic detectors (two in each area; three at control sites) recorded porpoise echolocation clicks during each of the two acoustic device deployments.

A replicated, controlled study in 2013–2014 of two pelagic areas in the North Sea and Baltic Sea, Denmark and Germany (*30*) found that fishing nets with acoustic devices attached had fewer harbour porpoise *Phocoena phocoena* entanglements than nets without devices in one area but not the other. In the Baltic Sea, no porpoises were entangled in nets with acoustic devices, whereas nine porpoises were entangled in nets without acoustic devices. In the North Sea, the number of entangled porpoises did not differ significantly between nets with acoustic devices (two porpoises) or without (three porpoises). In 2013–2014, commercial fishing vessels simultaneously deployed gill nets (number not reported) with and without acoustic devices across two areas. Acoustic devices ('PALfi' Porpoise Alerting Devices) emitted three synthetic porpoise alert calls/minute (1.3 second sweeps consisting of 700 clicks centred at 133 kHz). Devices were attached to the headrope of gill nets, spaced 200 m apart. Fishers reported entangled porpoises. Some fishing trips were additionally monitored by onboard video equipment and scientific observers (number not reported).

A controlled study in 2015 at a bay in the North Sea, Scotland, UK (*31*) found that using an active acoustic device alongside a bag-net reduced seal presence at the net and resulted in greater catches of undamaged fish (Salmonidae) compared to when the device was inactive. Seal presence was lower when the acoustic device was turned on than turned off (data reported as statistical model results; seal species not reported). Catch rates of fish without seal damage were greater with the acoustic device turned on than turned off (data reported as statistical model results). An acoustic device (Airmar dB Plus II) was deployed alongside a bag-net for five months in April–August 2015. The device was turned on (emitting acoustic signals; total 1,522 h) and off (silent; total 578 h) during randomly selected periods. An underwater video system recorded the presence of seals at the net with the acoustic device turned on (80 hauls) and off (39 hauls). Fishers recorded fish catches and seal damage during hauls with the acoustic device turned on (108 hauls) and off (50 hauls).

A controlled study in 2011–2012 of a pelagic site in Omura Bay, Japan (*32*) found that using two acoustic devices on a fishing net reduced the number of encounters of finless porpoises (Neophocaena) with the net. Fewer finless porpoise encounters were recorded each day at the net when the acoustic devices were turned on than when they were turned off (data reported as statistical model results). Two acoustic devices (Aquatec AQUAmark 100) were attached to a fishing net (one on the upper rope of the guide net, one at the entrance of the enclosure net) at a depth of 30 cm. The net was deployed in water 10–15 m deep. Both acoustic devices were turned on (emitting 200–300 ms pulses at 20–160 kHz) or off (silent) for alternating two-week periods in April–December 2011 and 2012. A passive acoustic event recorder deployed 40 m offshore from the net at a depth of 1.5 m recorded daily encounters of finless porpoises.

A controlled study in 2013 of a pelagic area in the Indian Ocean, northwest Australia (*33*) found that trawl nets with acoustic devices attached had a similar number and duration of common bottlenose dolphin *Tursiops truncatus* interactions compared to trawl nets without acoustic devices. Average daily interaction rates of dolphins with trawl nets did not differ significantly between nets with acoustic devices (0.7 interactions/minute) and without (0.4 interactions/minute). The average duration of interactions also did not differ significantly with acoustic devices (1.7 minutes) or without (1.3 minutes). Three commercial vessels carried out 14 trawls with acoustic devices attached to trawl nets and 17 trawls without acoustic devices. Dolphin Dissuasive Devices (emitting random frequencies between 2 and 500 kHz) were attached on either side of an underwater video camera installed within each trawl net. All trawls were carried out during the day with a single stern trawl net towed close to the seabed in water 50–100 m deep. Video cameras recorded dolphin interactions with the nets during each of the 31 trawls in January–February 2013.

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(27) Harris R.N., Harris C.M., Duck C.D. & Boyd I.L. (2014) The effectiveness of a seal scarer at a wild salmon net fishery. *ICES Journal of Marine Science*, 71, 1913–1920.
(28) Larsen F. & Eigaard O.R. (2014) Acoustic alarms reduce bycatch of harbour porpoises in Danish North Sea gillnet fisheries. *Fisheries Research*, 153, 108–112.
(29) Kyhn L.A., Jørgensen P.B., Carstensen J., Bech N.I., Tougaard J., Dabelsteen T. & Teilmann J. (2015) Pingers cause temporary habitat displacement in the harbour porpoise *Phocoena phocoena*. *Marine Ecology Progress Series*, 526, 253–265.
(30) Culik B., Dorrien C. von & Conrad M. (2016) *Porpoise Alerting Device (PAL): Synthetic harbour porpoise (Phocoena phocoena) communication signals influence behaviour and reduce by-catch*. Proceedings – Progress in Marine Conservation Europe 2015, Stralsund, Germany. BfN-Skripten 451, 150–155.
(31) Harris R.N. & Northridge S. (2016) *Seals and wild salmon fisheries*. Sea Mammal Research Unit, University of St Andrews, UK. Report to Scottish Government SSI.
(32) Amano M., Kusumoto M., Abe M. & Akamatsu T. (2017) Long-term effectiveness of pingers on a small population of finless porpoises in Japan. *Endangered Species Research*, 32, 35–40.
(33) Santana-Garcon J., Wakefield C.B., Dorman S.R., Denham A., Blight S., Molony B.W. & Newman S.J. (2018) Risk versus reward: Interactions, depredation rates, and bycatch mitigation of dolphins in demersal fish trawls. *Canadian Journal of Fisheries and Aquatic Sciences*, 75, 2233–2240.

6.32. Use acoustic devices on fishing vessels

- **Five studies** evaluated the effects on marine mammals of using acoustic devices on vessels. One study was in each of the Shannon Estuary[1] (Ireland), the Rainbow Channel[2a] (Australia), Keppel Bay[2b] (Australia), the North Atlantic Ocean[3] (Azores) and the Indian Ocean[4] (Crozet Islands).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (4 STUDIES)

- **Behaviour change (4 studies):** One controlled study in the Shannon Estuary[1] found that common bottlenose dolphins avoided a boat more frequently when acoustic devices of two types were deployed alongside it. One controlled study in the Indian Ocean[4] found that killer whales were recorded further from a fishing vessel when an acoustic device was used during hauls, but distances decreased after the first exposure to the device. Two before-and-after studies in the Rainbow Channel[2a] and Keppel Bay[2b] found that an acoustic device deployed alongside a vessel reduced surfacing and echolocation rates[2a] and time spent foraging[2a] or socializing[2b] of Indo-Pacific humpback dolphins[2a] and Australian snubfin dolphins[2b] but there was no effect on 8–10 other types of behaviour (e.g. vocalizing, diving, travelling etc.).

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One randomized, controlled study in the North Atlantic Ocean[3] found that using acoustic devices of two types did not reduce predation of squid catches by Risso's dolphins.

Background

Acoustic devices (sometimes referred to 'pingers') may be deployed on boats to deter marine or freshwater mammals at wild fisheries. This may reduce the risk of mammals becoming entangled or captured in fishing gear. Mammal predation on fish catches may also decrease, which may reduce human-wildlife conflict. However, acoustic devices should be used with caution as the effects can span large distances and mammals may be deterred from important habitats or migration routes (Carlström *et al.* 2009). The use of multiple acoustic devices in an area may also have cumulative effects (Findlay *et al.* 2018).

Studies have been summarised below if they tested acoustic devices for the purpose of deterring mammals at wild fisheries and the device was deployed from a vessel (including fishing boats and research vessels). For similar interventions, see '*Use acoustic devices on fishing gear*' and '*Use acoustic devices on moorings*'.

Interventions that use acoustic devices in response to other threats can be found in the following chapters: '*Threat: Aquaculture and agriculture*', '*Threat: Transportation and service corridors – Shipping lanes*', '*Threat: Energy production and mining – Renewable energy*', and '*Threat: Pollution – Noise pollution*'.

Carlström J., Berggren P. & Tregenza N.J.C. (2009) Spatial and temporal impact of pingers on porpoises. *Canadian Journal of Fisheries and Aquatic Sciences*, 66, 72–82

Findlay C.R., Ripple H.D., Coomber F., Froud K., Harries O., van Geel N.C.F., Calderan S.V., Benjamins S., Risch D. & Wilson B. (2018) Mapping widespread and increasing underwater noise pollution from acoustic deterrent devices. *Marine Pollution Bulletin,* 135, 1042–1050.

A controlled study in 2005 of a pelagic area in the Shannon Estuary, western Ireland (*1*) reported that deploying active 'continuous' or 'responsive' acoustic devices alongside a boat resulted in common bottlenose dolphins *Tursiops truncatus* avoiding the boat more frequently than when inactive acoustic devices were deployed. Results are not based on assessments of statistical significance. Dolphins avoided a boat during more trials with active 'continuous' devices (3 of 4 trials) and active 'responsive' devices (3 of 4 trials) than with inactive 'continuous' devices (1 of 4 trials) or inactive 'responsive' devices (0 of 1 trial). Active 'continuous' or 'responsive' acoustic devices were deployed from the back of a 5.4-m rigid inflatable boat for four trials each. Inactive (silent) 'continuous' and 'responsive' acoustic devices were deployed for four trials and one trial respectively. Dolphin groups were approached to 50 m prior to the deployment of each device. 'Continuous' devices (Loughborough University/Aquatech prototype) continuously emitted sounds (<1 second sounds every 5–20 seconds at 5–20 kHz). 'Responsive' devices (Aquatec AquaMark) emitted sounds (300 ms sounds at 35–160 kHz) when dolphin clicks were detected by an internal microphone. Dolphin behaviour was observed for four minutes during each of the 13 trials in July 2005.

A before-and-after study in 2007–2008 at a pelagic site in the Rainbow Channel, Queensland, Australia (*2a*) found that during and after an acoustic device was deployed alongside a vessel, Indo-Pacific humpback dolphins *Sousa chinensis* spent less time foraging and had reduced surfacing and echolocation rates compared to before the device was deployed, but eight other types of behaviour did not differ. Three types of dolphin behaviour (percentage of time spent foraging, active surfacing rates, echolocation click rates) were reduced during and after an acoustic device was deployed compared to before (data reported as statistical model results). Eight other types of behaviour (percentage of time spent travelling, socializing or vocalizing; rate of blows, dives, whistles, burst pulses or other behaviours) did not differ significantly before, during or after an acoustic device was deployed. An acoustic device (Fumunda acoustic alarm) was deployed alongside a stationary research vessel during a total of 17 trials near 37 dolphin groups (1–3 dolphins/group). Each trial had three 10-minute periods with no device, an active device submerged (emitting 300 ms pulses every 4 seconds at 10 kHz), and the device removed from the water. Dolphin behaviour was observed from the vessel and vocalizations were recorded with a hydrophone submerged at a depth of 3 m during each of the 17 trials in September 2007–April 2008.

A before-and-after study in 2007–2008 at a river mouth in Keppel Bay, Queensland, Australia (*2b*) found that deploying an acoustic device alongside a vessel reduced the percentage of time Australian snubfin dolphins *Orcaella heinsohni* spent socializing compared to before a device was deployed, but 10 other types of behaviour did not differ. Snubfin dolphins spent less time socializing during and after an acoustic device was deployed compared to before (data reported as statistical model results). Ten other types of behaviour (time spent foraging, travelling or vocalizing; rate of active surfacing, blows, dives, whistles, burst pulses, clicks or other behaviours) did not differ significantly before, during or after an acoustic device was deployed. An acoustic device (Fumunda acoustic alarm) was deployed alongside a stationary research vessel during a total of 10 trials near 13 dolphin groups (1–5 dolphins/group). Each trial had three 5-minute periods with no device, an active device submerged (emitting 300 ms pulses every 4 seconds at 10 kHz), and the device removed from the water. Dolphin behaviour was observed from the vessel and vocalizations were recorded with a hydrophone submerged at a depth of 3 m during each of the 10 trials in September 2007–April 2008.

A randomized, controlled study in 2010–2011 of a pelagic area in the North Atlantic Ocean off the Azores, Portugal (*3*) found that using active acoustic devices of two types did not reduce predation of squid catches by Risso's dolphins *Grampus griseus*. The proportion of fishing trials in which squid were taken by Risso's dolphins was similar with active acoustic devices (17–22%), inactive acoustic devices (17–23%) and no devices (19%). Average squid catches by fishers were also similar with active (1.5–2 squid/fisher/h), inactive (2–2.3 squid/fisher/h) and no acoustic devices (2.2 squid/fisher/h). Five squid fishing vessels (using hand lines and jigs) carried out 154 x 1 h trials during 45 fishing trips. Trials were carried out in a random order with active acoustic devices (emitting 10 kHz sounds) of each of two types (Future Oceans Fumunda Marine devices: 35 trials; Aquatec AQUAmark 300 devices: 27 trials), inactive (silent) acoustic devices (Fumunda: 35 trials; Aquatec: 25 trials) or no devices (32 trials). Acoustic devices were attached to a rope and deployed from the bow of each vessel at a depth of 60 m. Onboard observers recorded squid catches and squid predated by dolphins during each of the 154 trials in May 2010–August 2011.

A controlled study in 2011 of a pelagic area in the southern Indian Ocean off the Crozet Islands (*4*) found that when an acoustic device was turned on during fishing hauls, killer whales *Orcinus orca* were recorded further from the fishing vessel than when the device was turned off, but distances decreased after the first exposure to the device. Killer whales of two family groups were recorded at greater distances from the fishing vessel during hauls when an acoustic device was turned on for the first time (average 933 m) compared to when it was turned off (average 277 m). Average distances to the vessel decreased significantly during successive exposures to the acoustic device for both groups (first exposure: 800–1,000 m; after 5–22 exposures: 90–240 m). In February 2011, a fishing vessel targeting Patagonian toothfish *Dissostichus elegenoides* deployed an acoustic device (comprising 40 transducers placed 8–10 m below the vessel) during hauls of 23 'long lines' (each 5.4 km long with 4,500 hooks) with killer whales present. During 15–20-minute intervals, the device was alternately turned off (silent; total 31 intervals) or on (emitting 0.5–1 second sounds at 6.5 kHz; total 45 intervals). An onboard observer recorded the distance of killer whales from the vessel. Individuals within two family groups were identified from photographs.

(1) Leeney R.H., Berrow S., McGrath D., O'Brien J., Cosgrove R. & Godley B.J. (2007) Effects of pingers on the behaviour of bottlenose dolphins. *Journal of the Marine Biological Association of the United Kingdom*, 87, 129–133.

(2) Soto A.B., Cagnazzi D., Everingham Y., Parra G.J., Noad M. & Marsh H. (2013) Acoustic alarms elicit only subtle responses in the behaviour of tropical coastal dolphins in Queensland, Australia. *Endangered Species Research*, 20, 271–282.

(3) Cruz M.J., Jordao V.L., Pereira J.G., Santos R.S. & Silva M.A. (2014) Risso's dolphin depredation in the Azorean hand-jig squid fishery: assessing the impacts and evaluating effectiveness of acoustic deterrents. *ICES Journal of Marine Science*, 71, 2608–2620.

(4) Tixier P., Gasco N., Duhamel G. & Guinet C. (2015) Habituation to an acoustic harassment device (AHD) by killer whales depredating demersal longlines. *ICES Journal of Marine Science*, 72, 1673–1681.

6.33. Use acoustic devices on moorings

- **Eight studies** evaluated the effects on marine and freshwater mammals of using acoustic devices on moorings. Two studies were in the South Pacific Ocean[7,8] and one study was in each of the Puntledge River[1] (Canada), the Bay of Fundy[2] (Canada), the Shannon Estuary[3] (Ireland), the Rivers Conon and Esk[4] (UK), the Kyle of Sutherland estuary[5] (UK) and the North Atlantic Ocean[6] (UK).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (7 STUDIES)

- **Behaviour change (7 studies):** Two of four controlled studies in the South Pacific Ocean[7,8], the Kyle of Sutherland estuary[5] and the North Atlantic Ocean[6] found that deploying acoustic devices on moorings reduced numbers of grey and harbour seals[5], and the activity of harbour porpoises, short-beaked common dolphins and common bottlenose dolphins[6]. The two other studies found that using an acoustic device on a mooring did not have a significant effect on the number[7], direction of movement[7,8], speed[8], or dive durations[7,8] of migrating humpback whales. One controlled study in the Bay of Fundy[2] found that using an acoustic device on a mooring reduced harbour porpoise echolocation activity, but the probability of porpoises approaching within 125 m of the device increased over 10–11 days. One controlled study in the Shannon Estuary[3] found that one of two types of acoustic device reduced the activity of common bottlenose dolphins. One replicated, controlled study in the Rivers Conon and Esk[4] found that using acoustic devices reduced the number of grey and harbour seals upstream of the device but did not reduce seal numbers overall.

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One randomized controlled study in the Puntledge River[1] found that deploying an acoustic device on a mooring reduced the number of harbour seals feeding on migrating juvenile salmon.

Background

Acoustic devices (sometimes referred to as 'pingers') may be deployed on moorings to deter marine or freshwater mammals at wild fisheries. This may reduce the risk of mammals becoming entangled or captured in fishing gear. Mammal predation on fish catches may also decrease, which may reduce human-wildlife conflict. However, acoustic devices should be used with caution as the effects can span large distances and mammals may be deterred from important habitats or migration routes (Carlström *et al.* 2009). The use of multiple acoustic devices in an area may also have cumulative effects (Findlay *et al.* 2018).

Studies have been summarised below if they tested acoustic devices for the purpose of deterring mammals at wild fisheries and the device was deployed on a mooring. For similar interventions, see '*Use acoustic devices on fishing gear*' and '*Use acoustic devices on fishing vessels*'.

Interventions that use acoustic devices in response to other threats can be found in the following chapters: '*Threat: Aquaculture and agriculture*', '*Threat: Transportation* *and service corridors – Shipping lanes*', '*Threat: Energy production and mining – Renewable energy*', and '*Threat: Pollution – Noise pollution*.

Carlström J., Berggren P. & Tregenza N.J.C. (2009) Spatial and temporal impact of pingers on porpoises. *Canadian Journal of Fisheries and Aquatic Sciences*, 66, 72–82

Findlay C.R., Ripple H.D., Coomber F., Froud K., Harries O., van Geel N.C.F., Calderan S.V., Benjamins S., Risch D. & Wilson B. (2018) Mapping widespread and increasing underwater noise pollution from acoustic deterrent devices. *Marine Pollution Bulletin,* 135, 1042–1050.

A controlled study in 1996 at one site in the Puntledge River, British Columbia, Canada (*1*) found that deploying an acoustic device on a mooring under a bridge reduced the number of harbour seals *Phoca vitulina* feeding on migrating juvenile salmon *Oncorhynchus* spp. compared to when no device was used. The average number of seals feeding on salmon was lower with an acoustic device deployed (0.4 seals/night) than without (8 seals/night). In May 1996, an acoustic device (Airmar Seal Scarer with four projectors) was deployed for seven nights at a river below a bridge. The projectors were suspended 40 cm below the water surface attached to ropes and floats. The device emitted 2-second sound bursts at a frequency of 27 kHz. Two observers counted seals using a red-filtered spotlight every 30 minutes from 2100–0300 h during each of seven nights with the acoustic device active and seven randomly selected nights without the device.

A controlled study in 1998 at a pelagic site in the Bay of Fundy, Canada (*2*) found that an acoustic device attached to a mooring reduced harbour porpoise *Phocoena phocoena* echolocation activity, but the probability of porpoises approaching within 125 m of the device increased over 10–11 days. The average rate of harbour porpoise echolocation clicks and the proportion of 10-second intervals in which clicks were recorded were lower when the acoustic device was active (82 clicks/30 minutes; 0.04 intervals) than when it was inactive (516 clicks/30 minutes; 0.17 intervals). The probability of porpoises approaching within 125 m of the device initially decreased after the device was activated, then increased to equal the control (device inactive) over 10–11 days (data reported as statistical model results). An acoustic device (Dukane NetMark 1000) was attached 10 m below the water surface to a mooring located 1 km offshore. In June–September 1998, two trials were carried out in which the device was turned off (silent) for 2 weeks and turned on (emitting regular pulses at 10 kHz) for 2–4 weeks. Porpoises were tracked within a 500 m radius of the mooring using a theodolite. An acoustic detector attached to the mooring recorded porpoise echolocation clicks during one of the two trials.

A controlled study in 2005 at six pelagic sites in the Shannon Estuary, western Ireland (*3*) found that using 'continuous' acoustic devices on a mooring resulted in lower common bottlenose dolphin *Tursiops truncatus* echolocation activity compared to when inactive acoustic devices were used, but the difference was not significant for active and inactive 'responsive' acoustic devices. The average number of minutes in which dolphin echolocation clicks were detected was lower when 'continuous' acoustic devices were active (0 minutes/h; range: 0–0.05 minutes/h) than inactive (0.4 minutes/h; range: 0.2–1.1 minutes/h). The difference was not significant for 'responsive' acoustic devices that were active (0 minutes/h; range: 0–0.8 minutes/h) or inactive (0.6 minutes/h; range: 0.3–1.5 minutes/h). An active or inactive (silent) 'continuous' or 'responsive' acoustic device was randomly deployed at each of six sites for 3–5 x 24 h trials/treatment. 'Continuous' devices (Loughborough

University/Aquatech prototype) continuously emitted sounds (<1 second sounds every 5–20 seconds at 5–20 kHz). 'Responsive' devices (Aquatec AQUAmark) emitted sounds (300 ms sounds at 35–160 kHz) when dolphin clicks were detected by an internal microphone. Devices were attached to a static mooring (line between an anchor and buoy), 5–12 m below the water surface. An acoustic logger recorded dolphin activity alongside the acoustic devices during each of 18 trials in July 2005.

A replicated, controlled study in 2006–2008 at two sites in the Rivers Conon and North Esk, northeast Scotland, UK (*4*) found that using acoustic devices reduced the number of grey seals *Halichoerus grypus* and harbour seals *Phoca vitulina* upstream of the device but did not reduce the number of seals overall. Grey and harbour seals were observed upstream of the acoustic device during fewer surveys with the device turned on (North Esk: 5 surveys; Conon: 14 surveys) than turned off (North Esk: 9 surveys; Conon: 22 surveys). However, the overall number of seals did not differ significantly with the device turned on or off (data not reported). An acoustic device (Lofitech Seal Scarer) was deployed at each of the two rivers, 2–3 m from the bank at a depth of 2 m. The devices were turned on (emitting 500 ms pulses at 15kHz) or off (silent) for alternating periods of 1–30 days in January–May 2006 at one river and October–February 2007/2008 at the other. Both rivers (38–45 m wide) supported Atlantic salmon *Salmo salar* stocks. Seals were observed from the riverbank with binoculars during surveys (each lasting 1–1.5 h) with the device turned on (26–28 surveys) and off (29–36 surveys).

A controlled study in 2008–2011 at a river site in the Kyle of Sutherland estuary, Scotland, UK (*5*) found that using acoustic devices reduced the overall number of grey seal *Halichoerus grypus* and harbour seal *Phoca vitulina* sightings, and fewer seals were sighted upstream than downstream of the devices. Overall, fewer seals were sighted/hour with the acoustic devices turned on than off (data reported as statistical model results). Fewer seals were sighted upstream of the devices than downstream when they were turned on, whereas numbers were similar with the devices turned off. Two acoustic devices (Lofitech Seal Scarers) were attached to piping on the opposite sides of an estuary (100 m wide, 2 m deep), 1–10 m from the bank, 0.3–1 m above the river bed. Rivers upstream of the estuary supported Atlantic salmon *Salmo salar* fisheries. During each of three winters (October–January) in 2008–2011, the devices were turned on (emitting 500 ms tones at 15 kHz) and off (silent) for alternating periods of 3–13 days. Seals were guided downstream by a boat with an acoustic device prior to each 'on' treatment. Seals were observed from the riverbank during surveys (each lasting 2–3 h) with the devices turned on (72 surveys) and off (80 surveys).

A controlled study in 2012–2013 at a pelagic site in the North Atlantic Ocean, off the coast of Cornwall, UK (*6*) reported that when an acoustic device attached to a mooring was active, harbour porpoise *Phocoena phocoena*, short-beaked common dolphin *Delphinus delphis* and common bottlenose dolphin *Tursiops truncatus* echolocation activity was lower than when the device was inactive. Results are not based on assessments of statistical significance. Overall, 45 porpoise clicks/h and 4.9 dolphin clicks/h were recorded within 150 m of the mooring when the acoustic device was active, compared to 73 porpoise clicks/h and 6.6 dolphin clicks/h when the device was inactive. An acoustic device (Fishtek Banana Pinger) was attached to a fixed mooring in 40 m of water. The pinger was active (emitting 300 ms sounds at random intervals of 4–12 seconds with random frequencies between 50–120 kHz) and inactive (silent) for alternating 21 h periods. An acoustic logger deployed 150 m from the mooring recorded porpoise and dolphin echolocation clicks while the acoustic device was active (total 1,547 h) and inactive (total 1,420 h) between July 2012 and April 2013.

A controlled study in 2012 of a pelagic site in the South Pacific Ocean, Australia (*7*; same study area as *8*) found that when an acoustic device was deployed on a mooring, a similar number of migrating humpback whale *Megaptera novaeangliae* pods passed when the device was turned on or off, and the direction of whale pod movement and dive durations were also similar. The total number of whale pods passing within range (500 m) of the device did not differ significantly when the device was turned on (51 of 78, 65%) or off (31 of 59, 52%). The same was true for the average direction of whale pod movement (device on: 20° from north; device off: 19° from north) and average dive duration (device on or off: both 1.3 minutes). The acoustic device (Fumunda F3 Whale Pinger) was deployed at a depth of 5 m on a fixed mooring 1.3 km offshore in the centre of a whale migration route. The device was turned on (emitting 300 ms pulses at 3 kHz) for 18 days and off (silent) for 16 days. A total of 137 migrating whale pods were tracked from the shore using a theodolite during 430 h in June–August 2012.

A controlled study in 2013 of a pelagic site in the South Pacific Ocean, Australia (*8*; same study area as *7*) found that an active acoustic device deployed on a mooring did not have a significant effect on the movement, speed or dive durations of migrating humpback whale *Megaptera novaeangliae* pods. Whale pods that passed within range (500 m) of the acoustic device had a similar direction of movement, speed and dive durations when the device emitted 2 kHz tones (23° from north; 1.9 m/s; 5 minutes), 5.3 kHz tones (23° from north; 1.6 m/s; 7 minutes) or was inactive (22° from north; 1.9 m/s; 5 minutes). An acoustic device (an iPod attached to an amplifier and loudspeaker) was deployed at a depth of 5 m on a fixed mooring 1.3 km offshore in the centre of a whale migration route. During 11 h/day, the device emitted either 1.5 second tones every 8 seconds at 2–2.1 kHz (total 10 days), 400 ms tones every 5 seconds at 5.3 kHz (total 11 days) or was inactive (silent; total 12 days). A total of 108 migrating whale pods were tracked from the shore using a theodolite over the 33 days in June–August 2013.

(1) Yurk H. & Trites A.W. (2000) Experimental attempts to reduce predation by harbour seals on juvenile out-migrating salmonids. *Transactions of the American Fisheries Society*, 129, 1360–1366.

(2) Cox T.M., Read A.J., Solow A. & Tregenza N. (2001) Will harbour porpoises (*Phocoena phocoena*) habituate to pingers? *Journal of Cetacean Research and Management*, 3, 81–86.

(3) Leeney R.H., Berrow S., McGrath D., O'Brien J., Cosgrove R. & Godley B.J. (2007) Effects of pingers on the behaviour of bottlenose dolphins. *Journal of the Marine Biological Association of the United Kingdom*, 87, 129–133.

(4) Graham I.M., Harris R.N., Denny B., Fowden D. & Pullan D. (2009) Testing the effectiveness of an acoustic deterrent device for excluding seals from Atlantic salmon rivers in Scotland. *ICES Journal of Marine Science*, 66, 860–864.

(5) Harris R.N. (2011) *Long term effectiveness of an acoustic deterrent for seals in the Kyle of Sutherland*. Sea Mammal Research Unit, University of St Andrews, UK. Report to Scottish Government.

(6) Crosby, A., Tregenza, N. & Williams, R. (2013). *The Banana Pinger Trial: Investigation into the Fishtek Banana Pinger to reduce cetacean bycatch in an inshore set net fishery*. Report for the Wildlife Trusts.
(7) Harcourt R., Pirotta V., Heller G., Peddermors V. & Slip D. (2014) A whale alarm fails to deter migrating humpback whales: an empirical test. *Endangered Species Research*, 25, 35–42.
(8) Pirotta V., Slip D., Jonsen I.D., Peddemors V.M., Cato D.H., Ross G. & Harcourt R. (2016) Migrating humpback whales show no detectable response to whale alarms off Sydney, Australia. *Endangered Species Research*, 29, 201–209.

6.34. Play predator calls to deter mammals from fishing gear

- **One study** evaluated the effects of playing predator calls to deter mammals from fishing gear. The study was in the South Atlantic Ocean[1] (Africa).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One study in the South Atlantic Ocean[1] found that playing killer whale vocalisations did not deter Cape fur seals from feeding on fish catches in a purse-seine net or trawl net.

Background

Playing predator calls may deter marine and freshwater mammals from fishing gear. This may reduce the risk of mammals becoming entangled or captured in gear, as well as human-wildlife conflict resulting from mammal predation on fish catches. Caution is required, as this intervention may cause stress to mammals and could have negative impacts on mammal behaviour and habitat use.

A study in 1974 of pelagic sites in the South Atlantic Ocean, off the coast of southern Africa (*1*) reported that playing killer whale *Orcinus orca* vocalizations underwater did not deter Cape fur seals *Arctocephalus pusillus* from fishing nets. Results are not based on assessments of statistical significance. During two trials with a purse-seine net, all of 15–25 seals feeding in the net responded to killer whale vocalizations by diving. Some seals (48–100%) initially moved out of the net but all returned within 30 seconds. The authors report that floating two life-sized models of killer whale dorsal fins amongst the seals during one of the trials did not affect seal behaviour (no data provided). Results were similar during a trial at a trawl net (data not reported). Recordings of killer whale vocalizations (clicks, whistles, squeaks) were played back through an underwater loudspeaker. Two trials (each with 2–14 minutes of playback) were carried out by a purse-seine fishing vessel with the net pursed to a 10-m diameter. One trial was carried out by a side-trawler vessel with the 'cod-end' (containing fish) in the water. Observers on board the fishing vessels recorded seal behaviour during each of the three trials in 1974.

(1) Shaughnessy P.D., Semmelink A., Cooper J. & Frost P.G.H. (1981) Attempts to develop acoustic methods of keeping cape fur seals *Arctocephalus pusillus* from fishing nets. *Biological Conservation*, 21, 141–158.

6.35. Use an electric current to deter mammals from fishing gear

- **One study** evaluated the effects of using an electric current to deter mammals from fishing gear. The study was in the Fraser River (Canada)[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One controlled study in the Fraser River[1] found that using an electric current on a fishing net reduced Pacific harbour seal predation on salmon catches.

Background

Low-voltage electric currents may be used to deter marine and freshwater mammals from fishing gear. This may reduce the risk of mammals becoming entangled or captured in gear, as well as human-wildlife conflict resulting from mammal predation on fish catches. However, caution is required to ensure that mammals that have contact with the gear are not injured. There may also be safety risks for fishers operating electrified gear.

A controlled study in 2007 at a site in the Fraser River, Canada (*1*) found that using an electric current on a fishing net reduced Pacific harbour seal *Phoca vitulina richardsi* predation on catches of salmon *Oncorhynchus* spp. A section of fishing net treated with an electric current had higher catch rates of salmon (4 fish/km/minute) than an untreated section without an electric current (1 fish/km/minute). Seals were observed avoiding the electric section of the net (numbers not reported). An experimental nylon gill net (diagonal mesh size 133 mm, 60 meshes deep) was divided into two 91-m sections. One section was treated with a pulsed low-voltage electric current (produced by two horizontal wire electrodes spaced 2 m apart). The other section had no treatment. The net was deployed for 20 minutes three times/day on 22 days in August–September 2007. The electric treatment was alternated between the two sections of net. An observer on board the fishing vessel recorded salmon catches during a total of 67 net deployments.

(1) Forrest K.W., Cave J.D., Michielsens C.G.J., Haulena M. & Smith D.V. (2009) Evaluation of an electric gradient to deter seal predation on salmon caught in gill-net test fisheries. *North American Journal of Fisheries Management*, 29, 885–894.

6.36. Use noise aversive conditioning to deter mammals from fishing gear

- **One study** evaluated the effects on marine mammals of using noise aversive conditioning to deter mammals from fishing gear. The study was in the North Pacific Ocean[1] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One study in the North Pacific Ocean[1] found that noise aversive conditioning did not reduce bait foraging behaviour by California sea lions.

Background

Aversive conditioning is the process of associating a negative stimulus with a secondary behaviour or outcome. For this intervention, it involves associating a negative stimulus (a loud startling sound) with a neutral one (a non-startling sound) when marine and freshwater mammals are carrying out undesirable behaviour (predating on fish catches) to the extent that the neutral stimulus alone deters this behaviour. This may reduce the risk of mammals becoming entangled or captured in fishing gear. Mammal predation on fish catches may also decrease, which may reduce human-wildlife conflict at wild fisheries. The study summarised below tested the effects of the first step of this approach only, i.e. pairing a negative stimulus with a neutral one.

A controlled study in 2013–2014 of five pelagic areas in the North Pacific Ocean, off the coast of California, USA (*1*) found that attempts to condition California sea lions *Zalophus californianus* to avoid fishing lines by pairing a 'startle' sound with a 'neutral' sound did not reduce bait foraging behaviour. Playing 'startle' sounds alone reduced sea lion bait foraging behaviour by 83% and sea lions surfaced three times further from fishing vessels compared to when no sounds were played (data reported as statistical model results). However, there was no significant difference in sea lion behaviour when 'startle' sounds were played after a 'neutral' tone. Commercial passenger fishing vessels carried out fishing stops (each 0.1–2 h) across five areas with sounds played back through an underwater speaker (98 stops) or with no sounds (48 stops). Sounds were either a 'startle' pulse (200 ms of white noise at 10–11 kHz) or a 'startle' pulse played 2 seconds after a 'neutral' tone (6-second tone at 1–2 kHz with a 1.5 second long fade-in). Sound treatments were randomly selected during each fishing stop. Two observers on board each of the fishing vessels recorded bait foraging (sea lions taking bait from fishing lines during at least 50% of the time spent fishing) and distances of surfacing sea lions from vessels during each of the 146 fishing stops in May–September 2013 and 2014.

(1) Schakner Z.A., Gotz T., Janik V.M. & Blumstein D.T. (2017) Can fear conditioning repel California sea lions from fishing activities? Animal Conservation, 20, 425–432.

6.37. Use acoustic decoys to divert mammals away from fishing gear

- **One study** evaluated the effects on marine mammals of using acoustic decoys to divert mammals away from fishing gear. The study was in the Gulf of Alaska[1] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** One study in the Gulf of Alaska[1] found that increasing the distance between an acoustic decoy device and fishing lines resulted in fewer sperm whales at the lines, but sperm whale presence and time of arrival did not differ.

Background

Decoy devices may be used to divert marine and freshwater mammals away from fishing gear to reduce the risk of entanglement or capture. This may also reduce mammal predation on fish catches thereby reducing human-wildlife conflict.

A study in 2013 in a pelagic area in the western Gulf of Alaska, USA (*1*) found that increasing the distance between an acoustic decoy device and fishing lines resulted in fewer sperm whales *Physeter macrocephalus* at the lines, but sperm whale presence and time of arrival did not differ. Deploying acoustic decoy devices at greater distances from fishing lines resulted in fewer sperm whales at the lines during hauls (data reported as statistical model results). However, the distance between the decoy and fishing line did not have a significant effect on sperm whale presence during hauls or the time it took for sperm whales to arrive after hauling commenced. An acoustic decoy device was deployed at various distances (between 1.6 and 12.4 km) from 'long line' fishing lines (average 5 km in length) targeting sablefish *Anoplopoma fimbria* during a total of 14 deployments. The acoustic device (an underwater speaker attached to a buoy, 20 m deep) played recordings of vessel hauling sounds. Acoustic recorders deployed below the decoy and each fishing line at a depth of 100 m recorded sperm whale vocalizations. Fishers recorded sperm whale sightings and evidence of predation during each of the 14 hauls in June–July 2013.

(1) Wild L., Thode A., Straley J., Rhoads S., Falvey D. & Liddle J. (2017) Field trials of an acoustic decoy to attract sperm whales away from commercial longline fishing vessels in western Gulf of Alaska. *Fisheries Research*, 196, 141–150.

6.38. Use catch and hook protection devices on fishing gear

- **Five studies** evaluated the effects on marine mammals of using catch and hook protection devices on fishing gear. Two studies were in the South Pacific Ocean[1,4] (Chile, Australia and Fiji), two were in the Indian Ocean[3,5] (Seychelles, Madagascar) and one was in the Southwest Atlantic Ocean[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (5 STUDIES)

- **Reduction in entanglements/unwanted catch (1 study):** One study in the South Pacific Ocean[4] found that using cage or chain devices on fishing hooks resulted in fewer unwanted catches of toothed whales.
- **Human-wildlife conflict (5 studies):** Two of four studies (including three controlled and one before-and-after study) in the South Pacific Ocean[1,4], the Southwest Atlantic Ocean[2] and the Indian Ocean[3] found that net sleeves[1] or cage and chain devices[4] on fishing hooks reduced damage to fish catches by sperm whales[1], killer whales[1] and toothed whales[4]. The two other

studies found that attaching 'umbrella'[2] or 'spider'[3] devices on fishing hooks did not reduce predation and/or damage to fish catches by sperm whales[2] or toothed whales[3]. One controlled study in the Indian Ocean[5] found that attaching catch protection devices made from streamers to fishing lines reduced Indo-Pacific bottlenose and spinner dolphin predation on fish bait, but only during the first two trials.

Background

Catch and hook protection devices may be used to cover caught fish and hooks during hauling to reduce predation by marine and freshwater mammals and the subsequent capture of mammals. This may include 'net sleeves' which cover caught fish and hooks with the downward pressure of hauling, or triggered devices (e.g. chains, cages, cones etc.) that automatically release when a fish is hooked. This may prevent mammal injury or death due to hooking. A reduction in mammal predation on fish catches may also reduce human-wildlife conflict at wild fisheries. However, there are reports of automated protection devices failing to trigger or becoming tangled in fishing gear (Hamer *et al.* 2015, Rabearisoa *et al.* 2015).

Hamer D.J., Childerhouse S.J., McKinlay J.P., Double M.C. & Gales N.J. (2015) Two devices for mitigating odontocete bycatch and depredation at the hook in tropical pelagic longline fisheries. *ICES Journal of Marine Science*, 72, 1691–1705.

Rabearisoa N., Bach P. & Marsac F. (2015) Assessing interactions between dolphins and small pelagic fish on branchline to design a depredation mitigation device in pelagic longline fisheries. *ICES Journal of Marine Science*, 72, 1682–1690.

A before-and-after study in 2002 and 2006 of a pelagic area in the South Pacific Ocean, Chile (*1*) reported that using net sleeves on fishing hooks resulted in less sperm whale *Physeter macrocephalus* and killer whale *Orcinus orca* damage to catches of Patagonian toothfish *Dissostichus eleginoides*. Results are not based on assessments of statistical significance. The average percentage of fish damaged/haul by sperm or killer whales was lower when net sleeves were used on fishing hooks (0.4%) than when conventional fishing gear without net sleeves were used (3%). Eleven industrial vessels targeting Patagonian toothfish each deployed 99–120 'long line' fishing lines. Each deployment consisted of a main line with vertical branch lines (15–20 m long) and hooks at 40 m intervals. A cone-shaped net sleeve (1–1.2 m long) on each branch line covered caught fish during hauling. Fish damaged by whales were recorded by fishers and onboard observers as each line was hauled in September–December 2006. Data for 2002 were taken from a previous study in which the same area was fished with conventional 'long line' fishing gear without net sleeves (see original paper for details).

A replicated, controlled study in 2007–2008 of two pelagic areas in the Southwest Atlantic Ocean (*2*) found that using 'umbrella' devices on fishing hooks did not reduce sperm whale *Physeter macrocephalus* predation or damage to catches of Patagonian toothfish *Dissostichus eleginoides*. The proportion of hauls in which toothfish were taken or damaged by sperm whales did not differ significantly between fishing lines with all hooks covered by 'umbrella' devices (0–17% of hauls) and fishing lines with two-thirds or half of the hooks covered (0% and 8–16% respectively). Fewer toothfish were caught on hooks with 'umbrella' devices than on those without (data not reported). A total of 297 'long line' fishing lines (each with 900–3,000 hooks) were deployed across two fishing areas with different proportions of hooks (all, two-thirds or half) covered by 'umbrella' devices. 'Umbrella' devices were cone-shaped net sleeves (1.5–2 m long) that covered caught fish during hauling. An observer on board the fishing vessel recorded catches and whale-damaged fish or hooks during each of the 297 hauls in November–April 2007/2008.

A controlled study in 2007 of a pelagic area in the Indian Ocean off the Seychelles (*3*) reported that using 'spider' devices on fishing hooks did not reduce toothed whale (Odontoceti) predation and damage to fish catches. Results are not based on assessments of statistical significance. The proportion of fish damaged by toothed whales was higher on hooks protected with 'spider' devices (4 of 6 fish, 67%) than on unprotected hooks (8 of 15 fish, 53%). Fishing trials were carried out by a 'long line' fishery targeting tuna *Thunnus* spp. and swordfish *Xiphias gladius*. On each of 13 days, two fishing line sections were deployed, each with 480 hooks and 27–126 'spider' devices (one device on every 2–4 hooks). Devices (8 x 120 cm polyester strands attached to a plastic disc on the branch line) were designed to automatically trigger and cover hooked fish. Fish damage by toothed whales (ragged wounds, torn flesh, conical tooth marks) were recorded during each of the 26 hauls in November–December 2007.

