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Describing Cetacean Habitat in Australian Waters

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Abstract: An understanding of habitat has been acknowledged as a priority for cetacean science in Australian waters. Global reviews suggest that the definition of cetacean habitat should be relatively broad and include multiple variables and factors, yet also tailored to both species and region . It has also been noted that variables and factors need to be measured at a scale that matches the appropriate process, phenomena, pattern and scale at which the given variables operate. In Australia, cetacean habitat research to date has focussed primarily on small coastal species, covers a restricted geographic range, and includes a limited number of factors such as water depth, sea surface temperature and migratory pathways. Specific habitat–related information is available for less than a quarter of the known Australian cetacean species. The investigation of cetacean habitat in Australian waters should be undertaken in a broad and quantitative manner as effective habitat protection and associated threat mitigation serves as key and timely tools in cetacean conservation efforts.

Keywords: *Australia, cetacean, habitat, environmental variables*

1. Introduction

Describing and understanding habitat is consistently noted as a necessary and meaningful component of cetacean science (BANNISTER *et al.* 1996, REEVES *et al.* 2003, HOYT 2005). Cetacean habitat is often defined in terms of critical behaviours such as breeding, foraging and migration yet is sometimes expanded to include those parts of the distributional range that are important for day–to–day survival and reproductive fitness (HARWOOD 2001, HOYT 2005). Habitat of cetaceans is typically described by measurement of environmental, spatial, and temporal variables as well as those factors that may influence distribution in the immediate marine environment of a given species. A review of cetacean studies revealed that some of the common variables used to describe cetacean habitat include water temperature, salinity, dissolved oxygen, turbidity, habitat type, water depth, distance from shore, and topography (GASKIN 1968, KENNEY 1990, BALLANCE 1992, BAUMGARTNER 1997, WILSON *et al.* 1997, ALLEN *et al.* 2001, HASTIE *et al.* 2002, INGRAM and ROGAN 2002, JAQUET and GENDRON 2002, BRAGER *et al.* 2003, MILLER 2003, TYNAN *et al.* 2005, CRIBB 2006, PARRA *et al.* 2006, AZEVEDO *et al.* 2007). From this review it was also evident that cetacean habitat studies differ in the given combinations of variables measured, the scales and methods of quantification, and the analytical techniques and inferences invoked. These differences are in part due to the various ways in which cetacean habitat is measured, geographic region, research technique, time frame, objectives and intended application of the given study, and determination of what constitutes habitat for a given cetacean species (HARWOOD 2001, HOYT 2005, REDFERN *et al.* 2006).

In a comprehensive review of Australian cetaceans, BANNISTER *et al.* (1996) listed general habitat characteristics (water depth, water temperature, latitude, and prey type) for forty –three cetacean species. However, more detailed information about many of these species was evidently lacking as the status of half of these

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species was classified1 as 'No Category Assigned due to insufficient information' (Table 1) (BANNISTER *et al.* 1996). This particular classification may be due to lack of information in regard to population, habitat or perhaps both. A more recent national report focusing only on smaller whales and dolphins (ROSS 2005) provided similar results. More specifically, most species (26 out of 33) did not have a change in conservation status from that designated in BANNISTER *et al.* (1996) (Table 1). Conservation status designations and habitat types for Australian cetaceans are also contained in the IUCN listings (www.iucnredlist.org accessed in July 2008) yet again this information does not differ significantly from the findings of BANNISTER *et al.* (1996) and ROSS (2005) (Table 1).

BANNISTER *et al.* (1996) emphasized that effective cetacean conservation in Australian waters is intrinsically related to protection of appropriate habitat and associated ecosystems, and that the identification of key habitats was an important component of this objective. Given these noted priorities this current paper briefly investigates how cetacean habitat has been described, quantified and applied in terms of conservation and management in Australian waters.

