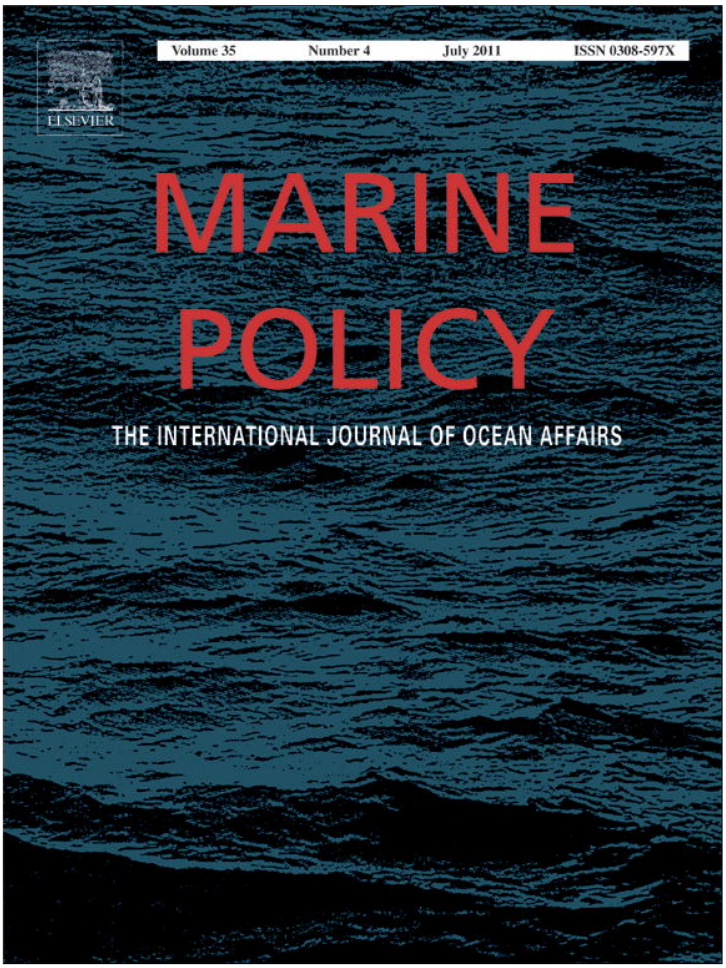

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Ten guiding principles for the delineation of priority habitat for endangered small cetaceans

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ABSTRACT

The adoption of endangered species laws in various nations has intensified efforts to better understand, and protect, at-risk species or populations, and their habitats. In many countries, delineating a portion of a species' habitat as particularly worthy of protection has become a mantra of these laws. Unfortunately, the laws themselves often provide scientists and managers with few, if any, guidelines for how to define such habitat. Conservationists and scientists may view protecting part of the habitat of an endangered species as an ineffectual compromise, while managers may be under pressure to allow a range of human activities within the species' habitat. In the case of small cetaceans, establishing boundaries for such areas can also be complicated by their mobility, the fluid nature of their environment, and the often ephemeral nature of their habitat features. The convergence of multiple human impacts in coastal waters around the world is impacting many small cetaceans (and other species) that rely on these areas for feeding, reproducing, and resting. The ten guiding principles presented here provide a means to characterize the habitat needs of small, at-risk cetaceans, and serve as a basis for the delineation of 'priority habitat' boundaries. This conceptual approach should facilitate a constructive discourse between scientists and managers engaged in efforts to recover endangered species. The degree to which the recovery of an at-risk species can be reconciled with sustainable economic activity will depend in part on how well these principles are incorporated into the delineation of priority habitat.

A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community.
Aldo Leopold (1887–1948).

1. Introduction

Few would argue with the logic behind using endangered species legislation as a tool to protect and recover at-risk species. The enactment of such laws around the world is based on the almost universally held societal value that human action should not cause the extinction of a species. Central to these laws is the

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recognition that habitat must be protected, since habitat loss and destruction have played important roles in the decline of many endangered species [1,2]. The protection of particular areas, termed under various national laws *important*, *core*, *critical*, or *priority habitat*, among others, is based on the notion that, in some cases, a definable portion of habitat is of particular importance to the survival of the species, and that more stringent protection measures must be implemented in such areas. For the purposes of discussion, such habitat is termed here as *priority habitat*, and is defined as that habitat required for a species or population to be self-sustaining for the foreseeable future (including in the face of rare, but potentially catastrophic events). 'Population' is considered interchangeably with 'species', insofar as listing frameworks typically consider 'species' as including 'species, subspecies, variety, or geographically or genetically distinct population' (Canada), or 'any subspecies and any distinct segment of any species' (USA), or 'species, subspecies, or subpopulations' (IUCN).