A controlled study in 2010–2013 of two pelagic areas in the South Pacific Ocean, Australia, and Fiji (*4*) reported that using cage or chain devices on fishing hooks resulted in fewer catches of toothed whales (Odontoceti) and fewer whale-damaged fish. Results are not based on assessments of statistical significance. Overall, fewer whales were caught on hooks with cage or chain devices (0 whales) than on hooks without devices (4 whales). Whale-damaged fish were recorded on fewer hooks with cage or chain devices (3 hooks) than on those without (24 hooks). Catch rates of the five most abundant target fish species did not differ significantly between hooks with or without the devices (see original paper for data). Seven fishing vessels deployed a total of 94 'long line' fishing lines (34–42 km long) across two areas during eight trips. Each fishing line consisted of a treatment section (<1,000 branch lines with cage or chain devices attached to alternate hooks, each separated by a hook without a device) and a control section (<1,000 branch lines without devices). Devices were set to automatically trigger and cover caught fish with two steel chains or a cone-shaped nylon and aluminium cage. An observer on board each fishing vessel recorded catches and entangled whales during each of 94 hauls in 2010–2013.

A controlled study in 2011 in coastal waters in the Indian Ocean, off Reunion Island, near Madagascar (*5*) found that attaching catch protection devices made from streamers to fishing lines reduced Indo-Pacific bottlenose dolphin *Tursiops aduncus* and spinner dolphin *Stenella longirostris* predation on fish bait, but only during the first two hauls. Fishing lines with streamers attached had a lower proportion of fish partly or fully removed by bottlenose dolphins (15–26%) or spinner dolphins (3–15%) than lines without streamers (bottlenose dolphins: 50–68%; spinner dolphins: 24–65%) during the first two hauls. The proportion of partly or fully removed fish on lines with and without streamers did not differ significantly for four subsequent hauls with bottlenose dolphins present (with: 8–40%; without: 10–24%) and one subsequent haul with spinner dolphins present (with: 3%; without: 18%). Twenty 'long line' fishing lines (500 m long) baited with small fish were deployed in coastal waters. Each had 40 branch lines with streamers attached and 40 without. Streamers were 8 x 1 m lengths of tarpaulin (four of which were weighted) attached to the branch line above the fish. Fish status (intact, partly, or fully removed) on each branch line was recorded during six hauls with bottlenose dolphins present and three hauls with spinner dolphins present in March–June 2011.

(1) Moreno C.A., Castro R., Mujica L.J. & Reyes P. (2008) Significant conservation benefits obtained from the use of a new fishing gear in the Chilean Patagonian toothfish fishery. *CCAMLR Science*, 15, 79–91.

(2) Goetz S., Laporta M., Martinez Portela J., Begona Santos M. & Pierce G.J. (2011) Experimental fishing with an "umbrella-and-stones" system to reduce interactions of sperm whales (*Physeter macrocephalus*) and seabirds with bottom-set longlines for Patagonian toothfish (*Dissostichus eleginoides*) in the Southwest Atlantic. *ICES Journal of Marine Science*, 68, 228–238.

(3) Rabearisoa N., Bach P., Tixier P. & Guinet C. (2012) Pelagic longline fishing trials to shape a mitigation device of the depredation by toothed whales. *Journal of Experimental Marine Biology and Ecology*, 432–433, 55–63.

(4) Hamer D.J., Childerhouse S.J., McKinlay J.P., Double M.C. & Gales N.J. (2015) Two devices for mitigating odontocete bycatch and depredation at the hook in tropical pelagic longline fisheries. *ICES Journal of Marine Science*, 72, 1691–1705.

(5) Rabearisoa N., Bach P. & Marsac F. (2015) Assessing interactions between dolphins and small pelagic fish on branchline to design a depredation mitigation device in pelagic longline fisheries. *ICES Journal of Marine Science*, 72, 1682–1690.

6.39. Modify fishing pots and traps to exclude mammals

- **Six studies** evaluated the effects on marine mammals of modifying fishing pots and traps to exclude mammals. Two studies were in the North Sea[5,6] (UK, Sweden) and one study was in each of the Indian River Lagoon[1] (USA), the Gulf of Finland[2] (Finland), the Bothnian Sea[3] (Finland), the Indian Ocean[4] (Australia) and the Baltic Sea[6] (Sweden).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (6 STUDIES)

- **Reduction in entanglements/unwanted catch (2 studies):** Two controlled studies (including one replicated study) in the Indian Ocean[4], and the Baltic Sea and North Sea[6] found that installing steel rods on lobster pots[4] or metal frames on fishing pots[6] reduced the number of Australian sea lion pups[4] or grey seals and harbour seals[6] that entered[4] or became trapped[6] in pots.
- **Human wildlife conflict (4 studies):** Two controlled studies (including one replicated study) in the Bothnian Sea[3] and the North Sea[5] found that installing wire grids[3] or steel bars[5] on fishing trap-nets[3] or bag-nets[5], along with strengthened netting[3] or other modifications to prevent seal access[5], reduced damage to salmon catches by seals. One controlled study in the Indian River Lagoon[1] found that one of two methods of securing crab pot doors with a bungee cord reduced the number of common bottlenose dolphin interactions. One controlled study in the Gulf of Finland[2] found that installing wire grids on trap-nets, along with strengthened netting, resulted in higher catches of undamaged salmon but not whitefish, likely due to reduced seal predation.

Background

Marine and freshwater mammals may predate on catches in fishing pots and traps, which can result in mammals being trapped or entangled. Modifying traps to exclude mammals may reduce this risk. Losses to fishers and damage to gear may also be reduced, thereby reducing human-wildlife conflict at wild fisheries. Methods to exclude mammals may include changing the pot/trap configuration, securing pot/trap doors, using strengthened materials, or adding a physical device (sometimes referred to as a 'Depredation Mitigation Device') to prevent entry, such as a metal grid or rods.

A controlled study in 1998 in an estuary in the Indian River Lagoon, Florida, USA (*1*) found that securing crab pot doors with a V-shaped bungee cord strung through the wire mesh of the pot reduced the number of common bottlenose dolphin *Tursiops truncatus* interactions compared to conventional methods, but using a V-shaped bungee cord attached to three steel rings did not. Securing the door with a V-shaped bungee cord strung through the wire mesh on each side resulted in fewer dolphin interactions with the pot (1 in total) than conventional methods of securing the door (29 in total). The difference was not significant when a V-shaped bungee cord attached to three steel rings was used (total 38 interactions). Twenty wire crab pots (51 x 51 x 51 cm) were deployed by a blue crab *Callznectes sapidus* fishery with each of three methods of securing the bait-well door with 5-mm elastic bungee cords: V-shaped cord strung through wire mesh; V-shaped cord attached to three steel rings; conventional method (diagonal cord attached to two steel rings). The 60 pots were baited with herring and checked at 48 h intervals in July–October 1998. Fishers recorded signs of dolphin interactions (broken bungee cords, doors forced open, missing bait).

A controlled study in 2001 of a pelagic area in the Gulf of Finland, Finland (*2*) found that installing a wire grid and strengthened netting in trap-nets resulted in higher catches of undamaged salmon *Salmo salar* but not whitefish *Coregonus lavaretus*, likely due to reduced grey seal *Halichoerus grypus* predation. Average catch rates of undamaged salmon were greater in fish bags of modified trap-nets (6 kg/haul) than in conventional trap-nets (4 kg/haul). The difference was not significant for catch rates of undamaged whitefish (modified trap-nets: 33 kg/haul; conventional trap nets: 29 kg/haul). Five modified and five conventional salmon trap-nets were hauled 241 and 242 times respectively in June–August 2001. Four modified and four conventional whitefish trap-nets were hauled 173 and 180 times respectively in September–November 2001. Modified trap-nets had a wire grid (1.2 x 0.8 m with 2 mm wires spaced 175 mm apart) in the funnel of the trap and a fish bag made from Dyneema netting. Conventional trap-nets had an open funnel and fish bags made from elastic nylon (salmon trap-nets) or stiff polyethylene (whitefish trap-nets). Fish catches were weighed, and fish damaged by seals or seabirds were recorded, during each haul.

A replicated, controlled study in 2003–2004 of five pelagic areas in the Bothnian Sea, Finland (*3*) reported that five designs of modified trap-net with wire grids and strengthened netting had lower proportions of salmon *Salmo salar* damaged by seals than traditional trap-nets. One design of modified trap-net (a 'pontoon' trap) had a significantly lower average proportion of seal-damaged salmon/haul (1%) than two types of traditional trap-net (30%), and total catch rates were similar (modified trap-nets: 2.3 fish/haul; traditional trap-nets: 1.9–2.4 fish/haul). Four other designs of modified trap-net had lower proportions of seal-damaged salmon (4–27%) than traditional trap-nets, although statistical significance was either not assessed or not reported. Four commercial fishers each deployed modified trap-nets and two types of traditional trap-net (number of each not reported) at random locations within their fishing grounds. Four designs were tested for four weeks in June 2003 ('pontoon' trap, 'pipe' trap, 'protection-net' trap, 'large-mesh' trap). Two designs were tested for 19 days in June 2004 ('pontoon' trap, 'folded-hoop' trap). Modified trap-net designs had a wire-grid within the funnel and/or 'seal-safe' netting around the fish bag (see original paper for details). Each trap was hauled once/day. Researchers recorded fish catches and seal-damaged fish during each haul in 2003 and 2004.

A controlled study (year not stated) in coastal waters of the Indian Ocean, Western Australia (*4*) reported that installing steel rods on lobster pots resulted in fewer Australian sea lion *Neophoca cinerea* pups entering the pots, and a smaller gap at the pot opening excluded more sea lion pups. Results are not based on assessments of statistical significance. Fewer sea lion pups successfully entered pots with steel rods fitted (0–45%) than pots without (82%). More sea lion pups were excluded from pots with a smaller gap between the rod and pot opening (60 mm gap: 55% of pups excluded; 40 mm gap: 72%; 20 mm gap: 95%; 0 mm gap: 100%). Daily catch rates of target rock lobster *Panulirus cygnus* did not differ significantly between pots with or without steel rods (see original paper for data). A lobster pot with a steel rod and a control pot (without a steel rod) were filled with 10–15 lobsters and deployed in shallow water adjacent to a sea lion breeding colony. The height of the steel rod was varied to create four gap sizes at the pot opening (0, 20, 40 or 60 mm). Trials were carried out for each of the four pot treatments until all lobsters were removed or sea lions moved away from the area (dates not reported). Sea lion pups that placed their head into the pot (at risk of drowning) were counted as entering pots.

A controlled study in 2012 at a bay and harbour in the North Sea, Scotland, UK (*5*) found that fishing bag-nets with rigid steel bars, along with other modifications to prevent seal access, had greater catches of Atlantic salmon *Salmo salar* undamaged by seals than conventional bag-nets, but salmon took longer to pass through the modified net and a greater proportion escaped. Catch rates of undamaged salmon were almost twice as high in modified bag-nets than in conventional bag-nets (data reported as a catch rate index). However, salmon in the modified bag-net took longer to pass through the net (average 200 seconds) and a larger proportion swam back out of the net (65%) than in the conventional bag-net (average 44 seconds; 28%). A modified salmon bag-net and a conventional bag-net were deployed 250 m apart at a bay and a harbour. Modifications to the bag-net prevented seals from entering the inner chamber and trapping fish (e.g. rope-framed entrance replaced with rigid steel bars, heavier net material, a reduced mesh size in the net floor, tight corners inside the chamber closed off). Fishers reported fish catches and seal damage for modified and conventional bag-nets during a total of 130 hauls in July–August 2012.

A replicated, controlled study in 2009–2010 of three pelagic sites in the Baltic Sea and one seabed site in the North Sea, Sweden (*6*) found that fishing pots with metal frames installed had fewer trapped grey seals *Halichoerus grypus* and harbour seals *Phoca vitulina* than conventional pots. No seals were trapped in pots with metal frames installed, whereas 3–9 seals/site (11 grey seals and 13 harbour seals in total) were trapped in conventional pots without metal frames. Catches of target cod *Gadus* spp. varied with different designs of metal frame (see original paper for details). In 2009–2010, baited fishing pots (with two chambers and 1–2 entrances) were deployed in 5–12 floating strings of ≤8 pots (three sites), or individually with ≤6 pots secured to the seabed (one site). The pots were deployed for a total of 2–20 months without metal frames installed followed by 3–10 months with frames. Metal frames of five designs were vertically mounted to the narrow end of pot entrances (see original paper for details). Fishers or observers on board fishing vessels checked the pots every 1–28 days in 2009–2010 and recorded the number and species of trapped seals.

(1) Noke W.D. & Odell D.K. (2002) Interactions between the Indian River Lagoon blue crab fishery and the bottlenose dolphin, *Tursiops truncatus*. *Marine Mammal Science*, 18, 819–832.
(2) Lehtonen E. & Suuronen P. (2004) Mitigation of seal-induced damage in salmon and whitefish trapnet fisheries by modification of the fish bag. *ICES Journal of Marine Science*, 61, 1195–1200.
(3) Suuronen P., Siira A., Kauppinen T., Riikonen R., Lehtonen E. & Harjunpaa H. (2006) Reduction of seal-induced catch and gear damage by modification of trap-net design: Design principles for a seal-safe trap-net. *Fisheries Research*, 79, 129–138.
(4) Campbell R., Holley D., Christianopoulos D., Caputi N. & Gales N. (2008) Mitigation of incidental mortality of Australian sea lions in the west coast rock lobster fishery. *Endangered Species Research*, 5, 345–358.
(5) Harris, R.N., Fowden, D., Froude, M. & Northridge, S. (2014) *Marine mammal research at wild salmon fisheries, annual report for 2013*. Report to Marine Scotland, Sea Mammal Research Unit, University of St Andrews, UK.
(6) Konigson S., Lovgren J., Hjelm J., Ovegard M., Ljunghager F. & Lunneryd S.-G. (2015) Seal exclusion devices in cod pots prevent seal bycatch and affect their catchability of cod. *Fisheries Research*, 167, 114–122.

6.40. Install exclusion and/or escape devices for mammals on fishing nets

- **Seven studies** evaluated the effects on marine mammals of installing exclusion and/or escape devices on fishing nets. Four studies were in the Indian Ocean[2–5] (Australia, Tasmania) and/or Tasman Sea[4] (Tasmania) and three studies were in the South Atlantic Ocean[1a–c] (South Georgia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Survival (2 studies):** One study in the Indian Ocean[5] found that less than one third of common bottlenose dolphins exited escape hatches on trawl nets alive. One replicated study in the Tasman Sea and Indian Ocean[4] found that fewer fur seals died in exclusion devices with large escape openings than in those with small openings.

BEHAVIOUR (0 STUDIES)

OTHER (5 STUDIES)

- **Reduction in entanglements/unwanted catch (5 studies):** Three studies (including two controlled studies) in the South Atlantic Ocean[1a,1b] and Indian Ocean[2] found that installing exclusion and/or escape devices on trawl nets reduced the number of trapped or entangled Antarctic fur seals[1a,1b] and common bottlenose dolphins[2]. One before-and-after study in the Indian Ocean[3] found that installing exclusion and escape devices on trawl nets reduced common bottlenose dolphin entanglements for three of four fishing vessels. One study in the South Atlantic Ocean[1c] found that modifying an exclusion and escape device by enlarging and relocating the escape panel resulted in fewer Antarctic fur seal entanglements.

Background

Marine and freshwater mammals may become trapped or entangled in fishing nets, such as trawl nets. Exclusion devices, such as rigid or flexible grids, are designed to prevent access to mammals while allowing the target species to pass through into the narrow end ('cod-end') of the net. Escape holes may be installed in the top or bottom of the net in combination with exclusion devices to allow mammals to exit. However, exclusion devices may cause injury or distress to mammals and it is important to assess the survival of animals after escape (Hamilton & Baker 2015).

Hamilton S. & Baker G.B. (2015) Review of research and assessments on the efficacy of sea lion exclusion devices in reducing the incidental mortality of New Zealand sea lions *Phocarctos hookeri* in the Auckland Islands squid trawl fishery. *Fisheries Research,* 161, 200–206.

A controlled study in 2004 of a pelagic site in the South Atlantic Ocean, South Georgia (*1a*) reported that installing exclusion and escape devices on trawl nets resulted in fewer Antarctic fur seal *Arctocephalus gazella* entanglements compared to when no devices were installed. Results are not based on assessments of statistical significance. Fewer seals were entangled when exclusion and escape devices were installed within trawl nets (total 28 seals; 0.2 seals/trawl) than when no devices were installed (total 157 seals, 1.9 seals/trawl). A commercial fishing vessel ('Top Ocean', USA) trawling for krill (Euphausiacea) with two nets carried out 118 trawls with exclusion and escape devices on both nets, and 81 trawls without devices installed. Exclusion and escape devices on each net were modified throughout the study (see original paper for details). The final design had an inclined mesh barrier (140 mm mesh size) within the net, 1–3 escape openings (1–1.6 m diameter) in the roof of the net, and a large mesh barrier (14 x 12 m) inserted 47 m from the mouth of the net. Seal entanglements were recorded by fishers (30 trawls) and an independent observer (169 trawls) in June–July 2004.

A study in 2004 of a pelagic site in the South Atlantic Ocean, South Georgia (*1b*) reported that installing two designs of exclusion device on trawl nets resulted in fewer Antarctic fur seal *Arctocephalus gazella* entanglements compared to when no device was installed. Results are not based on assessments of statistical significance. Fewer seals were entangled in trawl nets with a mesh barrier (total 5 seals, 0.8 seals/trawl) or a mesh 'bag' (total 2 seals, 0.06 seals/trawl) installed at the mouth of the net compared to when no exclusion device was installed (total 76 seals, 1.4 seals/trawl). The mesh barrier also reduced target fish catches (data not reported). A commercial fishing vessel ('InSung Ho', Republic of Korea) trawling for krill (Euphausiacea) carried out six trawls with a mesh barrier, 42 trawls with a mesh 'bag' and 55 trawls without an exclusion device installed. The mesh barrier comprised two mesh panels (44 x 20 m; 240 mm mesh size) attached to the head rope and ground rope at the mouth of the trawl net. The mesh 'bag' comprised one mesh panel (240 mm mesh size) attached to the mouth of the trawl net and extending 20 m into the body of the net to form a large 'bag'. Seal entanglements were recorded by fishers (eight trawls) and an independent observer (95 trawls) in August 2004.

A study in 2004 of a pelagic site in the South Atlantic Ocean, South Georgia (*1c*) reported that modifying an exclusion and escape device by enlarging and relocating the escape panel resulted in fewer Antarctic fur seal *Arctocephalus gazella* entanglements. Results are not based on assessments of statistical significance. A total of 11 seals (6 seals/trawl) were entangled in trawl nets with an exclusion device angled towards a small escape panel in the roof of the net. However, after the exclusion device was angled towards a larger escape panel in the floor of the net, no seals were found entangled. A commercial fishing vessel ('Atlantic Navigator', Vanuatu) carried out a total of 15 trawls for krill (Euphausiacea) with a sloping metal grid angled towards an escape panel within the trawl net. In the first two trawls, a smaller escape panel (size not reported) was located within the roof of the net. In the following 13 trawls, the escape panel was larger (size not reported) and located in the floor of the net. During trawls, the net was kept at fishing depths for long periods and a pump used to remove krill. Seal entanglements were recorded by fishers (two trawls) and an independent observer (13 trawls) in June–July 2004.

A controlled study in 2005–2006 of a pelagic area in the Indian Ocean, Western Australia (*2*; same study area as *3*) reported that trawl nets with exclusion and escape devices installed had fewer trapped common bottlenose dolphins *Tursiops truncatus* than those without devices, but some dolphins exited the net dead or in distress. Results are not based on assessments of statistical significance. Eight dolphins/1,000 trawls were trapped in nets with exclusion devices, whereas 15–22 dolphins/1,000 trawls were trapped in nets without exclusion devices. Three of seven dolphins were observed exiting nets alive, through the escape opening or the mouth of the net. The other four dolphins died or were in distress and fell through the escape opening dead. Six commercial fishing vessels deployed trawl nets with exclusion devices (2006: total 1,156 trawls) and without (2005: 659 trawls; 2006: 229 trawls). Exclusion devices were semi-flexible metal grids (1.2 x 2 m; 15.5 cm vertical bar spacing) attached to the start of the net extension, 10 m from the end of the net, with an escape opening below. Onboard observers recorded trapped dolphins during each haul in 2005–2006. Underwater video cameras recorded the activity of seven dolphins in trawl nets with exclusion devices in 2006.

A before-and-after study in 2003–2009 of a pelagic area in the Indian Ocean, Western Australia (*3*; same study area as *2*) found that installing exclusion and escape devices on trawl nets reduced common bottlenose dolphin *Tursiops truncatus* entanglements for three of four fishing vessels. Dolphin entanglement rates reported by skippers were significantly lower for three of four fishing vessels after exclusion and escape devices were installed (2.4–6.8 dolphins/1,000 trawls) than before (7.1–11.3 dolphins/1,000 trawls). The difference was not significant for the other vessel (after: 5.6 dolphins/1,000 trawls; before: 5.1 dolphins/1,000 trawls). Exclusion and escape devices were introduced to a trawl fishery in March 2006. A semi-flexible metal grid with vertical bars was fitted on trawl nets, either just before the 'cod-end' or at the start of the net extension. The grid was angled towards a bottom-opening escape hatch. Numbers of entangled dolphins were extracted from skippers' logbooks for periods before (August 2003–March 2006; total 11,168 trawls) and after (March 2006–September 2009; total 16,736 trawls) exclusion and escape devices were fitted.

A replicated study in 2006–2007 of three pelagic sites in the Tasman Sea and Indian Ocean, Tasmania, Australia (*4*) found that exclusion devices on trawl nets with large escape openings had lower fur seal *Arctocephalus* spp. mortality than those with small escape openings. Fewer fur seals died in exclusion devices with large escape openings (6 of 90 seals, 7%) than in exclusion devices with small escape openings (14 of 56 seals, 25%). Midwater trawls were carried out by a commercial fishing vessel at each of three sites using exclusion devices with a small escape opening (1 m^2; total 30 trawls) or large escape opening (1.9 m^2; total 48 trawls). Exclusion devices had two vertical steel grids (2.3 m^2) angled forwards with an escape opening at the base. An underwater video camera recorded behaviour and mortality of seals within the exclusion devices during each of the 78 trawls in 2006–2007.

A study in 2012 of a pelagic area in the Indian Ocean, Western Australia (*5*) found that less than 30% of common bottlenose dolphins *Tursiops truncatus* that entered exclusion and escape devices on trawl nets escaped alive through hatches. Two of seven dolphins that entered exclusion and escape devices on trawl nets escaped alive through an escape hatch in the roof of the net within 18 seconds and five minutes. The five other dolphins were retained at the grid of the exclusion device, one of which died and was expelled through an escape hatch. The seven dolphins were recorded interacting with exclusion and escape devices during five of 774 day-trawls carried out by a commercial fishery targeting groundfish. Exclusion and escape devices were installed between the body and 'cod-end' extension panel of each trawl net. The devices consisted of a steel grid angled either up or down towards an escape hatch and/or slit in the roof or floor of the net. Underwater video cameras recorded dolphins within the nets during each of the five trawls in June–September 2012.

(1) Hooper J., Clark J.M., Charman C. & Agnew D. (2005) Seal mitigation measures on trawl vessels fishing for krill in CCAMLR subarea 48.3. *CCAMLR Science*, 12, 195–205.

(2) Stephenson P.C., Wells S. & King J.A. (2006) *Evaluation of exclusion grids to reduce the catch of dolphins, turtles, sharks and rays in Pilbara trawl fishery. DBIF Funded Project.* Fisheries Research Report No. 171, Department of Fisheries Western Australia.

(3) Allen S.J., Tyne J.A., Kobryn H.T., Bejder L., Pollock K.H. & Loneragan N.R. (2014) Patterns of dolphin bycatch in a north-western Australian trawl fishery. *PLoS ONE*, 9, e93178.

(4) Lyle J.M., Willcox S.T. & Hartmann K. (2015) Underwater observations of seal-fishery interactions and the effectiveness of an exclusion device in reducing bycatch in a midwater trawl fishery. *Canadian Journal of Fisheries and Aquatic Sciences*, 73, 436–444.

(5) Wakefield C.B., Santana-Garcon J., Dorman S.R., Blight S., Denham A., Wakeford J., Molony B.W. & Newman S.J. (2017) Performance of bycatch reduction devices varies for chondrichthyan, reptile, and cetacean mitigation in demersal fish trawls: assimilating subsurface interactions and unaccounted mortality. *ICES Journal of Marine Science*, 74, 343–358.

6.41. Install barriers at wild fisheries

- **One study** evaluated the effects on freshwater mammals of installing a barrier at a wild fishery. The study was in the Puntledge River[1] (Canada).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One randomized, controlled study in the Puntledge River[1] found that installing a 'cork line' barrier did not deter harbour seals from feeding on salmon released from a hatchery.

Background

Barriers may be installed at wild fisheries to deter marine and freshwater mammals from feeding on fish. This may reduce human-wildlife conflict and the motivation to use lethal or harmful deterrents.

A controlled study in 1996 at a site in the Puntledge River, British Columbia, Canada (*1*) found that installing a 'cork line' barrier did not reduce the number of harbour seals *Phoca vitulina* feeding on migrating juvenile salmon *Oncorhynchus* spp. under a bridge. Results are not based on assessments of statistical significance. Average numbers of seals feeding on juvenile salmon under the bridge were similar with a 'cork line' barrier installed (2–3 seals/30 minutes) and without (2 seals/30 minutes). Seals were observed 'playing' with the barrier. In April 1996, a 'cork line' (a 60-m rope with cork floats attached at 1 m intervals) was strung across a river below a bridge for an average of 3 h during each of two nights. Juvenile salmon were released from a hatchery. Two observers counted seals feeding on salmon using a red-filtered spotlight every 30 minutes from 2100–0300 h during each of two nights with the barrier and one randomly selected night without.

(1) Yurk H. & Trites A.W. (2000) Experimental attempts to reduce predation by harbour seals on juvenile out-migrating salmonids. *Transactions of the American Fisheries Society*, 129, 1360–1366.

6.42. Switch off artificial lighting at wild fisheries

- **One study** evaluated the effects on freshwater mammals of switching off artificial lights at a wild fishery. The study was in the Puntledge River[1] (Canada).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One randomized, controlled study in the Puntledge River[1] found that switching off artificial lights on a bridge did not deter harbour seals from feeding on salmon released from a hatchery.

Background

Marine and freshwater mammals, such as seals, may use artificial lighting to feed on fish at wild fisheries at night. Switching off lighting that shines onto the water may reduce mammal predation, thereby reducing human-wildlife conflict and the motivation to use lethal or harmful deterrents.

A controlled study in 1996 at a site in the Puntledge River, British Columbia, Canada (*1*) found that switching off artificial lights on a bridge did not reduce the number of harbour seals *Phoca vitulina* feeding on migrating juvenile salmon *Oncorhynchus* spp. Average numbers of seals feeding on salmon under the bridge did not differ significantly with artificial lights switched off (1–10 seals/30 minutes) or on (2–15 seals/30 minutes). In April–May 1996, fourteen artificial lights on a bridge over the river were switched off for four nights. Juvenile salmon were released from a hatchery. Two observers counted seals feeding on salmon using a red-filtered spotlight every 30 minutes from 2100–0300 h during each of the four treatment nights and eight randomly selected nights with no treatments.

(1) Yurk H. & Trites A.W. (2000) Experimental attempts to reduce predation by harbour seals on juvenile out-migrating salmonids. *Transactions of the American Fisheries Society*, 129, 1360–1366.

6.43. Use different bait species for fishing that are less attractive to mammals

- We found no studies that evaluated the effects of using different bait species for fishing that are less attractive to mammals on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Using alternative bait species that are less attractive to marine and freshwater mammals may reduce entanglement and capture of mammals in fishing gear. Losses to fishers may also be reduced thereby reducing human-wildlife conflict and the motivation to use lethal or harmful deterrents.

6.44. Retain offal on fishing vessels instead of discarding overboard

- We found no studies that evaluated the effects of retaining offal on fishing vessels instead of discarding overboard on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Discarding offal overboard during fishing may attract marine and freshwater mammals and increase the risk of entanglement or capture in gear. Retaining offal on board or disposing of offal at locations and times away from fishing operations may reduce this risk.

6.45. Use 'mammal-safe' nets to capture and release mammals trapped in fishing structures

- **One study** evaluated the effects on marine mammals of using 'mammal-safe' nets to capture and release mammals trapped in fishing structures. The study was in the Bay of Fundy[1] (Canada).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** One controlled study in the Bay of Fundy[1] found that using 'marine mammal nets' with a larger mesh size to release harbour porpoises from herring weirs resulted in lower porpoise mortality compared to using conventional herring nets.

BEHAVIOUR (0 STUDIES)

Background

Marine and freshwater mammals may enter fixed fishing structures, such as herring weirs, and become trapped. This intervention involves the use of specially designed nets, e.g. made with buoyant materials and a larger mesh size, to capture and release mammals instead of conventional fishing nets. This may reduce the risk of injury or death during release.

A controlled study in 1992–2001 at coastal fishing sites in the Bay of Fundy, Canada (*1*) found that using specialised 'marine mammal nets' with a large mesh size to release harbour porpoises *Phocoena phocoena* from herring weirs resulted in lower porpoise mortality compared to when conventional nets were used. Overall porpoise mortality rates were lower when released from weirs with 'marine mammal nets' (6 of 240 porpoises, 3%) than with conventional herring nets (44 of 239 porpoises, 18%). Porpoises trapped in herring weirs were captured and released using two types of purse-seine net: 'marine mammal nets' (buoyant polypropylene with mesh size 7.5 cm; 240 porpoises) and conventional herring nets (mesh size 0.75–1.25 cm; 239 porpoises). Herring weirs (comprising 1-cm nylon mesh strung between wooden stakes in a kidney-shape, 3–20 m deep) were built near the shore to catch Atlantic herring *Clupea harengus*. Trapped porpoises were enclosed within the purse-seine nets, transferred to boats and released outside of the weirs. Researchers recorded porpoise deaths during each of the 479 release attempts in 1992–2001.

(1) Neimanis A.S., Koopman H.N., Westgate A.J., Murison L.D. & Read A.J. (2004) Entrapment of harbour porpoises (*Phocoena phocoena*) in herring weirs in the Bay of Fundy, Canada. *Journal of Cetacean Research and Management*, 6, 7–18.

6.46. Establish handling and release protocols for mammals captured by fisheries

- **One study** evaluated the effects on marine mammals of establishing handling and release protocols for mammals captured by wild fisheries. The study was in the Great Australian Bight[1] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** One before-and-after study in the Great Australian Bight[1] found that introducing a code of conduct for releasing dolphins trapped in nets, along with avoiding dolphins during fishing, resulted in lower mortality of short-beaked common dolphins.

BEHAVIOUR (0 STUDIES)

Background

Establishing best practice protocols for handling and releasing marine and freshwater mammals entangled or captured in fishing gear may reduce the risk of injury and improve post-release survival. This may involve releasing mammals without delay, using appropriate techniques to remove fishing gear from entangled or hooked mammals, and using appropriate procedures to release mammals encircled in nets. See also '*Provide training and tools for safe release of mammals captured by fisheries*'.

For an intervention related to releasing mammals from derelict fishing gear, see '*Threat: Pollution – Garbage and solid waste – Fishing gear – Remove derelict fishing gear from mammals found entangled*'.

A before-and-after study in 2004–2006 of a pelagic area in the Great Australian Bight, Australia (*1*) found that introducing a code of practice for releasing dolphins trapped in fishing nets, along with avoiding dolphins during fishing, resulted in fewer deaths of short-beaked common dolphins *Delphinus delphis*. The study did not distinguish between the effects of releasing and avoiding dolphins. Mortality rates of dolphins in purse-seine nets were lower after the code of conduct was put in place (0.01 dolphins killed/net) than before (0.4 dolphins killed/net). The code of practice was introduced to a sardine *Sardinops sagax* fishery in September 2005. At least one crew member/vessel was required to observe for dolphins. Fishing was delayed or relocated if dolphins were present. Release procedures for encircled dolphins included opening the net or a dolphin gate within the net, using weights to submerge the float line, physical removal of dolphins or stopping fishing. An independent observer recorded dolphin encirclements and deaths during 49 fishing events by eight vessels in November–June 2004/2005 (before the code of conduct) and 89 fishing events by 12 vessels in November–June 2005/2006 (after).

(1) Hamer D.J., Ward T.M. & McGarvey R. (2008) Measurement, management and mitigation of operational interactions between the South Australian Sardine Fishery and short-beaked common dolphins (*Delphinus delphis*). *Biological Conservation*, 141, 2865–2878.

6.47. Provide training and tools for safe release of mammals captured by fisheries

- We found no studies that evaluated the effects of providing training and tools for the safe release of mammals captured by fisheries on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Providing training and tools for the safe release of marine and freshwater mammals captured by fisheries may increase the survival of released mammals. Specially designed tools may reduce stress and potential injury to captured mammals (e.g. Bergmann *et al.* 2016). Training may be provided on best practice handling and release protocols. See '*Establish handling and release protocols for mammals captured by fisheries*'.

For an intervention related to releasing mammals from derelict fishing gear, see '*Threat: Pollution – Garbage and solid waste – Fishing gear – Remove derelict fishing gear from mammals found entangled*'.

Bergmann C., Barbour J., LaForce L. & Driggers W.B. (2016) Line cutter for use when releasing large marine organisms caught on longline gear. *Fisheries Research,* 177, 124–127.

6.48. Introduce legislation to prohibit or restrict the use of fishing gear types or methods that are harmful to mammals

- We found no studies that evaluated the effects of introducing legislation to prohibit or restrict the use of fishing gear types or methods that are harmful to mammals on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves introducing legislation to prohibit or restrict the use of fishing gear types or methods that have a high risk of injuring or killing marine and freshwater mammals, e.g. by entanglement or incidental capture. For example, large-scale pelagic drift nets were banned in international waters by a United Nations resolution adopted in 1992 due to high levels of bycatch of cetaceans and other taxa (United Nations General Assembly 1990). Enforcement may be required if compliance is low. See '*Enforce legislation to control illegal fishing using gear or methods that are harmful to mammals*'.

United Nations General Assembly (1990) *Large-scale pelagic driftnet fishing and its impact on the living marine resources of the world's oceans and seas: Report of the Secretary-General*. UN Doc. A/45/663.

6.49. Enforce legislation to control illegal fishing using gear or methods that are harmful to mammals

- We found no studies that evaluated the effects of enforcing legislation to control illegal fishing using gear or methods that are harmful to mammals on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Legislation has been put in place in some countries to prohibit or restrict the use of certain types of fishing gear or methods that are harmful to marine and freshwater mammals. However, illegal fishing activities may still occur (e.g. Tudela *et al.* 2005). This intervention involves enforcing existing legislation to reduce illegal fishing with gear types or methods that are harmful to mammals. This may involve measures such as deploying patrol boats, introducing vessel monitoring procedures (such as onboard human observers or CCTV), establishing stricter port controls, reporting of fishing effort, and issuing fines and penalties for non-compliance. Local communities may also be involved, e.g. by reporting illegal fishing activities (Butler *et al.* 2017).

Butler J.R.A., McKelvey S.A., McMyn I.A.G. & Leyshon B. (2017) Does community surveillance mitigate by-catch risk to coastal cetaceans? Insights from salmon poaching and bottlenose dolphins in Scotland. *Fisheries and Oceanography,* 3, 555603.

Tudela S., Kai Kai A., Maynou F., El Andalossi M. & Guglielmi P. (2005) Driftnet fishing and biodiversity conservation: the case study of the large-scale Moroccan driftnet fleet operating in the Alboran Sea (SW Mediterranean). *Biological Conservation,* 121, 65–78.

Stakeholder engagement and behaviour change

6.50. Involve fishers in designing and trialling new fishing gear types to encourage uptake of gear that reduces unwanted catch of mammals

- We found no studies that evaluated the effects of involving fishers in designing and trialling new fishing gear types to encourage uptake of gear that reduces unwanted catch of mammals on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Involving fishers in designing and trialling new fishing gear types that reduce the unwanted catch ('bycatch') of marine and freshwater mammals may lead to greater uptake of new gear types.

See also '*Finance low interest loans to convert to fishing gear that reduces unwanted catch of mammals*' and '*Introduce fishing gear exchange programmes to encourage fishers to use gear that reduces unwanted catch of mammals*'.

6.51. Introduce fishing gear exchange programmes to encourage fishers to use gear that reduces unwanted catch of mammals

- We found no studies that evaluated the effects of introducing fishing gear exchange programmes to encourage fishers to use gear that reduces unwanted catch of mammals on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Introducing fishing gear exchange programmes may encourage fishers to use gear types that reduce the unwanted catch ('bycatch') of marine and freshwater mammals. Fishers may be provided with alternative gear types that are less harmful to mammals after surrendering their existing gear. Training on the use of new fishing gear may also be required.

See also '*Finance low interest loans to convert to fishing gear that reduces unwanted catch of mammals*' and '*Involve fishers in designing and trialling new fishing gear types to encourage uptake of gear that reduces unwanted catch of mammals*'.

6.52. Finance low interest loans to convert to fishing gear that reduces unwanted catch of mammals

- We found no studies that evaluated the effects of financing low interest loans to convert to fishing gear that reduces unwanted catch of mammals on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Providing financial assistance, such as low interest loans, may encourage fishers to convert to fishing gear types that reduce the unwanted catch ('bycatch') of marine and freshwater mammals.

See also '*Introduce fishing gear exchange programmes to encourage fishers to use gear that reduces unwanted catch of mammals*' and '*Involve fishers in designing and trialling new fishing gear types to encourage uptake of gear that reduces unwanted catch of mammals*'.

Public engagement and behaviour change

6.53. Promote fish and seafood certification (e.g. ecolabels) to reduce consumer demand for fisheries that threaten mammals

- We found no studies that evaluated the effects of promoting fish and seafood certification (e.g. ecolabels) to reduce consumer demand for fisheries that threaten mammals on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Fish and seafood certification (e.g. ecolabels) may reduce consumer demand for fisheries that threaten marine and freshwater mammals. For example, 'dolphin-safe' ecolabels have been used widely on tuna products from fisheries that claim to use practices that reduce dolphin bycatch. However, the accuracy of such labels and the motivations for using them have been questioned, and greater regulation may be required (Ward 2008).

See also '*Educate the public to reduce consumer demand for fisheries that threaten mammals*'.

Ward T.J. (2008) Barriers to biodiversity conservation in marine fishery certification. *Fish and Fisheries,* 9, 169–177.

6.54. Educate the public to reduce consumer demand for fisheries that threaten mammals

- We found no studies that evaluated the effects of educating the public to reduce consumer demand for fisheries that threaten mammals on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Educating the public about fishing practices that threaten marine and freshwater mammals may reduce consumer demand for the products of such fisheries.

See also '*Promote fish and seafood certification (e.g. ecolabels) to reduce consumer demand for fisheries that threaten mammals*'.

7. Threat: Human intrusions and disturbance

Background

Human intrusions and disturbances can originate from a wide range of activities and impact on marine and freshwater mammals. These include residential and commercial development, aquaculture, shipping and transportation, energy production and mining, and biological resource use. Interventions related to these threats are described in previous chapters. Interventions related to protecting, restoring, and recreating habitats following intrusions and disturbances are described in '*Habitat protection*' and '*Habitat restoration and creation*', respectively.

This chapter focuses on interventions related to human intrusions and disturbances from recreational activities, tourism (including 'mammal watching'), work and other small-scale activities. Such activities can cause disturbance to marine and freshwater mammals and may result in changes in behaviour that can potentially lead to population-level effects (Bejder 2006, Stensland & Berggren 2007, Christiansen *et al.* 2013). Evidence related to pollution from recreational activities, such as vessel noise, marine litter and chemical pollution, has been summarised in '*Threat: Pollution*'.

Bejder L., Samuels A., Whitehead H., Gales N., Mann J., Connor R., Heithaus M., Watson-Capps J., Flaherty C. & Krützen M. (2006) Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology,* 20, 1791–1798.

Christiansen F., Rasmussen M. & Lusseau D. (2013) Whale watching disrupts feeding activities of minke whales on a feeding ground. *Marine Ecology Progress Series,* 478, 239–251.

Stensland E. & Berggren P. (2007) Behavioural changes in female Indo-Pacific bottlenose dolphins in response to boat-based tourism. *Marine Ecology Progress Series,* 332, 225–234.

Recreational activities and tourism

7.1. Introduce and enforce regulations for marine and freshwater mammal watching tours

- **Four studies** evaluated the effects of introducing regulations for marine and freshwater mammal watching tours on marine mammals. One study was in each of the North Atlantic Ocean[1] (the Azores), the Cananéia estuary (Brazil)[2], the South Pacific Ocean[3] (Australia) and the Bass Strait[4] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (4 STUDIES)

- **Behaviour change (4 studies):** Two controlled studies in the North Atlantic Ocean[1] and South Pacific Ocean[3] found that when whale-watching vessels followed approach regulations, fewer sperm whales[1] and humpback whale pods[3] changed their behaviours (e.g. swimming speed, aerial displays)[1] or avoided the vessels[3] compared to when regulations were not followed, but direction of movement and diving patterns[1] or diving behaviours[3] did not differ. One replicated, controlled study in the Cananéia estuary[2] found that when tour boats followed approach regulations, fewer Guiana dolphins displayed negative behaviours (e.g. moving away, diving, groups separating). One study in the Bass Strait[4] found that when boats approached a seal colony to 75 m, more seals remained on shore than when boats approached to 25 m.