2. Methods

Studies relating to cetacean habitat in Australian waters were collated from published and unpublished reports, database searches and direct approaches to researchers. Each study was examined on an individual basis to determine how habitat had been defined and quantified. Two criteria were used to determine whether a given study was subsequently included in our results section. Firstly, the given study had to include a variable that had a potential effect on description of habitat. This premise meant that any environmental, biological, physical, chemical, spatial or temporal factor related to habitat could potentially be considered as a habitat variable. In addition, factors that drove movement were also listed here due to their inherent influence on distribution and consequent habitat used by cetaceans. Examples of factors influencing movement included migration pathways, avoidance of areas of high boat traffic and attraction to areas of increased feeding opportunity. Secondly, when a study was deemed to include a habitat–related variable it was then confirmed whether the variable had been directly quantified during the course of the study. A variable was considered quantified if it was directly measured via in–situ field measurements (e.g., water temperature, salinity and turbidity), referenced from in–field GPS locations via remote sensing or detailed reference maps (e.g., distance from shore, chlorophyll *a* concentration and water depth), classified via a pre–determined criteria (e.g., distinct habitat types such as seagrass or bare sand substrate), or counted in a consistent manner (e.g., number of boats in a given area over a specific time frame).

The above criteria precluded inclusion of studies that referred only to location or population bounds rather than a habitat related component of these factors. However, special consideration was given to studies in which feeding, breeding, migration and calving were observed as these behaviours could potentially be correlated with a given habitat, and therefore deemed important drivers of spatial and temporal distribution. In some instances it was found that although variables were measured according to study design no analysis of these variables was reported. These studies were therefore excluded. Numerous studies discussed the implications of their findings in relation to habitat, yet if these factors were not specifically measured during the study they were omitted also. Each study was considered on an individual basis yet it is possible there are omissions due to interpretation as well as difficulty in sourcing all relevant studies. Hence, this paper is not presented as an exhaustive listing of cetacean habitat studies in Australia but rather a discussion and analysis of how habitat has been defined and quantified in this region. Selected studies were tabulated and categorized according to species studied, location of study, and habitat variables measured.

Table 1. Conservation status of cetacean species found in Australian waters

Species	IUCN (2006)	Bannister et al. (1996)	Ross (2005)
Eubalaena australis	LR/cd	V	
Balaenoptera acutorostrata	LR/nt	NCA (a)	
Balaenoptera acutorostrata bonaerensis		S	
Balaenoptera borealis	EN	V	
Balaenoptera edeni	DD	NCA (a)	
Balaenoptera musculus	EN	EN	
Balaenoptera musculus brevicauda		NCA (a)	
Balaenoptera physalus	EN	V	
Megaptera novaeangliae	VU	V	
Caperea marginata	LR/lc	NCA (b)	
Delphinus delphis	LR/lc	NCA (b)	*
Globicephala macrorhynchus	LR/cd	NCA (b)	*
Globicephala melas	LR/lc	NCA (b)	*
Grampus griseus	DD	NCA (a)	*
Lagenodelphis hosei	DD	NCA (a)	*
Lagenorhynchus cruciger	LR/lc	NCA (b)	*
Lagenorhynchus obscurus	DD	NCA (a)	*
Lissodelphis peronii	DD	NCA (b)	NCA (a)
Orcaella heinsohni			
Orcinus orca	LR/cd	NCA (c)	NCA (b)
Peponocephala electra	LR	NCA (a)	NCA (b)
Pseudorca crassidens	LR/lc	NCA (a)	NCA (b)
Sousa chinensis	DD	K	*
Stenella attenuata	LR/cd	NCA (a)	*
Stenella coeruleoalba	LR	NCA (a)	*
Stenella longirostris	LR	K	*
Steno bredanensis	DD	NCA (a)	*
Tursiops aduncus	DD		NCA (a)
Tursiops truncatus	DD	NCA (a)	NCA (b)
Phocoena dioptrica	DD	NCA (a)	*
Kogia breviceps	LR/lc	NCA (a)	NCA (b)
Kogia sima	LR/lc	NCA (a)	*
Physeter macrocephalus	VU	K	
Berardius arnuxii	LR/cd	NCA (b)	*
Hyperoodon planifrons	LR/cd	NCA (b)	*
Indopacetus pacificus		NCA (a)	
Mesoplodon bowdoini	DD	NCA (a)	*
Mesoplodon densirostris	DD	NCA (a)	*
Mesoplodon ginkgodens	DD	NCA (a)	*
Mesoplodon grayi	DD	NCA (b)	*
Mesoplodon hectori	DD	NCA (a)	*
Mesoplodon layardii	DD	NCA (b)	*
Mesoplodon mirus	DD	NCA (a)	*
Tasmacetus shepherdi	DD	NCA (a)	*
Ziphius cavirostris	DD	NCA (b)	*

* Conservation status is the same as Bannister *et al.* (1996)