Surprisingly, however, there exists no clearly accepted approach to describing priority habitat for species deemed to be at risk. As a result, an uneasy discourse often exists between scientists and the managers who are attempting to delineate such habitat in accordance with endangered species laws. Scientists and managers tend to view conservation issues through different lenses, often resulting in legal confusion and underscoring the need for an improved dialogue between science and policymakers [3]. Countless lawsuits and conflicts reflect in large part differing views on the interpretation of priority habitat (US Endangered Species Act: 'critical habitat') delineation among the legislative, policy, judicial, and biological communities [4,5]. In the case of aquatic species, an added level of complexity in describing priority habitat comes from the inherent difficulties in delineating fixed boundaries to a mobile organism that inhabits a fluid medium [6,7]. The guiding principles developed here provide a step-by-step scientific approach to priority habitat delineation, and do so using concepts that should be of practical use to managers tasked with the protection and recovery of endangered species. Small cetaceans have been used to highlight a particularly poignant example of a group of species of special concern.

Small cetaceans around the world currently face an increasing barrage of human impacts, and targeted regulations and specific protection measures have proven ineffectual in many cases at halting or reversing declines of populations or species at risk [8–11]. The reasons for this are varied, but two key factors underlie the plight of small cetaceans: (1) their life history features make them particularly vulnerable to human impacts (e.g. long lives, low reproductive rates, and/or high trophic levels); and (2) many rely on relatively shallow freshwater, estuarine, and/or near-shore marine habitats that are often heavily impacted by human activities. Coastal environments around the world are particularly vulnerable to, and impacted by, human activities. These impacts in coastal environments are related to fisheries practices, reduction of freshwater inputs, pollution, noise and disturbance, and other forms of habitat destruction or degradation [11–13]. Isolated coastal cetaceans with limited geographic ranges are especially vulnerable to anthropogenic impacts [14].

2. Small cetaceans at risk

The need for effective habitat protections for small cetaceans is clearly illustrated by several troubling examples. The most cautionary is that of the recent (functional) extinction of the baiji, or Yangtze River dolphin (*Lipotes vexillifer*). The baiji finally succumbed after years of unsustainable mortality associated with entanglement in fishing gear and boat strikes, as well as habitat degradation and loss associated with pollution, overfishing and shoreline development [15,16]. This first human-caused extinction of a cetacean occurred despite the existence of a number of legal and practical protection measures.

The vaquita, or Gulf of California harbour porpoise (*Phocoena sinus*), is seriously endangered in large part due to fishery bycatch, with fewer than 150 individuals thought to remain of this endemic Mexican species as of 2007 [17]. In this case, a vaquita refuge was finally established by the Government of Mexico, with a number of fisheries management and enforcement measures occurring both inside and outside of the reserve, including a ban on gillnet fishing within the boundaries [18]. Whether such measures will be sufficient to reverse the decline in vaquita abundance and to prevent its extinction is not yet clear.

The 2008 IUCN listing of the Eastern Taiwan Strait (ETS) population of Indo-Pacific humpback dolphins (*Sousa chinensis*) as 'Critically Endangered' followed reports that this population numbered fewer than 100 individuals [19]. These dolphins are adversely affected by pollution, noise and disturbance, bycatch, reduced freshwater flow into estuarine and coastal habitat, and habitat loss due to land reclamation and other coastal alterations [11,20]. There exists little doubt that this population will go extinct if existing protections are not enforced and significant new measures implemented.

Bycatch of Hector's dolphins (*Cephalorhynchus hectori*) in gillnets in New Zealand has caused a steep decline in abundance [21]. The establishment of protected areas under the Marine Mammals Protection Act and the Fisheries Act is enabling some populations to recover [22], but others are predicted to continue declining, either because protection is ineffective or the protected areas are too small [21].

