

Trawling and bottlenose dolphins' social structure

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Human activities can affect the behaviour of mammals through the modification of habitats, changes in predation pressure or alterations in food distribution and availability. We analysed the association and ranging patterns of 242 individually identified bottlenose dolphins (*Tursiops aduncus*) in eastern Moreton Bay, Queensland, Australia, and distinguished two separate communities of dolphins. Unlike bottlenose dolphins elsewhere, the communities' core areas overlapped substantially. There was a correlation between the dolphins' responses to fishing activities and community membership—members of one community feed in association with trawlers and members of the other do not. Apart from feeding mode, the communities differed in habitat preference and group sizes. Inadvertent anthropogenic impacts on animals' societies are likely to be far more widespread than just this study and can increase conservation challenges. In this instance, managers need to consider the two communities' differing habitat requirements and their behavioural traditions in conservation planning.

Keywords: human impacts; bottlenose dolphin; *Tursiops aduncus*; social structure

1. INTRODUCTION

Behavioural studies can contribute to the knowledge base required for animal conservation (Clemmons & Bucholz 1997; Caro 1998). Human activities can lead directly and indirectly to changes in the behaviour of terrestrial mammals (Berger 1999). Humans have caused extinctions in the marine environment (Carlton *et al.* 1999), but examples of behavioural impacts on marine species are rare. Anthropogenic concentrations of food can alter mammals' foraging behaviour and deliberate provisioning can cause changes in animals' social interactions (Wrangham 1974).

Bottlenose dolphins (*Tursiops* spp.) live in fission–fusion societies within which individuals form unstable schools, with associations between individuals demonstrating patterns that vary according to the animals' age and gender (reviewed in Connor *et al.* 2000a). Following Connor *et al.* (1998), we distinguish between 'schools', which are aggregations of animals that are observed together at one instant in the field and 'groups', which are longer term associations that are revealed through analyses of school sightings. In some areas adult male bottlenose dolphins tend to form groups of two or three animals that live in almost constant association, while adult female groups occur in networks of more individuals with somewhat lower rates of association (Connor *et al.* 2000a). These groups can occur within the context of communities where animals within one area associate, but tend not to interact with animals in neighbouring (spatially separate) communities (e.g. Wells 1991). However, in other areas bottlenose dolphins show no clear community structure, but instead display 'a continuous mosaic of overlapping home ranges' (Connor *et al.* 2000a, p. 104).

Benthic trawling for penaeid prawns in shallow inshore waters is internationally widespread and bottlenose dolphins have been documented obtaining food from

trawlers at many sites around the world (Fertl & Leatherwood 1997). Trawlers provide a reliable food source for dolphins through the provision of usually unobtainable prey while trawler gear is in use and discarded by-catch. We refer to this as 'trawler foraging'. Through the sounds of trawlers' engines, food patches created by trawlers are detectable by dolphins over kilometres (Norris & Prescott 1961).

Several hundred bottlenose dolphins (*Tursiops aduncus* (Ehrenberg, 1833)) live in Moreton Bay, southeast Queensland, Australia (Corkeron 1990; Chilvers 2001). Trawling started in Moreton Bay in the 1950s (Quinn 1992) and *ca.* 150 trawlers currently work in the bay. Trawling in the bay is banned at weekends. Bottlenose dolphins of both sexes including calves engage in trawler foraging (Corkeron *et al.* 1990). Here we describe the patterns of association of bottlenose dolphins in eastern Moreton Bay and describe the way in which their social separation is related to the way in which animals respond to the food patches created by humans.

2. METHODS

(a) *Field methods*

Our study area was the eastern area of central Moreton Bay and covered an area of *ca.* 350 km². Photo-identification surveys were conducted intermittently throughout the study area on 89 days between 30 July 1997 and 19 August 1999. All parts of the study area received approximately equal coverage over the course of the study.

Attempts were made to photograph the dorsal fins of all animals in a school with approximately three frames of film taken for each individual estimated to be in the school (excluding calves). Location (from global positioning system (GPS)) time, school size, the number of calves and behaviour was recorded for each sighting. A school was defined as dolphins in close-knit spatial cohesion, with individuals within 10 m of any other member (from Smolker *et al.* 1992). The sizes of schools were estimated independently by at least two observers at each sighting and the mean of these school size estimates was recorded.

The dolphins' behavioural states were classified into four categories following previous work (Shane 1990): travelling

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behaviour, active surface behaviour, feeding behaviour and motionless behaviour.