IUCN categories： Extinct *EX*, Near Threatened NT, Extinct in the Wild, *EW*, Least Concern *LC*, Critically Endangered *CR*,, Data Deficient *DD*, Endangered *EN*, Not Evaluated *NE*, Vulnerable *VU*

Bannister et al. (1996) and Ross (2005) conservation status categories： Endangered *EN*, vulnerable *V*, insufficiently known *K*, No category assigned because of insufficient information *NCA* (*a*) , No category assigned, but possibly secure *NCA* (*b*) , No category assigned, but probably secure *NCA* (*c*)

3. Results

Twenty–four cetacean habitat studies were further analyzed for their method of habitat description (Table 2). Most of these studies were reported from Western Australian and Queensland waters, with bottlenose dolphins (*Tursiops* sp.) being the most frequently studied species. In total, research involving nine different species were noted to have incorporated quantitatively defined habitat variables, specifically: southern right whale (*Eubalaena australis*), sei whale (*Balaenoptera borealis*), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), Indo–Pacific humpback dolphin (*Sousa chinensis*), common bottlenose dolphin (*Tursiops truncatus*), Indo–Pacific bottlenose dolphin (*Tursiops aduncus*) and the Australian snubfin dolphin (*Orcaella heinsohni*). The habitat variables measured within these studies included: water depth, sea surface temperature, salinity, dissolved oxygen, turbidity, pH, phytoplankton biomass, distance to land, distance to freshwater, Euclidean distance to habitat type, bathymetry and thermal fronts. In addition, factors deemed to drive distribution included human influences (the presence of tourism vessels, aquaculture and fisheries), migratory routes and calving areas, and the presence of both predators and prey. In several cases, additional analyses into home range, seasonal movement, residency, genetics and site fidelity were investigated concurrently.

4. Discussion

Despite strong recommendations from national reviews (Bannister *et al.* 1996, Ross 2005) cetacean habitat has only been considered on a relatively limited basis within cetacean research projects conducted in Australian waters. A greater understanding of cetacean distribution, behaviour and migration patterns' in the context of their habitat and environment would not only provide insight into the ecology and life history of a given species, but would also enable more effective ecosystem protection and mitigation of potential threats. This current lack of information presents an obstacle towards cetacean conservation efforts in Australia.

However, some exceptions are apparent. In far north Queensland environmental correlates (distance to land, distance to river mouth, and water depth) were examined in relation to the spatial distribution of Australian snubfin (*Orcaella heinsohni*) and Indo–Pacific humpback dolphins (*Sousa chinensis*) (Parra *et al.* 2006). Findings from this work indicated that both of these species demonstrated a preference for near–shore, estuarine waters. In discussion the authors noted that these same areas were subject to potentially threatening fishing nets and therefore suggested regulation of such activities in those near–shore, estuarine waters that had been identified as important cetacean habitat. In Shark Bay, Western Australia, behavioural studies on Indo–Pacific bottlenose dolphin (*Tursiops* sp.) populations documented reactions such as changes in spatial positioning within groups and irregular swimming behaviour in response to boat traffic (Bejder *et al.* 2006a). Although the level of boat traffic could not be correlated with the relative occurrence or absence of a response, a complementary study inferred that the cumulative impact of boat traffic over the longer–term could be linked to changes in overall population numbers (Bejder *et al.* 2006b) and therefore a change in habitat used by these impacted individuals. In response to these findings, the scientific committee of the International Whaling Commission recommended protection of these populations (IWC 2006). Consequently the Western Australian government reduced the number of tourism licenses operating in proximity to this population of bottlenose dolphins (IWC 2007).

The quantification of appropriate factors and variables to describe cetacean habitat presents unique challenges as it necessarily requires the measurement of factors such as changing prey fields, modulating species assemblages, and dynamic marine ecosystems. These oceanographic processes and properties can vary on distinctive spatial and temporal scales, and may be intermittently independent or correlated with one another (Ricklefs 1993, Garrison 1998, Redfern *et al.* 2006). Additional variables such as boat traffic and

Table 2. Examples from Australian cetacean studies of quantified environmental variables and factors measured in relation to species' distribution.