Irrawaddy dolphin (*Orcaella brevirostris*) populations in Asia are at increasing risk, especially those exclusively inhabiting freshwater rivers and lakes in India, Myanmar, Thailand, Cambodia, Laos, Vietnam, and Indonesia [23]. Each of these populations is estimated to have fewer than 200 individuals, and most are clearly declining. Incidental catch in fishing nets and declining water levels are cited as major threats to these cetaceans [23].

3. Understanding habitat needs of small cetaceans

Recent scientific advances provide an increasingly rich array of methods for understanding cetaceans and their habitat needs, with non-invasive techniques being of particular value when studying species at risk. These include surveys of distribution, abundance and habitat use, photographic-identification studies, remote sensing, passive acoustics, multidimensional habitat modeling tools, and other means of understanding the biology and ecology of cetaceans. More invasive studies may be considered under some circumstances but must be carefully scrutinized in the context of the value of the data in support of management goals, the conservation status of the species involved, and adequate animal care protocols. These include physiological and molecular measures of cetacean feeding ecology and health using microsamples collected from free-ranging animals, as well as satellite and radio tracking technologies.

Despite these advances, it is still not always a straightforward task to quantitatively describe habitat for species that are mobile and inhabit a fluid environment. Of particular note is the legislated requirement (or interpretation thereof) to define fixed area boundaries for enhanced habitat protection under the terms of many national endangered species laws. Such legal context has its origins with terrestrial species for which habitat boundaries may more readily be drawn (e.g. nesting areas, dens, burrows, or migratory corridors). The delineation of fixed boundaries for protected habitat areas for organisms inhabiting the ocean is with little doubt more complicated, but it is not impossible [2,24]. Some

have proposed classification schemes to delineate boundaries in the marine environment that consider fixed or variable elements, such as 'static bathymetric', 'persistent hydrographic', or 'ephemeral hydrographic' features [25]. Regardless of whether priority habitat boundaries are fixed or mobile (e.g. varying seasonally or depending on hydrographic features), these boundaries must incorporate the key habitat features for the species.

Cetacean habitat is generally delineated on the basis of the best available scientific data combined with expert opinion and some degree of scientific consensus. Prior to the delineation of priority habitat, all available relevant information on the species and its habitat needs should be collected and evaluated. This might include conservation status according to the laws of a nation, a conservation organisation, and/or an international ranking system such as that of the IUCN Red List (e.g. critically endangered, endangered, or vulnerable). In addition, a description of the population size, trend, and demographics should be prepared, if not already available.

4. Guiding principles for priority habitat delineation

Although the guiding principles below were developed for at-risk small cetaceans, most of the principles are also relevant for other cetaceans and many can be extrapolated to other marine species:

4.1. Food: priority habitat should contain a sufficient quantity and quality of food to sustain the population

Priority habitat should incorporate areas that provide ample access to sufficient quantity and quality of preferred prey. Positive associations between prey density and dolphin density underscore the central role that food plays in defining cetacean habitat [26–28]. In one example, a series of fisheries management measures have been proposed to stem the decline in endangered short-beaked common dolphins (*Delphinus delphis*) in western Greece attributed to overfishing of their prey base [29]. These include a moratorium on purse seining, restrictions on bottom trawling, and stricter enforcement and implementation measures.

4.2. Habitat features: priority habitat must include the full range of physical, chemical, and biological features that are required for the persistence of the population

Priority habitat designations should consider those physical, chemical, and/or biological features (aside from prey) that attract the cetaceans and/or contribute to the productivity of their prey. These include such features as primary and secondary productivity, bathymetry/topography, natural ambient noise levels, temperature, salinity, turbidity, tides, and/or currents. For example, the reliance of Indo-Pacific humpback dolphins in SE Asia on shallow (<30 m), nearshore waters reflects particular bathymetric, salinity, and temperature conditions that support the productivity of their preferred prey [10,20,30]. In contrast, bathymetric (i.e. physical) features proved almost irrelevant for common bottlenose dolphins (*Tursiops truncatus*) in the Adriatic Sea, whereas hydrologic features were important in shaping habitat [31]. Including areas exhibiting such conditions in priority habitat has been recommended where it is deemed relevant for endangered cetaceans [11].