Background

Introducing regulations for marine and freshwater mammal watching tours may reduce disturbance. This may involve setting limits on approach distances, vessel speeds and manoeuvres, observation times, group sizes and number of visits (e.g. Notarbartolo di Sciara *et al.* 2009). Interactions with mammals during tours, such as feeding, touching, or swimming with mammals, may also be regulated (e.g. see '*Limit, cease or prohibit feeding of marine and freshwater mammals by tourists*'). Enforcement of regulations may be required if compliance is low (e.g. Whitt & Read 2006).

Notarbartolo di Sciara G., Hanafy M.H., Fouda M.M., Afifi A. & Costa M. (2009) Spinner dolphin (*Stenella longirostris*) resting habitat in Samadai Reef (Egypt, Red Sea) protected through tourism management. *Journal of the Marine Biological Association of the United Kingdom,* 89, 211–216.

Whitt A.D. & Read A.J. (2006) Assessing compliance to guidelines by dolphin-watching operators in Clearwater, Florida, USA. *Tourism in Marine Environments,* 3, 117–130.

A controlled study in 1998 of a pelagic area in the North Atlantic Ocean around the Azores (*1*) found that when whale-watching boats followed regulations for approaching whales, sperm whales *Physeter macrocephalus* changed their swimming speed and performed aerial displays less often than when boats did not follow regulations, but direction of movement, swimming and diving patterns did not differ. When boats followed regulations, whales changed their swimming speed less often (three occasions) and performed fewer aerial displays (two occasions) than when boats did not follow regulations (changed swimming speed: 19 occasions; aerial displays: 20 occasions). No significant changes in direction of movement or swimming and diving patterns were observed when boats did or did not follow regulations (see original paper for details). Regulations were followed during 16 of 40 encounters between whale-watching boats and sperm whales. Regulations required boats to approach whales from behind at an angle of 60°; to maintain a distance of at least 100 m (400 m for ≥2 boats); and to limit encounters to ≤30 minutes. The behaviour of 80 sperm whales was recorded by a researcher on board a whale-watching vessel during each of the 40 encounters in July–September 1998.

A replicated, controlled study in 2004–2006 at three sites in the Cananéia estuary, São Paulo, Brazil (*2*) found that when tour boats followed regulations for approaching dolphins, fewer Guiana dolphins *Sotalia guianensis* had negative reactions to the boats compared to when regulations were not followed. Overall, fewer Guiana dolphins moved away, changed direction, altered their dives or separated from groups when tour boats followed approach regulations (6 of 84, 7%) than when they did not (18 of 19 dolphins, 95%). The other Guiana dolphins encountered did not appear to react (with regulations: 37 of 84 dolphins, 44%; without regulations: 0 of 19 dolphins, 0%) or had positive reactions (following, fishing or surfing alongside the boat; with regulations: 41 of 84 dolphins, 49%; without regulations: 1 of 19 dolphins; 5%). Dolphin-watching tours of three types (59 short cruises, 16 long cruises, eight educational courses) were carried out between December and March 2004–2006. Skippers either followed approach regulations (approached to 100 m slowly and from the side) or did not (approached within 3–50 m, passed through or chased groups of dolphins; number of tours for each not reported). Onboard observers recorded approach procedures and dolphin behaviour during each of 83 tours for a total of 112 h.

A controlled study in 2002–2003 and 2005 in a pelagic area in the South Pacific Ocean, Australia (*3*) found that when whale-watching vessels followed regulations for approaching whales, fewer humpback whale *Megaptera novaeangliae* pods avoided vessels and fewer pods with calves slipped under the water surface compared to when vessels did not follow regulations, but diving behaviours did not differ. A lower percentage of whale pods with or without calves avoided vessels when regulations were followed (combined total with and without calves: 16 of 137 pods, 12%) than when they were not (17 of 67 pods, 25%). 'Slip-under' rates were lower for pods with calves (but not pods without calves) when vessels followed regulations than when they did not (data not reported). Diving behaviours (dive rates, blow rates, average dive times, average blow intervals and the percentage of time spent submerged) did not differ significantly for whale pods with or without calves when vessels did or did not follow regulations (data not reported). In September–November 2002, 2003 and 2005, five commercial vessels (12–16 m long, carrying 23–72 passengers) conducted 98 whale-watching tours. Regulations required vessels to maintain minimum approach distances of ≥200 m for pods with calves and ≥100 m for pods without calves. An onboard observer recorded the behaviour of whale pods during tours that followed regulations (total 137 pods) or did not follow regulations (total 67 pods).

A study (year not stated) on a rocky island shoreline in the northern Bass Strait, Australia (*4*) found that increasing the approach distance of boats to an Australian fur seal *Arctocephalus pusillus doriferus* colony resulted in more seals remaining on the shore and fewer seals entering the water. When boats approached the seal colony to 75 m, a similar number of seals remained on the shore before, during and after the approaches in both the morning and the afternoon (data reported as statistical model results). Whereas, when boats approached to 25 m, the number of seals on shore declined by 47% during morning boat approaches and 21% during afternoon boat approaches. A breeding seal colony at a haul-out site was approached by boats (5.4–10 m in length) to distances of 75 m (20 approaches) or 25 m (18 approaches) during the morning and afternoon. Two video cameras and an observer recorded seal numbers and behaviour for 30 minutes before, 15 minutes during and 60 minutes after each of the 38 boat approaches in January–September.

(1) Magalhães S., Prieto R., Silva M.A., Gonçalves J., Afonso-Dias M. & Santos R.S. (2002) Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores. *Aquatic Mammals*, 28, 267–274.

(2) Filla G.d.F. & Monteiro-Filho E.L.d.A. (2009) Monitoring tourism schooners observing estuarine dolphins (*Sotalia guianensis*) in the Estuarine Complex of Cananéia, south-east Brazil. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 19, 772–778.

(3) Stamation K.A., Croft D.B., Shaughnessy P.D., Waples K.A. & Briggs S.V. (2010) Behavioral responses of humpback whales (*Megaptera novaeangliae*) to whale-watching vessels on the southeastern coast of Australia. *Marine Mammal Science*, 26, 98–122.

(4) Back J.J., Hoskins A.J., Kirkwood R. & Arnould J.P.Y. (2018) Behavioral responses of Australian fur seals to boat approaches at a breeding colony. *Nature Conservation*, 31, 35–52.

7.2. Introduce permits or licences for marine and freshwater mammal watching tours

- We found no studies that evaluated the effects of introducing permits or licences for marine and freshwater mammal watching tours on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Introducing permits or licences for marine and freshwater mammal watching tours may reduce disturbance. This may involve limiting the number of vessels and/or operations that can take place in an area. Conditions of permits/licences may require that tour operators follow specific regulations (e.g. see '*Introduce and enforce regulations for marine and freshwater mammal watching tours*') and report their activities and observations.

7.3. Train tourist guides to minimize disturbance and promote marine and freshwater mammal conservation

- **One study** evaluated the effects of training tourist guides to minimize disturbance and promote marine and freshwater mammal conservation. The study was in the Kenai Fjords[1] (Alaska).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** One before-and-after study in the Kenai Fjords[1] found that fewer harbour seals were disturbed during kayak excursions after training was provided to kayak guides.

Background

Tourist guides may be trained to minimize disturbance to marine and freshwater mammals during tours, and to promote conservation. This may include training to follow specific guidelines (e.g. see '*Introduce and enforce regulations for marine and freshwater mammal watching tours*'). Promoting marine and freshwater mammal conservation during tours may help to improve the behaviour of attendees towards mammals, not only during tours but also in future.

A before-and-after study in 2002–2011 at a glacial lake in the Kenai Fjords, Alaska (*1*) reported that after training was provided to kayak guides, fewer harbour seals *Phoca vitulina* were disturbed in the presence of kayaks than before training. Results are not based on assessments of statistical significance. Numbers of seal disturbances (seals moving from the ice into the water) each year during kayak excursions were lower after training was provided to guides (total 0–9 disturbances; 0–0.02 disturbances/hour) than before (total 0–30 disturbances; 0–0.05 disturbances/hour). Training was provided to tourist guides in 2006 to operate kayaks more carefully around seals (details reported in Jezierski 2009). Voluntary guidelines for viewing marine mammals from vessels were introduced in 2000, and multiple outreach activities took place in 2002–2011 (public presentations, workshops etc.). Remote-controlled video cameras recorded seal disturbances during kayak excursions in May–September 2002–2011. Observations were made during 81–92 days in each of four years before training (2002–2005) and during 70–92 days in each of six years after training (2006–2011).

Jezierski, C. M. (2009) *The impact of sea kayak tourism and recreation on harbor seal behavior in Kenai Fjords National Park: integrating research with outreach, education, and tourism*. Thesis, University of Alaska, USA.

(1) Hoover-Miller A., Bishop A., Prewitt J., Conlon S., Jezierski C. & Armato P. (2013) Efficacy of voluntary mitigation in reducing harbor seal disturbance. *The Journal of Wildlife Management*, 77, 689–700.

7.4. Introduce permits or licences for recreational watersports

- We found no studies that evaluated the effects of introducing permits or licences for recreational watersports on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Introducing permits or licences for recreational watersports (e.g. boating, kayaking, jet-skiing, diving, snorkelling, recreational fishing etc.) may reduce disturbance to marine and freshwater mammals. This may involve limiting the number and/or type of activities that are permitted to take place in an area. Conditions of permits/licences may also require that individuals follow specific guidelines while carrying out watersports (e.g. minimum approach distances, speed limits etc.), and report marine mammal encounters.

7.5. Create designated areas or access points for recreational activities

- We found no studies that evaluated the effects of creating designated areas or access points for recreational activities on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Creating designated areas or access points (e.g. slip ways) for recreational activities that are located away from important marine and freshwater mammal habitats may reduce disturbance.

7.6. Inform the public of ways to reduce disturbance to marine and freshwater mammals (e.g. use educational signs)

- **One study** evaluated the effects of informing the public of ways to reduce disturbance to marine and freshwater mammals. The study was in the South Pacific Ocean[1] (New Zealand).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Change in human behaviour (1 study):** One controlled study in the South Pacific Ocean[1] found that tourist groups that observed information signs approached and disturbed New Zealand fur seals in similar numbers to those that did not.

Background

This intervention involves providing information to the public, e.g. in the form of educational signs, with the aim of reducing disturbance to marine and freshwater mammals during recreational activities. This may be particularly beneficial at tourist sites that receive a high number of visitors, or in areas that are popular for watersports. Information may include guidance on approach distances, how to safely operate vessels around mammals, and instructions not to touch, feed, photograph or interact with mammals.

See also '*Use volunteers to deter tourists from harassing marine and freshwater mammals at wildlife-viewing sites*'.

A controlled study in 2009 at a peninsula in the South Pacific Ocean, New Zealand (*1*) found that tourist groups that observed information signs approached and disturbed New Zealand fur seals *Arctocephalus forsteri* in similar numbers to those that did not observe signs. The percentage of tourist groups that remained >5 m from seals was similar whether they had observed signs (61%) or not (66%). The percentage of groups in which at least one person attempted to touch seals also did not differ significantly (observed signs: 1.4%; did not observe signs: 2.4%). The same was true for the percentage of groups that caused seals to move away (observed signs: 12%; did not observe signs: 9%). In summer 2009, a total of 362 tourist groups (each with an average of three people) visited a seal colony over 20 days. Each visit lasted an average of 25–26 minutes. Several signs posted around the site stated that visitors must remain >10 m from seals on land. A total of 236 groups observed signs, 126 groups did not. Trained observers on a cliff top recorded whether each of the 362 tourist groups observed signs (walked up to them) and how they interacted with the seals.

(1) Acevedo-Gutierrez A., Acevedo L., Belonovich O. & Boren L. (2011) How effective are posted signs to regulate tourism? An example with New Zealand fur seals. *Tourism in Marine Environments*, 7, 39–41.

7.7. Use volunteers to deter tourists from harassing marine and freshwater mammals at wildlife-viewing sites

- **One study** evaluated the effects of using volunteers to deter tourists from harassing marine and freshwater mammals at wildlife-viewing sites. The study was at the Ohau Stream waterfall[1] (New Zealand).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Change in human behaviour (1 study):** One randomized, controlled study at the Ohau Stream waterfall[1] found that the presence of an official-looking volunteer resulted in fewer tourists harassing New Zealand fur seals at a waterfall.

Background

The presence of an authority figure at wildlife-viewing sites may deter tourists from harassing marine and freshwater mammals. The use of official-looking volunteers may be a cheaper alternative to using paid enforcement officials.

See also '*Inform the public of ways to reduce disturbance to marine and freshwater mammals (e.g. use educational signs)*'.

A randomized, controlled study in 2008–2009 at a waterfall of the Ohau Stream, New Zealand (*1*) found that the presence of an official-looking volunteer resulted in fewer tourists harassing New Zealand fur seals *Arctocephalus forsteri* than when a volunteer was not present. The number of tourist groups in which at least one tourist harassed seals was lower when an official-looking volunteer was present (14 of 108 groups, 13%) than when a volunteer was not present (56 of 146 groups, 38%). A total of 19,102 tourists visited the waterfall in 254 groups (108 groups with volunteer present, 146 groups without). The official-looking volunteer wore a neon vest and sat on a rock on a viewing platform located 500–1,000 m from a waterfall visited by seal young from a nearby breeding colony. Tourists harassed seals by approaching, touching, or throwing objects at them. The behaviour of each of 254 tourist groups was recorded by a hidden observer on 68 random days at random times between October 2008 and June 2009.

(1) Acevedo-Gutierrez A., Acevedo L. & Boren L. (2011) Effects of the presence of official-looking volunteers on harassment of New Zealand fur seals. *Conservation Biology*, 25, 623–627.

7.8. Limit, cease or prohibit feeding of marine and freshwater mammals by tourists

- **One study** evaluated the effects of setting limits on feeding of marine mammals by tourists. The study was in Shark Bay[1] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** One controlled, before-and-after study in Shark Bay[1] found that after setting limits on feeding of bottlenose dolphins by tourists, the survival of calves born to females being fed increased and was similar to calves of non-fed mothers.

BEHAVIOUR (0 STUDIES)

Background

The feeding of wild marine and freshwater mammals at tourist destinations can have negative impacts on mammal behaviour and population dynamics (Mann & Kemps 2003). This intervention involves limiting, ceasing or prohibiting the feeding of marine and freshwater mammals by tourists to reduce these effects. Enforcement may also be required to prevent illegal feeding (Powell *et al.* 2018).

Mann J. & Kemps C. (2003) The effects of provisioning on maternal care in wild bottlenose dolphins, Shark Bay, Australia. Pages 292–305 in: *Marine mammals: fisheries, tourism and management issues.* CSIRO Publishing, Collingwood.

Powell J.R., Machernis A.F., Engleby L.K., Farmer N.A. & Spradlin T.R. (2018) Sixteen years later: an updated evaluation of the impacts of chronic human interactions with bottlenose dolphins (*Tursiops truncatus truncatus*) at Panama City, Florida, USA. *Journal of Cetacean Research and Management,* 19, 79–93.

A controlled, before-and-after study in 1988–2011 at a marine reserve in Shark Bay, Western Australia (*1*) found that after setting limits on feeding of bottlenose dolphins *Tursiops* spp. by tourists, the survival of calves born to females being fed increased and was similar to calves of non-fed females, but calf behaviour differed to those of non-fed females. The survival rate of calves born to females being fed was higher after feeding limits were set (87%) than before (23%) and did not differ significantly to calves of non-fed females (62%). However, calves of females fed limited amounts spent less time in close contact with their mothers (average 33% of their time) and more time foraging (22%) than calves of non-fed females (with mother: 39%; foraging: 16%). In 1988–2011, dolphins were hand-fed fish by tourists in knee-deep water along 90 m of beach. In 1988–1993, dolphins were fed up to 120 kg of fish/month. In 1994–2011, feeding was limited to 2 kg of fish/day during a maximum of three sessions between 07:30 h and 13:00 h. Dolphins (seven fed females with 19–22 calves, 53 non-fed females with 82 calves) were observed during feeding sessions (total 308 h) and offshore (total 2,181 h) in 1988–2011 before and after feeding was limited (number of observations before and after not reported).

(1) Foroughirad V. & Mann J. (2013) Long-term impacts of fish provisioning on the behavior and survival of wild bottlenose dolphins. *Biological Conservation*, 160, 242–249.

Work and other activities

7.9. Introduce regulations for the use of underwater drones in proximity to marine and freshwater mammals

- We found no studies that evaluated the effects of introducing regulations for the use of underwater drones in proximity to marine and freshwater mammals.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Underwater drones (also known as 'Unmanned Underwater Vehicles') may be used for a wide range of purposes, such as research and monitoring, exploration, inspecting and repairing ship hulls, search and rescue, and military purposes, e.g. terminating underwater mines. This intervention involves introducing regulations for the use of underwater drones in proximity to marine and freshwater mammals, with the aim of reducing disturbance. This may involve setting minimum distances for approaching mammals, and avoiding deployment or removing drones from the water if mammals are present.

See also '*Introduce regulations for flying drones over marine and freshwater mammals*'.

7.10. Introduce regulations for flying drones over marine and freshwater mammals

- We found no studies that evaluated the effects of introducing regulations for flying drones over marine and freshwater mammals.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Aerial drones (also known as 'Unmanned Aerial Vehicles') may be used for research and monitoring of marine and freshwater mammals, or for recreational activities. However, flying drones over mammals may cause disturbance and elicit an avoidance response (e.g. Ramos *et al*. 2018). Introducing regulations for the use of aerial drones in proximity to mammals may reduce disturbance. This could involve setting minimum flight heights, avoiding direct approaches, minimising flight times above the same group of animals, avoiding flights over animals with young, using camouflaged or low-noise devices and/or aborting flights if disturbance occurs.

See also '*Introduce regulations for the use of underwater drones in proximity to marine and freshwater mammals*'.

Ramos E.A., Maloney B., Magnasco M.O. & Reiss D. (2018) Bottlenose dolphins and Antillean manatees respond to small multi-rotor unmanned aerial systems. *Frontiers in Marine Science,* 5.

8. Threat: Natural system modifications

Background

This chapter includes interventions to address threats that convert or degrade habitat as part of the management of natural or semi-natural systems, often to improve human welfare. This includes changing the natural flow of water along rivers, e.g. by creating dams or flood gates.

Dams and water management/use

8.1. Install bypass channels in dams

- We found no studies that evaluated the effects of installing bypass channels in dams on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Dams may prevent the movement of marine or freshwater mammals along estuaries and rivers resulting in isolation and habitat loss. Installing bypass channels may allow mammals to swim around dams and access habitats on both sides.

8.2. Use automated detection systems to prevent flood gates and locks from closing when mammals are present

- We found no studies that evaluated the effects of using automated detection systems to prevent flood gates and locks from closing when mammals are present on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals may swim through water structures, such as flood gates or navigation locks, and may be stranded, drowned or crushed (e.g. Ackerman *et al.* 1995). This intervention involves using automated detection systems to prevent gates/locks from closing when mammals are present.

Ackerman B.B., Wright S.D., Bonde R., Odell D. & Banowetz D.J. (1995) Trends and patterns in mortality of manatees in Florida, 1974–1991. Pages 223–258 in: *Population biology of the Florida manatee.* National Biological Service, Information and Technical Report 1, Washington D.C.

8.3. Maintain water level and flow along regulated rivers

- We found no studies that evaluated the effects of maintaining water level and flow along regulated rivers on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves maintaining water levels and flow along regulated rivers to ensure that freshwater mammal habitats, such as deep pools, are conserved and remain accessible. This may involve identifying minimum flow thresholds.

9. Threat: Invasive or problematic species and disease

Background

Invasive or other problematic species of animals, plants, algae, and diseases can have significant adverse consequences for aquatic environments with impacts on marine and freshwater mammals (Bax *et al.* 2003, Molnar *et al.* 2008). Invasive or problematic species may prey on mammals, provide competition for resources, alter or contaminate habitats, or infect mammals with new diseases. This chapter describes the evidence from interventions designed to prevent or reduce the threat from invasive or problematic species and disease on marine and freshwater mammals.

Bax N., Williamson A., Aguero M., Gonzalez E. & Geeves W. (2003) Marine invasive alien species: A threat to global biodiversity. *Marine Policy,* 27, 313–323.

Molnar J.L., Gamboa R.L., Revenga C. & Spalding M.D. (2008) Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment,* 6, 485–492.

Invasive or problematic species

9.1. Physically remove invasive or problematic species

- We found no studies that evaluated the effects of physically removing invasive or other problematic species on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Invasive or problematic species may be captured and physically removed from the environment to reduce the impacts on marine and freshwater mammals.

9.2. Use biocides or other chemicals to control invasive or problematic species

- We found no studies that evaluated the effects of using biocides or other chemicals to control invasive or problematic species on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Biocides are chemical substances or microorganisms used with the intention of controlling an invasive or problematic species. Using biocides or other chemicals, such as chemical inhibitors, to reduce or control invasive or problematic species may lower the risk they pose to marine and freshwater mammals. However, some biocides are toxic and may contaminate marine and freshwater environments.

9.3. Use biological control to manage invasive or problematic species

- We found no studies that evaluated the effects of using biological control to manage invasive or problematic species on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Biological control may be used to reduce the population of invasive or problematic species, such as those that form harmful algal blooms (e.g. Nagasaki *et al.* 1999). This may involve releasing native or non-native predators, parasites or diseases that are likely to affect specific invasive or other problematic species. However, there are risks involved and the use of native species as biological control should be prioritised over non-native species (Secord 2003).

Nagasaki K., Tarutani K. & Yamaguchi M. (1999) Growth characteristics of *Heterosigma akashiwo* virus and its possible use as a microbiological agent for red tide control. *Applied and environmental microbiology,* 65, 898–902.

Secord D. (2003) Biological control of marine invasive species: cautionary tales and land-based lessons. *Biological Invasions,* 5, 117–131.

9.4. Limit, cease or prohibit ballast water exchange in specific areas

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting ballast water exchange in specific areas on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Ballasting is the process by which sea water (ballast water) is discharged from a ship when at port or at sea. Ballast water can contain species from other locations taken up during water intake, which are then accidentally released in a new environment during de-ballasting (water release). Ballast water is one of the major processes of introduction of invasive or problematic species, including those that form harmful algal blooms (Barry *et al.* 2008, Molnar *et al.* 2008). Limiting, ceasing or prohibiting ballast water exchange in specific areas may help prevent the introduction, establishment and spread of invasive and problematic species. This may involve setting zones where ballasting is allowed, setting timings for ballasting when risk is reduced, or setting limits on the number of ships allowed to ballast in an area.

See also '*Treat ballast water before release*'.

Barry S.C., Hayes K.R., Hewitt C.L., Behrens H.L., Dragsund E. & Bakke S.M. (2008) Ballast water risk assessment: principles, processes, and methods. *Ices Journal of Marine Science,* 65, 121–131.

Molnar J.L., Gamboa R.L., Revenga C. & Spalding M.D. (2008) Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment,* 6, 485–492.

9.5. Treat ballast water before release

- We found no studies that evaluated the effects of treating ballast water before release, on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Ballasting is the process by which sea water (ballast water) is taken out of the ship when at port or at sea. Ballast water can contain species from other locations taken up during water intake, which are then accidentally released in a new environment during de-ballasting (water release). Ballast water is one of the major processes of introduction of invasive or problematic species, including those that form harmful algal blooms (Barry *et al.* 2008, Molnar *et al.* 2008). Treating ballast water before release may reduce the risk of accidentally introducing invasive and problematic species. This may involve using filters, oxidizing or disinfecting chemicals, or ultraviolet radiation. However, some treatments may have toxic effects (Werschkun *et al.* 2014).

See also '*Limit, cease or prohibit ballast water exchange in specific areas*'.

Barry S.C., Hayes K.R., Hewitt C.L., Behrens H.L., Dragsund E. & Bakke S.M. (2008) Ballast water risk assessment: principles, processes, and methods. *Ices Journal of Marine Science,* 65, 121–131.

Molnar J.L., Gamboa R.L., Revenga C. & Spalding M.D. (2008) Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment,* 6, 485–492.

Werschkun B., Banerji S., Basurko O.C., David M., Fuhr F., Gollasch S., Grummt T., Haarich M., Jha A.N., Kacan S., Kehrer A., Linders J., Mesbahi E., Pughiuc D., Richardson S.D., Schwarz-Schulz B., Shah A., Theobald N., von Gunten U., Wieck S. & Höfer T. (2014) Emerging risks from ballast water treatment: The run-up to the International Ballast Water Management Convention. *Chemosphere,* 112, 256–266.

9.6. Use deterrents to reduce predation on marine and freshwater mammals by native species

- **One study** evaluated the effects of using deterrents to reduce predation by native species on marine mammals. The study was in the North Pacific Ocean[1] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** One controlled study in the North Pacific Ocean[1] found that neither boat motor sounds nor the presence of humans reduced Galapagos shark predation on Hawaiian monk seal pups, although shark presence was low throughout the study.

BEHAVIOUR (0 STUDIES)

Background

This intervention involves using deterrents to reduce predation on marine and freshwater mammals by native species. This may be attempted when particularly endangered mammal populations are threatened by unsustainable levels of predation. Deterrents may include the presence of humans or playback of human-related sounds.

A controlled study in 2009 at two small islands in the North Pacific Ocean, Hawaii, USA (*1*) found that two types of deterrent (boat motor sounds or a continuous human presence) did not reduce Galapagos shark *Carcharhinus galapagensis* predation on Hawaiian monk seal *Monachus schauinslandi* pups. The total number of predation events did not differ significantly when boat motor sounds were played (0 events) or when humans were continuously present (2 events) compared to when no deterrent was used (4 events). However, the authors state that shark presence was low at both sites throughout the study (12 sharks observed at one site, number not reported for the other). In May–August 2006, the two deterrent treatments and a control (no deterrent) were rotated weekly between two sites. Deterrents were boat motor sounds played back through underwater speakers (with or without a boat anchored nearby) or 1–2 people camping on the island for ≥23 h/day. Surveyors recorded shark predation events (bite wounds, pups disappearing) at both sites every 1–3 days in May–August 2006. Video cameras recorded shark presence at one site for a total of 57 days.

(1) Gobush K.S. & Farry S.C. (2012) Non-lethal efforts to deter shark predation of Hawaiian monk seal pups. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 22, 751–761.

9.7. Use baited lines instead of nets for shark control

- **Two studies** evaluated the effects on marine mammals of using baited lines instead of nets for shark control. One study was in the Indian Ocean[1] (South Africa) and one in the South Pacific Ocean[2] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** One site comparison study in the South Pacific Ocean[2] found that using baited lines instead of nets increased the survival of entangled common and bottlenose dolphins.

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Reduction in entanglements/unwanted catch (2 studies):** Two site comparison studies in the Indian Ocean[1] and South Pacific Ocean[2] found that baited lines used for shark control had fewer entanglements of dolphins[1,2], whales[1,2] and dugongs[2] than nets.

Background

Methods of controlling problematic species may have negative impacts on marine and freshwater mammals. For example, shark control nets, which are deployed to protect the public at swimming beaches, may entangle and kill non-target species, such as marine mammals (Gribble *et al.* 1998). Using alternative methods to capture and remove problematic shark species, such as baited lines, may reduce the risk of marine mammal entanglement and mortality.

Gribble N.A., McPherson G. & Lane B. (1999) Effect of the Queensland Shark Control Program on non-target species: whale, dugong, turtle and dolphin: a review. *Marine and Freshwater Research,* 49, 645–651.

A site comparison study in 2007–2010 at 17 coastal sites in the Indian Ocean, South Africa (*1*) reported that baited lines used for shark control had fewer entanglements of dolphins and whales than nets. No whales or dolphins were found entangled in baited lines, whereas an average of seven dolphins and two whales (species not reported) were found entangled each year in nets. Catch rates and survival of target sharks on baited lines and in nets differed between species (see original paper for details). In 2007, half of the shark-control nets (214 m long x 6 m deep; number not reported) previously deployed to protect 17 beaches were replaced with 76 baited 'drum' lines (single lines suspended beneath a float with a baited 'J hook'). The nets and lines were checked 18 times/month in 2007–2010.

A site comparison study in 1992–2008 at three coastal sites in the South Pacific Ocean, Queensland, Australia (*2*) found that baited lines used for shark control had fewer entanglements of four dolphin species, humpback whales *Megaptera novaeangliae* and dugongs *Dugong dugon* than nets, and survival of entangled dolphins was higher on baited lines. Overall, baited lines had fewer entanglements than nets of common dolphins *Delphinus delphis* (5 vs 74 respectively), bottlenose dolphins *Tursiops* spp. (6 vs 26), Indo-Pacific humpback dolphins *Sousa chinensis* (0 vs 12), spinner dolphins *Stenella longirostris* (0 vs 12), humpback whales (0 vs 26) and dugongs (0 vs 9). Survival of entangled common and bottlenose dolphins was higher on baited lines (both 100%) than in nets (common: 5%; bottlenose: 8%). Catch rates and survival of target sharks on baited lines and in nets differed between species (see original paper for details). At each of three locations, 9–35 baited 'drum' lines (single lines suspended beneath a buoy with a baited shark hook) and 3–11 shark-control nets (186 m long x 6 m deep, 50 cm stretched mesh size) were deployed to protect beaches. All lines and nets were deployed parallel to the shore in water 6–12 m deep. Fishers checked and re-baited the 56 lines and 17 nets during 15–20 days/month in 1992–2008.

(1) Cliff G. & Dudley S.F.J. (2011) Reducing the environmental impact of shark-control programs: A case study from KwaZulu-Natal, South Africa. *Marine and Freshwater Research*, 62, 700–709.
(2) Sumpton W.D., Taylor S.M., Gribble N.A., McPherson G. & Ham T. (2011) Gear selectivity of large-mesh nets and drumlines used to catch sharks in the Queensland Shark Control Program. *African Journal of Marine Science*, 33, 37–43.

Disease

9.8. Carry out surveillance for diseases

- We found no studies that evaluated the effects of carrying out surveillance for diseases on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Carrying out surveillance of marine and freshwater mammals for diseases could provide an early warning system for new outbreaks and may allow preventative measures to be taken. Surveillance programmes and sampling protocols should aim to minimize disturbance to mammals.

9.9. Vaccinate against disease

- We found no studies that evaluated the effects of vaccinating against disease on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Vaccinating marine and freshwater mammals against disease could reduce the spread of disease. However, vaccinating wild mammals can be challenging, due to difficulties in administering vaccines in appropriate doses and on a large scale. Vaccination is only likely to be attempted in certain cases, such as when mammals may be affected by a zoonotic disease that could spread to humans, or when particularly endangered mammal populations are threatened.

See also '*Treat disease in wild marine and freshwater mammals*'.

9.10. Translocate or temporarily bring marine and freshwater mammals into captivity to reduce exposure to disease

- We found no studies that evaluated the effects of translocating or temporarily bringing marine and freshwater mammals into captivity to reduce exposure to disease.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Translocating or temporarily bringing marine and freshwater mammals into captivity could reduce disease exposure and spread. However, this may not be feasible where large numbers of animals are affected. There may also be a risk of spreading pathogens to previously unexposed areas.

For other interventions related to translocations, see '*Species management – Translocation* and '*Threat: Aquaculture and agriculture – Translocate mammals away from aquaculture systems to reduce human-wildlife conflict*'.

9.11. Treat disease in wild marine and freshwater mammals

- We found no studies that evaluated the effects of treating disease in wild marine and freshwater mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Treatment of diseases in wild marine and freshwater mammals can be problematic. It can be difficult to diagnose causes of illness and the direct administration of medicines to target individuals can be challenging. The treatment of disease in wild marine and freshwater mammals is usually only carried out in cases of highly threatened species, or when there are potential public health risks or economic costs associated with not treating. This intervention involves treating wild mammals or those temporarily confined for treatment, with the aim of releasing treated individuals to improve the health of wild populations. For studies that treated mammals for disease in captivity as part of a rehabilitation programme, see '*Species recovery – Rehabilitate and release injured, sick or weak marine and freshwater mammals*'.

See also '*Vaccinate against disease*'.

9.12. Use drugs to treat parasites

- **Two studies** evaluated the effects on marine mammals of using drugs to treat parasites. Both studies were in the North Pacific Ocean[1,2] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Survival (2 studies):** One of two controlled studies (including one before-and-after study) in the North Pacific Ocean[1,2] found that treating northern fur seal pups with an anti-parasitic drug (ivermectin) reduced mortality rates[1]. The other study[2] found that Hawaiian monk seal pups treated with an anti-parasitic drug (praziquantel) had similar survival rates to untreated pups.
- **Condition (2 studies):** One of two controlled studies (including one before-and-after study) in the North Pacific Ocean[1,2] found that northern fur seal pups treated with an anti-parasitic drug (ivermectin) had reduced hookworm infections and greater growth rates than untreated pups[1]. The other study[2] found that Hawaiian monk seal pups treated with an anti-parasitic drug (praziquantel) had similar parasite loads to untreated pups.

BEHAVIOUR (0 STUDIES)

Background

High parasite loads may reduce the fitness of marine and freshwater mammals and lead to higher levels of mortality (Aznar *et al.* 2001). Drugs are available to reduce the infestation levels of some parasites. Attempts to treat wild marine and freshwater mammals are most likely to be made when a species is highly threatened or when there are public health risks or economic costs associated with not treating. In such cases, mammals may be captured, treated, and released with the aim of improving the health of wild populations. For studies that treated mammals for parasites in captivity as part of a rehabilitation programme, see '*Species recovery – Rehabilitate and release injured, sick or weak marine and freshwater mammals*'.

Aznar F.J., Balbuena J.A., Fernández M. & Raga J.A. (2001) Living together: the parasites of marine mammals. Pages 385–423 in*:* Evans P. G. H. & Raga J. A. (eds.) *Marine Mammals: Biology and Conservation.* Springer US, Boston, MA.

A controlled, before-and-after study in 2006 on an island in the North Pacific Ocean, off the coast of California, USA (*1*) found that northern fur seal *Callorhinus ursinus* pups treated with an anti-parasitic drug (ivermectin) had reduced hookworm *Uncinaria lucasi* infections, lower mortality rates and greater growth rates than untreated pups. The number of treated pups with hookworm infections decreased from 24% (36 of 151 pups) to 6% (2 of 34 pups) 19–34 days after treatment with ivermectin. In comparison, the number of infected untreated pups increased from 24% (36 of 149 pups) to 67% (20 of 30 pups). Mortality rates were lower for pups treated with ivermectin (10 of 149 pups died, 7%) than untreated pups (50 of 151 pups died, 33%), and growth rates were greater (treated: 0.06 kg/day; untreated: 0.04 kg/day). In July 2006, seal pups were captured, tagged and alternately assigned to a treatment group (injected with ivermectin; 151 pups) or untreated control group (injected with saline solution; 149 pups). Hookworm eggs were counted in faecal samples in July (all of 300 pups) and August 2006 (34 treated pups, 30 untreated pups). Pups were weighed in July (all of 300 pups) and September 2006 (number not reported). Mortality surveys were carried out every 3–20 days in July–December 2006.

A controlled study in 2009–2010 on an island in the North Pacific Ocean, Hawaii, USA (*2*) found that Hawaiian monk seal *Monachus schauinslandi* pups treated with an anti-parasitic drug (praziquantel) had similar parasite loads and survival rates to untreated pups. The number of faecal samples containing parasitic worms (cestodes *Diphyllobothrium* spp.) did not differ significantly between treated pups (44 of 46 samples, 96%) and untreated pups (43 of 44 samples, 98%). Survival rates also did not differ significantly between treated pups (20 of 23 pups survived, 87%) and untreated pups (19 of 20 pups survived, 95%). Forty-three tagged seal pups (<2 years old) were randomly assigned to a treatment group (injected with praziquantel; 23 pups) or an untreated control group (20 pups). Each of 43 pups was captured, weighed, measured, injected (treatment group only) and had faeces sampled up to four times, 8–16 weeks apart, between December 2009 and May 2010.

(1) DeLong R.L., Orr A.J., Jenkinson R.S. & Lyons E.T. (2009) Treatment of northern fur seal (*Callorhinus ursinus*) pups with ivermectin reduces hookworm-induced mortality. *Marine Mammal Science*, 25, 944–948.

(2) Gobush K.S., Baker J.D. & Gulland F.M.D. (2011) Effectiveness of an antihelminthic treatment in improving the body condition and survival of Hawaiian monk seals. *Endangered Species Research*, 15, 29–37.

10. Threat: Pollution

Background

Pollution from a wide variety of sources can have major direct and indirect negative impacts on marine and freshwater mammals. Sources include domestic and urban wastewaters, industrial, military, agricultural and forestry effluents, garbage and solid wastes, and pollution from excess energy, such as underwater noise. Environmental pollutants may contaminate and alter marine and freshwater habitats, cause harmful algal blooms, and accumulate in mammal tissues causing impaired reproduction and immune function, disease, and direct mortality (Reijnders *et al.* 2009, Desforges *et al.* 2016, Jepson *et al.* 2016). Oil spills are a threat to marine mammals (Helm *et al.* 2014), while solid waste and garbage, including derelict fishing gear and plastic debris, are of increasing concern (Kühn *et al.* 2015). Underwater noise pollution from vessel traffic and activities such as seismic surveys, dredging, pile-driving and sonar can also affect large areas and may impair the normal functioning and behaviour of marine and freshwater mammals with potential population-level effects (Erbe *et al.* 2018, Nabi *et al.* 2018). This chapter describes the evidence for interventions that aim to prevent or reduce the threat from various pollution sources.

Desforges J.-P.W., Sonne C., Levin M., Siebert U., De Guise S. & Dietz R. (2016) Immunotoxic effects of environmental pollutants in marine mammals. *Environment International,* 86, 126–139.

Erbe C., Dunlop R. & Dolman S. (2018) Effects of noise on marine mammals. Pages 277–309 in: Slabbekoorn H., Dooling R. J., Popper A. N. & Fay R. R. (eds.) *Effects of Anthropogenic Noise on Animals.* Springer, New York.

Helm R.C., Costa D.P., DeBruyn T.D., O'Shea T.J., Wells R.S. & Williams T.M. (2014) Overview of effects of oil spills on marine mammals. Pages 455–475 in: Fingas M. (ed.) *Handbook of Oil Spill Science and Technology.* John Wiley & Sons, Inc.

Jepson P.D., Deaville R., Barber J.L., Aguilar À., Borrell A., Murphy S., Barry J., Brownlow A., Barnett J., Berrow S., Cunningham A.A., Davison N.J., ten Doeschate M., Esteban R., Ferreira M., Foote A.D., Genov T., Giménez J., Loveridge J., Llavona Á., Martin V., Maxwell D.L., Papachlimitzou A., Penrose R., Perkins M.W., Smith B., de Stephanis R., Tregenza N., Verborgh P., Fernandez A. & Law R.J. (2016) PCB pollution continues to impact populations of orcas and other dolphins in European waters. *Scientific Reports,* 6, 18573.

Kühn S., Bravo Rebolledo E.L. & van Franeker J.A. (2015) Deleterious effects of litter on marine life. Pages 75–116 in: Bergmann M., Gutow L. & Klages M. (eds.) *Marine Anthropogenic Litter.* Springer International Publishing, Cham.

Nabi G., McLaughlin R.W., Hao Y., Wang K., Zeng X., Khan S. & Wang D. (2018) The possible effects of anthropogenic acoustic pollution on marine mammals' reproduction: an emerging threat to animal extinction. *Environmental Science and Pollution Research,* 25, 19338–19345.

Reijnders P.J.H., Aguilar A. & Borrell A. (2009) Pollution and Marine Mammals. Pages 890–898 in: Perrin W. F., Würsig B. & Thewissen J. G. M. (eds.) *Encyclopedia of Marine Mammals (Second Edition).* Academic Press, London.

General

10.1. Establish pollution emergency plans

- We found no studies that evaluated the effects of establishing emergency pollution plans on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Sudden acute pollution events, such as oil spills, can cause serious disturbances and harm to marine and freshwater mammals (Helm *et al.* 2014). Pollution emergency plans provide an overview of possible procedures, as well as details of which authorities to contact, should a pollution event occur. The aim of emergency plans is to increase the speed and effectiveness of the response to minimize harmful impacts (Li *et al.* 2016).

Helm R.C., Costa D.P., DeBruyn T.D., O'Shea T.J., Wells R.S. & Williams T.M. (2014) Overview of effects of oil spills on marine mammals. Pages 455–475 in: Fingas M. (ed.) *Handbook of Oil Spill Science and Technology.* John Wiley & Sons, Inc.

Li P., Cai Q., Lin W., Chen B. & Zhang B. (2016) Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin,* 110, 6–27.

10.2. Use 'bioremediating' organisms to remove or neutralize pollutants

- We found no studies that evaluated the effects of using 'bioremediating' organisms to remove or neutralize pollutants on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Some sources of pollution can be biologically 'remediated' by transplanting or translocating particular organisms to the affected area (e.g. Sode *et al.* 2013, Xue *et al.* 2015). These 'bioremediating' organisms can naturally remove or neutralize pollutants and improve water quality. Transplanting or translocating such organisms to an affected area may reduce pollution levels and potential harm to marine and freshwater mammals.

Sode S., Bruhn A., Balsby T.J.S., Larsen M.M., Gotfredsen A. & Rasmussen M.B. (2013) Bioremediation of reject water from anaerobically digested waste water sludge with macroalgae (*Ulva lactuca, Chlorophyta*). Bioresource Technology, 146, 426–435.

Xue J., Yu Y., Bai Y., Wang L. & Wu Y. (2015) Marine oil-degrading microorganisms and biodegradation process of petroleum hydrocarbon in marine environments: a review. *Current Microbiology,* 71, 220–228.

10.3. Add chemicals or minerals to sediment to remove or neutralize pollutants

- We found no studies that evaluated the effects of adding chemicals or minerals to sediment to remove or neutralize pollutants on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Sediments within aquatic environments can accumulate pollutants over time, such as those leaching from aquaculture systems, sewage outfalls or nearby agricultural fields. Marine or freshwater mammals may be negatively affected by polluted sediments, particularly those feeding on or near the bottom of rivers or seas, or in areas where sediments are frequently disturbed. Chemicals or minerals may be added to sediments to reduce or remove pollutants (e.g. Kim *et al.* 2014, Shin & Kim 2016).