- (i) Travelling behaviour was defined as swimming in a consistent direction with regular surfacing intervals, with each school member spaced within three body lengths of another.
- (ii) Feeding behaviour was defined by either dives of changeable direction, frequency and length (which were often preceded by fluke up or peduncle arches) or erratic movements at the surface, which are indicative of chasing fish. Feeding as defined by long dives (which were preceded by fluke up or peduncle arches) in the vicinity of trawlers' nets or taking fish discarded from trawlers was considered as 'trawler foraging'.
- (iii) Active surface behaviour was defined as active surface behaviour that included interactions with other school members. The units of behaviour observed during socializing included breaching, fluke slapping, head slapping and rolling.
- (iv) Motionless behaviour was defined as slow and or minimal movements at the surface with a tendency for animals to remain or spend long periods of time within the same area.

(b) *Analyses*

(i) *Photo-identifications*

The photographs obtained were classified into four grades according to their focus, contrast between the dorsal fin and background and the size of the dorsal fin in relation to the frame. The two best quality photographs of each individual from each sighting were scanned onto computer and hand drawn into a catalogue that was split into eight general categories of distinguishing features. Both drawings and scanned photos were then compared and matched using a catalogue of identified individuals from the current study. Only animals re-identified using this catalogue (i.e. animals for which identification photographs were obtained on two occasions) were considered 'identified' for the purposes of this study.

(ii) *Associations*

We selected individuals who were sighted more than eight times for analysis, with only photographed animals being used for analysis. Individuals that were seen but not photographed were not included. If an individual animal was sighted twice on the same day the second sighting (including all members of the school in the second sighting) was excluded from the analyses in order to ensure independence of sampling and minimize auto-correlation between sightings. All dolphins photographed in the same school were recorded as being associated. We used the half-weight index (HWI) for analysis of association (Cairns & Schwager 1987; Ginsberg & Young 1992). This index results in values ranging from zero to unity with zero representing two animals never seen together and unity representing two animals never seen apart. The HWI was calculated and a dendrogram of associations was generated using SOCPROG (Whitehead 1997) in MATLAB 5.3 (Matlab, The Maths Works, Inc., Natick, MA, USA).

(iii) *Ranges*

Animals were categorized as belonging to either the 'trawler' or 'non-trawler' communities (see below) based on whether identified individuals in the school had ever been observed trawler

foraging. Kernel ranges were generated from the position records for the sightings of each community using the animal movement extension (Hooge & Eichenlaub 1997) of ARCVIEW (ESRI Inc., Redlands, CA, USA).

Other statistical analyses were carried out in SPSS and SAS.

3. RESULTS

Two hundred and forty-two individual dolphins were identified in 463 sightings. Individual animals were re-identified between one and 23 times. Two distinct communities were identified, as demonstrated by their patterns of association (figure 1). One community (trawler dolphins) comprised 154 animals that were observed trawler foraging. Non-trawler dolphins (88 individuals) were never observed doing so. There were only three sightings (0.65% out of 463) that included animals of both communities. Two of these were of one close-knit group (association index of > 0.8) of non-trawler males associated with trawler females and involved different females on each occasion. The third was of a trawler animal of unknown gender associated with a (different) close-knit group of two non-trawler males. The probability of the observed separation of associations occurring by chance is less than 0.0001.

The core areas (as delineated by 50% kernel isopleths) of both communities overlapped (the raw sighting data that were used to derive ranges are in figure 2). The overlap of the core areas was 7.7 km², which was 31% of the trawler dolphins' core area (of 25 km²) and 14.5% of the non-trawler dolphins' core area (of 53.1 km²). Trawler dolphins were found slightly further from the nearest land (one-way ANOVA, $F_{(1,456)} = 27.13$ and $p < 0.001$) in deeper water (one-way ANOVA, $F_{(1,456)} = 56.8$ and $p < 0.001$). Trawler dolphins occurred in larger schools than non-trawler dolphins, regardless of whether they were feeding or not (table 1). The school size data were not normally distributed and transformations did not improve their normality, so Kruskal–Wallis tests were used in this analysis. The proportion of trawler dolphins bearing scars from shark attacks did not differ significantly from that of non-trawler dolphins (47.4 versus 38.6%, respectively) ($\chi^2_1 = 2.84$ and $p > 0.05$), although the power of this test was low (0.61).

