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The role of social aggregations and protected areas in killer whale conservation: The mixed blessing of critical habitat

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ABSTRACT

Protected areas are often proposed as tools for conserving endangered populations of marine megafauna. Our study area includes a voluntary no-entry reserve embedded within wider critical habitat for Threatened 'northern resident' killer whales under Canada's Species at Risk Act. Our study quantified the reserve's importance to whales by assessing habitat preference in a behavioural context, and population-level implications of that preference given threats from human activities, such as oil spills resulting from shipping traffic. We recorded summertime activities of whales from 1995 to 2002. Whales were observed on 397 of 530 (74.9%) days. Whales showed strong preference for the reserve over adjacent waters, and used it preferentially for feeding and beach-rubbing. While the area comprises ~0.001% of the whales' range, an overall average of 6.5% of the population was present each day. Frequently, >50% of this small population was aggregated in the restricted and heavily trafficked waterway of Johnstone Strait. Using the Potential Biological Removal equation, we calculated potential annual mortality limits (ML) of 2.2 animals. Mean group size in the area exceeded ML on 55.8% of days overall, and 98.8% of days when conditioning on whale presence. The whales' high reliance on a trivial fraction of their range means that opportunities are routine for one stochastic, catastrophic event to cause population decline. On 20 August 2007, a barge loaded with ~10,000 L of diesel sank in the area, exposing 25% of the population. This underscores the importance of identifying critical habitat for threatened populations, and ensuring meaningful protection.

"Hemmed-in ground – Ground which is reached through narrow gorges, and from which we can only retire by tortuous paths, so that a small number of the enemy would suffice to crush a large body of our men: this is hemmed-in ground."

Sun Tzu – *The Art of War*

1. Introduction

Anthropogenic activities are commonly identified as conservation threats to top predators, and a mitigation measure often proposed is the use of protected areas. In the terrestrial realm, protected areas have been used to mitigate effects of human activities on mammals such as grizzly bears (Noss et al., 1996), African dogs (Woodroffe and Ginsburg, 1999),

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and Eurasian badgers (Revilla et al., 2001). Protected areas have been found also to provide crucial nocturnal feeding habitat for dabbling ducks (Guillemain et al., 2002) and wintering grounds for many duck species in France (Duncan et al., 1999). However, protected areas take on a wide range of meanings in marine management (Reeves, 2000; Hoyt, 2005). Marine protected areas (MPAs) aim to protect habitat that encompasses the whole species (or other management unit) or important habitats that are frequented by the management unit in question. Sometimes, protecting small patches of habitat is the only feasible socioeconomic option open to managers working in either the terrestrial or marine realm (Fischer and Lindenmayer, 2002), but providing effective habitat protection for highly mobile marine predators is fraught with difficulty (Wilson et al., 2004).

Much attention has been paid in recent years to desirable attributes of protected areas for marine megafaunal conservation (Hooker et al., 1999; Hooker and Gerber, 2004; Hoyt, 2005; Reeves, 2000; Wilson et al., 2004). It has been argued that protected areas should be designed also to protect ecosystem components that are "original" in the sense that they perform unique functions in their ecosystems (Mouillot et al., 2008). Top predators such as killer whales may satisfy such a criterion as biological originality. There are benefits to identifying and protecting habitat in which prey densities are high, so that marine reserves can satisfy nutritional needs of target species (Hooker et al., 1999). Alternatively, protected areas can be designed to protect large fractions of the population. The latter objective is frequently criticised as implausible, given the high rates of dispersal of highly mobile predators (Gerber et al., 2005). However, there are cases where large fractions of small populations may aggregate temporarily; we believe that protected-area management can play a useful role in protecting vulnerable populations from anthropogenic activities during these periods of assembly. Ehrenfeld (1970) compiled a now-classic list of attributes of a hypothetical composite, "most endangered animal." Marine megafauna possess many of these traits, but one that has received little attention is a propensity to breed or feed in aggregations, which make populations vulnerable to catastrophic events.