Kim K., Hibino T., Yamamoto T., Hayakawa S., Mito Y., Nakamoto K. & Lee I.-C. (2014) Field experiments on remediation of coastal sediments using granulated coal ash. *Marine Pollution Bulletin,* 83, 132–137.

Shin W. & Kim Y.-K. (2016) Stabilization of heavy metal contaminated marine sediments with red mud and apatite composite. *Journal of Soils and Sediments,* 16, 726–735.

Domestic and urban wastewater

10.4. Limit, cease or prohibit dumping of untreated sewage

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting dumping of untreated sewage on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Untreated sewage reaching aquatic environments may impact marine and freshwater mammals through the introduction of bacteria and viruses, excess nutrients, toxic substances, and solid particles. Limiting, ceasing or prohibiting the dumping of untreated sewage in an area may reduce the risk of contaminating marine and freshwater mammals and their habitats.

10.5. Limit, cease or prohibit dumping of sewage sludge

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting dumping of sewage sludge on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Sewage sludge is the residual, semi-solid material produced as a by-product during sewage treatment. Sewage sludge can be disposed of at sea or in rivers and may impact marine and freshwater mammals through the introduction of bacteria and viruses, heavy metals, and chemicals. Limiting, ceasing or prohibiting the dumping of sewage sludge in an area may reduce the risk of contaminating marine and freshwater mammals and their habitats.

10.6. Set or improve minimum sewage treatment standards

- We found no studies that evaluated the effects of setting or improving minimum sewage treatment standards on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Untreated sewage reaching aquatic environments may impact marine and freshwater mammals through the introduction of bacteria, viruses and parasites, excess nutrients, toxic substances, and solid particles. Setting minimum sewage treatment standards, or improving the standards already in place, could potentially ensure that pollution levels and associated risks to marine and freshwater mammals are minimized. This may involve carrying out secondary or tertiary treatment of wastewater to further reduce pollutant levels.

10.7. Limit the amount of storm wastewater overflow

- We found no studies that evaluated the effects of limiting the amount of storm wastewater overflow on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Some sewer systems collect rainwater runoff, sewage, and industrial wastewater in the same pipe, where it is then transported to a sewage treatment plant. During heavy rainfall events or snow melt, the volume of wastewater can exceed the capacity of treatment facilities. In such instances, sewer systems can overflow and discharge untreated storm water and wastewater directly into rivers and seas (Moffa 1997). Untreated wastewater reaching aquatic environments may impact marine and freshwater mammals through the introduction of bacteria and viruses, excess nutrients, toxic substances, and solid particles. Limiting the amount of untreated storm and wastewaters overflowing, for instance by increasing the capacity of treatment facilities, may reduce pollution levels and associated risks to marine and freshwater mammals.

For an intervention related to reducing litter in stormwater, see '*Threat: Pollution – Garbage and solid waste – Install stormwater traps or grids*'.

Moffa P.E. (1997) *The control and treatment of combined sewer overflows*. John Wiley & Sons.

Industrial and military effluents

10.8. Use double hulls to prevent oil spills

- We found no studies that evaluated the effects of using double hulls to prevent oil spills on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Oil spills can cause serious harm to marine and freshwater mammals (Helm *et al.* 2014). Double hulls, where the bottom and sides of ships have two layers of watertight surfaces, can be used to prevent oil spills and have been required in some countries since the 1990s (Alcock 1992). Double hulls can reduce vessel damage to tankers when involved in accidents, and their use has been shown to significantly reduce the number of accidental oil spills (Glen 2010, Yip *et al.* 2011).

Alcock T.M. (1992) "Ecology Tankers" and the Oil Pollution Act of 1990: a history of efforts to require double hulls on oil tankers. *Ecology Law Quarterly,* 19, 97–145.

Glen D. (2010) Modelling the impact of double hull technology on oil spill numbers. *Maritime Policy & Management,* 37, 475–487.

Helm R.C., Costa D.P., DeBruyn T.D., O'Shea T.J., Wells R.S. & Williams T.M. (2014) Overview of effects of oil spills on marine mammals. Pages 455–475 in*:* Fingas M. (ed.) *Handbook of Oil Spill Science and Technology.* John Wiley & Sons, Inc.

Yip T.L., Talley W.K. & Jin D. (2011) The effectiveness of double hulls in reducing vessel-accident oil spillage. *Marine Pollution Bulletin,* 62, 2427–2432.

10.9. Remove or clean-up oil pollution following a spill

- We found no studies that evaluated the effects of removing or cleaning up oil pollution following a spill on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Oil spills can cause serious harm to marine and freshwater mammals (Helm *et al.* 2014). The control and remediation of oil spills can be undertaken in a multitude of ways, e.g. using booms (floating barriers that contain a spill to a delimited zone) and skimmers (devices that collect oil) to remove oil from the water surface, dispersants that break oil into small droplets, sorbents (materials that adsorb oil), or by controlled burning of the oil (Dave & Ghaly 2011). Different methods have different outcomes and side-effects, but when successful may potentially reduce the risks of toxicity and direct harm to marine and freshwater mammals.

See also '*Use 'bioremediating' organisms to remove or neutralize pollutants*'.

Dave D. & Ghaly A.E. (2011) Remediation technologies for marine oil spills: a critical review and comparative analysis. *American Journal of Environmental Sciences,* 7, 423–440.
Helm R.C., Costa D.P., DeBruyn T.D., O'Shea T.J., Wells R.S. & Williams T.M. (2014) Overview of effects of oil spills on marine mammals. Pages 455–475 in*:* Fingas M. (ed.) *Handbook of Oil Spill Science and Technology.* John Wiley & Sons, Inc.

10.10. Rehabilitate and release marine and freshwater mammals following oil spills

- We found no studies that evaluated the effects of rehabilitating and releasing marine and freshwater mammals following oil spills.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Marine and freshwater mammals affected by oil spills may be rescued, rehabilitated, and released back into the wild. One study in the USA reported that a live-stranded dolphin was successfully de-oiled at a rehabilitation facility using vegetable oil and detergent and subsequently survived (Wilkin *et al.* 2017). However, the dolphin was considered unsuitable for release due to its young age and was kept in captivity.

Wilkin S.M., Rowles T.K., Stratton E., Adimey N., Field C.L., Wissmann S., Shigenaka G., Fougères E., Mase B. & Ziccardi M.H. (2017) Marine mammal response operations during the Deepwater Horizon oil spill. *Endangered Species Research,* 33, 107–118.

10.11. Relocate marine and freshwater mammals following oil spills

- We found no studies that evaluated the effects of relocating marine and freshwater mammals following oil spills.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

If an oil spill has the potential to affect marine and freshwater mammals and there is sufficient warning, it may be possible to temporarily relocate mammals away from the danger. However, this may be expensive and there is the risk that relocated mammals will not be able to return to the original site and/or may have a negative impact on native populations. Some mammals may also attempt to return before clean-up operations are complete.

10.12. Cease or prohibit the disposal of mining waste (tailings) at sea or in rivers

- We found no studies that evaluated the effects of ceasing or prohibiting the disposal of mining waste (tailings) at sea or in rivers on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Mine tailings (the ore waste of mines, typically in the form of a mud-like material) originate from both coastal and land-based mining activities and can be disposed of in aquatic environments causing chemical contamination. Ceasing or prohibiting the disposal of mining waste at sea or in rivers may reduce pollution and potential harm to marine and freshwater mammals.

10.13. Cease or prohibit the disposal of drill cuttings at sea or in rivers

- We found no studies that evaluated the effects of ceasing or prohibiting the disposal of drill cuttings at sea or in rivers on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Drill cuttings from oil and gas drilling activities are often discharged onto the sea floor or river bed to form a cuttings pile. Drill cuttings consist of fragments of rock contaminated with drilling fluids, oil, and chemicals, which may have adverse impacts on marine and freshwater mammals. Ceasing or prohibiting the disposal of drill cuttings at sea or in rivers may reduce pollution and potential harm to marine and freshwater mammals.

10.14. Set regulatory ban on marine burial of nuclear waste

- We found no studies that evaluated the effects of setting a regulatory ban on marine burial of nuclear waste on marine mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

The disposal of nuclear and radioactive waste at sea was practised by 13 countries from 1946 until 1993, when it was banned following international treaties. However, enforcement is lacking in parts of the world, where illegal dumping is reported to occur. Disposal within the sediment (sub-sea burial) is currently prohibited but has been proposed by various countries and may be an option in the future (Hollister & Nadis 1998). Setting pre-emptive regulatory bans on the sub-sea burial of nuclear waste may help prevent the occurrence of associated threats to marine mammals.

Hollister C.D. & Nadis S. (1998) Burial of radioactive waste under the seabed. *Scientific American,* 278, 60–65.

Aquaculture effluents

10.15. Introduce and enforce water quality regulations for aquaculture systems

- We found no studies that evaluated the effects of introducing and enforcing water quality regulations for aquaculture systems on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Aquaculture systems may discharge water with waste and effluents into aquatic environments causing pollution and habitat degradation with adverse impacts on marine and freshwater mammals. Typical wastes include faeces, excess feed and nutrients, and chemicals, such as disinfectants, antifoulants, pesticides, herbicides, and drugs for disease control. Current water quality regulations at aquaculture systems vary widely between different countries, and some have no or very few regulations in place. Introducing and enforcing water quality regulations for aquaculture systems may reduce pollution and harmful impacts on marine and freshwater mammals.

10.16. Reduce the amount of pesticides used in aquaculture systems

- We found no studies that evaluated the effects of reducing the amount of pesticides used in aquaculture systems on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Pesticides are chemicals used in aquaculture to reduce or eliminate pests. However, pesticides may contaminate aquatic environments with adverse impacts on marine and freshwater mammals. The risks associated with using pesticides may be reduced by applying them in smaller doses, less frequently or across a smaller area. Alternatively, live organisms may be used instead of chemicals to control pests (Thresher 2005).

Treasurer J.W. (2005) Cleaner fish: a natural approach to the control of sea lice on farmed fish. *Veterinary Bulletin,* 75, 17–29.

10.17. Reduce the amount of antibiotics used in aquaculture systems

- We found no studies that evaluated the effects of reducing the amount of antibiotics used in aquaculture systems on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Antibiotics are used in aquaculture to reduce or eliminate harmful bacteria. However, some antibiotics have been shown to accumulate and persist in aquatic environments, with potential negative effects on marine and freshwater mammals. The risks associated with the use of antibiotics may be reduced by applying them in smaller doses, less frequently or across a smaller area. In addition, research has shown that alternatives to antibiotics can be used successfully in aquaculture (Defoirdt *et al.* 2011).

Defoirdt T., Sorgeloos P. & Bossier P. (2011) Alternatives to antibiotics for the control of bacterial disease in aquaculture. *Current Opinion in Microbiology,* 14, 251–258.

Agricultural and forestry effluents

10.18. Reduce pesticide, herbicide or fertilizer use

- We found no studies that evaluated the effects of reducing pesticide, herbicide or fertilizer use on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Chemicals are often used in agriculture, such as pesticides, herbicides and fertilizers. They are designed to have long-lasting effects on living organisms, are often toxic to non-target species, and as such are a major source of pollution and toxicity in aquatic environments (Jepson *et al.* 2016). Agricultural run-off, including excess nutrients and toxic substances, can reach rivers and other watercourses and be discharged into the sea. Reducing the use of pesticides, herbicides and fertilizers in agriculture may reduce pollution levels and associated impacts on marine and freshwater mammals.

Jepson P.D., Deaville R., Barber J.L., Aguilar À., Borrell A., Murphy S., Barry J., Brownlow A., Barnett J., Berrow S., Cunningham A.A., Davison N.J., ten Doeschate M., Esteban R., Ferreira M., Foote A.D., Genov T., Giménez J., Loveridge J., Llavona Á., Martin V., Maxwell D.L., Papachlimitzou A., Penrose R., Perkins M.W., Smith B., de Stephanis R., Tregenza N., Verborgh P., Fernandez A. & Law R.J. (2016) PCB pollution continues to impact populations of orcas and other dolphins in European waters. *Scientific Reports,* 6, 18573.

10.19. Treat wastewater from intensive livestock holdings

- We found no studies that evaluated the effects of treating wastewater from intensive livestock holdings on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Intensive agriculture constitutes a major source of pollution to marine and freshwater environments. Wastewater from intensive livestock holdings containing bacteria, excess nutrients, chemical residues, and solid particles can enter rivers and other watercourses and be discharged into the sea. Treating wastewater from intensive livestock holdings may reduce the pollution levels in aquatic environments, and therefore reduce the associated impacts on marine and freshwater mammals.

10.20. Create artificial wetlands to reduce the amount of pollutants reaching rivers and the sea

- We found no studies that evaluated the effects of creating artificial wetlands to reduce effluent reaching rivers and the sea on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Agricultural and forestry effluents, which may contain chemicals, bacteria, excess nutrients, solid particles, and sediment, can enter rivers and other watercourses, and be discharged into the sea. Artificial wetlands may be created with the aim of retaining such pollution. For example, solid particles and sediment may sink in areas of slow water flow and plants growing on wetlands may remove excess nutrients (Brix 1994). Creating artificial wetlands near agricultural lands or forestry plantations may reduce the amount of pollutants reaching rivers and the sea, and therefore reduce the associated impacts on marine and freshwater mammals.

Brix H. (1994) Use of constructed wetlands in water pollution control: historical development, present status, and future perspectives. *Water science and technology,* 30, 209–223.

10.21. Establish riparian buffers to reduce the amount of pollutants reaching rivers and the sea

- We found no studies that evaluated the effects of establishing riparian buffers to reduce the amount of pollutants reaching rivers and the sea on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Agricultural and forestry effluents, which may contain chemicals, bacteria, excess nutrients, solid particles, and sediment, can enter rivers and other watercourses, and be discharged into the sea. Riparian buffers (uncultivated strips of vegetation along waterways) may be created to help reduce diffuse pollution from agriculture and forestry. For example, trees and plants within riparian buffers may trap sediments and solid particles and uptake excess nutrients (Collins *et al.* 2009). Establishing riparian buffers in agricultural and forestry areas may reduce the amount of pollutants reaching rivers and the sea, and therefore reduce the associated impacts on marine and freshwater mammals.

Collins A.L., Hughes G., Zhang Y. & Whitehead J. (2009) Mitigating diffuse water pollution from agriculture: riparian buffer strip performance with width. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources,* 4, 1–15.

10.22. Establish aquaculture to extract the nutrients from run-offs

- We found no studies that evaluated the effects of establishing aquaculture to extract the nutrients from run-offs on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Intensive agriculture constitutes a major source of pollution to marine and freshwater environments. Agricultural waste and pollutants can enter rivers and other watercourses and be discharged into the sea. Excess nutrients from agricultural waste can lead to diminished water quality and eutrophication events, including harmful algal blooms. Some species used in aquaculture can naturally improve water quality through feeding (e.g. filter feeding species, such as mussels) or through photosynthesis (e.g. algae species). Establishing certain types of aquaculture near polluted areas may be an effective method for the removal of excess nutrients (Duarte & Krause-Jensen 2018).

Duarte C.M. & Krause-Jensen D. (2018) Intervention options to accelerate ecosystem recovery from coastal eutrophication. *Frontiers in Marine Science,* 5.

Garbage and solid waste

Fishing gear

10.23. Use biodegradable fishing gear

- We found no studies that evaluated the effects of using of biodegradable fishing gear on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Abandoned, lost or otherwise discarded fishing gear (or 'ghost' gear) is a major threat to marine and freshwater mammals. Mammals may become entangled in 'ghost' gear, such as nets, lines and ropes, resulting in injury or death (Stelfox *et al.* 2016). Synthetic materials used for fishing gear, such as nylon, may persist for decades leading to an accumulation of 'ghost' gear in marine and freshwater environments. Using biodegradable materials, which are naturally broken down by microbes or ultraviolet light, may reduce the persistence of 'ghost' gear in the environment (Kim *et al.* 2016), and therefore reduce the risk of mammal entanglement. The degraded products of biodegradable materials (carbon dioxide, methane, water) also have no impact on marine ecosystems, unlike synthetic materials which eventually degrade into microplastics.

Kim S., Kim P., Lim J., An H. & Suuronen P. (2016) Use of biodegradable driftnets to prevent ghost fishing: physical properties and fishing performance for yellow croaker. *Animal Conservation,* 19, 309–319.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

10.24. Recover lost or discarded fishing gear

- We found no studies that evaluated the effects of recovering lost or discarded fishing gear on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Abandoned, lost or otherwise discarded fishing gear (or 'ghost' gear) is a major threat to marine and freshwater mammals. Mammals may become entangled in 'ghost' gear, such as nets, lines and ropes, resulting in injury or death (Stelfox *et al.* 2016). Recovering derelict fishing gear from marine and freshwater environments may reduce the risk of mammal entanglement. However, derelict gear may be difficult to locate and retrieve. Specialist techniques may be required, such as acoustic sonar surveys, aerial surveys, or underwater diver and camera surveys (Drinkman 2018).

For an intervention that involves offering incentives for recovering gear, see '*Offer incentives to fishers for recovering, reusing or recycling fishing gear*'. For an intervention related to removing other litter, see '*Threat: Pollution – Garbage and solid waste – Remove litter from marine and freshwater environments*'.

Drinkwin J. (2018) *Methods to locate derelict fishing gear in marine waters*. Natural Resources Consultants, Inc.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

10.25. Offer incentives to fishers for recovering, reusing or recycling fishing gear

- We found no studies that evaluated the effects of offering incentives to fishers for recovering, reusing or recycling fishing gear on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Mammals may become entangled in lost or abandoned fishing gear resulting in injury or death (Stelfox *et al.* 2016). Offering incentives may encourage fishers to recover, reuse or recycle fishing gear. For example, 'buyback' programmes offer fishers a financial reward for retrieving and returning derelict gear (e.g. Cho 2009).

See also '*Recover lost or discarded fishing gear*' and '*Equip ports with dedicated fishing gear disposal facilities*'.

Cho D.-O. (2009) The incentive program for fishermen to collect marine debris in Korea. *Marine Pollution Bulletin,* 58, 415–417.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

10.26. Equip ports with dedicated fishing gear disposal facilities

- We found no studies that evaluated the effects of equipping ports with dedicated fishing gear disposal facilities on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Mammals may become entangled in abandoned fishing gear resulting in injury or death (Stelfox *et al.* 2016). Equipping ports with dedicated fishing gear disposal facilities may encourage fishers to dispose of gear responsibly and may therefore reduce the risk of mammal entanglement.

See also '*Offer incentives to fishers for recovering, reusing or recycling fishing gear*'.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

10.27. Improve methods for locating fishing gear

- We found no studies that evaluated the effects of improving methods for locating fishing gear on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Abandoned, lost or otherwise discarded fishing gear (or 'ghost' gear) is a major threat to marine and freshwater mammals. Mammals may become entangled in 'ghost' gear, such as nets, lines and ropes, resulting in injury or death (Stelfox *et al.* 2016). Improving methods for locating fishing gear, such as using markers, acoustic transponders or onboard systems, may reduce the amount of gear that is lost and therefore reduce the risk of mammal entanglement.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

10.28. Establish fishing gear registration programmes

- We found no studies that evaluated the effects of establishing fishing gear registration programmes on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Mammals may become entangled in lost or abandoned fishing gear resulting in injury or death (Stelfox *et al.* 2016). Establishing fishing gear registration programmes (e.g. with gear markers displaying vessel, permit or licence numbers) may allow lost or abandoned gear to be traced back to the owner. This may encourage the responsible disposal of gear by fishers and reduce the risk of mammal entanglement.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

10.29. Inform fishers of the impacts of derelict fishing gear on mammals to encourage responsible disposal

- We found no studies that evaluated the effects of informing fishers of the impacts of derelict fishing gear on mammals to encourage responsible disposal.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Mammals may become entangled in lost or abandoned fishing gear resulting in injury or death (Stelfox *et al.* 2016). Informing fishers of the impacts of derelict fishing gear on marine and freshwater mammals may encourage the responsible disposal of gear and reduce the risk of mammal entanglement. This may involve erecting information boards or signs at ports and marinas, placing advertisements in fishing publications, or outreach at marine/fishing events.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

10.30. Remove derelict fishing gear from mammals found entangled

- **Two studies** evaluated the effects of removing derelict fishing gear from mammals found entangled. One study was in the North Pacific Ocean[1] (USA) and one in the North Atlantic Ocean[2] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Reproductive success (1 study):** One review in the North Pacific Ocean[1] found that after removing derelict fishing gear from Hawaiian monk seals, along with at least seven other interventions to enhance survival, more than a quarter of the seals reproduced.
- **Survival (2 studies):** One review in the North Pacific Ocean[1] found that removing derelict fishing gear from Hawaiian monk seals, along with at least seven other interventions to enhance survival, resulted in more than a quarter of the seals surviving. One review in the North Atlantic Ocean[2] found that three common bottlenose dolphins survived for at least 1–4 years after they were disentangled from derelict fishing gear and released.

BEHAVIOUR (0 STUDIES)

Background

Abandoned, lost or otherwise discarded fishing gear (or 'ghost' gear) is a major threat to marine and freshwater mammals. Mammals may become entangled in 'ghost' gear, such as nets, lines and ropes resulting in injury or death (Stelfox *et al.* 2016). Attempts may be made to remove derelict gear from mammals found entangled to improve survival. This may require specialist techniques, tools and training. Injuries or wounds caused by entanglement may also require treatment. Evidence is summarised below for studies that removed derelict gear from mammals in the wild. For studies that removed fishing gear from mammals in captivity as part of rehabilitation, see '*Species recovery – Rehabilitate and release injured, sick or weak marine and freshwater mammals*'.

For interventions related to the release of mammals captured by wild fisheries, see '*Threat: Biological resource use – Fishing and harvesting aquatic resources – Reduce unwanted catch ('bycatch') of mammals and improve survival of released or escaped mammals*'.

Stelfox M., Hudgins J. & Sweet M. (2016) A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Marine Pollution Bulletin,* 111, 6–17.

A review of interventions in 1980–2012 for Hawaiian monk seals *Monachus schauinslandi* in the North Pacific Ocean, Hawaii, USA (*1*) found that removing derelict fishing gear from seals, along with at least seven other interventions to enhance survival, resulted in 139 of 532 (26%) seals surviving and reproducing. The study did not distinguish between the effects of removing derelict fishing gear and the other interventions carried out. The 139 surviving seals (including 71 females) produced at least 147 pups, which also went on to reproduce (15 pups). In 2012, the number of surviving seals and their offspring were estimated to make up 17–24% of the seal population (198–271 of 1,153 seals). In 1980–2012, a total of 885 intervention events of seven types were carried out: removal of derelict fishing gear from seals (275 events); translocation (284 events); rescue of stranded or trapped seals (37 events); pups reunited with mothers (113 events); umbilical cord removed or other medical treatment (84 events); other actions, such as deterring aggressive male seals (120 events). Field biologists monitored the seal population in 1980–2012. Data were analysed for 532 individual seals facing severe mortality risks and involved in 698 of the 885 intervention events.

A review of three case studies in 2003–2010 in the North Atlantic Ocean, USA (*2*) found that three common bottlenose dolphins *Tursiops truncatus* entangled in derelict fishing gear that were rescued and released survived for at least 1–4 years. All of three rescued and disentangled dolphins (including one calf) were successfully tracked for 365–1,541 days after release. The dolphins (two males, one female calf) were found entangled in derelict fishing gear in 2003, 2006 and 2008. They were disentangled, treated, transported to appropriate habitats, and released immediately. All three dolphins were radio-tracked after release. Details of monitoring methods were not reported. Data were from published and unpublished studies.

(1) Harting A.L., Johanos T.C. & Littnan C.L. (2014) Benefits derived from opportunistic survival-enhancing interventions for the Hawaiian monk seal: the silver BB paradigm. *Endangered Species Research*, 25, 89–96.
(2) Wells R.S., Fauquier D.A., Gulland F.M.D., Townsend F.I. & DiGiovanni R.A. (2013) Evaluating postintervention survival of free-ranging odontocete cetaceans. *Marine Mammal Science*, 29, 463–483.

Other garbage and solid waste

10.31. Limit, cease or prohibit discharge of solid waste overboard from vessels

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting discharge of solid waste overboard from vessels on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Commercial and recreational vessels can generate large amounts of garbage and solid waste (Butt 2007). Wastes discharged overboard can pollute marine and freshwater environments through the introduction of bacteria, excess nutrients, toxic substances, solid particles, and litter. Limiting, ceasing or prohibiting the discharge of waste overboard from vessels in an area may reduce or stop the source of pollution, and therefore reduce associated impacts on marine and freshwater mammals. However, solid waste can accumulate and persist in aquatic environments for a long time due to slow degradation (Pham *et al.* 2014, Andrady 2015), therefore this intervention alone may not be sufficient.

For an intervention related to the discharge of waste effluents, see '*Threat: Pollution – Other pollution – Limit, cease or prohibit discharge of waste effluents overboard from vessels*'.

Andrady A.L. (2015) Persistence of plastic litter in the oceans. Pages 57-72 in*:* Bergmann M., Gutow L. & Klages M. (eds.) *Marine Anthropogenic Litter.* Springer International Publishing, Cham.

Butt N. (2007) The impact of cruise ship generated waste on home ports and ports of call: a study of Southampton. *Marine Policy,* 31, 591–598.

Pham C.K., Ramirez-Llodra E., Alt C.H.S., Amaro T., Bergmann M., Canals M., Company J.B., Davies J., Duineveld G., Galgani F., Howell K.L., Huvenne V.A.I., Isidro E., Jones D.O.B., Lastras G., Morato T., Gomes-Pereira J.N., Purser A., Stewart H., Tojeira I., Tubau X., Van Rooij D. & Tyler P.A. (2014) Marine litter distribution and density in European seas, from the shelves to deep basins. *PLOS ONE,* 9, e95839.

10.32. Install stormwater traps or grids

- We found no studies that evaluated the effects of installing stormwater traps or grids on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Urban debris can enter marine and freshwater environments in unprocessed stormwaters running off land via stormwater conduits and drainage systems (Armitage & Rooseboom 2000). Litter can negatively affect marine and freshwater mammals through entanglement, ingestion and the introduction of chemical contaminants (Kühn *et al.* 2015). Stormwater traps or grids are designed to prevent litter from entering stormwaters and may therefore reduce the amount of litter reaching marine and freshwater environments (Armitage 2007).

For an intervention related to stormwater polluted with sewage, see '*Threat: Pollution – Domestic and urban wastewater – Limit the amount of storm wastewater overflow*'.

Armitage N. & Rooseboom A. (2000) The removal of urban litter from stormwater conduits and streams: Paper 1 - The quantities involved and catchment litter management options. *Water Science and Technology,* 26, 181–188.

Armitage N. (2007) The reduction of urban litter in the stormwater drains of South Africa. *Urban Water Journal,* 4, 151–172

Kühn S., Bravo Rebolledo E.L. & van Franeker J.A. (2015) Deleterious effects of litter on marine life. Pages 75–116 in*:* Bergmann M., Gutow L. & Klages M. (eds.) *Marine Anthropogenic Litter.* Springer International Publishing, Cham.

10.33. Remove litter from marine and freshwater environments

- We found no studies that evaluated the effects of removing litter from marine and freshwater environments on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Litter can enter marine and freshwater environments through a multitude of pathways, such as vessels, storms, beaches, fishing etc., and can accumulate and persist for long periods (Pham *et al.* 2014, Andrady 2015). Litter can negatively affect marine and freshwater mammals through entanglement, ingestion, and the introduction of chemical contaminants (Kühn *et al.* 2015). Removing litter from the environment may reduce the risk of harm to mammals. However, this would not address the source or cause of the threat and can only be considered a temporary measure. Litter removal from aquatic environments can also be challenging, especially in remote or inaccessible areas.

For an intervention related to recovering derelict fishing gear, see '*Threat: Pollution – Fishing gear – Recover lost or discarded fishing gear*'.

Andrady A.L. (2015) Persistence of plastic litter in the oceans. Pages 57-72 in*:* Bergmann M., Gutow L. & Klages M. (eds.) *Marine Anthropogenic Litter.* Springer International Publishing, Cham.

Kühn S., Bravo Rebolledo E.L. & van Franeker J.A. (2015) Deleterious effects of litter on marine life. Pages 75–116 in*:* Bergmann M., Gutow L. & Klages M. (eds.) *Marine Anthropogenic Litter.* Springer International Publishing, Cham.

Pham C.K., Ramirez-Llodra E., Alt C.H.S., Amaro T., Bergmann M., Canals M., Company J.B., Davies J., Duineveld G., Galgani F., Howell K.L., Huvenne V.A.I., Isidro E., Jones D.O.B., Lastras G., Morato T., Gomes-Pereira J.N., Purser A., Stewart H., Tojeira I., Tubau X., Van Rooij D. & Tyler P.A. (2014) Marine litter distribution and density in European seas, from the shelves to deep basins. *PLOS ONE,* 9, e95839.

Excess energy

Noise pollution

10.34. Use acoustic devices to deter marine and freshwater mammals from an area to reduce noise exposure

- **Four studies** evaluated the effects of using acoustic devices to deter marine and freshwater mammals from an area to reduce noise exposure. Two studies were in the North Sea[1,3] (Germany), one study was in the Great Belt[2] (Denmark) and one was in Faxaflói Bay[4] (Iceland).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (4 STUDIES)

- **Behaviour change (4 studies):** Three studies (including two controlled and one before-and-after study) in the North Sea[1,3] and the Great Belt[2] found that using acoustic devices to deter mammals from an area at a wind farm construction site[3] or pelagic sites[1,2] reduced the activity and sightings of harbour porpoises at distances of 1–18 km from the devices. One before-and-after study in Faxaflói Bay[4] found that when an acoustic device was deployed from a boat, minke whales swam away from the device, increased their swimming speed, and swam more directly.

Background

Activities that produce large amounts of underwater noise, such as seismic airgun surveys, pile driving, dredging, explosives and sonar, may disturb or cause auditory injury to marine and freshwater mammals (Gordon *et al.* 2003, Bailey *et al.* 2010). Acoustic devices may be used to deter marine or freshwater mammals from an area prior to commencing such activities to reduce potential harm. However, it should be noted that high amplitude acoustic devices may cause hearing damage to target and non-target mammal species, and may disrupt biologically important behaviour or exclude mammals from important habitats (Johnston 2002, Morton & Symonds 2002, Olesiuk *et al*. 2002, Götz & Janik 2013).

Interventions that use acoustic devices in response to other threats can be found in the following chapters: '*Threat: Aquaculture and agriculture*', '*Threat: Biological resource use – Fishing and harvesting aquatic resources*', '*Threat: Energy production and mining*' and '*Threat: Transportation and service corridors – Shipping lanes*'.

Bailey H., Senior B., Simmons D., Rusin J., Picken G. & Thompson P.M. (2010) Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin,* 60, 888–897.

Gordon J., Gillespie D., Potter J., Frantzis A., Simmonds M.P., Swift R. & Thompson D. (2003) A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal,* 37, 16–34.

Götz T. & Janik V.M. (2013) Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series,* 492, 285–302.

Johnston D.W. (2002) The effect of acoustic harassment devices on harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy, Canada. *Biological Conservation,* 108, 113–118.

Morton A.B. & Symonds H.K. (2002) Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. *ICES Journal of Marine Science,* 59, 71–80.

Olesiuk P.F., Nichol L.M., Sowden M.J. & Ford J.K.B. (2002) Effect of the sound generated by an acoustic harassment device on the relative abundance and distribution of harbor porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia. *Marine Mammal Science,* 18, 843–862.

A controlled study in 2009 of a pelagic area in the North Sea, Germany (*1*) found that deploying an active acoustic device reduced harbour porpoise *Phocoena phocoena* echolocation activity and sightings at distances up to 7.5 km from the device. The average percentage of minutes/h with porpoise activity was lower with the acoustic device turned on than turned off at distances of 0 m (0.1% vs 2.6% respectively), 750 m (0.6% vs 4%), 3 km (2.5% vs 10.2%) and 7.5 km (0.1% vs 3.1%) from the device. The difference was not significant at 1.5 km (1.1% vs 2.4%) or 5 km (0.8% vs 0.9%). Fewer porpoises were observed in the study area with the device turned on (average 0.3 porpoises/km^2) than off (average 4 porpoises/km^2). In July–November 2009, an acoustic device (Lofitech Seal Scarer) was tested by deploying it from an anchored boat 80 km offshore, 7–10 m below the water surface. The device was turned on (emitting 0.5 second pulses at a frequency of 14 kHz) for 10 x 4-h trials, each separated by at least four days with the device turned off (silent). Sixteen acoustic detectors arranged in a star pattern recorded porpoise echolocation clicks at distances of 0 m, 750 m, 1.5 km, 3 km, and 7.5 km from the acoustic device. Data were compared for 3 h before and 3 h during each of the 10 trials. On 10 August 2009, two observers recorded porpoise sightings along 30 aerial transects over a 990 km^2 area before and after the acoustic device was turned on.

A randomized, controlled study in 2010–2011 of a pelagic site in the Great Belt, Denmark (*2*) found that when an active acoustic device was deployed, fewer harbour porpoises *Phocoena phocoena* were sighted within 1 km of the device. The average number of porpoise sightings was lower with the acoustic device turned on than turned off at distances of 0–150 m (0 vs 2 sightings/4h respectively), 151–450 m (0 vs 8 sightings/h) and 451–1,000 m (0.3 vs 20 sightings/h) from the device. Six porpoises also avoided the active device at distances of 1.1–2.4 km, and six porpoises had no obvious reaction at distances of 2.1–3.3 km (see original paper for details). In May–August 2010, an acoustic device (Lofitech Seal Scarer) was tested by deploying it from an anchored boat 150 m offshore, 4 m below the surface in water 2–15 m deep. The device was randomly turned on (emitting 0.6 second pulses at 14.5 kHz with random pauses of <1–90 seconds) or off (silent) during a total of seven and four days respectively. Porpoises within 1 km were observed and tracked with a theodolite from a cliff. Additional observations were made during three days in September 2010 and one day in August 2011, in which the device was deployed 1.1–3.3 km offshore and activated for 15 x 5-minute intervals.

A before-and-after study in 2013 at a wind farm construction site in the North Sea, Germany (*3*) found that using acoustic devices reduced harbour porpoise *Phocoena phocoena* activity prior to pile driving within 18 km of the site. At distances of 1.5–12 km and 15–18 km from the site, the average percentage of minutes with porpoise clicks detected was lower during periods in which acoustic devices were used (1.5–12 km: 1–5%; 15–18 km: 3%) compared to before devices were used (1.5–12 km: 4–7%; 15–18 km: 5%). At distances of 12–15 km, the difference was not significant (before: 4%; during: 3%). In February–December 2013, acoustic devices were used during 0.5–4 h periods prior to pile driving for 80 wind turbine foundations. Acoustic devices were Aquatec AQUAmark 100 pingers (emitting sounds at 20–160 kHz) and a Lofitech Seal Scrammer (emitting 0.5 second sounds at 14 kHz). Twelve acoustic detectors placed 1–31 km from the site recorded porpoise echolocation clicks for periods before (3 h) and during acoustic device use (0.5–4 h) for each of the 80 foundations.

A before-and-after study in 2016 of a pelagic area in Faxaflói Bay, Iceland (*4*) found that when an acoustic device was deployed, minke whales *Balaenoptera acutorostrata* swam away from the device, increased their swimming speed and swam more directly than before the device was deployed, although two of seven returned to the area soon after the device was turned off. All of 15 minke whales swam away from the acoustic device during 15 minutes in which it was active. The average swimming speed of the 15 tracked whales was greater while the device was active (15 km/h) than before (8 km/h), and the whales swam more directly (data reported as directness indices). Two of seven whales tracked for 30 minutes after the device was turned off returned to the area within 10–15 minutes. In August–September 2012, an acoustic device (Lofitech Seal Scarer) was deployed at a potential wind farm site during 15 trials from a 4.2-m rigid inflatable boat at distances of 300–1,500 m from minke whales. During each trial, the device was turned on (emitting 500 ms pulses at random intervals and frequencies of 10–20 kHz) for 15 minutes. Each of 15 whales was tracked from a research vessel using a video system for 45 minutes before, 15 minutes during and 30 minutes after (seven whales only) the device was activated.

(1) Brandt M.J., Höschle C., Diederichs A., Betke K., Matuschek R., Witte S. & Nehls G. (2013) Far-reaching effects of a seal scarer on harbour porpoises, *Phocoena phocoena*. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 23, 222–232.

(2) Brandt M.J., Höschle C., Diederichs A., Betke K., Matuschek R. & Nehls G. (2013) Seal scarers as a tool to deter harbour porpoises from offshore construction sites. *Marine Ecology Progress Series*, 475, 291–302.

(3) Dähne M., Tougaard J., Carstensen J., Rose A. & Nabe-Nielsen J. (2017) Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. *Marine Ecology Progress Series*, 580, 221-237.

(4) McGarry T., Boisseau O., Stephenson S. & Compton R. (2017) *Understanding the effectiveness of acoustic deterrent devices on minke whale (Balaenoptera acutorostrata), a low frequency cetacean.* ORJIP Project 4, Phase 2. RPS Report EOR0692. Prepared on behalf of The Carbon Trust.

10.35. Use 'soft start' procedures to deter marine and freshwater mammals to reduce noise exposure

- **Three studies** evaluated the effects of using 'soft start' procedures to deter marine and freshwater mammals to reduce noise exposure. One study was in each of the South Atlantic Ocean[1] (Gabon), the South Pacific Ocean[2] (Australia) and various water bodies[3] (UK).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (3 STUDIES)

- **Behaviour change (3 studies):** One study in various water bodies around the UK[3] found that a greater proportion of cetaceans (including whales, dolphins and porpoise) avoided or moved away from vessels during 'soft start' procedures with seismic airguns compared to when airguns were not firing. One study in the South Atlantic Ocean[1] found that during 'soft start' procedures using seismic airguns, a pod of short-finned whales initially moved away but remained within 900 m of the vessel as it passed by. One study in the South Pacific Ocean[2] found that during 'soft-start' procedures with a small experimental airgun array, migrating humpback whales slowed their speed towards the vessel but did not significantly alter their course.

Background

Activities that produce large amounts of underwater noise, such as seismic airgun surveys, pile driving and sonar, may disturb or cause auditory injury to marine and freshwater mammals (Gordon *et al.* 2003, Bailey *et al.* 2010). 'Soft start' (or 'ramp up') procedures may be used when commencing such activities to gradually increase the sound intensity over a period of time. The aim is to deter marine and freshwater mammals from the area before the full volume is reached so that noise exposure and the risk of injury are reduced (Von Benda-Beckmann *et al.* 2014). For example, seismic surveys may commence with a single airgun, with additional airguns activated over a period of time until the full array is operational. However, this relies on mammals having an avoidance response. Some mammals may be attracted to initially weak sounds and thus exposed to potentially harmful levels as the sound intensity increases (Compton *et al.* 2008). 'Soft-start' procedures may also prolong the total duration of operations, possibly increasing the total amount of acoustic energy that is transmitted into the environment.

Bailey H., Senior B., Simmons D., Rusin J., Picken G. & Thompson P.M. (2010) Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin,* 60, 888–897.

Von Benda-Beckmann A.M., Wensveen P.J., Kvadsheim P.H., Lam F.-P.A., Miller P.J.O., Tyack P.L. & Ainslie M.A. (2014) Modeling effectiveness of gradual increases in source level to mitigate effects of sonar on marine mammals. *Conservation Biology,* 28, 119–128.

Compton R., Goodwin L., Handy R. & Abbott V. (2008) A critical examination of worldwide guidelines for minimising the disturbance to marine mammals during seismic surveys. *Marine Policy,* 32, 255–262.

Gordon J., Gillespie D., Potter J., Frantzis A., Simmonds M.P., Swift R. & Thompson D. (2003) A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal,* 37, 16–34.

A study in 2008 in a pelagic area in the South Atlantic Ocean, Gabon (*1*) found that during a 'soft start' procedure using seismic airguns, a pod of short-finned whales *Globicephala macrorhynchus* changed course and travelled in the opposite direction to the seismic vessel for several minutes before milling at the water surface or travelling parallel to the vessel. Prior to the 'soft start' procedure, a pod of 15 short-finned whales was observed travelling steadily northeast for 24 minutes towards the seismic vessel. Nine minutes after the 'soft start' procedure commenced, the whales changed course by 180° and travelled southeast away from the vessel. Three minutes later, the whales were observed milling at the water surface or travelling parallel to the vessel as it passed their location within 900 m. In March 2008, a seismic survey was conducted using a single airgun array (consisting of six airgun strings) towed at a depth of 8.5 m and a speed of 4–5 knots y a 90-m vessel. An automated 'soft start' procedure was used with additional airgun signals added every 51 seconds during a 30-minute period. The whale pod was located 900 m away when the 'soft start' commenced. An observer on board the survey vessel recorded the position and behaviour of the 15 whales for 24 minutes before and 30 minutes during the 'soft start' procedure.

A study in 2011 of a pelagic area in the South Pacific Ocean off the east coast of Australia (*2*) found that during 'soft start' procedures using seismic airguns, migrating humpback whale *Megaptera novaeangliae* groups slowed their speed but did not significantly alter their course. Overall, migrating humpback whale groups swam more slowly as they approached a vessel during 'soft start' procedures compared to before 'soft starts' (data reported as statistical model results). However, whale groups did not significantly alter their course during 'soft starts'. The authors reported a similar response by whale groups to vessels without airguns firing (see original paper for details). During each of 22 trials, a 'soft start' procedure was carried out by a 28-m vessel towing a small experimental airgun array (six 20–150 cubic inch air guns) at a speed of 7.4 km/h across a humpback whale migration path. Airguns were progressively activated (at 2,000 psi) during four stages, in which the sound exposure level was increased in steps of 6 dB. Migrating whale groups (1–3 whales) were tracked with a theodolite from two land-based stations and observed from three small research vessels for 1-h before and 30-minutes during the 'soft start' procedure during each of the 22 trials in September–October 2011.