4. DISCUSSION

Separate communities of resident bottlenose dolphins occupying the same area have not been described elsewhere. As most of our data come from schools that were not engaged in feeding (table 1), the separation we describe is not simply an artefact of our data collection technique. Relatively discrete subgroups (of adult females with dependent young) within communities have been described elsewhere, for example 'female bands' (Wells 1991) and 'networks' of females (Smolker *et al.* 1992), but these subgroups associate to a far greater extent than the 0.65% of sightings reported here. Male alliances of bottlenose dolphins have been shown to herd oestrus females in order to increase the males' mating opportunities (Connor *et al.* 2000b). Our field observations suggest that this also occurs in Moreton Bay. Therefore, the observations of a (probable) alliance of non-trawler

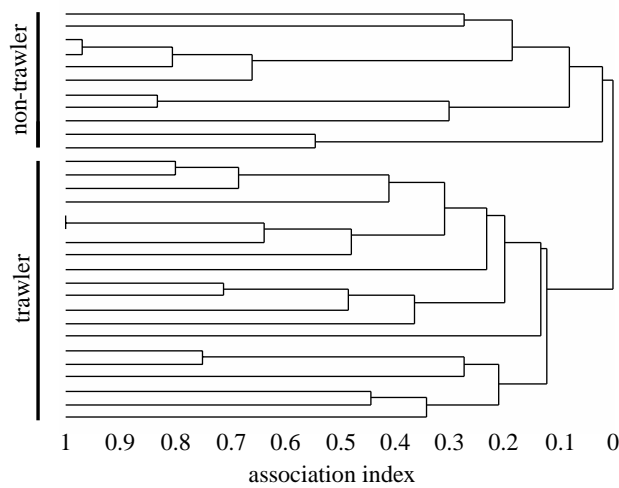


Figure 1. Average linkage dendrogram of the associations within and between dolphin communities. Associations between individuals observed on eight or more occasions were calculated using the HWI. Observations of feeding dolphins are excluded from the analysis as feeding type (trawler versus non-trawler) was used for classifying the animals into communities. Members of the trawler feeding and non-trawler feeding communities are indicated.

males associated with trawler females suggest that genetic interchange between the two communities could occur. More importantly in the context of this paper, these observations also clearly demonstrate that members of the two communities can interact. Association analyses show that members of the two communities do not interact in other circumstances. As it is highly improbable that this non-interaction occurs by chance, it appears that the members of the two communities usually ignore each other.

However, as we have no data on the dolphins' social structure prior to the start of the trawl fishery in the 1950s, we cannot demonstrate that trawling has caused the existing social structure. It is possible (to give one scenario) that the two communities existed separately prior to the trawl fishery and that the extent of overlap of their ranges is a result of changes in the ranging behaviour of what are now trawler dolphins. It is unlikely that studies documenting dolphin populations' responses to the commencement of trawl fisheries will take place, so comparisons of studies of bottlenose dolphins' social structures and ranging patterns where trawling occurs would be valuable. Other genera could also be considered. Pacific humpback dolphins (*Sousa chinensis*) in Hong Kong waters apparently show individual preferences for feeding in association with pair trawlers (two trawlers dragging a net between them). Some animals' primary mode of feeding was trawler foraging, while others never engaged in it (Jefferson 2000, pp. 37–38). Details of the social structure of this population of humpback dolphin remain undescribed. We encourage further analyses of such data using the techniques we describe here in order to assess the ubiquity (or otherwise) of the social structure we have observed.

Delphinids exhibit great flexibility in their foraging strategies (e.g. Baird 2000; Connor *et al.* 2000a) and

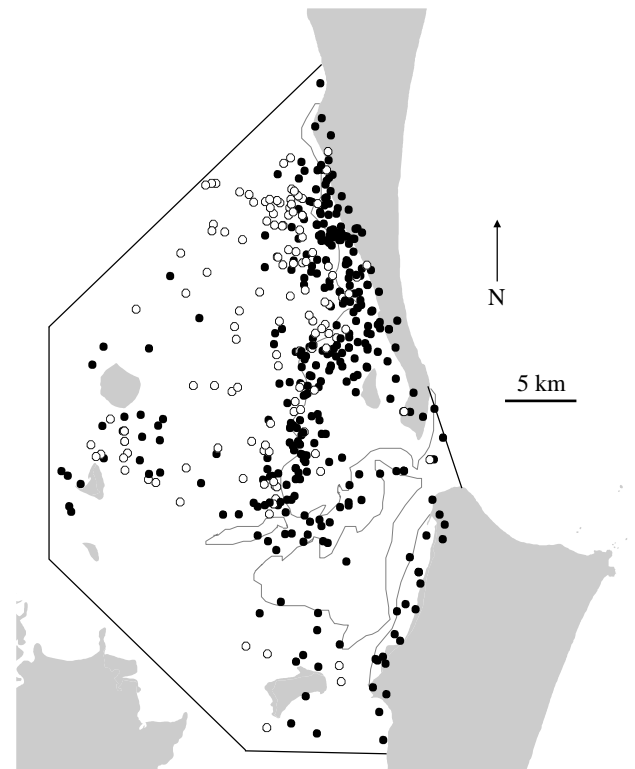


Figure 2. Raw sighting data for this study. Filled circles are sightings of non-trawler dolphins and open circles are sightings of trawler dolphins. The straight dark line indicates the boundaries of the study area and the dashed light lines indicate 10 m depth contours. Land masses are shaded grey. The positions of dolphins on land are due to GPS errors.