Common name	Location	Environmental habitat variables	Reference
Common bottlenose dolphin, Indo-Pacific humpback dolphin	Moreton Bay, QLD	Water depth, distance from shore	Corkeron (1990)
Irrawaddy dolphin	QLD coast	Distance to land, freshwater	Parra *et al.* (2002)
Humpback whale	Hervey Bay and Whitsundays, QLD	Sea surface temperature, depth, GPS location, calving areas, migrational routes	Forestell *et al.* (2003)
Snubfin dolphin, Indo-Pacific humpback dolphin	Cleveland Bay, QLD	Sea surface temperature, location to habitat type, bathymetry	Parra (2005)
Bottlenose dolphin	Port Adelaide, SA	Water depth, water temperature, total dissolved solids, dissolved oxygen, turbidity, pH, distribution according to habitat type	Cribb (2006)
Snubfin dolphin, Indo-Pacific humpback dolphin	Cleveland Bay, QLD	Water depth, Euclidean distance to habitat type (reef, seagrass, dredged channel)	Parra (2006)
Snubfin dolphin, Indo-Pacific humpback dolphin	Cleveland Bay, QLD	Distance to land, river mouths, water depth	Parra *et al.* (2006)
Bottlenose dolphin	Bunbury, WA	Water depth, temperature, turbidity/visibility, presence of vessels, home ranges, seasonal movement, residency, site fidelity, demography	Smith (pers. com.)
Southern right whale	Doubtful Island Bay, WA ; Warrnambool, VIC ; Head of Bight, SA Australian calving grounds	Distance from shore, position long-shore, depth, slope, substrate, breeding status, group type, behaviour, exposure, sinuosity, substrate, tidal range	Pirzl (pers. com.)
Pygmy blue whale	Bonney Upwelling, SA	Coastal upwelling, krill presence	Gill (2002)
Common Name	Location	Variable defining distribution	Reference
Bottlenose dolphin	Moreton Bay, QLD	Presence of predators	Corkeron *et al.* (1987)
Humpback whale	Stradbroke Island, QLD	Migrational routes	Paterson (1991)
Bottlenose dolphin	Tangalooma, QLD	Presence of feeding station	Orams (1995)
Various species	Shark Bay, Ningaloo Reef and Exmouth Gulf, WA	Sea surface temperature, abundance and distribution	Preen *et al.* (1997)
Bottlenose dolphin	Shark Bay, WA	Reproductive success, water depth, temperature	Mann *et al.* (2000)
Humpback whale	WA coast	Temporal and geographic movements according to migration	Jenner *et al.* (2001)
Bottlenose dolphin	Shark Bay, WA	Prey abundance, shark presence	Heithaus and Dill (2002, 2006)
Humpback whale, Southern right whale, blue whale, fin whale, sei whale	National	Aggregation areas for calving, resting, feeding, migratory pathways	Department Of The Environment And Heritage (2005 a,b,c)
Bottlenose dolphin	Shark Bay, WA	Aquaculture presence	Watson-Capps and Mann (2005)
Bottlenose dolphin	Shark Bay, WA	Vessel effect on abundance	Bejder *et al.* (2006b)
Bottlenose dolphin	Shark Bay, WA	Use of habitat in relation to vessel exposure	Bejder *et al.* (2006a)

Note : Irrawaddy dolphin listed by Parra *et al.* (2002) would now be described as a snubfin dolphin (Beasley *et al.* 2005)

construction may also have an impact on cetacean distribution, as do individual factors such as species, age–class, geographic location and conservation status. Given this complexity and flexibility it is appropriate that the definition and measurement of cetacean habitat be considered in an open and objective way and on a case–by–case basis to ensure all necessary factors have been accounted for. However, it is also imperative that investigations into cetacean habitat be quantified in such a manner as to allow appropriate inferences and management advice to be rendered if required.

The importance of habitat has been recognized by conservation initiatives that strive to progress protection mechanisms for cetaceans, their habitats and associated ecosystems (HOYT 2005, SOUTH AUSTRALIAN DEPARTMENT OF ENVIRONMENT AND HERITAGE 2006). Furthermore, there is global scientific support for recommendations regarding threat mitigation in instances of incomplete species understanding (REEVES *et al.* 2003, CMS 2006). Given these noted concerns it is necessary to place priority on quantifying habitat in cetacean research studies. It is therefore timely and necessary that in Australian waters useful investigations into cetacean habitat are prioritized, and in instances of limited baseline knowledge a risk–averse approach to habitat protection and threat mitigation is progressed.

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