A study in 1994–2010 of multiple pelagic areas around the UK (*3*) found that during 'soft start' procedures, a greater proportion of cetaceans avoided or moved away from survey vessels compared to when airguns were not firing. A greater proportion of cetaceans (including whales, dolphins, and porpoises) avoided or moved away from survey vessels during 'soft start' procedures (200 of 975; 21%) than with no airguns firing (98 of 975; 10%). The same was true when the data were analysed separately for dolphins (Delphinidae) ('soft start': 92 of 484, 19%; not firing: 39 of 484, 8%) and *Lagenorhynchus* spp. only ('soft start': 46 of 186, 25%; not firing: 15 of 186, 8%). Data were extracted from reports made by Marine Mammal Observers on board seismic survey vessels in 1994–2010. Observations were made of marine mammals during 'soft start' procedures with large airgun arrays (≥50 cubic inch total volume) and during periods when airguns were not firing.

(1) Weir C.R. (2008) Short-finned pilot whales (*Globicephala macrorhynchus*) respond to an airgun ramp-up procedure off Gabon. *Aquatic Mammals*, 34, 349–354.

(2) Dunlop R.A., Noad M.J., McCauley R.D., Kniest E., Slade R., Paton D. & Cato D.H. (2016) Response of humpback whales (*Megaptera novaeangliae*) to ramp-up of a small experimental air gun array. Marine Pollution Bulletin, 103, 72–83.

(3) Stone C.J., Hall K., Mendes S. & Tasker M.L. (2017) The effects of seismic operations in UK waters: analysis of Marine Mammal Observer data. *Journal of Cetacean Research and Management*, 16, 71–85.

10.36. Delay or cease operations if marine and freshwater mammals are detected within a specified zone

- We found no studies that evaluated the effects of delaying or ceasing operations if marine and freshwater mammals are detected within a specified zone on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Activities that produce large amounts of underwater noise, such as seismic airgun surveys, pile driving, dredging, explosives and sonar, may disturb or cause auditory injury to marine and freshwater mammals (Gordon *et al.* 2003, Bailey *et al.* 2010). Delaying or ceasing such activities for a specified time if marine or freshwater mammals are detected within an 'exclusion' zone may help to reduce negative impacts and the risk of injury. This may involve using trained observers, acoustic monitoring and/or automated systems to detect mammals (Verfuss *et al.* 2018).

Bailey H., Senior B., Simmons D., Rusin J., Picken G. & Thompson P.M. (2010) Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin,* 60, 888–897.

Gordon J., Gillespie D., Potter J., Frantzis A., Simmonds M.P., Swift R. & Thompson D. (2003) A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal,* 37, 16–34.

Verfuss U.K., Gillespie D., Gordon J., Marques T.A., Miller B., Plunkett R., Theriault J.A., Tollit D.J., Zitterbart D.P., Hubert P. & Thomas L. (2018) Comparing methods suitable for monitoring marine mammals in low visibility conditions during seismic surveys. *Marine Pollution Bulletin,* 126, 1–18.

10.37. Use alternative methods instead of airguns for seismic surveys

- We found no studies that evaluated the effects of using alternative methods instead of airguns for seismic surveys on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Airguns used for seismic surveys produce high intensity sounds that may disturb or cause auditory injury to marine and freshwater mammals (Gordon *et al.* 2003). Using alternative 'quieter' methods instead of airguns for seismic surveys may reduce these impacts. For example, a method called marine vibroseis, which uses lower intensity sounds over a longer duration, may reduce some of the impacts on marine mammals (Richardson & Ellison 2013).

Gordon J., Gillespie D., Potter J., Frantzis A., Simmonds M.P., Swift R. & Thompson D. (2003) A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal,* 37, 16–34.

Richardson W.J. & Ellison W.T. (2013) *Predicted relative effects of marine vibroseis versus airguns on marine mammals*. Proceedings – 75th European Association of Geoscientists & Engineers Conference & Exhibition - Workshops, cp-349-00047.

10.38. Reduce hammer energy during pile driving

- We found no studies that evaluated the effects of reducing hammer energy during pile driving on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Pile driving is the process of driving large supports or foundations ('piles') into the sea floor or river bed with an impact hammer during the construction of wind turbines, offshore oil and gas structures, bridges and wharfs etc. The high intensity sounds produced by pile driving may disturb and cause auditory injury to marine and freshwater mammals (Bailey *et al.* 2010). Reducing the hammer energy used during pile driving may reduce noise exposure and the risk of injury.

Bailey H., Senior B., Simmons D., Rusin J., Picken G. & Thompson P.M. (2010) Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin,* 60, 888–897.

10.39. Use methods to dampen underwater noise emissions (e.g. bubble curtains, screens)

- **One study** evaluated the effects on marine mammals of using bubble curtains or screens to dampen underwater noise emissions. The study was in the North Sea[1] (Germany).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** One before-and-after, site comparison study in the North Sea[1] found that using bubble curtains or screens during pile driving resulted in harbour porpoise detections within 15 km decreasing less compared to before pile driving than at sites without bubble curtains or screens.

Background

Activities that produce large amounts of underwater noise, such as seismic airgun surveys, pile driving, dredging, explosives and sonar, may disturb or cause auditory injury to marine and freshwater mammals (Gordon *et al.* 2003, Bailey *et al.* 2010). Various methods may be used to dampen underwater noise emissions. This may involve surrounding the sound source with devices to absorb energy, such as screens or physical barriers, bubble curtains (a 'curtain' of air bubbles), hydro-sound dampeners (nets with gas-filled balloons and foam attached), cofferdams (insulated sleeves) or a combination of these measures (Verfuss 2014).

See also '*Threat: Pollution – Other pollution – Use methods to reduce sediment disturbance during dredging (e.g. curtains, screens)*'.

Bailey H., Senior B., Simmons D., Rusin J., Picken G. & Thompson P.M. (2010) Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin,* 60, 888–897.

Gordon J., Gillespie D., Potter J., Frantzis A., Simmonds M.P., Swift R. & Thompson D. (2003) A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal,* 37, 16–34.

Verfuss T. (2014) Noise mitigation systems and low-noise installation technologies. Pages 181–191 in*:* Federal Maritime and Hydrographic Agency, Federal Ministry for the Environment, Nature Conservation & Nuclear Safety (eds.) *Ecological Research at the Offshore Windfarm alpha ventus: Challenges, Results and Perspectives.* Springer, Wiesbaden.

A before-and-after, site comparison study in 2010–2013 at seven wind farm construction sites in the North Sea, Germany (*1*) found that using bubble curtains or screens resulted in harbour porpoise *Phocoena phocoena* detections within 15 km decreasing less compared to before pile driving than at sites without bubble curtains or screens. Compared to 24–48 h before pile driving, porpoise detections at distances of 0–15 km from piling sites decreased less during pile driving with bubble curtains and screens (0–5 km: 63%; 5–10 km: 23%; 10–15 km: 17%) than during pile driving without curtains or screens (0–5 km: 80%; 5–10 km: 55%; 10–15 km: 50%). In 2010–2013, pile driving was carried out at seven wind farm sites with or without bubble curtains (air bubbles released from a hose on the sea floor) or screens (double-wall screen filled with air). One site constructed all of 30 foundations with screens. Five sites constructed most foundations with bubble curtains (30–79 with; 1–11 without), and one site constructed most without (1 with; 80 without). All seven sites also used acoustic deterrents (pingers and seal scarers) prior to pile driving and 'soft-start' procedures. Acoustic data loggers attached to moorings recorded porpoise echolocation clicks at multiple locations at all seven sites 24–48 h before and during each of 581 pile driving events.

(1) Brandt M.J., Dragon A.C., Diederichs A., Bellmann M.A., Wahl V., Piper W., Nabe-Nielsen J. & Nehls G. (2018) Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. *Marine Ecology Progress Series*, 596, 213–232.

10.40. Limit, cease or prohibit the use of sonars

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting the use of sonars on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Sonar (sound navigation and ranging) may be used for military, civil and scientific applications to navigate, communicate or detect objects underwater. Research suggests that the use of active sonar can have behavioural and physiological effects on marine mammals and can lead to mass stranding events (Frantzis 1998, Jepson *et al.* 2003, Parsons 2017). Limiting, ceasing or prohibiting the use of underwater sonar may reduce these negative impacts.

Frantzis A. (1998) Does acoustic testing strand whales? *Nature,* 392, 29.

Jepson P.D., Arbelo M., Deaville R., Patterson I.A.P., Castro P., Baker J.R., Degollada E., Ross H.M., Herráez P., Pocknell A.M., Rodríguez F., Howie F.E., Espinosa A., Reid R.J., Jaber J.R., Martin V., Cunningham A.A. & Fernández A. (2003) Gas-bubble lesions in stranded cetaceans. *Nature,* 425, 575–576.

Parsons E.C.M. (2017) Impacts of navy sonar on whales and dolphins: now beyond a smoking gun? *Frontiers in Marine Science,* 4.

10.41. Limit, cease or prohibit the use of underwater explosives

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting the use of underwater explosives on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Underwater explosives are used for military purposes (e.g. bomb disposal, training exercises) and for construction works or decommissioning. The detonation of explosives generates large amounts of sound energy and shock waves that may injure or kill marine and freshwater mammals (Ketten *et al.* 1993, Dolman & St. Leger 2011).

Limiting, ceasing or prohibiting the use of underwater explosives may reduce the risk of harm to mammals.

Danil K. & St. Leger J.A. (2011) Seabird and dolphin mortality associated with underwater detonation exercises. *Marine Technology Society Journal,* 45, 89–95.

Ketten D., Lien J. & Todd S. (1993) Blast injury in humpback whale ears: evidence and implications. *The Journal of the Acoustical Society of America,* 94, 1849–1850.

10.42. Modify vessels to reduce noise disturbance

- We found no studies that evaluated the effects of modifying vessels to reduce noise disturbance on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Underwater noise from vessels can disturb marine and freshwater mammals and may cause behavioural changes and stress (Erbe *et al.* 2018). Modifications may be made to vessels to reduce noise pollution. This may involve using alternative propellor, rudder or hull designs, or 'quieting' technologies, such as electric propulsion. Onboard machinery (e.g. engines, generators, pumps) may also be modified to reduce noise pollution. For example, machinery may be relocated within the vessel, attached to resilient mounts or surrounded by sound dampening materials (International Maritime Organization 2014).

Reducing vessel speeds may also reduce noise pollution. See '*Threat: Transportation and service corridors – Shipping lanes – Set and enforce vessel speed limits*'.

Erbe C., Dunlop R. & Dolman S. (2018) Effects of noise on marine mammals. Pages 277–309 in*:* Slabbekoorn H., Dooling R. J., Popper A. N. & Fay R. R. (eds.) *Effects of Anthropogenic Noise on Animals.* Springer, New York.

International Maritime Organization (2014) *Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life (IMO MEPC.1/Circ.833)*. IMO, London.

Thermal pollution

10.43. Limit, cease or prohibit the discharge of cooling effluents from power stations

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting the discharge of cooling effluents from power stations on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

The cooling water effluents of power stations may be released from power plants back into rivers, lakes, or the ocean. The discharge of warm water, often containing chemicals, can damage marine and freshwater mammal habitats and contribute to harmful algal blooms (Barnett 1972). Limiting, ceasing or prohibiting the discharge of cooling effluents from power stations may reduce these effects.

Barnett P.R.O. (1972) Effects of warm water effluents from power stations on marine life. *Proceedings of the Royal Society of London: B*, 180, 497–509.

Other pollution

10.44. Use methods to reduce sediment disturbance during dredging (e.g. curtains, screens)

- We found no studies that evaluated the effects of using methods to reduce sediment disturbance during dredging, on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Dredging disturbs the river or seabed, resulting in sediment plumes and increased turbidity, which may have negative impacts on marine and freshwater mammals (Todd *et al.* 2015). Methods may be used to reduce sediment disturbance during dredging. For example, fabric curtains or screens may be erected around the dredging site to retain suspended sediments (Oglivie *et al.* 2012).

See also '*Use methods to dampen underwater noise emissions (e.g. bubble curtains, screens)*'.

Oglivie J., Middlemiss D., Lee M., Crossouard N. & Feates N. (2012) *Silt curtains – a review of their role in dredging projects*. Proceedings – CEDA Dredging Days 2012, Abu Dhabi, United Arab Emirates.

Todd V.L.G., Todd I.B., Gardiner J.C., Morrin E.C.N., MacPherson N.A., DiMarzio N.A. & Thomsen F. (2015) A review of impacts of marine dredging activities on marine mammals. *ICES Journal of Marine Science,* 72, 328–340.

10.45. Limit, cease or prohibit discharge of waste effluents overboard from vessels

- We found no studies that evaluated the effects of limiting, ceasing or prohibiting discharge of waste effluents overboard from vessels, on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Commercial, recreational, industrial, and military vessels can generate large amounts of liquid waste, such as sewage, grey waters, and bilge waters (Welles 2003). Discharge of these wastes overboard can impact marine and freshwater mammals through the introduction of bacteria, excess nutrients, toxic substances, and solid particles. Limiting, ceasing or prohibiting the discharge of waste overboard from vessels in an area can potentially reduce or stop the source of pollution. In many parts of the world, it is illegal to dispose of waste effluents into coastal waters or delimited zones, for instance following local bylaws.

For an intervention related to the discharge of solid waste, see '*Threat: Pollution – Garbage and solid waste – Limit, cease or prohibit discharge of solid waste overboard from vessels*'.

Welles L.K. (2003) Comment: Due to loopholes in the Clean Water Act, what can a state do to combat cruise ship discharge of sewage and gray water. *Ocean & Coastal Law Journal,* 9, 99.

10.46. Use non-toxic antifouling coatings on surfaces

- We found no studies that evaluated the effects of using non-toxic antifouling coatings on surfaces, on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Antifouling paints and coatings are commonly used to manage 'biofouling' (organisms that attach to hard surfaces) on aquaculture gear (cages, nets, ponds) and other hard anthropogenic structures. However, some antifouling paints and coatings are highly toxic to aquatic wildlife, including marine and freshwater mammals. Tributyltin (TBT), for example, was widely used on vessels and has been found to accumulate in marine mammal tissues, with potentially lethal effects (Kannan *et al.* 1997). Using non-toxic or natural antifouling coatings (e.g. Magin *et al.* 2010, Kirschner & Brennan 2012) may reduce the risk of toxicity to marine and freshwater mammals.

Kannan K., Senthilkumar K., Loganathan B.G., Odell D.K. & Tanabe S. (1997) Elevated accumulation of tributyltin and its breakdown products in bottlenose dolphins (*Tursiops truncatus*) found stranded along the U.S. Atlantic and Gulf coasts. *Environmental Science & Technology,* 31, 296–301.

Kirschner C.M. & Brennan A.B. (2012) Bio-inspired antifouling strategies. *Annual Review of Materials Research,* 42, 211–229.

Magin C.M., Cooper S.P. & Brennan A.B. (2010) Non-toxic antifouling strategies. *Materials Today,* 13, 36–44.

10.47. Remove and clean-up shoreline waste disposal sites

- We found no studies that evaluated the effects of removing and cleaning up shoreline waste disposal sites on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

In parts of the world, such as Antarctica, waste has been dumped in landfill sites (and onto sea ice in Antarctica) for lack of better solutions (Stark *et al.* 2006). Waste disposal sites can be highly contaminated and when occurring near the coastal zone or inland waterways can pollute marine and freshwater mammal habitats. Removing and cleaning up shoreline waste disposal sites would remove this source of pollution. Appropriate alternative waste disposable sites may also need to be provided to ensure that waste dumping does not reoccur.

Stark J.S., Snape I. & Riddle M.J. (2006) Abandoned Antarctic waste disposal sites: monitoring remediation outcomes and limitations at Casey Station. *Ecological Management & Restoration,* 7, 21–31.

11. Threat: Climate change and severe weather

Background

Climate change and extreme weather are expected to severely alter global marine biodiversity (Cheung *et al.* 2009). There may be a variety of direct and indirect impacts on marine and freshwater mammals. Warming sea temperatures and changes in ocean circulation, ice coverage, sea levels and river flows may result in habitat loss, changes in the distribution and abundance of prey, and increased pollution, outbreaks of infectious disease, and eutrophication events, such as harmful algal blooms (Learmouth *et al.* 2006). Marine and freshwater mammal species that are most likely to be affected are those with limited ranges, those that depend on sea ice as an important part of their habitat, and those that migrate to feeding grounds in polar regions (Simmonds & Isaac 2007).

Climate change and extreme weather are large scale threats, and therefore most interventions used in response to them are general conservation interventions discussed in other chapters, such as reducing pollution, controlling invasive species and disease, restoring habitats, translocating species and captive breeding (discussed in '*Threat: Pollution*', '*Threat: Invasive and problematic species or disease*', '*Habitat restoration and creation*' and '*Species management*'). Most of the interventions described below are related to maintaining existing habitats as conditions change, as well as ensuring the availability of new habitats as range shifts occur. However, most actions are pre-emptive, and it may be difficult to directly evaluate their effects before significant climate change events have occurred.

Cheung W.W.L., Lam V.W.Y., Sarmiento J.L., Kearney K., Watson R. & Pauly D. (2009) Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries,* 10, 235–251.

Learmonth J.A., MacLeod C.D., Vazquez M.B.S., Pierce G.J., Crick H. & Robinson R. (2006) Potential effects of climate change on marine mammals. *Oceanography and Marine Biology: An Annual Review,* 44, 431–464.

Simmonds M.P. & Isaac S.J. (2007) The impacts of climate change on marine mammals: early signs of significant problems. *Oryx,* 41, 19–26.

11.1. Implement rapid response plans for stranded mammals following extreme events

- We found no studies that evaluated the effects of implementing rapid response plans for stranded mammals following extreme events.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Extreme weather events, such as storms and cyclones, may cause mass stranding of marine mammals. Rapid response plans may provide an overview of possible rescue protocols, as well as details of which authorities to contact, should a stranding event occur. The aim of such plans is to increase the speed and effectiveness of the response to improve the chances of survival of stranded mammals.

11.2. Legally protect areas where climate change impacts are predicted to be less severe

- We found no studies that evaluated the effects of legally protecting areas where climate change impacts are predicted to be less severe on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves protecting important habitats or 'refuges' for marine and freshwater mammals in areas where climate change impacts are predicted to be less severe, such as cooler upwelling areas. Restricting human activities in such areas is likely to increase resilience to the threats of climate change. See also '*Establish a network of legally protected areas*'.

For more general interventions related to legal protection, see the chapter '*Habitat protection*'.

11.3. Establish a network of legally protected areas

- We found no studies that evaluated the effects of establishing a network of legally protected areas on marine and freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves establishing a network of legally protected areas with connectivity, such as migration routes, between them. This may provide suitable habitats and safe routes for range expansion of marine and freshwater mammals in response to climate change. See also '*Legally protect areas where climate change impacts are predicted to be less severe*'.

For more general interventions related to legal protection, see the chapter '*Habitat protection*'.

11.4. Manage water levels and flow in rivers to maintain deep pools and connectivity

- We found no studies that evaluated the effects of managing water levels and flow in rivers to maintain deep pools and connectivity on freshwater mammal populations.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Rising temperatures and changes in precipitation may substantially alter river flows and lead to desiccation and fragmentation of freshwater habitats (Arnell & Gosling 2013). Managing water levels and flow in rivers to maintain deep pools and connectivity may help to conserve freshwater mammal species that rely on these habitats, such as river dolphins (Choudhary *et al.* 2005). This may be particularly important in arid areas or during the dry season.

Arnell N.W. & Gosling S.N. (2013) The impacts of climate change on river flow regimes at the global scale. *Journal of Hydrology,* 486, 351–364.

Choudhary S., Dey S., Dey S., Sagar V., Nair T. & Kelkar N. (2012) River dolphin distribution in regulated river systems: implications for dry-season flow regimes in the Gangetic basin. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 22, 11–25.

12. Habitat protection

Background

Habitat destruction is the largest single threat to biodiversity and habitat fragmentation and degradation often reduces the quality of remaining habitat. Habitat protection is therefore one of the most frequently used conservation interventions both on land and in aquatic systems.

Habitat protection can be achieved through the designation of legally protected areas, using national or local legislation, or through voluntary designations. Protection can be of entire habitat types, for example through the European Union's Habitats Directive, or occur on a smaller scale, restricting detrimental activities in a specific area. It can be difficult to measure the effectiveness of legally protected areas as there may not be suitable controls and appropriate replication can be difficult.

This chapter describes interventions that may be used to benefit marine and freshwater mammals by protecting the natural habitats they live in. Interventions that aim to protect marine and freshwater mammals from specific threats are described in the chapter on that threat category.

12.1. Legally protect habitat for marine and freshwater mammals

- **Four studies** evaluated the effects of legally protecting habitat for marine and freshwater mammals. One study was in each of the North Atlantic Ocean[1] (Portugal), the South Pacific Ocean[2] (New Zealand), the North Sea[3] (UK) and the Port River estuary (Australia)[4].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (4 STUDIES)

- **Abundance (2 studies):** One before-and-after study in the North Atlantic Ocean[1] found that a population of Mediterranean monk seals increased during eight years after the islands they inhabited were legally protected. One before-and-after study in the North Sea[3] found that a population of bottlenose dolphins was estimated to be a similar size before and after part of its range was protected.
- **Survival (2 studies):** One before-and-after study in the South Pacific Ocean[2] found that the survival rate of Hector's dolphins was higher after a coastal area was legally protected than before. One before-and-after study in the Port River estuary[3] found that after the area became legally protected a similar number of Indo-Pacific bottlenose dolphin strandings were recorded compared to before protection, but the number of strandings caused by humans decreased.

BEHAVIOUR (0 STUDIES)

Background

Legally protecting habitat may reduce degradation by humans. This may in turn increase the abundance and diversity of marine or freshwater mammals that make use of that habitat. Critically important habitats may be protected such as birthing, nursery and feeding grounds, and migration routes. Various spatial designations may be used for protected areas. For example, Marine Mammal Protected Area (MMPA) is a term used to define an area that is specially managed for the protection of marine mammals and their habitats (Hoyt 2010). Protected areas may be many different shapes and sizes, and may vary in the number of species protected and the range of threats addressed (Notarbartolo di Sciara 2016).

Assessing the effectiveness of protected areas is particularly difficult as there may be no suitable controls and appropriate replication can be difficult. Effectiveness is also best monitored over long timescales, but this increases the chance that other factors influence the ecosystem.

The studies summarised below are related to legally protected areas or habitats. Evidence related to the legal protection of marine and freshwater mammals from specific threats are described in the chapter on that threat category. For a general intervention related to legally protecting marine mammal species, see '*Species management – Species recovery – Legally protect marine and freshwater mammal species*'.

Hoyt E. (2010) *Marine mammal protected areas (MMPAs): the global picture. Nascent networks moving toward an interconnected future*. Proceedings – First International Conference on Marine Mammal Protected Areas, Maui, Hawaii, 11–13.

Notarbartolo di Sciara G., Hoyt E., Reeves R., Ardron J., Marsh H., Vongraven D. & Barr B. (2016) Place-based approaches to marine mammal conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 26, 85–100.

A before-and-after study in 1984, 1989 and 1992–1998 of three islands in the North Atlantic Ocean, Portugal (*1*) reported that after the area became legally protected, a population of Mediterranean monk seals *Monachus monachus* increased over eight years. Results are not based on assessments of statistical significance. The number of monk seals inhabiting the islands was estimated to be higher eight years after legal protection was put in place (20 seals) than six years before legal protection (6–8 seals). Annual pup production was higher during 5–8 years after legal protection (2–3 pups/year) than during one year before legal protection (1 pup/year). The islands (and surrounding waters to a depth of 100 m) were legally protected and designated as a nature reserve in 1990. Controlled commercial fishing without nets was permitted in one half of the reserve. Wardens patrolled the islands daily by boat and educated fishers. In 1992–1998, seals were photographed and observed with binoculars for 5 h/day at 12–24 points located along the three islands. Data for 1984 and 1989 were from previous studies.

A before-and-after study in 1986–2005 of a coastal area in the South Pacific Ocean, New Zealand (*2*) found that after the area became legally protected the survival rate of Hector's dolphins *Cephalorhynchus hectori* was higher than before protection. The average annual survival rate of Hector's dolphins was 5.4% higher after the area became legally protected (0.92) than before (0.86). However, the authors state that the survival rate may still have been too low for population recovery. In 1988, the 1,170 km^2 coastal area was designated as a marine mammal sanctuary. Commercial fishing with gill nets was prohibited in the protected area, and amateur fishing with gill nets was restricted to specific times and locations to reduce dolphin entanglements. Hector's dolphins (462 individuals) were identified from photographs taken during boat transects (number not reported) along the shore in November–February before (1986–1989) and after (1990–2005) the sanctuary was established.

A before-and-after study in 1990–2010 in an inlet of the North Sea, Scotland, UK (*3*) reported that after the area was protected, the resident population of bottlenose dolphins *Tursiops truncatus* was estimated to be of a similar size to before protection. The total bottlenose dolphin population was estimated to be 102–157 individuals/year during the 15 years before the area was protected, and 143–178 individuals/year during the six years after, although the difference was not tested for statistical significance. Overall, the population was estimated to be stable or increasing over the entire 21-year period. In 2005, part of the bottlenose dolphin population's range was designated as a protected area. In May–September 1990–2010, the area was surveyed during 10–39 boat surveys/year along fixed (1990–2000) or flexible routes (2001–2010). All dolphins encountered were recorded and photographs were taken of the left and right side of their dorsal fins. Annual abundance and population trends were estimated using sightings of distinctive individuals (26–92 individuals/year) and mark-recapture models.

A before-and-after study in 1987–2012 in the Port River estuary, South Australia (*4*) found that after the area became legally protected a similar number of Indo-Pacific bottlenose dolphin *Tursiops aduncus* strandings were recorded compared to before protection, but the number of strandings caused by humans decreased. There was no significant difference in the average number of dolphin strandings recorded before (1.1 strandings/year) and after (2.3 strandings/year) the area became legally protected. However, the authors note that more data may be required over a longer time period to detect changes. The proportion of dolphin strandings caused by humans (intentional killing, boat collisions, entanglement in fishing gear) vs. non-human causes (disease, natural causes, live strandings) was lower after the area became legally protected (2 vs. 20 strandings respectively) than before (6 vs. 9 strandings). The area (118 km^2) was adjacent to a major port and urban/industrial area and became a legally protected dolphin sanctuary in 2005. This involved higher fines for intentional harm, fishing restrictions (commercial and recreational), enforcement patrols and an education and awareness raising programme. Dolphin strandings (live and carcasses) were recorded before (1987–2004) and after (2005–2012) the area was legally protected.

(1) Pires R. & Neves H.C. (2001) Mediterranean monk seal *Monachus monachus* conservation: a case study in the Desertas Islands. *Mammalia*, 65, 301–308.

(2) Gormley A.M., Slooten E., Dawson S., Barker R.J., Rayment W., du Fresne S. & Bräger S. (2012) First evidence that marine protected areas can work for marine mammals. *Journal of Applied Ecology*, 49, 474–480.

(3) Cheney B., Corkrey R., Durban J.W., Grellier K., Hammond P.S., Islas-Villanueva V., Janik V.M., Lusseau S.M., Parsons K.M., Quick N.J., Wilson B. & Thompson P.M. (2014) Long-term trends in the use of a protected area by small cetaceans in relation to changes in population status. *Global Ecology and Conservation,* 2, 118–128.

(4) Adamczak S.K., Kemper C. & Tomo I. (2018) Strandings of dolphins in the Adelaide Dolphin Sanctuary, South Australia. *Journal of Cetacean Research and Management*, 19, 105–111.

12.2. Enforce existing legislation for habitat protection

- We found no studies that evaluated the effects of enforcing existing legislation for habitat protection on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Despite the legal protection of habitats or areas for marine and freshwater mammals, prohibited human activities may still occur. This intervention involves enforcing existing legislation for habitat protection to reduce illegal activities. This may involve surveillance, policing, and prosecution of offenders.

12.3. Cease or prohibit activities that cause disturbance in sensitive areas for marine and freshwater mammals

- **Two studies** evaluated the effects of prohibiting activities that cause disturbance in sensitive areas for marine mammals. One study was in the Kattegat Sea[1] (Denmark) and one in the Indian Ocean[2] (Australia).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** One before-and-after study in the Kattegat sea[1] found that harbour porpoise activity increased at a stony reef after fishing was prohibited and the reef was restored with boulders.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** One site comparison study in the Indian Ocean[2] found that a beach where human access was fully prohibited had fewer Australian sea lions showing aggression or retreating compared to a beach where access was partly prohibited.

Background

There are many human activities that may cause disturbance and harm to marine and freshwater mammals and their habitats. This intervention involves prohibiting any such activity that may cause disturbance in particularly sensitive areas for marine and freshwater mammals. For example, in important feeding or resting grounds.

For studies that involve prohibiting activities as part of legal protection of an area, see '*Habitat protection: Legally protect habitat for marine and freshwater mammals*'.

A before-and-after study in 2006–2012 of a stony reef in the Kattegat sea, Denmark (*1*) found that prohibiting fishing, along with restoring the reef, resulted in harbour porpoise *Phocoena phocoena* echolocation clicks being recorded more often and for longer periods than before protection and restoration. The average number of minutes with porpoise recordings and the average duration of porpoise encounters were higher at the reef in each of four years after fishing was prohibited and the reef restored (13–15 minutes/day; 4–5 minutes) than during two years before (6–10 minutes/day; 3 minutes). Porpoise activity at an intact reef 10 km away decreased over the same period ('before': 11–15 minutes/day; 'after': 3–7 minutes/day). In June–September 2008, a total of 100,000 t of norite boulders were dumped over 19 days to restore a 45,000 m^2 cavernous stony reef. Fishing was prohibited around the restored reef in 2009–2012. Porpoise activity was recorded with acoustic data loggers (two at the restored reef; two at an intact reef) for 33–75 days in June–August in each of two years before protection and restoration (2006 and 2007) and each of four years after (2009–2012).

A site comparison study in 2013–2014 of two beaches on islands in the Indian Ocean, Western Australia (*2*) found that a beach where human access was prohibited had fewer Australian sea lions *Neophoca cinerea* showing aggression or retreating compared to a beach where access was partly prohibited. The number of responses to vessels and people in which sea lions showed aggression (gaping or lunging) or retreated were lower at a beach where access was fully prohibited (aggression: 0 responses/h; retreated: 3 responses/h) than at a beach where access was partly prohibited (aggression: 14 responses/h; retreated: 21 responses/h). Less severe responses (e.g. sitting upright, lifting head, looking or entering the water) did not differ significantly between the two beaches (see original paper for data). Both beaches were sea lion haul-out sites designated as sanctuary zones. At one site, public access to the beach was fully prohibited, with viewing permitted from the water only via kayak or boat tours. At the other site, public access was permitted to part of the beach and prohibited in all other areas. Individual responses of sea lions to vessels and people were recorded by observers or remote live video cameras overlooking each of the two sites for a total of 134–142 h during 19–20 days in November–April 2013/2014.

(1) Mikkelsen L., Mouritsen K.N., Dahl K., Teilmann J. & Tougaard J. (2013) Re-established stony reef attracts harbour porpoises *Phocoena phocoena*. *Marine Ecology Progress Series*, 481, 239–248.
(2) Osterrieder S.K., Salgado Kent C. & Robinson R.W. (2017) Responses of Australian sea lions, *Neophoca cinerea*, to anthropogenic activities in the Perth metropolitan area, Western Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27, 414–435.

12.4. Cease or prohibit activities that cause disturbance during sensitive periods for marine and freshwater mammals

- We found no studies that evaluated the effects of ceasing or prohibiting activities that cause disturbance during sensitive periods for marine and freshwater mammals.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

There are many human activities that may cause disturbance and harm to marine and freshwater mammals and their habitats. This intervention involves prohibiting any such activity that may cause disturbance during particularly sensitive periods for marine and freshwater mammals. For example, during birthing and nursing periods, or migration.

12.5. Retain or create buffer zones around important habitats

- We found no studies that evaluated the effects of retaining or creating buffer zones around important habitats on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Protected areas are usually subject to the influence of human activities in surrounding areas. Retaining or creating buffer zones around important habitats may help to reduce disturbance and degradation on the periphery of protected areas. Buffer zones are usually areas that do not receive full protection and are not subject to the same management intensity of core areas, but in which there may be a degree of limit to activities, such as fishing, shipping or development.

13. Habitat restoration and creation

Background

Habitat destruction is the largest single threat to biodiversity and habitat fragmentation and degradation often reduces the quality of remaining habitat. While habitat protection remains one of the most important and frequently used conservation interventions (see chapter on '*Habitat protection*'), in many parts of the world restoring damaged habitats or creating new habitat patches may also be possible. Habitat restoration or creation activities may involve improving water quality, planting vegetation, transplanting natural materials, controlling invasive species, removing garbage and litter, or creating foraging habitats, such as artificial reefs.

Interventions that involve controlling invasive species and reducing pollution are described in the chapters '*Threat: Invasive or problematic species and disease*' and '*Threat: Pollution*'.

13.1. Restore habitat for marine and freshwater mammals

- **One study** evaluated the effects of restoring habitat for marine mammals. The study was in the Kattegat sea[1] (Denmark).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** One before-and-after study in the Kattegat sea[1] found that harbour porpoise activity increased at a stony reef after it was restored with boulders and fishing was prohibited.

BEHAVIOUR (0 STUDIES)

Background

Degraded habitats that are important to marine and freshwater mammals, such as reefs, seagrass meadows, mangrove forests, rivers and beaches, may be actively restored. This may involve planting vegetation species, transplanting natural materials, such as sediment or rocks, and improving water quality. Habitat restoration is often carried out in combination with habitat protection, which may prohibit degrading activities and allow restored habitats to recover.

A before-and-after study in 2006–2012 of a stony reef in the Kattegat sea, Denmark (*1*) found that restoring the reef, along with prohibiting fishing, resulted in harbour porpoise *Phocoena phocoena* echolocation clicks being recorded more often and for longer periods than before restoration and protection. The average number of minutes with porpoise recordings and the average duration of porpoise encounters were higher at the reef in each of four years after the reef was restored and fishing prohibited (13–15 minutes/day; 4–5 minutes) than during two years before (6–10 minutes/day; 3 minutes). Porpoise activity at an intact reef 10 km away decreased over the same period (‘before’: 11–15 minutes/day; ‘after’: 3–7 minutes/day). In June–September 2008, a total of 100,000 t of norite boulders were dumped over 19 days to restore a 45,000 m^2 cavernous stony reef. Fishing was prohibited around the restored reef in 2009–2012. Porpoise activity was recorded with acoustic data loggers (two at the restored reef; two at an intact reef) for 33–75 days in June–August in each of two years before restoration and protection (2006 and 2007) and each of four years after (2009–2012).

(1) Mikkelsen L., Mouritsen K.N., Dahl K., Teilmann J. & Tougaard J. (2013) Re-established stony reef attracts harbour porpoises *Phocoena phocoena*. *Marine Ecology Progress Series*, 481, 239–248.

13.2. Create artificial habitat for marine and freshwater mammals

- We found no studies that evaluated the effects of creating artificial habitat for marine and freshwater mammals.

  ‘We found no studies’ means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves creating artificial habitats for marine and freshwater mammals. For example, artificial reefs are structures intentionally built on the seafloor using natural or man-made materials, such as rocks or concrete blocks. These structures may attract a variety of marine life and form reef ecosystems, providing a foraging resource for predatory marine mammals. However, some man-made materials used for artificial reefs, such as scrap tyres, may have toxic effects (Collins *et al.* 2002). High concentrations of fish at artificial reefs may also attract fishing activities and increase the risk of mammal entanglement in fishing gear.

For a study that restored an existing reef with boulders, see ‘*Restore habitat for marine and freshwater mammals*’. See also ‘*Leave anthropogenic structures in place after decommissioning*’.

Collins K.J., Jensen A.C., Mallinson J.J., Roenelle V. & Smith I.P. (2002) Environmental impact assessment of a scrap tyre artificial reef. *ICES Journal of Marine Science,* 59, 243–249.

13.3. Leave anthropogenic structures in place after decommissioning

- We found no studies that evaluated the effects of leaving anthropogenic structures in place after decommissioning on marine and freshwater mammal populations.

  ‘We found no studies’ means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Anthropogenic structures on the sea floor, such as pipelines, cable routes, wind turbines and oil rigs, may form ‘artificial reefs’ as they are colonised by marine invertebrates and provide breeding grounds and shelter for fish. This may provide a foraging resource for predatory marine mammals, such as porpoises and seals (e.g. Dähne *et al.* 2014, Arnould *et al.* 2015). Leaving such structures in place after decommissioning may therefore be beneficial to some marine mammal species. However, artificial reefs may also act as 'ecological traps' for mammal prey, attracting species to less favourable habitats leading to a decrease in fitness (Russell *et al.* 2014).

See also '*Create artificial habitat for marine and freshwater mammals*'.

Arnould J.P.Y., Monk J., Ierodiaconou D., Hindell M.A., Semmens J., Hoskins A.J., Costa D.P., Abernathy K. & Marshall G.J. (2015) Use of anthropogenic sea floor structures by Australian fur seals: potential positive ecological impacts of marine industrial development? *PLOS ONE,* 10, e0130581.

Dähne M., Peschko V., Gilles A., Lucke K., Adler S., Ronnenberg K. & Siebert U. (2014) Marine mammals and windfarms: effects of alpha ventus on harbour porpoises. Pages 133–149 in*:* Federal Maritime and Hydrographic Agency, Federal Ministry for the Environment, Nature Conservation & Nuclear Safety (eds.) *Ecological Research at the Offshore Windfarm alpha ventus: Challenges, Results and Perspectives.* Springer, Wiesbaden.

Russell D.J.F., Brasseur S.M.J.M., Thompson D., Hastie G.D., Janik V.M., Aarts G., McClintock B.T., Matthiopoulos J., Moss S.E.W. & McConnell B. (2014) Marine mammals trace anthropogenic structures at sea. *Current Biology,* 24, 638–639.

14. Species management

Background

Most of the chapters in this book are aimed at minimizing threats, but there are also some interventions which aim specifically to increase population numbers by increasing reproductive rates and by introducing individuals. Such interventions may be used in response to a wide range of threats. This chapter describes interventions that can be used to increase population size by legally protecting wild mammal species, rescuing and/or rehabilitating wild mammals, breeding or rearing mammals in captivity (ex-situ conservation) to release back into the wild, or translocating wild mammals from one area to another.

Species recovery

14.1. Legally protect marine and freshwater mammal species

- We found no studies that evaluated the effects of legally protecting marine and freshwater mammal species.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Legal protection may be given to a threatened species on a national or international scale. Levels of protection may vary for different species and may include protection against hunting, killing, harassing, capturing, trading or disturbing and disrupting behavioural patterns, such as migration, breeding, feeding or sheltering.

Evidence related to the legal protection of habitats is described in '*Habitat protection: Legally protect habitat for marine and freshwater mammals*'. Evidence related to the legal protection of marine and freshwater mammals from specific threats are described in the chapter on that threat category.

14.2. Rescue and release stranded or trapped marine and freshwater mammals

- **Eleven studies** evaluated the effects of rescuing and releasing stranded or trapped marine and freshwater mammals. Five studies were in the North Atlantic Ocean[1,6–8,11] (USA), two studies were in the Indian Ocean[4,5] (Tasmania, South Africa), and one study was in each of the South Atlantic Ocean[2] (Brazil), the Cachoeira River estuary[3] (Brazil), the North Pacific Ocean[9] (USA) and the Shannon Estuary[10] (Ireland).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (11 STUDIES)

- **Reproductive success (2 studies):** One review in the North Pacific Ocean[9] found that after rescuing and releasing stranded or trapped Hawaiian monk seals, along with at least seven other interventions to enhance survival, more than a quarter of the seals reproduced. One study in the Shannon Estuary[10] found that a stranded common bottlenose dolphin that was rescued and released was observed with a calf a year later.
- **Survival (11 studies):** Seven studies (including one review) in the North Atlantic Ocean[1,6–8,11], Indian Ocean[5] and the Shannon Estuary[10] found that 17–100% of rescued and released Atlantic white-sided dolphins[1,6,11], short-beaked common dolphins[1,6,11], common bottlenose dolphins[7,10], long-finned pilot whales[1,11], short-finned[8] pilot whales, and Cape fur seals[5] survived during post-release monitoring periods, which ranged in length from three weeks[11] to three years[7]. Three studies in the South Atlantic Ocean[2], the Cachoeira estuary[3] and the Indian Ocean[4] found that a trapped rough-toothed dolphin[2], two stranded tucuxi dolphins[3] and seven stranded sperm whales[4] were successfully rescued and released, although long-term survival was not reported. One review in the North Pacific Ocean[9] found that rescuing and releasing stranded or trapped Hawaiian monk seals, along with at least seven other interventions to enhance survival, resulted in more than a quarter of the seals surviving.

BEHAVIOUR (0 STUDIES)

Background

Marine and freshwater mammals that are found stranded or trapped without significant injury or impairment may be rescued and released back into the wild. Often this is done more for animal welfare reasons than for species conservation, although for rare species, release of such animals may provide opportunities to augment wild populations. The success of rescuing and releasing mammals can be difficult to judge without long-term survival data. It is also important to note that most studies summarised below have small sample sizes, and that unsuccessful attempts are unlikely to have been reported.

Evidence is summarised below for studies that released trapped or stranded mammals immediately. For studies that rescued and rehabilitated mammals in captivity prior to release, see '*Rehabilitate and release injured, sick or weak marine and freshwater mammals*'.