examples exist of delphinids using anthropogenic food sources other than those created by prawn trawling, e.g. killer whales from long-line fishing off Alaska (Earle 1996). Cooperative feeding associations between fishers and dolphins represent an extreme development of this pattern. The cooperatives currently in existence include one with bottlenose dolphins (*Tursiops truncatus*) in Brazil (Pryor *et al.* 1990) and one with Irrawaddy dolphins (*Orcaella brevirostris*) in Myanmar (Smith *et al.* 1997). The dolphins engaged in the Brazilian fishery seem to belong to one matrilineal group, whereas the social structure of the dolphins in Myanmar has not yet been described. The history of the cooperative feeding association between killer whales (*Orcinus orca*) and whalers in Eden, south-eastern Australia (Dakin 1963), suggests that this involved one discrete social group of killer whales. Unlike the Brazilian bottlenose dolphins and the killer whales of Eden, the trawler community we describe includes numerous members.

Previous discussions of managing the dolphins in Moreton Bay have considered the bay population as one management unit (e.g. Preen *et al.* 1992; Corkeron 1997). What are the management implications of the existence of these two separate communities? An increased risk of drowning through net entanglement and a possible increase in exposure to toxic compounds in sediments disturbed by trawlers have been identified as possible costs that dolphins incur by trawler foraging (Fertl & Leatherwood 1997). On very rare occasions dolphins die

Table 1. School sizes of the trawler and non-trawler communities.

(The 'non-feeding' schools were all schools that were engaged in travelling, motionless or active surface behaviour (see §2a). There were too few records of schools engaged in active surface behaviour or motionless behaviour for individual analyses by each behavioural state.)

behavioural category	trawler dolphins			non-trawler dolphins			Kruskal–Wallis test	probability value
	median school size	range of school sizes	<i>n</i>	median school size	range of school sizes	<i>n</i>		
all	7.5	1–45	130	3.5	1–20	333	55.221	$p < 0.001$
feeding	8.0	1–45	77	4.0	1–17	112	7.765	$p < 0.001$
non-feeding	5.0	1–42	53	3.0	1–20	221	10.733	$p < 0.005$

through drowning in trawl nets. However, in Moreton Bay this occurs extremely infrequently and the animals killed tend to be juvenile (Corkeron *et al.* 1990). Therefore, it seems unlikely that this is affecting the viability of the trawler community. One dolphin has been observed gaining a new shark bite wound while trawler foraging in Moreton Bay (Corkeron *et al.* 1987). Whether trawler foraging increases their predation risk remains unclear. The comparison between the communities of the proportions of healed shark bite scars is a crude test of predation risk and the test of this comparison had low statistical power.

We suggest that the main management issues raised by our finding relate to the dolphins' habitats. The habitat usage patterns of members of the non-trawler community indicate that they rely heavily on sea grass areas for foraging (Chilvers 2001). The effects of pollutants from urban run-off may threaten sea grass viability (e.g. Abal *et al.* 1998; Prange & Dennison 2000) and recurrent blooms of the cyanobacterium *Lyngbya majuscula* are currently threatening sea grass beds in the non-trawler community's range (see Collier 2000). The feeding opportunities for trawler dolphins that are created by trawling have become part of their habitat requirements, although trawler dolphins are capable of foraging on other food sources (e.g. at weekends when trawling is banned). Recent fisheries management planning is calling for increased temporal and spatial closures of the trawl fishery in Moreton Bay (Queensland Fisheries Management Authority 1999). The behavioural responses of the trawler dolphins to these closures should be investigated.

Our finding has implications for managing populations of inshore delphinids in the many areas worldwide where trawling occurs, as the anthropogenic influences on the viability of populations of trawler foraging dolphins may differ from those of sympatric conspecifics that do not use trawlers as a food source. However, the implications of our finding may go further than this. The two communities that we describe appear to display cultural differences (Rendell & Whitehead 2001): should management strategies include considering maintaining these cultures?

Assessing the consequences of human activities with relatively obvious effects on animal populations can be difficult. When mammals display complex social responses to activities not directed at them, the task of maintaining viable wildlife populations can become even more challenging.

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