Aquatic Mammals 2007, *33*(2), 165-174, DOI 10.1578/AM.33.2.2007.165

Observations of Humpback Whales (*Megaptera novaeangliae*) Feeding During Their Southward Migration Along the Coast of Southeastern New South Wales, Australia: Identification of a Possible Supplemental Feeding Ground

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Abstract

There is anecdotal evidence of humpback whales (*Megaptera novaeangliae*) feeding in southeastern New South Wales (NSW) waters on their southward migration (Paterson, 1987). This paper reports the frequency of feeding whales observed from waters just north of Narooma (36° 5' S, 149° 55' E) to just south of Eden (37° 16' S, 150° 17' E). Observations were made from commercial whale-watching vessels from late September to early November in 2002, 2003, and 2005; and from two land-based whale-watching sites, Montague Island (36° 15' S, 150° 14' E) and Green Cape (37° 16' S, 150° 03' E), in the same period for 2002, 2003, 2004, and 2005. Feeding pods were seen on 24.5% of all whale-watching trips and during 14% of all observations made from land-based sites. Whales fed on schools of small pelagic fish as well as the coastal krill species (*Nyctiphanes australis*). The number of feeding pods observed in 2005 was more than four times that observed in the two previous years and most likely was due to the warmer current systems operating in the area in 2005. All observations from land-based sites were made when no vessels were in the vicinity of the focal pod. Feeding behaviour did not alter in the presence or absence of vessels; however, the time between feeding lunges increased when the movements of the vessel were not consistent with NSW whale-watching regulations and when more than one vessel was present. While many of the reports of humpback whales feeding in mid- to low-latitude waters in both the southern and northern hemisphere classify this behaviour as a rare opportunistic event, it is probable that southeastern NSW is a significant supplemental feeding ground for migrating whales, especially when oceanographic conditions are optimal for food productivity.

Key Words: Humpback whales, *Megaptera novaeangliae*, feeding, southern migration, whale-watching, Australia

Introduction

Humpback whales (*Megaptera novaeangliae*) in the southern hemisphere are said to rarely feed during their migration between high latitude feeding grounds (60°-70° S) and low latitude breeding grounds (15°-20° S) (Chittleborough, 1965; Brown & Lockyer, 1984). Even so, cases of opportunistic feeding by humpback whales during their migration have been documented. Dawbin (1956) first documented humpback whales from the Antarctic Area V feeding between New Zealand's North Cape and East Cape (34°-38° S). Some of the stomach contents of humpbacks killed by whalers in this area contained krill, predominately the coastal krill species *Nyctiphanes australis*. Dawbin (1956, 1966) also reported large numbers of humpbacks feeding in Foveaux Strait (46° 20' S) during the whales' southern migration past the New Zealand coast. Upwellings occur in this location, making it an area with high plankton production (Dawbin, 1956). More recently, Gill et al. (1998) documented the first case of humpback whales feeding in mid-latitude Tasmanian waters (42° 30'-43° S). These observations were made in October and November 1996, during the whales' southern migration. Zooplankton netted in water close to where the whales were feeding included *N. australis.* Even more recently, Stockin & Burgess (2004) made the first documented case of Group V humpback whales feeding on bait fish, most likely sardines (*Sardinops sagax*), on the northern migration in low-latitude waters (27° 02' S) around Moreton Island.

For some time, the southeastern New South Wales (NSW) coastline (35°-37° S) has been thought to be an opportunistic feeding ground for humpback whales during their southern migration to the Antarctic feeding grounds. Anecdotal evidence of whales feeding in southeastern NSW waters has existed since 1986 (Paterson, 1987). The first commercial whale-watching operation out of Eden (37° S, 150° E) began in 1990, and it was then that the operators of the whale-watching vessel first witnessed humpback whales displaying surface feeding behaviours. They noted seeing whales lunging laterally through the water with mouths agape and ventral pleats distended. Feeding humpbacks have been seen by this local commercial operator every whale-watching season since, with the exception of 2001 (R. Butt, pers. comm.).

The southeastern NSW coast is an area subject to high pelagic plankton productivity during the spring when nutrient-rich sub-Antarctic water is overlain with warmer East Australian Current (EAC) water (Hallegraeff & Jeffery, 1993; Bax et al., 2001). This leads to upper water-column stability and upwellings of nutrients, which is conducive for phytoplankton blooms. In addition, the topographic features may enhance nutrient uplifting at the continental shelf break in this area (Bax et al., 2001). These productive events, although sporadic and brief, are used by fish for breeding and feeding and create a diverse marine ecosystem (Prince, 2001).