A replicated study in 1990–1999 at multiple pelagic sites in the North Atlantic Ocean, Cape Cod Bay, USA (*1*) found that all stranded and rescued Atlantic white-sided dolphins *Lagenorhynchus acutus* and most short-beaked common dolphins *Delphinus delphis* and long-finned pilot whales *Globicephala melas* were successfully released and did not re-strand. All 16 white-sided dolphins, six of eight (75%) common dolphins, and 38 of 53 (72%) pilot whales were successfully released and were not found re-stranded. One common dolphin and three pilot whales died during transport to release sites. One common dolphin and 12 pilot whales re-stranded and died after release. The 77 dolphins and whales were rescued after mass stranding events in 1990–1999. They were either released at stranding sites or transported to sites up to 40 km away. Most were released within 3–10 h of stranding. All animals were individually marked with tags prior to release. Re-stranded animals were reported by members of the public and national stranding records were searched.

A study in 2001 at a pelagic site in the South Atlantic Ocean, near Salvador, Brazil (*2*) found that a trapped rough-toothed dolphin *Steno bredanensis* was successfully rescued and released. An adult female rough-toothed dolphin found trapped between wooden house stilts was successfully rescued and released in the open sea. The dolphin was observed swimming alongside the boat after release, although long-term survival was not reported. On 29 October 2001, the dolphin (2.3 m long) was found trapped in a suburban area within a bay. The next day after 4 h of observation, a nylon net (150 m long x 3 m deep, 0.4 mm nylon wires, 2 cm mesh size) and a silk cable net with foam floats attached (5 x 5 x 5 m, 8 mm silk cables, 10 cm mesh size) were dragged by small boats to encircle and capture the dolphin. Local fishers helped with the rescue, which took 3 h. The dolphin was treated with Dexametason, Diazepam, and Enrofloxacin just after capture to reduce the effects of stress. The dolphin was covered with wet white cloths and transported by motorboat to waters adjacent to a beach at a museum. She was contained in the silk net and treated with an anti-parasitic drug (Ivermectin). The dolphin was monitored for 1 h before being released at sea, one nautical mile offshore.

A study in 2003 in the Cachoeira River estuary, southern Bahia, Brazil (*3*) found that two stranded tucuxi dolphins *Sotalia fluviatilis* were successfully rescued and released. Two young, male tucuxi dolphins found trapped in a natural pool were successfully rescued and released in deep water nearby. Both dolphins were observed feeding within an hour of release and were not found re-stranded, although long-term survival was not reported. The dolphins were trapped within a natural pool (7 m deep x 50 m diameter) along a river for nine days. Nylon nets (120 m long x 6 m deep with 80 mm mesh) dragged by canoes were used to capture the dolphins in March 2003. Both dolphins were injected with a drug to prevent shock (4 mg of Dexamethasone), transported individually to the release site by a motorboat, and observed for 1 h after release.

A study in 2007 in an inlet of the Indian Ocean, west Tasmania (*4*) found that seven stranded sperm whales *Physeter macrocephalus* were successfully rescued and released. Seven male sperm whales found stranded in shallow water were successfully rescued and released back into the sea within 1–4 days of stranding. All seven whales were observed swimming away after release, although long-term survival was not reported. Five other sperm whales that stranded on the same day died before rescue could be attempted. On 7 March 2007, seven whales (11–15 m long) were found stranded in shallow water (approximately 1 m deep) separated from a deep channel by a sand bar. Wet sheets were placed over the whales and respiration rates monitored during rescue. Two of the seven whales were moved back into deep water using jet wash propulsion. The other five whales were re-floated and released using a modified panel-shaped net (20 m long x 4.5 m deep) towed between two vessels. Vessel engine noises and acoustic devices were used to deter released whales from the stranding site and direct them out to sea.

A study in 2008–2009 on an island off the coast of South Africa (*5*) found that at least nine of 52 stranded Cape fur seal *Arctocephalus pusillus pusillus* pups that were rescued and released survived for at least three months. At least nine of 52 (17%) rescued and tagged seal pups were observed alive three months after release. The authors estimated a survival rate of 23% to account for the potential loss of tags. A total of 200 seal pups (aged several days to five weeks old) were stranded on the mainland after a severe storm and taken to rehabilitation facilities in December 2008. Thirty-one seal pups died in captivity and 169 pups were released back into the wild within 1–5 days at a seal colony on a nearby island. Fifty-two of the 169 released pups were fitted with tags that were appropriate for post-release monitoring. The release site was visited on five occasions in January–April 2009. Tagged seals were identified and observed from a vessel 1–5 m from the shore.

A replicated study in 2005–2011 of multiple pelagic sites in the North Atlantic Ocean, near Cape Cod, USA (*6*) found that all stranded Atlantic white-sided dolphins *Lagenorhynchus acutus* and a third of stranded short-beaked common dolphins *Delphinus delphis* that were rescued and released survived for at least 1–7 months. All of eight Atlantic white-sided dolphins survived for at least 33–218 days after release. One of three short-beaked common dolphins survived for at least 65 days after release. Contact was lost with the two other common dolphins (including one juvenile) 8 h and 9 days after release, and it was not known if they died or satellite-tags failed. Eight Atlantic white-sided dolphins and three short-beaked common dolphins were rescued, satellite-tagged and released during seven mass stranding events in 2005–2010. Stranded dolphins were kept moist, shaded and comfortable. Behavioural observations, physical examinations and blood tests were carried out prior to release. The dolphins were released singly or in pairs at various locations on the same day as stranding. The 11 released dolphins were tracked for between 8 h and 218 days in 2005–2011.

A review of seven case studies in 2006–2010 in the North Atlantic Ocean, USA (*7*) found that five of seven trapped common bottlenose dolphins *Tursiops truncatus* that were rescued and released survived for at least 1–3 years. Five of seven rescued dolphins were successfully tracked for 365–1,040 days after release. Two other trapped and rescued dolphins were tracked for <1–2 days after release. One stranded and died, the other was considered unlikely to have survived. The dolphins (three males, three females, one unknown) were found trapped out of their natural habitats in 2006, 2007 and 2010. They were rescued, treated, transported to appropriate habitats, and released immediately. All seven dolphins were radio-tracked after release. Details of monitoring methods were not reported. Data were from published and unpublished studies.

A study in 2011 of a pelagic area in the North Atlantic Ocean, off the coast of Florida, USA (*8*) found that one of two stranded short-finned pilot whales *Globicephala macrorhynchus* that was rescued and released survived for at least two months. One of two stranded whales survived for at least 67 days after release. The whale occupied appropriate habitats (warm waters in high relief areas) and had dive depths (maximum average 1,000–1,500 m) and durations (99% of dives <30 minutes) within or greater than reported ranges for the species. Contact was lost with the other whale 16 days after release. A sudden decline in travel rates and dive depths suggested the whale died. The two adult male whales were released following a mass stranding event in May 2011. Both were considered healthy following assessment of body condition, behaviour and blood samples. The whales were satellite-tagged and released together 16 km offshore within two days of stranding. They were tracked to 118–319 locations during 16–67 days in 2011.

A review of interventions in 1980–2012 for Hawaiian monk seals *Monachus schauinslandi* in the North Pacific Ocean, Hawaii, USA (*9*) found that rescuing and releasing stranded or trapped seals, along with at least seven other interventions to enhance survival, resulted in 139 of 532 (26%) seals surviving and reproducing. The study did not distinguish between the effects of rescuing stranded or trapped seals and the other interventions carried out. The 139 surviving seals (including 71 females) produced at least 147 pups, which also went on to reproduce (15 pups). In 2012, the number of surviving seals and their offspring were estimated to make up 17–24% of the seal population (198–271 of 1,153 seals). In 1980–2012, a total of 885 intervention events of seven types were carried out: rescue of stranded or trapped seals (37 events), translocation (284 events); removal of derelict fishing gear from seals (275 events); pups reunited with mothers (113 events); umbilical cord removed or other medical treatment (84 events); other actions, such as deterring aggressive male seals (120 events). Field biologists monitored the seal population in 1980–2012. Data were analysed for 532 individual seals facing severe mortality risks and involved in 698 of the 885 intervention events.

A study in 2012–2013 in the Shannon Estuary, western Ireland (*10*) found that a stranded common bottlenose dolphin *Tursiops truncatus* that was rescued and released survived for over a year and was observed with a calf. The rescued adult female dolphin survived for at least 482 days after being released at sea in June 2012. She was observed with a dependent calf on 18 occasions in May–September 2013. The dolphin (3.5 m long) was found stranded on a beach during a receding tide on 1 June 2012. Wet towels were used to cool the dolphin. A transport box attached to a tractor was used to move the dolphin back into the water where she was directed by hand to the open sea. The rescue took 70 minutes to complete and the dolphin was observed swimming away. Researchers on board tour boats recorded sightings of the dolphin within the estuary during daily photo-identification surveys in 2012–2013.

A study in 2010–2012 of a pelagic area in the North Atlantic Ocean, near Cape Cod, USA (*11*) found that more than half of stranded and rescued dolphins *Delphinidae* spp. released back into the sea survived for at least 3–11 weeks. Eighteen of 34 dolphins were successfully tracked for 21–79 days after release and travelled an average of 1,395 km during that time. Eight dolphins were tracked for 6–14 days before contact was lost with their transmitters. Eight dolphins were tracked for only one day (one of which re-stranded and died). In 2010–2012, a total of 34 dolphins of three species (28 short-beaked common dolphins *Delphinus delphis*, five Atlantic white-sided dolphins *Lagenorhynchus acutus*, one long-finned pilot whale *Globicephala melas*) were rescued during 33 stranding events. Dolphins were provided with medical treatment at the stranding site before being satellite-tagged and released, either singly or in groups. Health assessments and blood tests were carried out prior to release. The 34 dolphins were tracked for 1–79 days after release in 2010–2012.

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14.3. Rehabilitate and release injured, sick or weak marine and freshwater mammals

- **Twenty-seven studies** evaluated the effects of rehabilitating and releasing injured, sick or weak marine and freshwater mammals. Nine studies were in the North Atlantic Ocean[4,5,7–9,11,14,16,22] (USA, UK, France), six studies were in the North Pacific Ocean[6,13,19,20,22,23] (USA), four studies were in the Gulf of Mexico[3,5,17,27] (USA), two studies were in each of the North Sea[1,12] (the Netherlands) and the Gulf of Maine[2,10] (USA), and one study was in each of the Indian River Lagoon[15] (USA), Bohai Bay[18] (China), The Wash estuary[21] (UK), water bodies in Florida[24] (USA), El Dorado Lake[25] (Peru), and the Gulf of California[26] (Mexico).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (26 STUDIES)

- **Reproductive success (1 study):** One replicated study in the North Pacific Ocean[20] found that more than a quarter of rehabilitated and released Hawaiian monk seals reproduced.
- **Survival (26 studies):** Twenty-one studies (including two controlled studies, four replicated studies and one review) in the North Atlantic Ocean[4,5,8,9,11,14,16,22], the Gulf of Maine[2,10], the Gulf of Mexico[3,5,17,27], the North Pacific Ocean[6,13,20,22], the Indian River Lagoon[15], The Wash estuary[21], water bodies in Florida[24], El Dorado Lake[25], and the Gulf of California[26] found that 10–100% of dolphins[2,3,5,13,15–17,22,27], porpoises[4,13,14,22], whales[8,10,11,13,22], seals[6,9,20,21], sea lions[26] and manatees[24,25] released after rehabilitation in captivity survived during post-release monitoring periods, which ranged in length from three days[13] to five years[9]. Five studies (including one replicated study) in the North Sea[1,12], the North Atlantic Ocean[7], Bohai Bay[18] and the North Pacific Ocean[23] found that two of three harbour porpoises[1], 152 of 188 grey

seal pups[7], a common seal[12], a west Pacific finless porpoise[18] and 14 of 35 California sea lions[23] were successfully rehabilitated and released but survival after release was not reported. One controlled study in the North Pacific Ocean[19] found that at least a quarter of California sea lions treated for toxic algae poisoning and released back into the wild died or had to be euthanized.

BEHAVIOUR (3 STUDIES)

- **Behaviour change (3 studies):** Two of three controlled studies in the North Atlantic Ocean[4], the North Pacific Ocean[19] and The Wash estuary[21] found that a harbour porpoise[4] and six harbour seals[21] that were rehabilitated and released had similar movements[4] and/or behaviours[4,21] to wild mammals. The other study[19] found that California sea lions treated for toxic algae poisoning and released travelled further from the shore, spent less time diving or hauled out and made shorter, shallower dives than wild sea lions without poisoning.

Background

Marine and freshwater mammals that are injured, sick or found in a weak condition may be taken into captivity by wildlife rehabilitators to be treated and released back into the wild. Often this is done more for animal welfare reasons than for species conservation, although for rare species, release of such animals may provide opportunities to augment wild populations. The success of such programmes can be difficult to judge without long-term survival data or benchmark data for survival of wild mammals that have not been taken into captivity. It is also important to note that most studies summarised below have small sample sizes, and that unsuccessful attempts are unlikely to have been reported.

Evidence has been summarised below for studies that brought mammals into captivity as part of a rehabilitation programme. For interventions that treat mammals for disease or parasites in the wild or during temporary confinement, see '*Threat: Invasive or problematic species and disease – Disease – Treat disease in wild marine and freshwater mammals*' and '*Use drugs to treat parasites*'. For studies that rescued and immediately released stranded or trapped mammals, see '*Rescue and release stranded or trapped marine and freshwater mammals*'.

A study in 1988 of a pelagic area in the North Sea, the Netherlands (*1*) found that two of three stranded harbour porpoises *Phocoena phocoena* were successfully rehabilitated and released back into the wild. Two stranded harbour porpoises (a young female and an adult male) were successfully rescued and released back into the wild after eight months of rehabilitation. Survival after release was not reported. The other porpoise (an adult male) was rescued and rehabilitated but died of an infection seven months after capture. The three porpoises were found stranded on a beach in March 1988 in poor condition (wounded, dehydrated and underweight) and taken to a rehabilitation facility. They were kept in a rectangular pool (8 x 3 m, 1 m deep), had wounds treated, were given antibiotics, parasite and hormone treatments, oral rehydration salts and vitamins, and fed fish (3–4 times/day). Two of the three porpoises were released back into the wild in November 1988.

A study in 1991 of a pelagic area in the Gulf of Maine, USA (*2*) found that a stranded Atlantic white-sided dolphin *Lagenorhynchus acutus* that was rehabilitated and released back into the wild survived for at least six days. The rehabilitated male dolphin was successfully tracked for six days before contact was lost with the transmitter following a storm. The dolphin travelled at least 309 km during that time at an average speed of 5.7 km/h and was recorded diving regularly (>4,000 dives during 45 h). The dolphin was rescued after stranding on an island and taken to a rehabilitation facility. After eight months of rehabilitation, the dolphin was satellite-tagged and released offshore in an area with known sightings of Atlantic white-sided dolphins. The dolphin was tracked to 53 locations during six days in October 1991.

A study in 1995 of a pelagic area in the Gulf of Mexico, USA (*3*) found that a stranded Atlantic spotted dolphin *Stenella frontalis* that was rehabilitated and released back into the wild survived for at least one month. The adult male dolphin was successfully tracked for 28 days after release before the transmitter detached. During that time, the dolphin travelled at least 1,711 km at an average rate of 72 km/day. He moved along 300 km of coast at an average distance of 52 km from the shore and made regular dives (average 698 dives/day). The dolphin was found stranded on an island on 10 February 1995 and transported to a rehabilitation facility. He was housed in a pool (7 m wide, 1.5 m deep) and fed fish (10 kg/day). On 17 March 1995, the dolphin was satellite-tagged and released 16 km offshore. He was tracked to 124 locations during 28 days in March–April 1995.

A controlled study in 1995–1996 of a pelagic area in the North Atlantic Ocean, off the coast of Maryland, USA (*4*) found that a stranded harbour porpoise *Phocoena phocoena* that was rehabilitated and released back into the wild survived for at least 50 days and had similar movements and behaviour to wild porpoises. The rehabilitated female porpoise was successfully tracked for 50 days after release before contact was lost with the transmitter. The average distance of the released porpoise from the shore (31 km), average daily distance travelled (33 km), average rate of travel (1.4 km/h) and proportion of time spent at the water surface (3%) were within the ranges of seven wild porpoises tracked by the authors in a previous study (see original paper for details). In April 1995, the porpoise was found stranded and underweight, and taken to a rehabilitation facility. The porpoise was kept in a 4-m deep, 370,000-l pool, treated for parasites and bacterial infections, and fed fish and squid at 11% of its body mass/day. After 13 months of rehabilitation, the porpoise (aged approximately two years old) was satellite-tagged and released offshore. The porpoise was tracked to 142 locations in April–June 1996.

A replicated study in 1996–1997 of two pelagic areas in the Gulf of Mexico and the North Atlantic Ocean, USA (*5*) found that two stranded common bottlenose dolphins *Tursiops truncatus* that were rehabilitated and released back into the wild survived for at least 1.5 months. The two adult male dolphins were successfully tracked for 43 and 47 days after release back into the wild. The dolphins travelled a total of 2,050 and 4,200 km at average rates of 48 and 89 km/day respectively, along the coast and into deeper offshore waters. The dolphins were found stranded in December 1996 and January 1997 and transported to rehabilitation facilities. They were housed in pools (200,000–800,000 l), given antibiotics and fed fish. After 39–85 days of rehabilitation, the dolphins were satellite-tagged and released at sites 46–70 km offshore. The dolphins were tracked to 10–69 locations in March–April and May–July 1997.

A study in 1998 of a pelagic area in the North Pacific Ocean, off the coast of California, USA (*6*) found that a stranded and underweight Guadalupe fur seal *Arctocephalus townsendi* that was rehabilitated and released back into the wild survived for at least seven weeks. The rehabilitated female seal was successfully tracked for seven weeks after release before contact was lost with the transmitter. During that time, the seal travelled at least 2,890 km at an average rate of 3 km/h. The adult seal was found stranded and underweight in January 1998 and taken to a rehabilitation facility. After eight weeks of rehabilitation, the seal was released at a peninsula with a satellite transmitter attached. The seal was recorded at 25 locations during seven weeks in March–April 1998.

A replicated study in 1992–1998 at multiple sites in the North Atlantic Ocean, off the coast of southwest England, UK (*7*) found that 152 of 188 (81%) sick or injured grey seal *Halichoerus grypus* pups were successfully rehabilitated and released. Eighty-one percent of rescued grey seal pups (152 of 188) were successfully rehabilitated and released back into the wild. Survival of the pups after release was not reported. The other 36 seal pups died during rehabilitation due to their original illness or injury (28 pups) or complications during rescue and rehabilitation (e.g. accidental drowning, reaction to treatment, hyperthermia; 8 pups). All of 188 sick or injured seal pups (aged <5 days to 10 months old) were rescued between August 1992 and February 1998 along the coast of southwest England, UK and taken to a rehabilitation facility by experienced handlers or members of the public. Following rehabilitation, 152 pups were released back into the wild (number of release sites not reported).

A study in 1993–1994 of a pelagic area in the North Atlantic Ocean, off the coast of Florida, USA (*8*) found that a stranded pygmy sperm whale *Kogia breviceps* that was rehabilitated and released back into the wild survived for at least four days. The female pygmy sperm whale was successfully tracked for four days after release before contact was lost with the transmitter. During that time, the whale travelled at least 425 km at an average speed of 5.5 km/h and made regular dives. In November 1993, the whale (aged 12–18 months old) was found stranded and in poor health and taken to a rehabilitation facility. Pieces of plastic were removed from the whale's stomach. In May 1994, the whale was transferred to an outdoor tank close to the release site for 25 days before being radio-tagged and released 65 km offshore. The whale was tracked every 30 minutes and observed daily from a vessel during four days in May–June 1994.

A study in 1989–1999 of multiple sites in the North Atlantic Ocean, off the coast of Brittany, France (*9*) found that at least a quarter of stranded grey seal pups *Halichoerus grypus* that were rehabilitated and released back into the wild survived and were re-sighted alive. Twenty-five of 92 (27%) rehabilitated seal pups were re-sighted alive 1–49 times up to five years after release. Nineteen pups (21%) were re-sighted dead. Survival was not known for the other 48 pups, which were not seen again. Seventeen of the seals re-sighted alive settled at two grey seal haul-out sites close to release sites or along the coast. Eight seals dispersed across the English Channel. In 1989–1999, ninety-two seal pups (aged a few days to a few months old) were found stranded and underweight and taken to a rehabilitation facility. They were released at sea after one month of rehabilitation (in 1989–1990) or after they reached a weight of 40–45 kg (in 1991–1999). All 92 pups were marked with flipper tags. Some were additionally marked with coloured markings (40 pups) or head tags (28 seals) or were photographed for identification (25 seals) or satellite-tagged (four seals). Opportunistic observations were made of released seals both on shore and at sea (dates not reported). The four satellite-tagged seals were tracked for 14–80 days in June–September 1997.

A study in 1999–2000 of a pelagic area in the Gulf of Maine, USA (*10*) found that two stranded juvenile long-finned pilot whales *Globicephala melas* that were rehabilitated and released back into the wild survived for at least four months. The two rehabilitated male whales were successfully tracked for 127–132 days after release back into the wild. During that time, they travelled at least 3,790 km at average speeds of 23–66 km/day. Tracking positions suggest that the two whales remained together after release. The two juvenile whales (220 and 313 cm long) were found stranded on a beach in June 1999 and taken to a rehabilitation facility. They were housed in a pool and fed herring (average 25 kg/day). After four months of rehabilitation, both whales were fitted with satellite-linked time-depth recorders and released at sea in October 1999. They were recorded at 329–386 locations during 127–132 days between October 1999 and February 2000.

A study in 1986–1987 of a pelagic area in the North Atlantic Ocean, near Cape Cod, USA (*11*) found that a stranded juvenile long-finned pilot whale *Globicephala melas* that was rehabilitated and released back into the wild survived for at least three months. The rehabilitated male whale was successfully tracked for 95 days after release and travelled at least 3,144 km during that time. The whale was observed with a group of wild long-finned pilot whales 20 days after release. The juvenile whale (aged two years old) was rescued after a mass stranding event in December 1986 and taken to an aquarium. After seven months of rehabilitation, the whale was fitted with a satellite tag and released in the ocean 160 km southeast of the stranding site. Two other juvenile whales rescued from the same site were also released but were not fitted with tags. The tagged whale was tracked to 204 locations during 95 days in June–September 1987.

A study in 1999 on an island in the North Sea, off the Netherlands (*12*) found that an injured common seal *Phoca vitulina* that had ingested a fishing hook was successfully rehabilitated and released back into the wild. The fishing hook was successfully removed from the female seal, and she was released back into the wild four months after capture. Survival after release was not reported. The seal was found stranded and in poor condition on the coast of an island on 9 April 1999. An x-ray showed an ingested fishing hook within the seal's stomach. The seal was fed small bits of loose cotton wool through a tube and given oral rehydration salts. On 30 May 1999, the seal defecated the remains of the hook and the cotton wool. The seal was released back into the wild on 6 August 1999. In 2005, a male common seal that had ingested a fishing hook and given the same treatment was also reported to have survived but the authors did not state whether the seal was successfully released.

A replicated study in 1977–2002 at multiple pelagic sites in the North Pacific Ocean, off the coast of California, USA (*13*) found that seven of 70 (10%) stranded toothed whales (Odontoceti) were successfully rescued, rehabilitated and released back into the wild, and three were known to survive for at least three days to five months after release. Seven of 70 (10%) stranded toothed whales were successfully rescued and released back into the wild. Two common dolphins *Delphinus delphis* and one harbour porpoise *Phocoena phocoena* were tracked after release for 3 days, 31 days and five months respectively. Survival of the other four released animals (two bottlenose dolphins *Tursiops truncatus*, two common dolphins *Delphinus* spp.) was not reported. The other 63 stranded animals either died during rescue (21), transport (five) or rehabilitation (34) or were kept in captivity (three). Seventy toothed whales of 13 species were found stranded alive in 1977–2002 (see original paper for details). Thirty-seven animals were given medical treatment at rehabilitation facilities. Two common dolphins and one harbour porpoise were satellite-tagged and tracked after release in 1994, 1995 and 2001–2002 respectively. Two bottlenose dolphins and two common dolphins were released but not tracked (dates not reported).

A study in 2003–2004 of a pelagic area in the North Atlantic Ocean, off the coast of Maryland, USA (*14*) found that a stranded juvenile harbour porpoise *Phocoena phocoena* that was rehabilitated and released back into the wild survived for at least two months. After release, the rehabilitated male porpoise was successfully tracked for 63 days before contact was lost with the transmitter due to battery failure. During that time, the porpoise travelled at least 2,880 km and returned to an area close to the original stranding site. In March 2003, the 10-month old harbour porpoise was found stranded and underweight with injuries from birds and fishing nets. After 10 months of rehabilitation at an aquarium, the porpoise was satellite-tagged and released offshore at a site >1,200 km north of the stranding location. Prior to release, the porpoise was gradually acclimatized to local sea water and ambient temperatures. The porpoise was tracked to >300 locations during six days in January–March 2004.

A study in 2000–2001 in an estuary in the Indian River Lagoon, Florida, USA (*15*) found that a stranded common bottlenose dolphin *Tursiops truncatus* that was rehabilitated and released back into the wild survived for three months. The adult male dolphin (aged 24 years) survived for 100 days after release but subsequently died after an invasive species of fish (black chin tilapia *Sarotherodon melanotheron*) became lodged in his larynx. The dolphin travelled 67 km from the release site and was observed socializing with other dolphins after release. In August 2000, the dolphin was found stranded on a boat ramp with severe shark bite wounds and transported to a rehabilitation facility. After six months of rehabilitation, the dolphin was radio-tagged and released back into the estuary. He was tracked twice weekly until June 2001 when his body was recovered 35 km from the release site.

A study in 2005 of a pelagic area in the North Atlantic Ocean, off the coast of Florida, USA (*16*) found that five stranded rough-toothed dolphins *Steno bredanensis* that were rehabilitated and released back into the wild survived for at least 2–7 weeks. The five dolphins were tracked for 12–49 days after release before contact was lost with their transmitters. They travelled a total of 687–3,488 km, at average rates of 4–6 km/h and 55–99 km/day, in both coastal and offshore waters. In March 2005, ten dolphins were rescued during a mass stranding event and taken to rehabilitation facilities. The dolphins were released in April, May and September 2005, five (one male, four females) with satellite-tags attached. The five satellite-tagged dolphins were tracked to 45–289 locations each in April–June or September 2005.

A study in 2005–2006 of a pelagic area in the Gulf of Mexico, USA (*17*) found that a stranded Risso's dolphin *Grampus griseus* that was rehabilitated and released back into the wild survived for at least three weeks. The released male dolphin was successfully tracked for 23 days before contact was lost with the transmitter. The dolphin travelled more than 3,300 km at an average speed of 7.2 km/h and occupied appropriate habitats (warm water over steep slopes) in areas known to be used by the species. The adult dolphin was taken to a rehabilitation facility after a mass stranding event in July 2005. He was treated with antibiotics, anti-fungal and anti-ulcer medications, and fed 18 kg squid/day. After seven months of rehabilitation, the dolphin was satellite-tagged and released 159 km offshore. The dolphin was tracked for 23 days in February–March 2006. A female adult Risso's dolphin rescued at the same time died during rehabilitation.

A study in 2008 of a pelagic area in Bohai Bay, China (*18*) found that a stranded west Pacific finless porpoise *Neophocaena phocaenoides sunameri* was successfully rehabilitated and released back into the wild. The stranded female porpoise was successfully released back into the wild after two months of rehabilitation. Survival after release was not reported. The porpoise was found stranded, dehydrated and infected with parasitic flatworms (*Nasilrema* spp. and *Zalophotrema hepaticum*) in March 2008. She was transported to an aquarium and placed in a medical pool (6 x 3 x 1 m, 1,500 l artificial saltwater) and given minced herring and shrimp (0.5–1.5 kg/day), vitamin powders, fluids, electrolytes and antibiotics. Water quality parameters (temperature, pH, dissolved oxygen, ammonia and nitrite) were monitored daily within the pool. After two months of rehabilitation, the porpoise was released 18.5 km offshore in shallow waters in June 2008.

A controlled study in 2003–2006 of multiple coastal and pelagic sites in the North Pacific Ocean, California, USA (*19*) found that at least a quarter of stranded California sea lions *Zalophus californianus* treated for toxic algae poisoning and released back into the wild died or had to be euthanized, and released sea lions travelled further from the shore, spent less time diving or hauled out and made shorter, shallower dives than wild sea lions without poisoning. Nine of 34 stranded sea lions treated for toxic algae poisoning died or were euthanized within 7–43 days of release. The fate of the other 25 sea lions was not known. Compared to wild sea lions without poisoning, treated sea lions on average travelled greater maximum distances from the shore (163–186 vs. 35 km), spent a lower percentage of time diving (20% vs. 22%) or hauled out (33% vs. 39%) and made shorter, shallower dives (9 vs. 15 minutes, maximum 203 vs 286 m). In 2003–2006, thirty-four stranded sea lions with toxic algae poisoning (domoic acid toxicosis; 12 acute, 22 chronic) were taken to a rehabilitation facility. Drugs were given to control seizures and reduce brain swelling (dexamethasone). All 34 sea lions were satellite-tagged and released. Nineteen sea lions with chronic poisoning were fitted with tags to record dive behaviour. Released sea lions were tracked for <1–129 days in 2003–2006. Sixty-seven wild sea lions without poisoning were captured, tagged and tracked in 2003–2006.

A replicated study in 1984–2005 of multiple sites on islands in the North Pacific Ocean, Hawaii, USA (*20*) found that approximately half of Hawaiian monk seal *Monachus schauinslandi* young that were rehabilitated, translocated, and released back into the wild survived for at least one year, and half of those produced offspring.

The study did not distinguish between the effects of rehabilitation and translocation. Thirty-five of 68 monk seal young (52%) that were rehabilitated, translocated, and released back into the wild survived for at least one year after release. By 2005, eighteen of the 35 surviving seals (51%) had produced offspring in the wild (at least 68 pups). Thirty other monk seal young captured for rehabilitation either died in captivity (17 seals) or were kept permanently in captivity for health or behavioural reasons (13 seals). In 1984–1985, a total of 98 weaned, female seals (aged <3 years old) that were underweight, sick or threatened (by human disturbance, shark predation or aggressive adult male seals) were collected from islands (the French Frigate Shoals) and brought into captivity. The seals were transported by plane or ship and kept at care facilities or in beach enclosures. Captive seals were given medical treatment and fed milk formula or fish with multivitamins. After 3–14 months of rehabilitation, the 68 seals were fitted with tags, released at different islands (Kure Atoll and Midway Islands), and observed annually in 1984–2005.

A controlled study in 2003–2004 in an estuary, The Wash, Norfolk, UK (*21*) found that six sick or injured harbour seal *Phoca vitulina* pups that were rehabilitated and released back into the wild survived for at least three months, were tracked for similar durations and had similar dive behaviour to wild seals. Six rehabilitated harbour seal pups were tracked for 100–175 days after release. On average, the six rehabilitated seals were tracked for similar durations (122 days) to five wild seals (150 days), indicating similar short-term survival. Average dive durations and percentage of time at-sea spent diving were also similar for rehabilitated seals (4.0 minutes; 81.6%) and wild seals (4.1 minutes; 81.5%). In September–October 2003, six juvenile seals (aged 2–3 months; four males, two females) were rescued with wounds and/or respiratory problems. After 134–169 days of rehabilitation, the six seals were satellite-tagged and released in an estuary in February 2004. Five wild adult harbour seals (one male, four females) were caught in the estuary and satellite-tagged in February 2004. Data were collected for each of the 11 seals during 100–170 days in February–August 2004. Average dive durations were adjusted according to body mass.

A review of 56 case studies in 1986–2008 in the North Atlantic Ocean and North Pacific Ocean, USA (*22*) found that approximately one third of rehabilitated common bottlenose dolphins *Tursiops truncatus* and other small cetacean species that were released back into the wild survived for at least six weeks and had normal behaviour. For common bottlenose dolphins, seven of 20 releases (35%) were considered successful (the dolphin was tracked for at least six weeks after release with normal behaviour for the species). Eight releases (40%) had unknown success, and five (25%) failed (the dolphin died, re-stranded or had abnormal behaviour). For other small cetaceans (including other dolphin species, porpoises and whales; see original paper for details), 13 of 36 releases (36%) were considered successful, 22 releases (61%) had unknown success, and one (3%) failed. The common bottlenose dolphins were found stranded (13 dolphins), trapped out of their natural habitats (three), entangled in fishing gear (three) or orphaned (one) in 1992–2008 and rehabilitated for 37–225 days before release. Thirty-six other small cetaceans were found stranded in 1986–2007 and rehabilitated for 35–394 days before release. Data were from published and unpublished studies. Eleven studies have also been summarized individually (see studies *2–5*, *8*, *10*, *11*, *13*, *15–17*). Details of monitoring methods were not reported.

A study in 2010–2012 of coastal sites in the North Pacific Ocean, California, USA (*23*) found that less than one half of stranded California sea lions *Zalophus californianus* were successfully rehabilitated and released back into the wild. Fourteen of 35 sea lions were rehabilitated and released back into the wild, although survival after release was not reported. The other 21 sea lions died shortly after admission to the rehabilitation facility. Antibiotic treatments eliminated a bacterial infection (leptospirosis) within 1–7 weeks for four of the 14 surviving sea lions. The other 10 sea lions tested positive for leptospirosis during final tests before their release (4–12 weeks after admission to the facility). In 2010–2011, thirty-five stranded sea lions were admitted to a rehabilitation facility and diagnosed with the bacterial infection leptospirosis. Fourteen surviving sea lions were treated with antibiotics, fluids, parasite treatments and anti-inflammatory drugs (see original paper for details). Urine and blood samples were collected approximately every 14 days from admission until release in 2010–2012. DNA analysis, urine cultures and tests for antibodies were used to detect leptospirosis infections.

A replicated study in 1988–2013 at multiple freshwater, marine and brackish water sites in Florida, USA (*24*) found that 41 of 51 (80%) sick or injured Florida manatees *Trichechus manatus latirostris* that were rehabilitated and released back into the wild survived for at least one year. Twenty-two of 25 sick manatees (88%) and 19 of 26 injured manatees (73%) that were rescued and rehabilitated survived for at least one year in the wild after release, occupied appropriate habitats, did not require additional rescue and were in good condition. Three sick and seven injured manatees required intervention or died within the first year (number for each not reported). Twenty-five rescued manatees were sick (exposed to toxic algae or severe cold weather) and 26 were injured (by boat collisions, fishing gear or entrapment). All 51 manatees were rehabilitated in captivity for between <1 and >10 years before being released back into the wild. Release sites were warm freshwater, marine or brackish water near rescue locations or alternative locations used by wild manatees (number of sites for each not reported). Each of 51 released manatees was monitored with radio-tracking and visual observations once or twice/week for at least one year in 1988–2013.

A study in 2011 at a freshwater site in El Dorado Lake, Pacaya Samiria National Reserve, Peru (*25*) found that three rehabilitated female Amazonian manatees *Trichechus inunguis* that were released into the wild survived for at least 3–5 months, and two rehabilitated male manatees dispersed away from the release site. Three rehabilitated female manatees were tracked for 91–161 days after release and were found to use appropriate habitats at the release site (areas with floating vegetation). Contact was lost with the two rehabilitated male manatees 1–11 days after release when they dispersed to other areas. Five rescued manatees that were either pets (two males, two females) or illegally traded (one female) were rehabilitated with veterinary treatment and a diet of water lettuce *Pistia stratiotes*. After 13–31 months of rehabilitation, each of the five manatees (aged 32–79 months) was transported by seaplane, fitted with a radio-tag and placed in a floating cage (10 x 10 x 3 m) within a lake for an acclimatization period of three months before being released in July 2011. Radio-tracking was carried out between 0600 and 1800 h during 161 days in July–November 2011.

A study in 2017 at a coastal site in the southern Gulf of California, Mexico (*26*) found that a rehabilitated blind California sea lion *Zalophus californianus* that was released back into the wild survived for at least 53 days after release. The male sea lion was observed 53 days after release at a beach located 1,500 km from the release site on a known migration route for the species. In February 2017, the blind sea lion (aged 5–6 years) was found stranded in poor condition and was transported to an aquarium for medical care. The sea lion was fed >11 kg of fish/day and increased in body mass by 74 kg during 106 days of rehabilitation. In May 2017, the sea lion was tagged and released at a known California sea lion colony in the southern Gulf of California. The sea lion was observed on an island in the North Pacific Ocean off the coast of Mexico in July 2017 during a field expedition.

A study in 2015–2016 of a pelagic area in the Gulf of Mexico, USA (*27*) found that one of two stranded pygmy killer whales *Feresa attenuata* that were rehabilitated and released back into the wild survived for at least three months. One of two rehabilitated male pygmy killer whales survived for at least 88 days after release, after which contact was lost with the transmitter. The pygmy killer whale used a 250-km span of continental shelf and travelled an average of 24 km/day. The other pygmy killer whale was tracked for 15 days before contact was lost and is likely to have died (diving behaviour was reduced before loss of contact). Two adult pygmy killer whales were found stranded in an estuary on 1 September 2015 and transported to a rehabilitation facility. On 11 July 2016, both pygmy killer whales were satellite-tagged and released offshore in water >200 m deep with known sightings of other pygmy killer whales. The whales were tracked to 129–947 locations during 15–88 days in July–October 2016.

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14.4. Hand-rear orphaned or abandoned marine and freshwater mammal young

- **Twelve studies** evaluated the effects of hand-rearing orphaned or abandoned marine and freshwater mammal young. Four studies were in the North Pacific Ocean[3–5,8] (USA), two studies were in captive facilities[2,6] (USA), and one study was in each of the North Atlantic Ocean[1] (USA), the Indian River Lagoon[7] (USA), the Salish Sea[9] (USA), the Guerrero Lagoon[10] (USA), the South Atlantic Ocean[11] (Brazil) and water bodies in Florida[12] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (11 STUDIES)

- **Reproductive success (1 study):** One replicated study in the South Atlantic Ocean[11] found that most captive-reared Antillean manatees released back into the wild reproduced.
- **Survival (11 studies):** Three studies (including one replicated and controlled study) in the North Pacific Ocean[3,5], and the Indian River Lagoon[7] found that a gray whale calf[3], three Steller sea lion pups[5], and a common bottlenose dolphin calf[7] that were released after being reared in captivity survived during post-release monitoring periods of between three days[3] to three months[5]. Two replicated studies in the South Atlantic Ocean[11] and water bodies in Florida[12] found that approximately three-quarters of Antillean manatees[11] and two-thirds of Florida manatees[12] that were captive-reared and released were known to survive for at least one year[11,12], and some survived for more than seven years[11]. Three studies in the North Atlantic Ocean[1], the North Pacific Ocean[8] and the Guerrero Lagoon[10] found that three West Indian manatee calves[1], seven Hawaiian monk seal pups[8] and one Antillean manatee calf[10] that were captive-reared either died before[1,8] or after release[8,10], had to be returned to captivity after release[10], or survived in the wild only with supplemental feeding[1]. Two studies at captive facilities[2,6] found that a captive-reared grey whale calf[2] and five pygmy and dwarf sperm whale calves[6] increased in body weight but were either not released[2] or died in captivity[6]. One controlled study in the North Pacific Ocean[4] found that captive-reared, released Pacific harbour seal pups had similar survival estimates to wild pups.

BEHAVIOUR (3 STUDIES)

- **Behaviour change (3 studies):** Two controlled studies (including one replicated study) in the North Pacific Ocean[4,5] found that captive-reared and released Pacific harbour seal pups[4] and Steller sea lion pups[5] had similar diving behaviour to wild pups. One controlled study in the Salish Sea[9] found that captive-reared and released harbour seal pups travelled greater distances and further from the release site than wild pups born at the same site and in the same season.

Background

Young marine and freshwater mammals believed to be orphaned or abandoned are sometimes taken into captivity by wildlife rehabilitators, to be reared and released back into the wild. Often this is done more for animal welfare reasons than for species conservation, although for rare species, release of such animals may provide opportunities to augment wild populations. The success of such programmes can be difficult to judge without long-term survival data or benchmark data for survival of wild-reared mammals.

See also '*Reunite abandoned marine and freshwater mammal young with parents*' and '*Place orphaned or abandoned marine and freshwater mammal young with foster parents*'. For studies that hand-reared captive-born mammals, see '*Breed marine and freshwater mammals in captivity*'. For studies that brought mammal young into captivity for rehabilitation (as opposed to hand-rearing), see '*Rehabilitate and release injured, sick or weak marine and freshwater mammals*'.

A study in 1991–1998 of a pelagic area in the North Atlantic Ocean off the coast of Puerto Rico, USA (*1*) found that one of three West Indian manatee *Trichechus manatus* calves reared in captivity was released back into the wild and survived for at least four years with supplemental feeding. One stranded male manatee calf was released back into the wild after 27 months in captivity. The calf survived for at least four years in the wild and was observed feeding, visiting freshwater sites and interacting with wild manatees. Supplemental food was periodically provided from two years after release when the calf was observed to be underweight. The other two calves (one female, one male) died in captivity (after two weeks and 20 months respectively). The three calves (102–122 cm in length) were found stranded at coastal sites in 1991, 1993 and 1995. They were taken to rehabilitation facilities, housed in saltwater pools and given medical treatment. The surviving calf was fitted with a satellite tag and released in a protected bay used by wild manatees after a six-month period of adaptation in an enclosed sea-pen. The calf was tracked and sighted for four years after release in 1994–1998.