4.3. Habitat size: Priority habitat should be of sufficient size to allow the long-term persistence of the species

Priority habitat should include all habitat areas required for a population or species to be self-sustaining for the foreseeable future. This should include sufficient habitat to prevent depletion of the population or species and allow a recovery of the population to a size that is robust enough to withstand not only stochastic variation but also the occasional natural or anthropogenic catastrophic event, such as a disease outbreak or oil spill. While the complexities of describing a fixed priority habitat area for a highly mobile species remain, population viability analysis and other risk analysis approaches can help determine the size of protected area needed to ensure sustainable populations [22]. Another issue arises when taking into account the acoustic habitat, since noise from activities beyond the boundaries can still enter any protected area and additional buffer zones may be required [32]. Furthermore, if the current range is smaller than the historic range, consideration should also be given to including habitat known or inferred to have been used by the species in the past, as well as other adjacent areas with similar habitat features, in addition to current habitat [11]. Where priority habitat boundaries are too small, or the species migrates beyond the boundaries of its designated priority habitat, there is a substantial risk that 'edge effects' may become a sink for individuals and cause further depletion of the population [33].

4.4. External connections: priority habitat should explicitly consider the surrounding habitat that is necessary to maintain the integrity of priority habitat

Priority habitat cannot be considered in isolation. Instead, the various functional linkages to important attributes or influences that fall outside of its boundaries must also be considered. For example, air quality, adjacent shorelines, substrates, and connected watersheds should all be taken into account as inherently linked to the quality (if not as integral components) of priority habitat for small cetaceans. Diminished river flow to estuaries as a consequence of anthropogenic activities threaten the habitat of Ganges River dolphins (*Platanista gangetica gangetica*), Irrawaddy dolphins and the ETS population of Indo-Pacific humpback dolphins, and their prey, highlighting the need to consider upstream influences when designing protected areas or conservation strategies [11,18,34,35]. Again, the risk is that otherwise individuals will be impacted as a result of edge effects [33].

4.5. Nurseries: priority habitat should provide adequate protection for reproduction (mating, calving, and nursing)

Pregnant females, mothers, and calves merit particular attention in the delineation of priority habitat, due to their exceptional vulnerability and importance for the reproductive potential of the population. If clear breeding or nursery grounds exist, priority habitat must include such habitat to allow for undisturbed reproduction and the rearing of young. For instance, high proportions of common bottlenose dolphin females and calves occur in a temperate bay in Wales, suggesting its use as a nursery area [36]. An application of such knowledge emanates from the Hauraki Gulf Marine Park in New Zealand, where a level of protection is afforded to all short-beaked common dolphins, but additional specific protection measures have been recommended to protect calving and nursing [37].

4.6. Social and behavioural considerations: priority habitat should include any areas used for specialized behaviours or that are of social significance

Priority habitat delineation should consider the importance of social behaviours, communication, and refuge/rest areas. For example, spinner dolphin (*Stenella longirostris*) aggregations in the offshore Samadai Reef in Egypt appear to have social and resting functions [38]. Management measures to reduce ecotourism impacts on the dolphins

in this area include no-go zones in this area, temporal restrictions for ecotourism, enforcement, education, and training and certification for ecotourism guides [38]. Protection of the aptly-named 'rubbing beaches' for the northern resident killer whales (*Orcinus orca*) in British Columbia followed acknowledgement of the social and/or physical importance of these areas [14].

4.7. Temporal patterns: priority habitat should include areas that are occupied by the species at certain times of the day, tide, or season, if individuals regularly move through that area

Any temporal variations in habitat use and/or quality should be considered in the delineation of priority habitat. Seasonal changes in the distribution of coastal dolphins [39,40] may appear to undermine the delineation of a fixed priority habitat area. However, it is both important and indeed possible to incorporate such variation into priority habitat size and management frameworks [41]. Fishing regulations in protected areas based only on summer distribution of Hector's dolphins in New Zealand proved ineffective at reducing fisheries mortality. This problem could be solved by increasing the size of the Marine Protected Area to take into account dolphin distribution year-round [39,42]. Regardless of the legal definition of the respective jurisdiction, it is imperative that temporal variation in habitat use be incorporated into the designation of either fixed or variable (e.g. seasonal) boundaries.