Marine conservation biologists recognise the role of clustered distribution and clustered removals of wildlife in the context of fishing pressure on spawning aggregations of coral reef fishes. Some tropical reef fish stocks have been lost entirely because unsustainable fishing targets the spawning aggregations themselves (Sadovy and Domeier, 2005). On a much larger scale, international management and conservation efforts for southern bluefin tuna have been complicated by the fact that this widely dispersed predator appears to comprise a single spawning stock (Grewe et al., 1997). While the phenomenon is recognised for harvested species, we see similar potential for highly concentrated aggregations of non-harvested marine megafauna to be exposed to elevated levels of extinction risk due to anthropogenic catastrophes. Many marine megafauna associate in such a way that large fractions of populations are aggregated (at least temporarily) in relatively small places. Seasonal aggregations bring together hundreds of whale sharks each year at Ningaloo Reef, Western Australia (Colman, 1997). The Gulf of California provides breeding habitat for 70–98% of the global populations of six seabird species (Tershy et al., 1993). The upper Gulf of California is also home to one of the world's most critically endangered odontocete species, the vaquita. This endemic species numbers only hundreds of individuals, and the majority of those tend to be found within a small core area of the species' range (Jaramillo-Legorreta et al., 1999). The western gray whale is critically endangered, and its feeding grounds off Sakhalin Island overlap with an area of intense offshore oil and gas production (Weller et al., 2002).

In migratory baleen whales, life-history processes like feeding, mating and calving may take place in widely separated but well-defined areas that lend themselves amenable to protected-areas management strategies (Hooker and Gerber, 2004). For odontocetes, these life-history processes may occur in the same habitats, which may not always be easily defined. Odontocete social structure may involve a propensity for large fractions of populations to congregate occasionally in one area. The 1989 *Exxon Valdez* oil spill is estimated to have caused losses of 33% and 41%, respectively, to two groups of killer whales that have yet to recover to pre-spill numbers (Matkin et al., 2008).

Three killer whale (*Orcinus orca*) ecotypes are found in the coastal waters of British Columbia (BC), Canada (Ford et al., 2000): mammal-hunting *transients*; rarely seen *offshores*; and northern and southern communities of fish-eating *resident* killer whales. 'Northern resident' killer whales (NRKW) are individually recognisable, and their population size ranged between 201 and 220 animals during the course of our study (Fisheries and Oceans Canada, 2008). A core NRKW area is found in Johnstone and Queen Charlotte Straits and this area has been proposed as critical habitat for this population (Fig. 1; Fisheries and Oceans Canada, 2008). The NRKW recovery strategy does not define what is meant by the term "critical habitat" in this context. It draws from the generic definition of the term under Canada's Species at Risk Act, which defines critical habitat, somewhat circularly, as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species" (Species at Risk Act, 2003). The theme of critical habitat as it pertains to cetaceans has been explored at length in reviews (Reeves, 2000; Hoyt, 2005), and we do not aim to duplicate that review here. Our point is not to support the claim that Johnstone Strait should be designated as critical habitat for these whales, but simply to note that the region's importance to whales has been recognised formally (Fisheries and Oceans Canada, 2008).

The NRKW community comprises ~35 matrilines (Ellis et al., 2007) or natal groups, many of which return to the area each summer to feed, mate, and rub their bodies on smooth pebble beaches. Narrow Johnstone Strait tends to concentrate migratory salmon, and inter-annual variability in chinook salmon abundance influences whale grouping behaviour (Lusseau et al., 2004). A number of vessel types also use the area heavily. Intensity of cargo and bulk carrier vessel movements in narrow Johnstone Strait is one to three orders of magnitude higher than that in less constricted waters of the BC coast (O'Hara and Morgan, 2006). Robson Bight (Michael Bigg) Ecological Reserve (RBMBER; Fig. 1) was recognised as a NRKW sanctuary by the provincial government of BC in 1982. Our study area includes both the reserve, and an area in John-