A study in 1997–1998 at an aquarium in San Diego, USA (*2*) found that an orphaned California gray whale *Eschrichtius robustus* calf reared in captivity survived for over 14 months and increased in body weight and length. Between September 1997 and March 1998, the whale calf increased in body weight (4,800–8,200 kg) and length (7.5–9.2 m). The female calf was brought into captivity in September 1997 and fed warm water and dextrose via a stomach tube followed by an artificial milk formula every 2 h for the first three days. This was replaced with a mixture of herring *Clupea* spp., milk formula, amino acid supplements, water and cream, which the calf suckled through a tube during seven feeding sessions/day. After 7–8 months, the calf was weaned onto solid food (small fish, squid and krill) fed at least four times/day. The calf was kept in a holding pool (9.1 m deep) and enrichment was provided (kelp and marine invertebrates).

A study in 1997–1998 of a pelagic area in the North Pacific Ocean, off the coast of San Diego, USA (*3*) found that a gray whale *Eschrichtius robustus* calf reared in captivity and released back into the wild survived for at least three days. The rehabilitated whale calf was successfully tracked for three days after release and was observed swimming strongly before the satellite transmitter became detached. The female calf was found stranded in 1997 and taken to a rehabilitation facility where she was given formula and weaned onto fish and invertebrates. After 14 months in captivity, the calf was satellite-tagged and released several kilometres offshore on 31 March 1998. The calf was tracked and observed from a boat for three days after release before the satellite transmitter dislodged and was found washed ashore.

A controlled study in 1995–1996 and 1998 at a beach in the North Pacific Ocean, California, USA (*4*) found that Pacific harbour seal *Phoca vitulina richardsi* pups reared in captivity and released back into the wild had similar survival estimates and diving behaviour to wild pups. Overall, survival estimates did not differ significantly between captive-reared seal pups and wild seal pups during the first 15 weeks after release for (data reported as statistical model results). Captive-reared and wild pups also dived for similar durations (average 1.2 vs 1.3 minutes respectively) and surfaced at similar intervals (average 0.4 minutes for both). Twenty-nine stranded seal pups were taken to a rehabilitation facility during March–May 1995, 1996 and 1998. They were treated with antibiotics, fed milk formula, and weaned onto herring *Clupea* spp. The 29 pups were radio-tagged and released in pairs/groups of three at a beach in 1995, 1996 and 1998 once they had reached a weight of at least 20 kg and had suitable behaviour. Twenty-four newly weaned, wild Pacific harbour seal pups were captured in 1995, 1996 and 1998 at three locations along the same coast and fitted with radio-tags. Each of 53 pups was radio-tracked for 3–5 months and dive behaviour monitored for 9–24 h (captive-reared pups) or 15–22 h (wild pups) after release during 1995, 1996 or 1998.

A replicated, controlled study in 1995–1996 and 1999–2000 at two islands in the North Pacific Ocean, off the coast of California, USA (*5*) found that three Steller sea lion *Eumetopias juba* pups reared in captivity and released back into the wild survived for at least 1–3 months and had similar diving behaviour to wild sea lions. The three captive-reared sea lion pups were successfully tracked for 1–3 months after release back into the wild. All three pups dived to similar average depths (18–30 m) and for similar average durations (0.9–1.6 minutes) compared to 25 wild juvenile Steller sea lions (depth: 18 m; duration: 1.1 minutes) although statistical significance was not assessed. Three Steller sea lion pups (aged 2 weeks old) found stranded, dehydrated and underweight were taken to a rehabilitation facility in June 1995 (two males) and June 1999 (one female). The pups were fed formula and weaned onto fish at 3 months old. After 10 months in captivity, the pups were tagged and fitted with satellite time-depth recorders and released at sea near two islands in April 1996 (two sea lions) and April 2000 (one sea lion). Each of three sea lions was tracked for 1–3 months after release in 1996 and 2000. Data for the 25 wild sea lions were from a previous study.

A study over nine years (dates not stated) at a rehabilitation facility in Florida, USA (*6*) found that five orphaned pygmy and dwarf sperm whale *Kogia* spp. calves reared in captivity increased in body weight but died after 3–20 months. Four captive-reared pygmy sperm whales *Kogia breviceps* increased in body weight from 33–57 kg to 60–232 kg but died after 91–631 days in captivity due to intestinal problems (three calves) or liver failure (one calf). One captive-reared dwarf sperm whale *Kogia sima* increased in body weight from 27–75 kg but died after 465 days in captivity due to an impacted colon. Each of the five calves was found stranded, transported to a rehabilitation facility and treated for dehydration and constipation. The calves were fed artificial formula mixed with electrolytes through a stomach tube. Squid was fed from six months of age. Ulcers were treated with antibiotics and anti-fungal drugs. The calves were considered unsuitable for release due to their inexperience in the wild.

A study in 2003 in an estuary in the Indian River Lagoon, Florida, USA (*7*) found that an orphaned common bottlenose dolphin *Tursiops truncatus* calf reared in captivity and released back into the wild survived for at least seven days. The orphaned male calf was successfully tracked for seven days after release before contact was lost with his transmitter. During this time, the calf remained within 10 km of the release site and was observed foraging and interacting with other dolphins. The orphaned calf (one year old) was found stranded, underweight and dehydrated in August 2003 and transported to a rehabilitation facility. He was treated with antibiotics and provided with appropriate nutrition. After three months in captivity, the calf was radio-tagged and held in a temporary enclosure (7 x 12 x 2 m) within the estuary for 1 h before release. The calf was tracked daily for seven days in October 2003. Attempts to locate the calf were made for a further 10 days after contact was lost, including multiple vessel and aerial surveys.

A study in 2006–2007 on an atoll in the North Pacific Ocean, Hawaii, USA (*8*) found that most Hawaiian monk seal *Neomonachus schauinslandi* pups reared in captivity gained weight, but none survived after release back into the wild. Six of seven seal pups reared in captivity increased in body weight by 31–141% but died within 3–5 months after release back into the wild, aged <2 years old. The other seal pup lost body weight and died after 23 days in captivity. Two of three wild seal pups born on the same atoll in the same breeding season survived to at least four years of age. In May–December 2006, seven female juvenile Hawaiian monk seal pups were captured in the wild and kept in shoreline net pens (9 x 40 m) to increase their survival over winter. The pups were given multivitamins and fed frozen Pacific herring *Clupea pallasii* 2–3 times/day and larger live reef fish. In March 2007, the six surviving seal pups were radio-tagged and released after 89–279 days in captivity. Three wild seal pups (two males, one female) from the same atoll were radio-tagged in March 2007. Tagged seals were tracked for 37–146 days (released pups) or 74–311 days (wild pups) in 2007–2008. Visual sightings were made during annual surveys in 2007–2010 (methods not reported).

A controlled study in 2010–2011 on an island in the Salish Sea, San Juan County, USA (*9*) found that harbour seal *Phoca vitulina richardii* pups reared in captivity and released back into the wild travelled greater distances and further from the release site than wild pups born at the same site and in the same season. On average, captive-reared seal pups travelled greater total distances (562 km), greater daily distances (7.5 km/day) and further from the release site (212 km) than wild pups (total 309 km; 2.6 km/day; 65 km from the site). Ten stranded seal pups that were rescued (at 3–8 days old) and captive-reared were fitted with satellite and radio tags and released at a seal weaning site on an island in September–October 2010 (at an average age of 81 days old). Ten wild seal pups (estimated to be 33 days old) were captured at the same site in August 2010 and fitted with identical tags. Tracking was carried out for an average of 77 days (captive-reared pups) or 133 days (wild pups) in 2010–2011.

A study in 2003–2009 at a coastal site in Guerrero Lagoon in Quintana Roo, Mexico (*10*) found that an orphaned Antillean manatee *Trichechus manatus manatus* calf reared in captivity and released back into the wild was unable to survive on its own and had to be returned to captivity. Five months after release, the male manatee calf (aged 2.5 years) had lost 33% of his body weight (30 kg) and had a skin condition (hyperkeratosis). An earlier release attempt also failed. The calf was returned to semi-captivity, in which food was provided (fruit and vegetables) and the calf could move freely between a captive facility and the wild. In 2009, the manatee (aged 6 years) was reported to be dependent on human care. The manatee calf was rescued in September 2003 and reared for eight months in a plastic pool. The calf was then transferred to an enclosure within a lagoon inhabited by wild manatees. Release was attempted in July 2005, but the manatee followed people and returned to the enclosure. The manatee was finally released in September 2005 before being returned to captivity in February 2006. The manatee was monitored in 2005–2009. Behavioural observations were carried out in 2008–2009.

A replicated study in 1994–2012 at three coastal sites in the South Atlantic Ocean, northeast Brazil (*11*) found that more than three-quarters of orphaned Antillean manatees *Trichechus manatus manatus* reared in captivity and released back into the wild survived for at least one year, and most manatees monitored for longer periods reproduced. Twenty-one of 26 orphaned, captive-reared manatees (81%) survived for at least one year in the wild, although five had to be rescued and re-released. Four males and two of three females monitored for an average of seven years bred with wild or released manatees. The other five captive-reared manatees died in the first year after release or had to be returned permanently to captivity. One captive-reared manatee died before release. Twenty-seven stranded manatee calves (16 males, 11 females) were rescued and reared in captivity. They were kept in pools and fed soya milk compound, algae and sea grass, supplemented with vegetables and vitamins. After 1–17 years, 26 manatees were fitted with satellite tags and released at three sites within marine protected areas between 1994 and 2012. Manatees were kept in enclosures at release sites for 15 days or 3–12 months prior to release. Released manatees were tracked for an average of 972 days. Seven of the 26 released manatees (four males, three females) were tracked and observed for an average of seven years.

A replicated study in 1988–2013 at multiple freshwater, marine and brackish water sites in Florida, USA (*12*) found that 24 of 40 (60%) orphaned Florida manatee *Trichechus manatus latirostris* calves reared in captivity and released back into the wild survived for at least one year. Twenty-four of 40 orphaned, captive-reared manatee calves survived for at least one year in the wild after release, occupied appropriate habitats, did not require additional rescue and were in good condition. The other 16 manatee calves required intervention or died within the first year (number for each not reported). All of 40 manatees were rescued as calves (<235 cm in length) and kept in captivity for between <1 and >10 years before release back into the wild. Release sites were warm freshwater, marine or brackish water near rescue locations or alternative locations used by wild manatees (number of sites for each not reported). Each of 40 released manatees was monitored with radio-tracking and visual observations once or twice/week for at least one year in 1988–2013.

(1) Mignucci-Giannoni A.A. (1998) Marine mammal captivity in the northeastern Caribbean, with notes on the rehabilitation of stranded whales, dolphins and manatees. *Caribbean Journal of Science*, 34, 191–203.

(2) Bruehler G.L., DiRocco S., Ryan T. & Robinson K. (2001) Husbandry and hand-rearing of a rehabilitating California gray whale calf. *Aquatic Mammals*, 27, 222–227.

(3) Stewart B.S., Harvey J. & Yochem P.K. (2001) Post-release monitoring and tracking of a rehabilitated California gray whale. *Aquatic Mammals*, 27, 294–300.

(4) Lander M.E., James T. Harvey K.D.H. & Lance E.M. (2002) Behavior, movements, and apparent survival of rehabilitated and free-ranging harbor seal pups. *The Journal of Wildlife Management*, 66, 19–28.

(5) Lander M.E. & Gulland F.M.D. (2003) Rehabilitation and post-release monitoring of Steller sea lion pups raised in captivity. *Wildlife Society Bulletin*, 31, 1047–1053.

(6) Manire C.A., Rhinehart H.L., Barros N.l.B., Byrd L. & Cunningham-Smith P. (2004) An approach to the rehabilitation of *Kogia* spp. *Aquatic Mammals*, 30, 257–270.

(7) Mazzoil M.S., McCulloch S.D., Youngbluth M.J., Kilpatrick D.S., Murdoch M.E., Mase-Guthrie B., Odell D.K. & Bossart G.D. (2008) Radio-tracking and survivorship of two rehabilitated bottlenose dolphins (*Tursiops truncatus*) in the Indian River Lagoon, Florida. *Aquatic Mammals*, 34, 54–64.

(8) Norris T.A., Littnan C.L. & Gulland F.M.D. (2011) Evaluation of the captive care and post-release behavior and survival of seven juvenile female Hawaiian monk seals (*Monachus schauinslandi*). *Aquatic Mammals*, 37, 342–353.

(9) Gaydos J.K., Ignacio Vilchis L., Lance M.M., Jeffries S.J., Thomas A., Greenwood V., Harner P. & Ziccardi M.H. (2013) Postrelease movement of rehabilitated harbor seal (*Phoca vitulina richardii*) pups compared with cohort-matched wild seal pups. *Marine Mammal Science*, 29, E282–E294.
(10) Mercadillo-Elguero M.I., Castelblanco-Martínez D.N., & Padilla-Saldívar, J.A. (2015) Behavioral patterns of a manatee in semi-captivity: implications for its adaptation to the wild. *Journal of Marine Animals and their Ecology*, 7, 31–41.
(11) Normande I.C., Luna F.D.O., Malhado A.C.M., Borges J.C.G., Viana Junior P.C., Attademo F.L.N. & Ladle R.J. (2015) Eighteen years of Antillean manatee *Trichechus manatus manatus* releases in Brazil: lessons learnt. *Oryx*, 49, 338–344.
(12) Adimey N.M., Ross M., Hall M., Reid J.P., Barlas M.E., Diagne L.W.K. & Bonde R.K. (2016) Twenty-six years of post-release monitoring of Florida manatees (*Trichechus manatus latirostris*): Evaluation of a cooperative rehabilitation program. *Aquatic Mammals*, 42, 376–391.

14.5. Reunite abandoned marine and freshwater mammal young with parents

- **One study** evaluated the effects of reuniting abandoned marine and freshwater mammal young with parents. The study was in the North Pacific Ocean[1] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Reproductive success (1 study):** One review in the North Pacific Ocean[1] found that after reuniting Hawaiian monk seal pups with their mothers, along with at least seven other interventions to enhance survival, more than a quarter of the seals reproduced.
- **Survival (1 study):** One review in the North Pacific Ocean[1] found that after reuniting Hawaiian monk seal pups with their mothers, along with at least seven other interventions to enhance survival, more than a quarter of the seals survived.

BEHAVIOUR (0 STUDIES)

Background

Dependent marine and freshwater mammal young may be abandoned or become separated from their parents. To increase chances of survival, abandoned young may be rescued and reunited with their parents. For rare or threatened species, this may help to maintain or boost population sizes.

See also '*Place orphaned or abandoned marine and freshwater mammal young with foster parents*'.

A review of interventions in 1980–2012 for Hawaiian monk seals *Monachus schauinslandi* in the North Pacific Ocean, Hawaii, USA (*1*) found that reuniting seal pups with their mothers, along with at least seven other interventions to enhance survival, resulted in 139 of 532 (26%) seals surviving and reproducing. The study did not distinguish between the effects of reuniting pups with their mothers and the other interventions carried out. The 139 surviving seals (including 71 females) produced at least 147 pups, which also went on to reproduce (15 pups). In 2012, the number of surviving seals and their offspring were estimated to make up 17–24% of the seal population (198–271 of 1,153 seals). In 1980–2012, a total of 885 intervention events of seven types were carried out: pups reunited with mothers (113 events); removal of derelict fishing gear from seals (275 events); translocation (284 events); rescue of stranded or trapped seals (37 events); umbilical cord removed or other medical treatment (84 events); other actions, such as deterring aggressive male seals (120 events). Field biologists and monitored the seal population in 1980–2012. Data were analysed for 532 individual seals facing severe mortality risks and involved in 698 of the 885 intervention events.

(1) Harting A.L., Johanos T.C. & Littnan C.L. (2014) Benefits derived from opportunistic survival-enhancing interventions for the Hawaiian monk seal: the silver BB paradigm. *Endangered Species Research*, 25, 89–96.

14.6. Place orphaned or abandoned marine and freshwater mammal young with foster parents

- We found no studies that evaluated the effects of placing orphaned or abandoned marine and freshwater mammal young with foster parents.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

To increase chances of survival, orphaned or abandoned marine and freshwater mammal young may be rescued and placed with wild foster parents. For rare or threatened species, this may help to maintain or boost population sizes. The adoption of an orphaned Indo-Pacific dolphin calf by an unrelated adult female was observed in the wild without human intervention (Sakai *et al.* 2016).

See also '*Reunite abandoned marine and freshwater mammal young with parents*'.

Sakai M., Kita Y.F., Kogi K., Shinohara M., Morisaka T., Shiina T. & Inoue-Murayama M. (2016) A wild Indo-Pacific bottlenose dolphin adopts a socially and genetically distant neonate. *Scientific Reports,* 6, 23902.

14.7. Remove individual marine and freshwater mammals exhibiting aggressive behaviours that may limit population recovery

- **One study** evaluated the effects of removing individual marine mammals exhibiting aggressive behaviours that may limit population recovery. The study was in the North Pacific Ocean[1] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** One before-and-after study in the North Pacific Ocean[1] found that after removing aggressive male Hawaiian monk seals, the survival of adult female Hawaiian monk seals increased.

- **Condition (1 study):** One before-and-after study in the North Pacific Ocean[1] found that fewer female Hawaiian monk seals were injured after aggressive male Hawaiian monk seals were removed.

BEHAVIOUR (0 STUDIES)

Background

Individual marine and freshwater mammals may exhibit aggressive behaviours that may limit the recovery of threatened populations. For example, male Hawaiian monk seals *Monachus schauinslandi* may attack and injure adult females resulting in high levels of female mortality and reduced reproductive success (Hiruki 1993a). Pups of both sexes may also be injured and killed (Hiruki 1993b). Removing such individuals from colonies, e.g. by translocating them to other areas, may help threatened populations to recover. However, careful consideration must be given to appropriate release sites to ensure that the threat is not transferred to other colonies.

Hiruki L.M., Stirling I., Gilmartin W.G., Johanos T.C. & Becker B.L. (1993a) Significance of wounding to female reproductive success in Hawaiian monk seals (*Monachus schauinslandi*) at Laysan Island. *Canadian Journal of Zoology,* 71, 469–474.

Hiruki L.M., Gilmartin W.G., Becker B.L. & Stirling I. (1993b) Wounding in Hawaiian monk seals (*Monachus schauinslandi*). *Canadian Journal of Zoology,* 71, 458–468.

A before-and-after study in 1983–2005 on an island in the North Pacific Ocean, Hawaii, USA (*1*) found that removing individual adult male Hawaiian monk seals *Monachus schauinslandi* exhibiting aggressive behaviours resulted in fewer injured and greater survival of adult female seals compared to before removal. After removal of aggressive adult males, a greater proportion of adult female seals survived each year (average 99.7% survived; total 3 seals died) than before the males were removed (average 95.9% survived; total 30 seals died). The average proportion of injured (but not killed) adult female seals each year was lower after aggressive males were removed (2%) than before (11%, numbers not reported). In 1984–1994, a total of 37 adult males exhibiting aggressive behaviours (attacking or harassing female seals) were removed from an island and either released in a different area (30 seals), were taken into captivity permanently (five seals) or died during capture/in captivity (two seals). Seals were monitored daily on the island for 3–9 months during spring and summer in each of 10 years before (1983–1994) and after (1995–2005) the removal of aggressive adult males.

(1) Johanos T.C., Becker B.L., Baker J.D., Ragen T.J., Gilmartin W.G. & Gerrodette T. (2010) Impacts of sex ratio reduction on male aggression in the Critically endangered Hawaiian monk seal *Monachus schauinslandi*. *Endangered Species Research*, 11, 123–132.

Translocation

14.8. Translocate marine and freshwater mammals to re-establish or boost native populations

- **Four studies** evaluated the effects of translocating marine mammals to re-establish or boost native populations. The four studies were in the North Pacific Ocean[1–4] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (4 STUDIES)

- **Reproductive success (2 studies):** One replicated study[2] and one review[3] in the North Pacific Ocean found that after translocating Hawaiian monk seals, along with rehabilitation[2] or at least seven other interventions to enhance survival[3], more than a quarter of the seals reproduced.
- **Survival (4 studies):** Two studies (including one replicated and one controlled study) in the North Pacific Ocean[2,4] found that 50–83% of translocated[2,4], and 52% of rehabilitated and translocated[2], Hawaiian monk seal pups survived for at least one year. One of the studies[4] and one review[1] in the North Pacific Ocean found that translocated seal pups had similar survival rates to non-translocated pups born at release sites[1] or greater survival rates than non-translocated pups remaining at the original site[4]. One review in the North Pacific Ocean[3] found that translocating Hawaiian monk seals, along with at least seven other interventions to enhance survival, resulted in more than a quarter of the seals surviving.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** One review in the North Pacific Ocean[1] found that translocated Hawaiian monk seal pups had similar dispersal times to non-translocated seal pups born at release sites.

Background

Translocations involve the intentional capture, movement and release of wild-caught marine and freshwater mammals into the wild to re-establish a population that has been lost or to augment an existing population. This can reduce the risk of inbreeding, help safeguard small populations from extinction due to catastrophic events, and/or increase the range of a species and therefore the maximum possible population. Translocations may also be used to move mammals to areas where the chances of survival are likely to be higher, such as areas with reduced predation or better foraging conditions.

For other interventions related to translocations, see '*Translocate marine and freshwater mammal species before onset of impactful activities*', '*Threat: Aquaculture and agriculture – Translocate mammals away from aquaculture systems to reduce human-wildlife conflict*' and '*Threat: Invasive or problematic species and disease – Disease – Translocate or temporarily bring marine and freshwater mammals into captivity to reduce exposure to disease*'.

A review of multiple translocations in 1994–2009 in the North Pacific Ocean, Hawaii, USA (*1*) found that translocated Hawaiian monk seal *Monachus schauinslandi* pups had similar survival rates and dispersal times to non-translocated seal pups born at release sites. The first-year survival rate of 161 translocated seal pups (45%) was similar to that of non-translocated seal pups born at release sites (43%). The average minimum time between weaning and dispersal of seal pups to other sites was also reported to be similar for 72 translocated pups (43 days) and non-translocated pups born at release sites (data not provided). Hawaiian monk seal pups were translocated between islands in 1994–2009 to reduce the risk of shark predation and male aggression, or to be fostered. Survival was estimated for 291 pups (161 translocated;

130 non-translocated) born in 1997 and 2001–2008. Dispersal times were estimated for 72 seal pups translocated in 1994–2009 and non-translocated pups born at release sites (number not reported). All translocations were part of a long-term research programme. Seal populations were monitored during annual field camps for 2–5 months in the spring and summer in 1994–2009.

A replicated study in 1984–2005 of multiple sites on islands in the North Pacific Ocean, Hawaii, USA (*2*) found that nearly all translocated Hawaiian monk seal *Monachus schauinslandi* young, and approximately half of rehabilitated and translocated monk seal young, survived for at least one year after release and some reproduced. Five of six translocated monk seal young (83%) were known to survive for at least one year. Thirty-five of 68 rehabilitated and translocated monk seal young (52%) were known to survive for at least one year after release, 18 of which reproduced in the wild (at least 68 pups in 1984–2005). Thirty other rescued monk seal young died in captivity (17 seals) or were kept permanently in captivity for health or behavioural reasons (13 seals). In 1984–1995, a total of 104 weaned, female seals (aged <3 years old) that were underweight, ill or threatened (by human disturbance, shark predation or aggressive adult male seals) were translocated directly to new sites (six seals) or brought into captivity for 3–14 months before release at new sites (98 seals). Captive seals were given medical treatment and fed milk formula or fish with multivitamins. The seals were transported between islands by plane or ship, and either released immediately or held in beach enclosures before release. All released seals were tagged and observed annually in 1984–2005.

A review of interventions in 1980–2012 for Hawaiian monk seals *Monachus schauinslandi* in the North Pacific Ocean, Hawaii, USA (*3*) found that translocating seals, along with at least seven other interventions to enhance survival, resulted in 139 of 532 (26%) seals surviving and reproducing. The study did not distinguish between the effects of translocation and the other interventions carried out. The 139 surviving seals (including 71 females) produced at least 147 pups, which went on to reproduce (15 pups). In 2012, the number of surviving seals and their offspring were estimated to make up 17–24% of the seal population (198–271 of 1,153 seals). In 1980–2012, a total of 885 intervention events of seven types were carried out: translocation (284 events); removal of derelict fishing gear from seals (275 events); rescue of stranded or trapped seals (37 events); pups reunited with mothers (113 events); umbilical cord removed or other medical treatment (84 events); other actions, such as deterring aggressive male seals (120 events). Field biologists monitored the seal population in 1980–2012. Data were analysed for 532 individual seals facing severe mortality risks and involved in 698 of the 885 intervention events.

A controlled study in 2008–2011 at two islands in the North Pacific Ocean, Hawaii, USA (*4*) reported that at least half of translocated Hawaiian monk seal *Neomonachus schauinslandi* pups survived their first year, and survival rates were greater than those of non-translocated pups remaining at the original site. Results are not based on assessments of statistical significance. At least six of 12 seal pups (50%) survived to one year of age after translocation. Survival of translocated seal pups was higher than that of non-translocated seal pups remaining at the original site (11 of 36 pups, 31%). However, the authors state that survival estimates may not be reliable due to small sample sizes and low survey effort at the release site (<1% of that at the original site). In August 2008 and 2009, twelve newly weaned seal pups (average 78 days old) were translocated 450 km to an island with better foraging conditions to improve their chances of survival. Attempts were made to re-sight the 12 translocated seal pups and 36 non-translocated seal pups of the same age during surveys. Biannual surveys were carried out at the release site during a total of 12 days in 2009–2011. Surveys of non-translocated pups were carried out at the original site in 2009–2011 (details not reported).

(1) Baker J.D., Becker B.L., Wurth T.A., Johanos T.C., Littnan C.L. & Henderson J.R. (2011) Translocation as a tool for conservation of the Hawaiian monk seal. *Biological Conservation*, 144, 2692–2701.

(2) Gilmartin W.G., Sloan A.C., Harting A.L., Johanos T.C., Baker J.D., Breese M. & Ragen T.J. (2011) Rehabilitation and relocation of young Hawaiian monk seals (*Monachus schauinslandi*). *Aquatic Mammals*, 37, 332–341.

(3) Harting A.L., Johanos T.C. & Littnan C.L. (2014) Benefits derived from opportunistic survival-enhancing interventions for the Hawaiian monk seal: the silver BB paradigm. *Endangered Species Research*, 25, 89–96.

(4) Norris T.A., Littnan C.L., Gulland F.M.D., Baker J.D. & Harvey J.T. (2017) An integrated approach for assessing translocation as an effective conservation tool for Hawaiian monk seals. *Endangered Species Research*, 32, 103–115.

14.9. Translocate marine and freshwater mammal species before onset of impactful activities

- We found no studies that evaluated the effects of translocating marine and freshwater mammal species before onset of impactful activities.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Translocations involve the intentional capture, movement and release of wild-caught marine and freshwater mammals into the wild. Translocations may be carried out prior to the onset of impactful activities to reduce harm to mammals. For example, mammals may be translocated away from potential energy production sites prior to construction. However, this may not be feasible where large numbers of animals are affected. There is also the risk of disease transmission, competition and social disruption at the release site (Germano *et al.* 2015).

For other interventions related to translocations, see '*Translocate marine and freshwater mammals to re-establish or boost native populations*', '*Threat: Aquaculture and agriculture – Translocate mammals away from aquaculture systems to reduce human-wildlife conflict*' and '*Threat: Invasive or problematic species and disease – Disease – Translocate or temporarily bring marine and freshwater mammals into captivity to reduce exposure to disease*'.

Germano J.M., Field K.J., Griffiths R.A., Clulow S., Foster J., Harding G. & Swaisgood R.R. (2015) Mitigation-driven translocations: are we moving wildlife in the right direction? *Frontiers in Ecology and the Environment,* 13, 100–105.

Captive breeding, rearing and releases (ex-situ conservation)

14.10. Breed marine and freshwater mammals in captivity

- **Six studies** evaluated the effects of breeding marine and freshwater mammals in captivity. Three studies were in the USA[4–6], one study was also in China, Indonesia and Venezuela[5], and one study was in each of South Africa[1], Hong Kong[2] and China[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (6 STUDIES)

- **Reproductive success (2 studies):** One study in Hong Kong[2] found that four of six female Indo-Pacific dolphins successfully conceived during a controlled captive breeding programme and gave birth to a total of nine calves. One study in China[3] found that wild-caught Yangtze finless porpoises successfully reproduced in semi-captive conditions.
- **Survival (4 studies):** Two studies in South Africa[1] and the USA[6] found that a captive-born common bottlenose dolphin[1], and a captive-born and hand-reared common bottlenose dolphin[6], survived in captivity for at least two and a half years and four years respectively. One review in the USA[4] found that 80% of common bottlenose dolphins born in captivity over two decades survived, and survival increased with improved husbandry techniques. One review in the USA, China, Indonesia and Venezuela[5] found that most captive-born Amazon river dolphins, narrow-ridged finless porpoises and Irrawaddy dolphins did not survive in captivity.
- **Condition (1 study):** One study in China[3] found that a population of Yangtze finless porpoises breeding in semi-captive conditions had low genetic diversity.

BEHAVIOUR (1 STUDY)

- **Behaviour change (1 study):** One study in the USA[6] found that a captive-born and hand-reared common bottlenose dolphin displayed normal behaviour for the species and joined a dolphin social group in captivity.

Background

Captive breeding involves taking wild animals into captivity and establishing and maintaining breeding populations. For conservation purposes, it tends to be undertaken when wild populations become very small or fragmented or when they are declining rapidly. Captive populations can be maintained while threats in the wild are reduced or removed and can provide an insurance policy against catastrophe in the wild. Captive breeding also potentially provides a method of increasing reproductive output beyond what would be possible in the wild. However, captive breeding can result in problems associated with inbreeding depression, removal of natural selection, adaptation to captive conditions and familiarity with humans.

The aim is usually to release captive-bred animals back to natural habitats, either to original sites once conditions are suitable, to reintroduce a species to sites that were previously occupied, or to introduce species to new sites.

The studies summarised below evaluated the effects of captive-breeding only. For evidence related to the release of captive-bred mammals, see '*Release captive-bred marine and freshwater mammals*'.

A study (year not stated) at an aquarium in Durban, South Africa (*1*) found that a captive-born common bottlenose dolphin *Tursiops truncatus* successfully suckled from its mother, weaned onto fish and survived for at least two and a half years. The male calf successfully suckled from its mother and began eating fish at 11 months of age. The calf survived for at least 30 months and grew in length (1.2–2.7 m) and body mass (50–240 kg) during that time. The calf was born in captivity from a wild-born mother (aged 6.5 years) captured three months earlier from the South Atlantic Ocean, Namibia. The mother and calf were kept in a pool and observed from an underwater window for a total of 1,149 h over 18 months (dates not reported). The length and weight of the calf were estimated at birth. The calf was measured directly from 2–30 months of age and weighed from 16–30 months of age on regular occasions.

A study in 1993–2003 at a marine park in Hong Kong (*2*) found that during a controlled captive-breeding programme, four of six female Indo-Pacific dolphins *Tursiops aduncus* successfully conceived and gave birth to nine calves, seven of which survived. Four of six female dolphins successfully conceived in captivity and gave birth to a total of nine live-born calves (1–3 calves each). One other female mated but did not conceive, and one female conceived but the calf was stillborn. Seven of the nine live-born calves survived (length of time not reported) and were considered healthy. The other two calves died within 1–3 days due to lung infections or trauma caused by the mother. On 11 occasions in 1993–2003, one of six ovulating female dolphins (aged 10–25 years) was placed in a pool with one of five male dolphins (aged 10–31 years). Male and female dolphins were housed separately at all other times. Ultrasound was used to predict the timing of ovulation and to monitor each of the 10 pregnancies during gestation periods of 349–382 days.

A study in 1990–2002 at the Tian-e-Zhou Oxbow in China (*3*) found that wild-caught Yangtze finless porpoises *Neophocaena phocaenoides asiaeorientalis* successfully reproduced in semi-captive conditions, but genetic diversity within the population was low. Between 1990 and 2002, wild-caught Yangtze finless porpoises introduced to an oxbow successfully gave birth to 1–3 calves/year. However, measures of genetic diversity within the population in 2002 were reported to be low (see original paper for details). Wild Yangtze finless porpoises captured from the Yangtze river (number not reported) were originally introduced to the oxbow in 1990. The naturally formed oxbow (21 km long, 1–1.5 m wide, average depth 4.5 m) was cut off from the main channel of the Yangtze River in 1972 and designated as a reserve in 1992. Following the escape and release of some individuals, four porpoises remained in the oxbow in 1997. A further nine wild-caught individuals were introduced in 1998–1999. In 2002, DNA samples were extracted from all 22 porpoises within the oxbow population (seven females, 15 males) and an additional female that was transferred to a captive facility in 1999.

A review of case studies in 1990–2009 at three captive facilities in the USA (*4*) reported that most common bottlenose dolphins *Tursiops truncatus* born in captivity survived for at least one year, and survival increased with improved husbandry techniques. Results are not based on assessments of statistical significance. A total of 249 common bottlenose dolphins were born in captivity over 20 years. Of those, 201 calves (80%) survived to at least one year of age. Calf survival within 30 days of birth was higher during the second decade of the study with improved husbandry techniques (126 of 139 calves; 91%) than during the first decade of the study (86 of 110; 78%). Data on live-births and survival of common bottlenose dolphin calves in captivity were collected from three public display/research facilities for 10 years before (1990–1999) and 10 years after (2000–2009) improvements to husbandry techniques. This included standardized monitoring of mothers and calves and interventions (medical treatments, nutritional supplements etc.; see original paper for details).

A review of case studies in 1970–2011 at five captive facilities in the USA, China, Indonesia and Venezuela (*5*) found that small numbers of Amazon river dolphins *Inia geoffrensis*, narrow-ridged finless porpoises *Neophocaena asiaeorientalis* and Irrawaddy dolphins *Orcaella brevirostris* were born in captivity but most did not survive. Two Amazon river dolphin calves born in captivity in the 1970s died within 15 days of birth, and two of three calves born in 2000–2009 died within 1.5–5 years. The other calf survived for at least six years. Two of three narrow-ridged finless porpoises born in captivity in 2005–2008 died within 5–39 days of birth. The other calf survived for at least six years. Two Irrawaddy dolphins born in captivity in 1979 were known to survive for at least five years. Live births and the survival of calves in captivity were recorded for each of the three dolphin or porpoise species at five facilities between 1970 and 2011.

A study in 2013–2017 at a captive facility in the USA (*6*) found that a common bottlenose dolphin *Tursiops truncatus* calf that was born in captivity and hand-reared survived for at least four years, displayed normal behaviour for the species and successfully joined a dolphin social group at the facility. In 2015, the hand-reared male dolphin (aged 15 months) had fully integrated into a mixed social group at the facility consisting of seven other bottlenose dolphins. In 2017, the hand-reared dolphin (aged four years) was observed to be healthy and displaying normal behaviours (feeding, social interactions). The calf was born in captivity in October 2013, housed in a nursery pool and given intensive medical care after being rejected and injured by its mother. The calf was fed milk and serum from the mother followed by formula via a gastric tube before being weaned onto herring at 4–6 months. At four months old, the calf was gradually reintroduced to other dolphins.

(1) Peddemors V.M., Fothergill M. & Cockcroft V.G. (1992) Feeding and growth in a captive-born bottle-nosed-dolphin *Tursiops truncatus*. *South African Journal of Zoology*, 27, 74–80.

(2) Brook F.M. & Kinoshita R.E. (2005) Controlled unassisted breeding of captive Indo-Pacific bottlenose dolphins, *Tursiops aduncus*, using ultrasonography. *Aquatic Mammals*, 31, 89–95.

(3) Xia J.H., Zheng J.S. & Wang D. (2005) Ex situ conservation status of an endangered Yangtze finless porpoise population (*Neophocaena phocaenoides asiaeorientalis*) as measured from microsatellites and mtDNA diversity. *ICES Journal of Marine Science*, 62, 1711–1716.

(4) Sweeney J.C., Stone R., Campbell M., McBain J., St Leger J., Xitco M., Jensen E. & Ridgway S. (2010) Comparative survivability of *Tursiops* neonates from three US institutions for the decades 1990–1999 and 2000–2009. *Aquatic Mammals*, 36, 248–261.

(5) Curry B.E., Ralls K. & Brownell Jr R.L. (2013) Prospects for captive breeding of poorly known small cetacean species. *Endangered Species Research*, 19, 223–243.

(6) Flower J.E., Langan J.N., Nevitt B.N., Chinnadurai S.K., Stacey R., Ivancic M. & Adkesson M.J. (2018) Neonatal critical care and hand-rearing of a bottlenose dolphin (*Tursiops truncatus*) calf. *Aquatic Mammals*, 44, 482–490.

14.11. Release captive-bred marine and freshwater mammals to re-establish or boost native populations

- **Two studies** evaluated the effects of releasing captive-bred marine and freshwater mammals to re-establish or boost native populations. One study was in the Porto de Pedras estuary[1] (Brazil) and one in water bodies in Florida[2] (USA).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Survival (2 studies):** Two studies in the Porto de Pedras estuary[1] and water bodies in Florida[2] found that two of three Antillean manatees and two of 14 Florida manatees born in captivity and released into the wild survived for at least one year without further intervention.

BEHAVIOUR (0 STUDIES)

Background

Captive breeding for conservation purposes is normally used to provide individuals which can then be released into the wild (often called 'reintroduction') to either re-establish a population that has been lost, or to augment an existing population ('restocking').

This intervention involves the release of captive-bred marine and freshwater mammals into the wild. For studies related to captive-breeding, see '*Breed marine and freshwater mammals in captivity*'.

A study in 1994–2012 in an estuary near Porto de Pedras, northeast Brazil (*1*) found that two of three captive-born Antillean manatees *Trichechus manatus manatus* released into the wild survived for at least one year. Two of three captive-born manatees (a male and a female) survived for at least one year after release into the wild and did not need to be rescued. The other male manatee died in the first year after release. Three manatees born in captivity (two males, one female) were released (aged 3–5 years old) in an estuary within a marine protected area between 1994 and 2012. Manatees were kept in enclosures at release sites for 15 days or 3–12 months prior to release. Manatees were fitted with satellite tags and tracked for an average of 972 days after release.

A replicated study in 1988–2013 at multiple freshwater, marine and brackish water sites in Florida, USA (*2*) found that two of 14 captive-born Florida manatees *Trichechus manatus latirostris* released into the wild survived for at least one year. Two of 14 captive-born manatees (14%) survived for at least one year in the wild after release, occupied appropriate habitats, did not need to be rescued and were in good condition. The other 12 manatees required additional rescue(s) or medical treatment or died within the first year (number for each not reported). All of 14 manatees born in captivity were tagged and released (aged between <1 and >10 years old) at warm freshwater, marine or brackish water sites (number of each not reported) used by wild manatees. Each of 14 released manatees was monitored with radio-tracking and visual observations once or twice/week for at least one year in 1988–2013.

(1) Normande I.C., Luna F.D.O., Malhado A.C.M., Borges J.C.G., Viana Junior P.C., Attademo F.L.N. & Ladle R.J. (2015) Eighteen years of Antillean manatee *Trichechus manatus manatus* releases in Brazil: lessons learnt. *Oryx*, 49, 338–344.

(2) Adimey N.M., Ross M., Hall M., Reid J.P., Barlas M.E., Diagne L.W.K. & Bonde R.K. (2016) Twenty-six years of post-release monitoring of Florida manatees (*Trichechus manatus latirostris*): Evaluation of a cooperative rehabilitation program. *Aquatic Mammals*, 42, 376–391.

15. Education and awareness raising

Background

This intervention includes actions such as education and awareness raising campaigns in response to a range of threats. Studies are included that measure the effect of an action that may be done to change human behaviour for the benefit of marine and freshwater mammal populations.

It should be noted that there are many complex factors that influence human behaviours and providing education does not guarantee that behaviour will change. It may be necessary to collaborate with social scientists to design appropriate education programmes that consider the attitudes, values and social norms of the target audience.

Studies describing educational campaigns in response to specific threats are summarised in the chapter on that threat category.

15.1. Engage policymakers to make policy changes beneficial to marine and freshwater mammals

- **One study** evaluated the effects of engaging policymakers to make changes beneficial to marine and freshwater mammals. The study was in the Catazajá wetlands[1] (Mexico).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (1 STUDY)

- **Change in human behaviour (1 study):** One study in the Catazajá wetlands[1] reported that engaging policymakers resulted in the designation of a protected area for West Indian manatees.

Background

Engaging with and raising awareness amongst policymakers about specific threats to marine and freshwater mammals, and the need for conservation, may result in improved legal protection of mammals and their habitats.

A study in 2001–2008 in the Catazajá wetlands, northeast Chiapas, Mexico (*1*) reported that engaging policymakers in West Indian manatee *Trichechus manatus manatus* conservation resulted in the designation of a protected area. Policymakers were engaged in manatee conservation over a seven-year period in 2001–2007. In November 2006, wetlands (41,000 ha) used by West Indian manatees were designated as a protected area by local and regional governments. In February 2008, the area was designated as an internationally important site. In 2001–2007, local government officials, fishers and students were informed about the value of conserving manatees and their habitats. A total of 4,540 participants attended 23 workshops and 80 public talks. Publications on manatee conservation (four posters, five videos, two leaflets, one booklet) were distributed to community government officials and local schools. Local community members assisted researchers in recording manatee sightings and rescuing stranded manatees.

(1) Rodas-Trejo J., Romero-Berny E.I. & Estrada A. (2008) Distribution and conservation of the West Indian manatee (*Trichechus manatus manatus*) in the Catazaja wetlands of northeast Chiapas, Mexico. *Tropical Conservation Science*, 1, 321–333.

15.2. Educate the public to improve behaviour towards marine and freshwater mammals

- **Three studies** evaluated the effects of educating the public to improve behaviour towards marine and freshwater mammals. One study was in each of the North Atlantic Ocean[1] (USA), the Sundarbans mangroves[2] (Bangladesh) and the South Pacific Ocean[3] (Peru).