4.8. Threat description: the designation of priority habitat should be informed by a consideration of all anthropogenic threats to the species and the geographic distribution of those threats

Anthropogenic activities that threaten the cetacean at risk, and/or its habitat, must be described to the fullest extent possible, in order to inform the delineation, and most importantly, the protection of, priority habitat. Small cetaceans are exceptionally vulnerable to a myriad of anthropogenic activities, including bycatch, watershed alterations, chemical and biological pollution, noise, and habitat degradation and loss [10,11,40,43]. Since difficulties in identifying and ranking threats to aquatic biota can undermine recovery efforts, use of all scientific data and knowledge is key to prompt and cost-effective action [44]. Strategies to mitigate threats within priority habitat can be achieved through stakeholder education, enforcement of existing protections, and enhanced threat-specific mitigation measures [45,46]. Such measures are typically listed in recovery or conservation plans, with legislation generally emphasizing the need for greater protection within priority habitat.

4.9. Precaution: in the face of scientific uncertainty, a precautionary approach can help ensure that priority habitat delineation gives the best chance for recovery of the species

Where the possibility of serious or irreversible harm exists, a lack of full scientific certainty must not be used to justify postponing management action to prevent environmental degradation or the further decline of a species. In the case of priority habitat for at-risk cetaceans, such uncertainty should dictate the designation of larger areas, including a zone surrounding locations of known high importance to ensure that the boundaries are all-encompassing and/or that additional areas of uncertain importance are included. The highly endangered vaquita highlights this dilemma for scientists and managers in Mexico: its very low numbers (estimated at <150) make it difficult to accurately count or monitor the population in a cost-effective manner. However, the unsustainability of even low fisheries bycatch rates highlights the need for urgent conservation measures and the application of the precautionary principle [17]. In this context, a priority habitat area that encompasses all known sighting locations of the vaquita to date (something that the current refuge falls notably short of), in addition to a buffer area around these, would be appropriate. 'Precautionary management' is increasingly espoused for at-risk small cetaceans owing to their vulnerability, the often data-deficient state of knowledge about them, and the cumulative impacts they face from numerous anthropogenic activities [47]. And while the precautionary principle continues to be subject to some of the vagaries of legal interpretation, the concept is crystallizing on the international stage as an applied principle when considering the environment [48,49].

4.10. Adaptive management: priority habitat designations need to be reconsidered as new information becomes available

Reconsideration of established priority habitat boundaries may be required when new scientific information emerges, or when changes to demographics or habitat requirements of a species at risk, become apparent. Without a feedback loop within the management process to allow for the modification of the size or location of established priority habitat, or the protection measures in place, the previously established priority habitat may become inadequate or inappropriate [41,45,50]. Information about cetacean habitat use, distribution, and ecology is continuously being gathered, especially for poorly understood at-risk species.

5. Conclusions

Ultimately, the delineation of priority habitat for endangered cetaceans will accomplish little without the development and application of protection measures, complemented by compliance, and driven by enforcement. Management actions implemented within legally designated priority habitat afford conservationists and managers the opportunity to conserve and recover the at-risk cetacean species. As such, protections within priority habitat should only augment other wider protective measures, existing or yet-to-be-adopted. Owing to the apex nature of many small cetaceans in aquatic environments, legally based protected habitat designations may lead to a cascade of benefits to a multitude of other species, including plants or algae, invertebrates, fishes, seabirds, and terrestrial organisms that form a part of near-shore ecosystems. Human societies adjacent to priority habitat areas will also benefit in various ways from increased fish abundance and ecotourism, and wider ecosystem services (e.g. enhanced hurricane and tsunami protections resulting from a more natural shoreline). While effective protection measures require implementation and enforcement, these can and should be supported, and enhanced, by extensive public outreach.

The ten principles presented here should facilitate the delineation of priority habitat for small cetaceans, as they capture the legal simplicity of static boundaries while incorporating the dynamic nature of their biological and ecological needs. Improved population trends for endangered species for which 'critical habitat' had been established in the U.S. highlight the potential benefits of such designations [51]. These principles will enable operational approaches to science-based priority habitat designations, and foster constructive dialogue between scientists and managers. Further work on the quantitative underpinnings of aquatic habitat will not only advance the effectiveness of endangered species laws but should also benefit marine protected area designation and ecosystem-based management.

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