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (3 STUDIES)

- **Change in human behaviour (3 studies):** Three before-and-after studies in the North Atlantic Ocean[1], the Sundarbans mangroves[2] and the South Pacific Ocean[3] found that after educational whale-watching tours[1,3] or an educational exhibition[2], participants were more willing to change their behaviour to support marine conservation[1,3], to donate money to marine conservation[3], or to cut their fishing nets to save entangled dolphins[2].

Background

Marine and freshwater mammals face a range of threats from humans. This may include exploitation through hunting or persecution if the mammal is perceived as a threat or nuisance. Education programmes may be designed to educate the public about the importance of marine and freshwater mammals and their conservation to reduce behaviours that are a threat to mammals and to encourage positive behaviours. This may involve a variety of media from broadcasting and social media through to educational events. This may also include educating the public during mammal watching tours. However, careful implementation may be required as unregulated tours can cause considerable disturbance to marine and freshwater mammals (Zapetis *et al.* 2017).

See also '*Involve local communities in marine and freshwater mammal conservation projects*'.

Zapetis M.E., Samuelson M.M., Acosta N. & Kuczaj S. (2017) Evaluation of a developing ecotourism industry: whale watching in the Gulf of Tribugá, Colombia. *International Journal of Comparative Psychology,* 30.

A before-and-after study in 2011 of whale-watching tours in the North Atlantic Ocean, off the coast of Massachusetts, USA (*1*) found that after educational tours, 40 of 544 (7%) participants were more willing to change their behaviour to support marine conservation than before the tours. After the tours, 40 of 544 participants (7%) stated that they were more willing to change their behaviour to protect the marine environment and/or contribute money to support marine conservation than before the tours. A total of 486 participants (89%) stated that their willingness to change their behaviour had not changed, and 18 participants (3%) were less willing to change their behaviour. A total of 544 tourists completed questionnaires before and after whale-watching tours in June–August 2011. Two tour operators conducted the tours, each with 1–2 vessels running 2–3 trips/day. Three statements in the questionnaire assessed behavioural intentions (actual behavioural change was not assessed).

A before-and-after study in 2011–2013 of 12 villages near the Sundarbans mangroves, Bangladesh (*2*) reported that after an educational exhibition, the number of fishers willing to cut their fishing nets to save entangled freshwater dolphins increased. Results are not based on assessments of statistical significance. After the exhibition, 98% of fishers stated that they were willing to cut their nets to save entangled dolphins, compared to 83% before the exhibition. A month-long boat-based educational exhibition visited villages adjacent to three sanctuaries for Ganges River dolphins *Platanista gangetica* and Irrawaddy dolphins *Orcaella brevirostris*. Trained interpreters guided visitors through the exhibition comprising informative panels, interactive displays and educational films about dolphins. In 2011–2013, yearly interviews were conducted in 12 villages visited by the exhibition 1–3 times (total 603 participants).

A before-and-after study in 2014 of whale-watching tours in the South Pacific Ocean, off the coast of northern Peru (*3*) found that after educational tours, a greater number of participants were willing to change their behaviour towards the marine environment or donate money for marine conservation than before the tours. After the tours, a greater number of 196 participants were willing to change their behaviour to protect the marine environment (130 participants) than before the tours (114 participants). The same was true for the number of participants willing to donate money to support marine conservation (before: 42 participants; after: 54 participants). A total of 196 tourists completed questionnaires before and after educational whale-watching tours lasting an average of 3 h in August–September 2014. Three boats (each with a capacity of 20 people) operated the tours targeting humpback whales *Megaptera novaeangliae*. Two of 10 statements in the questionnaire assessed behavioural intentions (actual behavioural change was not assessed).

(1) Harms M., Asmutis-Silvia R. & Rosner A. (2013) *Whale watching: more than meets the eyes.* Report to NOAA's Fisheries Northeast Region Program Office (NERO), Gloucester, USA.

(2) Mansur E.F., Akhtar F. & Smith B.D. (2014) An educational outreach strategy for freshwater dolphin conservation: measuring the results. Pages 17–24 in: Sinha R.K. & Ahmed B. (eds.) *Rivers for Life - Proceedings of the International Symposium on River Biodiversity: Ganges-Brahmaputra-Meghna River System*. IUCN, International Union for Conservation of Nature.

(3) García-Cegarra A.M. & Pacheco A.S. (2017) Whale-watching trips in Peru lead to increases in tourist knowledge, pro-conservation intentions and tourist concern for the impacts of whale-watching on humpback whales. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27, 1011–1020.

15.3. Involve local communities in marine and freshwater mammal conservation projects

- We found no studies that evaluated the effects of involving local communities in marine and freshwater mammal conservation projects on marine and freshwater mammal populations.

  'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

When local communities are involved in conservation projects, they may have a greater interest in ensuring the long-term sustainability of conservation efforts. The engagement of local communities may also reduce persecution of marine and freshwater mammals. One study in Mexico found that local communities were successfully involved in recording sightings and rescuing threatened West Indian manatees *Trichechus manatus manatus*, although the outcomes for the manatee population were not reported (Rodas-Trejo *et al.* 2008).

See also '*Educate the public to improve behaviour towards marine and freshwater mammals*'.

Rodas-Trejo J., Romero-Berny E.I. & Estrada A. (2008) Distribution and conservation of the West Indian manatee (*Trichechus manatus manatus*) in the Catazaja wetlands of northeast Chiapas, Mexico. *Tropical Conservation Science*, 1, 321–333.

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Appendix 1: English journals (and years) searched

A total of 299 English journals were searched.

a) English journals (and years) for which new (7) or updated (26) searches were carried out by the authors of this synopsis

An asterisk indicates new journal searches.

Journal	Years searched
Acta Theriologica Sinica	1981–2018
African Journal of Marine Science	1983–2018
Antarctic Science*	1980–2018
Aquatic Biology*	2007–2018
Aquatic Conservation: Marine and Freshwater Ecosystems	1991–2018
Aquatic Ecology	1968–2018
Aquatic Living Resources	1988–2018
Aquatic Mammals	1972–2018
Australian Mammalogy	2000–2018
Canadian Journal of Fisheries and Aquatic Sciences	1901–2018
Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Science*	1985–2016
Freshwater Science	1982–2018
Frontiers in Marine Science*	2017–2018
Hydrobiologia	2000–2018
Hystrix, the Italian Journal of Mammalogy	1986–2018
ICES Journal of Marine Science	1990–2018
Journal of Cetacean Research and Management	1999–2018
Journal of Mammalogy	1919–2018
Journal of Sea Research	1961–2018
Journal of the Marine Biological Association of the United Kingdom	1887–2018
Latin American Journal of Aquatic Mammals	2002–2018
Mammal Research	2001–2018
Mammal Review	1970–2018
Mammal Study	2005–2018
Mammalia	1937–2018
Mammalian Biology	2002–2018
Marine and Freshwater Research*	1980–2018
Marine Ecology*	1980–2018
Marine Environmental Research	1978–2018
Marine Mammal Science	1985–2018
Marine Pollution Bulletin	2010–2018
New Zealand Journal of Marine and Freshwater Research*	1980–2018
Regional Studies in Marine Science	2015–2018

b) All other English journals (and years) searched for the discipline-wide Conservation Evidence database (267)

An asterisk indicates the journals most relevant to this synopsis.

Journal	Years Searched	Topic
Acrocephalus	2009–2018	All biodiversity
Acta Chiropterologica	1999–2018	All biodiversity
Acta Herpetologica	2006–2018	All biodiversity
Acta Oecologica-International Journal of Ecology	1990–2018	All biodiversity
Acta Theriologica	1977–2014	All biodiversity
African Bird Club Bulletin	2010–2016	Bird conservation
African Journal of Ecology	1963–2016	All biodiversity
African Journal of Herpetology	1990–2018	Reptile & amphibian conservation
African Primates	1995–2012	Primate conservation
African Zoology	1979–2013	All biodiversity
Agriculture, Ecosystems and Environment	1983–2018	All biodiversity
Agroforestry Systems	1982–2007	All biodiversity
Aliens: The Invasive Species Bulletin (IUCN)	1995–2013	All biodiversity
Ambio	1972–2011	All biodiversity
American Journal of Primatology	1981–2014	Primate conservation
American Naturalist	1867–2018	All biodiversity
Amphibian and Reptile Conservation	1996–2018	Reptile & amphibian conservation
Amphibia-Reptilia	1980–2018	Reptile & amphibian conservation
Animal Biology	2003–2013	All biodiversity
Animal Conservation*	1998–2018	All biodiversity
Animal Welfare	1992–2016	Primate and amphibian conservation
Annales Zoologici Fennici	1964–2013	All biodiversity
Annales Zoologici Societatis Zoologicae Botanicae Fennicae Vanamo	1932–1963	All biodiversity
Annual Review of Ecology, Evolution and Systematics	1970–2018	All biodiversity
Anthrozoos	1987–2013	All biodiversity
Apidologie	1958–2009	All biodiversity
Applied Animal Behaviour Science	1998–2014	All biodiversity
Applied Herpetology	2003–2009	Reptile & amphibian conservation
Applied Vegetation Science	1998–2017	All biodiversity
Aquatic Botany	1975–2017	All biodiversity
Aquatic Ecosystem Health & Management*	1998–2018	All biodiversity

Aquatic Invasions*	2006–2016	All biodiversity
Ardeola	1996–2018	All biodiversity
Arid Land Research and Management	1987–2013	All biodiversity
Asian Primates	2008–2012	Primate conservation
Asian Herpetological Research	2010–2018	All biodiversity
Asiatic Herpetological Research	1993–2008	Reptile & amphibian conservation
Auk	1980–2016	Bird conservation
Austral Ecology	1977–2018	All biodiversity
Australasian Journal of Herpetology	2009–2012	Reptile & amphibian conservation
Avian Conservation and Ecology	2005–2016	Bird conservation
Basic and Applied Ecology*	2000–2018	All biodiversity
Basic and Applied Herpetology	2011–2018	Reptile & amphibian conservation
Behaviour	1948–2013	All biodiversity
Behavioral Ecology	1990–2013	All biodiversity
Bibliotheca Herpetologica	1999–2017	Reptile & amphibian conservation
Biocontrol	1956–2016	All biodiversity
Biocontrol Science and Technology	1991–1996	All biodiversity
Biodiversity and Conservation*	1994–2018	All biodiversity
Biological Conservation*	1981–2018	All biodiversity
Biological Control	1991–2017	All biodiversity
Biological Invasions	1999–2017	All biodiversity
Biology and Environment	1993–2017	All biodiversity
Biology Letters	2005–2018	All biodiversity
Biotropica	1990–2018	All biodiversity
Bird Conservation International	1991–2016	Bird conservation
Bird Study	1980–2016	Bird conservation
Boreal Environment Research	1996–2014	All biodiversity
Bulletin Français de la Pêche et de la Pisciculture	1986–2007	All biodiversity
Bulletin of the Herpetological Society of Japan	1999–2008	Reptile & amphibian conservation
Canadian Field Naturalist	1987–2018	All biodiversity
Canadian Journal of Forest Research	1971–2018	All biodiversity
Caribbean Journal of Science	1961–2013	Reptile & amphibian conservation
Chelonian Conservation and Biology	2006–2016	All biodiversity
Chelonian Research Monographs	1996–2017	All biodiversity
Coastal Engineering	2000–2018	All biodiversity
Community Ecology	2000–2012	All biodiversity

Conservation Biology*	1987–2018	All biodiversity
Conservation Evidence*	2004–2018	All biodiversity
Conservation Genetics	2000–2013	All biodiversity
Conservation Letters*	2008–2018	All biodiversity
Contemporary Herpetology	1998–2009	Reptile & amphibian conservation
Contributions to Primatology	1974–1991	Primate conservation
Copeia	1910–2018	Reptile & amphibian conservation
Cunninghamia	1981–2016	All biodiversity
Current Herpetology	1964–2018	Reptile & amphibian conservation
Dodo	1977–2001	All biodiversity
Ecological and Environmental Anthropology	2005–2008	All biodiversity
Ecological Applications*	1991–2018	All biodiversity
Ecological Indicators	2001–2007	All biodiversity
Ecological Management & Restoration	2000–2018	All biodiversity
Ecological Restoration*	1981–2018	All biodiversity
Ecology*	1936–2018	All biodiversity
Ecology Letters	1998–2013	All biodiversity
Ecoscience	1994–2013	All biodiversity
Ecosystems	1998–2013	All biodiversity
Emu	1980–2016	Bird conservation
Endangered Species Bulletin	1966–2003	All biodiversity
Endangered Species Research	2004–2017	All biodiversity
Entomologia Experimentalis et Applicata	2015–2018	All biodiversity
Environmental Conservation*	1974–2018	All biodiversity
Environmental Entomology	1990–2018	All biodiversity
Environmental Evidence*	2012–2017	All biodiversity
Environmental Management*	1977–2017	All biodiversity
Environmentalist	1981–1988	All biodiversity
Estuaries and Coasts	2013–2017	All biodiversity
Ethology Ecology and Evolution	1989–2014	All biodiversity
European Journal of Soil Science	1950–2012	Soil Fertility
European Journal of Wildlife Research*	1955–2017	All biodiversity
Evolutionary Anthropology	1992–2014	Primate conservation
Evolutionary Ecology	1987–2014	All biodiversity
Evolutionary Ecology Research	1999–2014	All biodiversity
Fire Ecology	2005–2016	All biodiversity
Fish and Fisheries	2000–2018	All biodiversity
Fisheries	2017–2018	All biodiversity
Fisheries Management and Ecology*	1994–2018	All biodiversity
Fisheries Oceanography	1992–2018	All biodiversity
Fisheries Research*	1990–2018	All biodiversity

Flora	1991–2017	All biodiversity
Folia Primatologica	1963–2014	Primate conservation
Folia Zoologica	1959–2013	All biodiversity
Forest Ecology and Management	1976–2018	All biodiversity
Freshwater Biology	1975–2017	All biodiversity
Functional Ecology	1987–2013	All biodiversity
Genetics and Molecular Research	2002–2013	All biodiversity
Geoderma	1967–2012	Soil Fertility
Gibbon Journal	2005–2011	Primate conservation
Global Change Biology	1995–2017	All biodiversity
Global Ecology and Biogeography	1991–2014	All biodiversity
Global Ecology and Conservation	2014–2018	All biodiversity
Grass and Forage Science	1980–2017	All biodiversity
Herpetofauna	2003–2007	Reptile & amphibian conservation
Herpetologica	1936–2018	Reptile & amphibian conservation
Herpetological Bulletin	2000–2016	Reptile & amphibian conservation
Herpetological Conservation and Biology	2006–2018	Reptile & amphibian conservation
Herpetological Journal	2005–2014	Reptile & amphibian conservation
Herpetological Monographs	1982–2018	Reptile & amphibian conservation
Herpetological Review	1967–2018	Reptile & amphibian conservation
Herpetology Notes	2008–2018	Reptile & amphibian conservation
Herpetozoa	1988–2018	All biodiversity
Human Wildlife Interactions*	2007–2017	All biodiversity
Ibis	1980–2016	Bird conservation
iForest	2008–2016	All biodiversity
Insect Conservation and Diversity	2008–2018	All biodiversity
Integrative Zoology	2006–2013	All biodiversity
International Journal of Pest Management (formerly PANS Pest Articles & News Summaries 1969 - 1975, PANS 1976-1979 & Tropical Pest Management 1980-1992)	1969–1979	All biodiversity

International Journal of Primatology	1980–2012	All biodiversity
International Journal of the Commons	2007–2016	All biodiversity
International Journal of Wildland Fire	1991–2016	All biodiversity
International Wader Studies	1970–1972	All biodiversity
International Zoo Yearbook	1960–2015	Management of Captive Animals
Invasive Plant Science and Management	2008–2016	All biodiversity
Israel Journal of Ecology & Evolution	1963–2013	All biodiversity
Italian Journal of Zoology	1978–2013	All biodiversity
Journal for Nature Conservation*	2002–2018	All biodiversity
Journal of Animal Ecology*	1932–2018	All biodiversity
Journal of Apicultural Research	1962–2009	All biodiversity
Journal of Applied Ecology*	1964–2018	All biodiversity
Journal of Aquatic Plant Management	1962–2016	All biodiversity
Journal of Arid Environments	1993–2017	All biodiversity
Journal of Avian Biology	1980–2016	Bird conservation
Journal of Bat Research & Conservation	2000–2018	All biodiversity
Journal of Coastal Research*	2015–2018	All biodiversity
Journal of Ecology*	1933–2018	All biodiversity
Journal of Environmental Management*	1973–2018	All biodiversity
Journal of Experimental Marine Biology & Ecology*	1980–2018	All biodiversity
Journal of Field Ornithology	1980–2016	Bird conservation
Journal of Forest Research	1996–2018	All biodiversity
Journal of Great Lakes Research	1975–2017	All biodiversity
Journal of Herpetological Medicine and Surgery	2009–2016	Reptile & amphibian conservation
Journal of Herpetology	1968–2016	Reptile & amphibian conservation
Journal of Insect Science	2003–2018	All biodiversity
Journal of Insect Conservation	1997–2018	All biodiversity
Journal of Kansas Herpetology	2002–2016	Reptile & amphibian conservation
Journal of Mammalian Evolution	1993–2014	All biodiversity
Journal of Mountain Science	2004–2016	All biodiversity
Journal of Negative Results: Ecology & Evolutionary Biology	2004–2016	All biodiversity
Journal of North American Herpetology	2014–2017	All biodiversity
Journal of Ornithology	2004–2018	All biodiversity
Journal of Primatology	2012–2013	Primate conservation
Journal of Raptor Research	1966–2016	Bird conservation
Journal of Tropical Ecology*	1986–2018	All biodiversity
Journal of Vegetation Science	1990–2017	All biodiversity
Journal of Wetlands Ecology	2008–2012	All biodiversity
Journal of Wetlands Environmental Management	2012–2016	All biodiversity
Journal of Wildlife Diseases	1965–2012	All biodiversity

Journal of Zoo and Aquarium Research*	2013–2016	All biodiversity
Journal of Zoology*	1966–2018	All biodiversity
Jurnal Primatologi Indonesia	2009	Primate conservation
Kansas Herpetological Society Newsletter	1977–2001	All biodiversity
Knowledge and Management of Aquatic Ecosystems*	2008–2018	All biodiversity
Lake and Reservoir Management	1984–2016	All biodiversity
Land Degradation and Development	1989–2016	All biodiversity
Land Use Policy	1984–2012	Soil Fertility
Lemur News	1993–2012	All biodiversity
Limnologica - Ecology and Management of Inland Waters	1999–2018	All biodiversity
Mammalian Genome	1991–2013	All biodiversity
Management of Biological Invasions	2010–2016	All biodiversity
Mangroves and Salt Marshes	1996–1999	All biodiversity
Marine Ecological Progress Series*	2000–2018	All biodiversity
Marine Turtle Newsletter	1976–2018	All biodiversity
Mires and Peat	2006–2016	All biodiversity
Natural Areas Journal	1992–2017	All biodiversity
Nature Conservation	2012–2018	All biodiversity
Neobiota	2011–2017	All biodiversity
Neotropical Entomology	2004–2018	All biodiversity
Neotropical Primates	1993–2014	Primate conservation
New Journal of Botany	2011–2013	Plant conservation
New Zealand Journal of Zoology*	1974–2018	All biodiversity
New Zealand Plant Protection	2000–2016	All biodiversity
Northwest Science	2007–2016	All biodiversity
Oecologia*	1969–2018	All biodiversity
Oikos*	1949–2018	All biodiversity
Ornitologia Neotropical	1990–2018	All biodiversity
Oryx*	1950–2018	All biodiversity
Ostrich	1980–2016	Bird conservation
Pacific Conservation Biology*	1993–2018	All biodiversity
Pakistan Journal of Zoology	2004–2013	All biodiversity
Phyllomedusa	2002–2018	All bio
Plant Ecology	1948–2007	All biodiversity
Plant Protection Quarterly	2008–2016	All biodiversity
Polish Journal of Ecology	2002–2013	All biodiversity
Population Ecology	1952–2013	All biodiversity
Preslia	1973–2017	All biodiversity
Primate Conservation	1981–2014	Primate conservation
Primates	1957–2013	All biodiversity
Rangeland Ecology & Management (previously Journal of Range Management 1948-2004)	1948–2016	All biodiversity
Raptors Conservation	2005–2016	All biodiversity

Restoration Ecology*	1993–2017	All biodiversity
Revista Chilena de Historia Natural	2000–2016	All biodiversity
Revista de Biología Tropical	1976–2018	All biodiversity
River Research and Applications*	1987–2016	All biodiversity
Russian Journal of Herpetology	1994–2016	Reptile & amphibian conservation
Salamandra	2000–2018	Amphibian captive breeding
Slovak Raptor Journal	2007–2016	All biodiversity
Small Ruminant Research	1988–2017	All biodiversity
Soil Biology & Biochemistry	1969–2012	Soil Fertility
Soil Use and Management	1985–2012	Soil Fertility
South African Journal of Botany	1982–2016	All biodiversity
South African Journal of Wildlife Research	1971–2014	All biodiversity
South American Journal of Herpetology	2006–2018	Reptile & amphibian conservation
Southern Forests	2008–2013	All biodiversity
Southwestern Naturalist	1956–2018	All biodiversity
Systematic Reviews Centre for Evidence-Based Conservation*	2004–2017	All biodiversity
Testudo	1978–2017	All biodiversity
The Condor	1980–2016	All biodiversity
The Journal of Wildlife Management*	1945–2018	All biodiversity
The Open Ornithology Journal	2008–2016	All biodiversity
The Rangeland Journal	1976–2016	All biodiversity
Trends in Ecology and Evolution*	1986–2017	All biodiversity
Tropical Conservation Science	2008–2018	All biodiversity
Tropical Ecology	1960–2018	All biodiversity
Tropical Grasslands	1967–2010	All biodiversity
Tropical Zoology	1988–2018	All biodiversity
Turkish Journal of Zoology	1996–2014	All biodiversity
Vietnamese Journal of Primatology	2007–2009	Primate conservation
Wader Study Group Bulletin	1970–1977	All biodiversity
Waterbirds	1983–2016	Bird conservation
Weed Biology and Management	2001–2016	All biodiversity
Weed Research	1961–2017	All biodiversity
West African Journal of Applied Ecology	2000–2016	All biodiversity
Western North American Naturalist	2000–2016	All biodiversity
Wetlands	1981–2016	All biodiversity
Wetlands Ecology and Management	1989–2016	All biodiversity
Wildfowl	1948–2018	Bird conservation
Wildlife Biology	1995–2013	All biodiversity
Wildlife Monographs	1958–2013	All biodiversity
Wildlife Research	1974–2018	All biodiversity
Wildlife Society Bulletin	1973–2018	All biodiversity

Wilson Journal of Ornithology	1980–2016	Bird conservation
Zhurnal Obshchei Biologii	1972–2013	All biodiversity
Zoo Biology	1982–2016	All biodiversity
ZooKeys	2008–2013	All biodiversity
Zoologica Scripta	1971–2014	All biodiversity
Zoological Journal of the Linnean Society	1856–2013	All biodiversity
Zootaxa	2004–2014	All biodiversity

Appendix 2: Non-English journals (and years) searched

A total of 161 non-English journals were searched and relevant papers added to the Conservation Evidence discipline-wide literature database. An asterisk indicates the journals most relevant to this synopsis.

Journal	Years searched	Topic	Language
Bois et Forêts des Tropiques Tropical Woodlands and Forests	2009–2018	All biodiversity	French
Alauda	2000–2005	All biodiversity	French
Ecologia Mediterranea Mediterranean Ecology	2000–2018	All biodiversity	French
Revue d'Écologie (previously La Terre et la Vie) Earth and Life	2006–2018	All biodiversity	French
Biotechnologie, Agronomie, Société et Environnement Biotechnology, Agronomy, Society and Environment	2008–2018	All biodiversity	French
Travaux Scientifiques du Parc National de Port-Cros Scientific Reports of the Port-Cros National Park	2000–2018	All biodiversity	French
Travaux Scientifiques du Parc National de la Vanoise Scientific Reports of the Vanoise National Park	1986–2009	All biodiversity	French
Naturae	2017–2018	All biodiversity	French
Bulletin de la Société Zoologique de France Bulletin of the French Zoology Society	1973–2015	All biodiversity	French
Le Naturaliste Canadien The Canadian Naturalist	2008–2018	All biodiversity	French
VertigO	2009–2018	All biodiversity	French
Mertensiella	1988–2017	All biodiversity	German
Salamandra	1965–2018	All biodiversity	German
Der Zoologische Garten: Zeitschrift für die gesamte Tiergärtnerei (Neue Folge) The Zoological Garden	2007–2017	All biodiversity	German
Insecta	1992–2014	All biodiversity	German
Tuexenia	1981–2016	All biodiversity	German
Libellula	1982–2016	All biodiversity	German
Forstarchiv Forestry Archive	2007–2017	All biodiversity	German
Zeitschrift für Feldherpetologie Journal for Field Herpetology	1994–2017	All biodiversity	German
Arachnologische Mitteilungen Arachnological Letters	1991–2017	All biodiversity	German
Fachzeitschrift für Waldökologie, Landschaftsforschung und Naturschutz	2004–2016	All biodiversity	German

Journal for Forest Ecology, Landscape Research and Nature Conservation			
Silva Fera: Wissenschaftliche Nachrichten aus dem Wildnisgebiet Dürrenstein Silva Fera: Scientific News from the Dürrenstein Wilderness Area	2012–2017	All biodiversity	German
Inatura Forschung Online Inatura Research Online	1996–2007	All biodiversity	German
ABU-Info (Arbeitsgemeinschaft Biologischer Umweltschutz im Kreis Soest e.V.) ABU-Info (Working Group for Biological Environmental Protection in Soest District	2006–2017	All biodiversity	German
ANLiegen Natur: 'Zeitschrift für Naturschutz, Pflege der Kulturlandschaft und Nachhaltige Entwicklung Concerning Nature: Journal for Nature Conservation and Applied Landscape Ecology	2006–2017	All biodiversity	German
Natur und Landschaft Nature and Landscape	1990–2017	All biodiversity	German
Pulsatilla	2000–2007	All biodiversity	German
Ornithologische Beobachter Ornithological Observer	1950–2017	All biodiversity	German
Die Orchidee The Orchid	1949–2016	All biodiversity	German
Naturschutz und Landschaftsplanung Conservation and Landscape Planning	2003–2017	All biodiversity	German
Hercynia	1963–2017	All biodiversity	German
Allgemeine Forst und Jagdzeitung German Journal of Forest Research	2000–2016	All biodiversity	German
Nyctalus International Bat Journal	2005–2017	All biodiversity	German
Ornithologischer Anzeiger Ornithological Journal	1951–2017	All biodiversity	German
Archiv für Forstwesen und Landschaftsökologie Archive for Forestry and Landscape Ecology	2013	All biodiversity	German
Botanik und Naturschutz in Hessen Botany and Nature Conservation in Hessen	1987–2018	All biodiversity	German
The Bird Fauna Die Vogelwelt	2005–2017	All biodiversity	German
Biodiversität und Naturschutz in Ostösterreich Biodiversity and Conservation in Eastern Austria	2015–2018	All biodiversity	German
Journal für Ornithologie Journal of Ornithology	1959–2003	All biodiversity	German
Mitteilungen des Badischen Landesvereins für Naturkunde und Naturschutz Communications of the Baden Association for Natural History and Nature Conservation	1953–2015	All biodiversity	German

Freiberg Online Geoscience - FOG	1998–2017	All biodiversity	German
Gesunde Pflanzen: Pflanzenschutz, Verbraucherschutz, Umweltschutz Healthy Plants: Crop Protection, Consumer Protection, Environment Protection	2002–2017	All biodiversity	German
Vogelwarte The Bird Observatory	2005–2017	All biodiversity	German
Die Bodenkultur: Journal of Land Management, Food and Environment The Soil Culture: Journal for Land Management, Food and Environment	2016–2017	All biodiversity	German
RANA - Mitteilungen für Feldherpetologie und Ichthyofaunistik RANA - Communications for Field Herpetology and Ichthyofauna	1983–2016	All biodiversity	German
Die Erde The Earth	1952–2004	All biodiversity	German
Auenmagazin Floodplains Journal	2010–2017	All biodiversity	German
Bulletin de la Société des Naturalistes Luxembourgeois Bulletin of the Luxemburgian Naturalist Society	1950–2017	All biodiversity	German and French
Mammalian Science* 哺乳類科学	1961–2016	All biodiversity	Japanese
The Journal of the Japanese Landscape Architectural Society 造園学雑誌	1925–1927	All biodiversity	Japanese
Landscape Ecology and Management 景観生態学	2005–2016	All biodiversity	Japanese
Japanese Journal of Ecology 日本生態学会誌	1954–2017	All biodiversity	Japanese
Doubutsugaku zasshi 動物学雑誌	1888–1983	All biodiversity	Japanese
Bulletin of the Herpetological Society of Japan 爬虫両棲類学会報	1999–2008	All biodiversity	Japanese
Journal of the Japanese Forest Society 日本森林学会誌	2005–2017	All biodiversity	Japanese
Wildlife and Human Society 野生生物と社会	2013–2017	All biodiversity	Japanese
Ecology and Civil Engineering 応用生態工学	1998–2017	All biodiversity	Japanese
Japanese Journal of Conservation Ecology 保全生態学研究	1996–2016	All biodiversity	Japanese
Journal of Mammalogical Society of Japan* 哺乳動物学雑誌	1959–1986	All biodiversity	Japanese
Landscape Research Japan Online ランドスケープ研究(オンライン論文集)	2008–2017	All biodiversity	Japanese

Bulletin of the International Association for Landscape Ecology-Japan 国際景観生態学会日本支部会報	2002–2003	All biodiversity	Japanese
Strix ストリクス	1982–2017	All biodiversity	Japanese
Journal of the Japanese Forestry Society 日本林学会誌	1985–2004	All biodiversity	Japanese
Japanese Journal of Ornithology 日本鳥学会誌	1917–2015	All biodiversity	Japanese
Wildlife Conservation Japan 野生生物保護	1995–2013	All biodiversity	Japanese
Journal of Natural Environment نشریه محیط زیست طبیعی	2010–2017	All biodiversity	Persian
Experimental Animal Biology زیست شناسی جانوری تجربی	2012–2017	All biodiversity	Persian
Journal of Environmental Sciences علوم محیعلوم محیطیطی	2004–2017	All biodiversity	Persian
Journal of Animal Environment فصلنامه محیط زیست جانوری	2014–2017	All biodiversity	Persian
Journal of Environmental Studies محیط شناسی	1975–2017	All biodiversity	Persian
Environmental Researches پژوهش های محیط زیست	2010–2017	All biodiversity	Persian
Iranian Journal of Applied Ecology بوم شناسی کاربردی	2012–2017	All biodiversity	Persian
Iranian Journal of Natural Resources مجله منابع طبیعی ایران	2002–2009	All biodiversity	Persian
Journal of Animal Researches پژوهش های جانوری	2013–2017	All biodiversity	Persian
Iheringia Série Zoologia	2000–2018	All biodiversity	Portuguese
Revista Bioikos	1987–2016	All biodiversity	Portuguese
Brazilian Journal of Ecology Revista Brasileira de Ecologia	1997–2009	All biodiversity	Portuguese
Biota Neotropica	2001–2011	All biodiversity	Portuguese
Floresta	1969–2017	All biodiversity	Portuguese
Boletim da Sociedade Brasileira de Mastozoologi*	1985–2017	All biodiversity	Portuguese
Biodiversidade Brasileira	2011–2016	All biodiversity	Portuguese
Revista Brasileira de Gestão Ambiental e Sustentabilidade	2014–2017	All biodiversity	Portuguese
MG Biota	2008–2016	All biodiversity	Portuguese
Chiroptera Neotropical	1995–2015	All biodiversity	Portuguese
Evolução e Conservação da Biodiversidade	2010–2011	All biodiversity	Portuguese
Megadiversidade	2005–2009	All biodiversity	Portuguese
Revista CEPSUL - Biodiversidade e Conservação Marinha	2010–2017	All biodiversity	Portuguese
Brazilian Journal for Nature Conservation Natureza & Conservação	2003–2009	All biodiversity	Portuguese
Neotropical Biology and Conservation	2006–2017	All biodiversity	Portuguese

Russian Journal of Ornithology Русский орнитологический журнал	1993–2017	All biodiversity	Russian
Herald of Game Management Вестник охотоведения	2007–2016	All biodiversity	Russian
Bulletin of Moscow Society of Naturalists. Biological series Бюллетень МОИП, серия биологическая	1935–2016	All biodiversity	Russian
Russian Journal of Ecology Экология	1993–2017	All biodiversity	Russian
Povolzhsky Journal of Ecology Поволжский экологический журнал	2002–2016	All biodiversity	Russian
Current Studies in Herpetology Современная герпетология	2000–2016	All biodiversity	Russian
Biology Bulletin Известия РАН, серия биологическая	1957–2017	All biodiversity	Russian
Russian Journal of Zoology Зоологический журнал	1939–2017	All biodiversity	Russian
Steppe Bulletin Степной бюллетень	1998–2016	All biodiversity	Russian
Journal of Ichthyology Вопросы ихтиологии	1961–2017	All biodiversity	Russian
Contemporary Problems of Ecology Сибирский экологический журнал	1994–2017	All biodiversity	Russian
Mammalogy Notes*	2014–2017	All biodiversity	Spanish
Mastozoología Neotropical* Neotropical Mastozoology	1994–2017	All biodiversity	Spanish
Edentata	1994–2018	All biodiversity	Spanish
Ecología Austral Austral Ecology	2001–2018	All biodiversity	Spanish
Revista Catalana de Ornitologia Catalan Journal of Ornithology	2002–2018	All biodiversity	Spanish
Ardeola	1954– 2018	All biodiversity	Spanish
Hidrobiológica Hydrobiology	1991–2018	All biodiversity	Spanish
Gestión Ambiental	1999–2017	All biodiversity	Spanish
Ocelotlán	2003–2012	All biodiversity	Spanish
A Carriza: Sociedad Gallega de Ornitologia	2001–2009	All biodiversity	Spanish
Revista Chilena de Ornitología Chilean Journal of Ornithology	2016–2018	All biodiversity	Spanish
Novitates Caribaea	1999–2018	All biodiversity	Spanish
Madera y Bosques Wood and Forests	1995–2018	All biodiversity	Spanish
Revista Nicaragüense de Biodiversidad Nicaraguan Journal of Biodiversity	2015–2018	All biodiversity	Spanish
Revista Mexicana de Biodiversidad Mexican Journal of Biodiversity	2005–2018	All biodiversity	Spanish
Mediterránea Mediterranean	1982–2015	All biodiversity	Spanish
Semiárida	2013–2018	All biodiversity	Spanish

Boletín de la Real Sociedad Española de Historia Natural Bulletin of the Royal Spanish Society of Natural History	2003–2017	All biodiversity	Spanish
Bosques Latitud Cero Forests Latitude Zero	2014–2018	All biodiversity	Spanish
Anales de Biología	1984–2018	All biodiversity	Spanish
Revista Peruana de Biología Peruvian Journal of Biology	1974–2018	All biodiversity	Spanish
Boletín Científico Centro de Museos Bulletin of the Museum Scientific Center	1996–2018	All biodiversity	Spanish
Revista de Biología Tropical Journal of Tropical Biology	1976–2018	All biodiversity	Spanish
Revista Chilena de Historia Natural Chilean Journal of Natural History	1897–2018	All biodiversity	Spanish
Therya*	2010–2018	All biodiversity	Spanish
Cuadernos de Herpetología Herpetology notes	2010–2018	All biodiversity	Spanish
Boletín de la Sociedad Argentina de Botánica Bulletin of the Argentinean Society of Botany	2013–2018	All biodiversity	Spanish
Butlletí del Grup Català d'Anellament Bulletin of the Catalan Ring Group	1981–2001	All biodiversity	Spanish
Orinoquia	2003–2018	All biodiversity	Spanish
Acta Zoológica Mexicana Mexican Zoological Journal	1984–2018	All biodiversity	Spanish
Biodiversity and Natural History	2015–2017	All biodiversity	Spanish
Galemys*	1997–2017	All biodiversity	Spanish
Boletín Chileno de Ornitología Chilean Ornithology Bulletin	1994–2015	All biodiversity	Spanish
Zoologica Baetica	1990–2015	All biodiversity	Spanish
Centros: Revista Cientifica Universitaria Centros: Scientific Journal of the University	2012–2018	All biodiversity	Spanish
Huitzil: Revista Mexicana de Ornitología Journal of Mexican Ornithology	2000–2018	All biodiversity	Spanish
Bioma (El Salvador)	2012–2016	All biodiversity	Spanish
Quebracho	2008–2018	All biodiversity	Spanish
Etología Ethology	1989–2003	All biodiversity	Spanish
Historia Natural Natural History	2011–2018	All biodiversity	Spanish
Arxius of Miscel·lània Zoològica	2003–2018	All biodiversity	Spanish
Agrociencia Uruguay Agroscience Uruguay	1997–2017	All biodiversity	Spanish
Ecología Aplicada Applied Ecology	2002–2018	All biodiversity	Spanish
Boletín de la Asociación Herpetológica Española Bulletin of the Spanish Herpetological Association	2004–2018	All biodiversity	Spanish

El Hornero: Revista de Ornitología Neotropical	2003–2017	All biodiversity	Spanish
Revista Española de Herpetologia Spanish Journal of Herpethology	2003–2007	All biodiversity	Spanish
Revista Internacional de Contaminación Ambiental International Journal of Pollution	1985–2018	All biodiversity	Spanish
Colombia Forestal	2000–2018	All biodiversity	Spanish
Revista Mexicana de Mastozoología*	1995–2017	All biodiversity	Spanish
Revista Mexicana de Ciencias Forestales Mexican Journal of Forestry Sciences	2010–2018	All biodiversity	Spanish
Boletín de Biodiversidad de Chile Bulletin of Biodiversity of Chile	2009–2014	All biodiversity	Spanish
Studia Oecológica	1981–1995	All biodiversity	Spanish
Grupo Jaragua	1997–2011	All biodiversity	Spanish
Ecosistemas y Recursos Agropecuarios Ecosystems and Agropecuary Resources	1994–2018	All biodiversity	Spanish
BioScriba	2008–2017	All biodiversity	Spanish
Ecosistemas Ecosystems Journal	2001–2018	All biodiversity	Spanish
Cedamaz	2014–2018	All biodiversity	Spanish
Animal Biodiversity and Conservation	2001–2018	All biodiversity	Spanish
Folia Amazónica	1988–2018	All biodiversity	Spanish
Notulas Faunisticas	2008–2018	All biodiversity	Spanish
Caldasia	1940–2018	All biodiversity	Spanish

Appendix 3: Conservation reports (and years) searched

Conservation reports published by a total of 20 organisations were searched.

a) New searches for this synopsis

Organisation	Years searched	Details
Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS)	Not dated	Resolutions for conservation actions at www.accobams.org/documents-resolutions/resolutions/
Convention on the Conservation of Migratory Species of Wild Animals	1998–2018	Documents at www.cms.int/en/publications
International Council for the Exploration of the Sea (ICES)	2003–2018	Working Group on Marine Mammal Ecology (WGMME) Expert Reports at www.ices.dk/publications/library/Pages/default.aspx
International Council for the Exploration of the Sea (ICES)	2011–2018	Working Group on Bycatch of Protected Species (WGBYC) Expert Reports at www.ices.dk/publications/library/Pages/default.aspx
IUCN-SSC Cetacean Specialist Group	1989–2018	Dated reports at www.iucn-csg.org/downloads/
IUCN-SSC Marine Mammal Protected Area Specialist Group	2017–2018	Dated documents at www.marinemammalhabitat.org/downloads/
National Academies Press Reports	All years up to 2018	Key word searches (for 'cetacean', 'pinniped' 'sirenian', 'whale', 'dolphin', 'porpoise', 'seal', 'sea lion', 'dugong', and 'manatee') within the topic 'Biology and Life Sciences' at www.nap.edu/
National Oceanic and Atmospheric Administration (NOAA) Fisheries	All resources up to 2018	Science & Data/Research resources for species categories: whales, dolphins and porpoises, seals and sea lions at www.fisheries.noaa.gov/resources
North Atlantic Marine Mammal Commission (NAMMCO)	1998–2018	Scientific publication series Vol 1 (1998) – 10 (2018) at www.nammco.no/library
Sea Mammal Research Unit (SMRU)	2012–2018	Marine Mammal Scientific Support to Scottish Government reports at www.smru.st-andrews.ac.uk/research-policy/reports-to-scottish-government
Sea Mammal Research Unit (SMRU)	1990–2018	SMRU reports for funders at www.smru.st-andrews.ac.uk/reports
Scientific Committee on Antarctic Research (SCAR)	2014–2018	Expert Group on Birds and Marine Mammals (EGBAMM) publications at www.scar.org/science/eg-bamm
Whale and Dolphin Conservation	2001–2018	Reports at https://uk.whales.org/policy/wdc-publications-and-reports/

b) All other conservation reports searched for the discipline-wide Conservation Evidence database

An asterisk indicates the reports most relevant to this synopsis.

Organisation	Years searched	Details
Amphibian Survival Alliance	1994–2012	Vol 9 – Vol 104
British Trust for Ornithology	1981–2016	Report 1–687
IUCN-SSC Crocodile Specialist Group	2006–2018	CSG Articles
IUCN-SSC Crocodile Specialist Group	2005–2017	CSG Reports
IUCN-SSC Invasive Species Specialist Group	1995–2013	Aliens: The Invasive Species Bulletin (IUCN) Vol 1–33
Joint Nature Conservation Committee*	1991–2018	Reports 1–627
Natural England*	1991–2018	
NatureScot*	2004–2018	Reports 1–945

Appendix 4: Literature reviewed for the Marine and Freshwater Mammal Synopsis

The diagram below shows the total numbers of journals and report series searched for this synopsis, the total number of publications searched (title and abstract) within those, and the number of publications that were summarized from each source of literature.