This paper reports on the occurrence of humpback whales from the Antarctic Area V population feeding along the southeastern coast of NSW. It includes observations made from waters just north of Narooma to just south of Eden (36° 5' to 37° 16' S) over three seasons. It also investigates the importance of southeastern NSW waters as a supplemental feeding ground for humpback whales and the implications for management of the area.

Materials and Methods

This study is based on behavioural observations made as part of a larger project looking into the management of the NSW whale-watching industry. Behavioural observations were recorded from commercial whale-watching vessels operating out of three ports on the NSW southeastern coast—Narooma, (36° 13' S, 150° 08' E), Merimbula (36° 53' S, 149° 55' E), and Eden (37° 04' S, 149° 54' E)—and from two land observation sites—Montague Island (36° 15' S, 150° 14' E) and Green Cape (37° 16' S, 150° 03' E).

Rates of occurrence of behaviours by the entire whale pod were obtained using a group-follow protocol and continuous sampling technique (Mann, 1999). The group-follow protocol was optimal in this study for several reasons. Individuals could not be confidently and rapidly identified with each surfacing (especially when no part of the dorsal fin or fluke was exposed). Pods were usually small (average group size was 2.5 individuals, maximum group size was six individuals) and easily defined (usually traveling within two body lengths of each other). Thus, observers were able to see all whales if they surfaced simultaneously. On occasions when there was a large pod (> 4 whales) or a very active pod, digital video footage was taken to ensure that the timing of each behaviour event was determined accurately through later review.

A pod was defined as one or more whales within 100 m of each other, generally moving in the same direction and coordinating their behaviour (Whitehead, 1983; Mobley & Herman, 1985; Corkeron, 1995). A calf was defined as a whale in close proximity to another whale (with usually less than one whale length separating the pair) and visually estimated to be less than 50% of the length of the accompanying animal (Chittleborough, 1965; Bryden, 1972; Corkeron, 1995).

Observations onboard whale-watching vessels began once the focal pod was within 1,000 m of the vessel. If there was more than one pod in the vicinity of the whale-watching vessel, the closest was chosen as the focal pod. Observations were continued until the pod was > 1,000 m from the whale-watching vessel. When pods disaffiliated, the observation for that pod was terminated before recommencing a new observation block on the closest sub-pod. Observations were usually terminated if it was time to head back to port or if the skipper of the vessel decided to move to another pod in the area. Hence, the duration of feeding time is underestimated by these data.

Observations onboard whale-watching vessels were recorded using a Sony digital mini-disc walkman (MZ-R900) with Sony tie-tack lapel microphone (ECM-T6) and JVC digital video recorder (GR-DVL1020). The mini-disc walkman recorded continuously throughout the duration of each observation. During playback of the track, the time elapsed was displayed so that the onset of each behaviour was recorded to the nearest second. A handheld Garmin II plus GPS receiver was used to track location, speed, and direction of travel of the whale-watching vessel. A Brunton Outback digital compass was used to obtain a bearing of the whale. Distance from whale to vessel was either estimated subjectively by the observer or measured, when practical, using a Bushnell laser range-finder (Lytespeed 400) when the whale was <= 300 m. Distances > 300 m were always estimated subjectively by the researcher.

Land-based observations were made over the same period as vessel-based ones, late September to early November, but included 2004 as well as 2002, 2003, and 2005. Observations were made by seven volunteers. Three volunteers observed for two seasons (2003 and 2005) and one volunteer for all four seasons. Each volunteer was trained by the researcher (KS) on how to identify and record humpback whale behaviour, and was given a key to behaviours (adapted from Corkeron, 1995) that they were likely to see.

The observer stated the onset of each behaviour onto a continuously taped record (Panasonic RQ-L11) for the duration of the observation. If the observer lost sight of the pod, the tape continued recording for a further 20 min. If the whales were not re-sighted after 20 min, the observation was terminated. The tape was played back to time the onset of each behaviour to the nearest second using a stopwatch by the researcher (KS). The cassette recorder was fitted with a battery-level indicator, and the batteries were changed frequently to ensure the tape was running at the correct speed. Other information recorded for each observation included (1) time it began, (2) bearing of pod when first sighted, (3) bearing of pod when observation was terminated, (4) approximate distance pod was offshore (initially and at end of observation), (5) direction of travel (initially and if there was any change in direction during observation), (6) number of whales in the pod, and (7) presence or absence of a calf.

All observations were made within approximately 2 km of the land-based site using binoculars of 8 × 30 magnification or higher. Observers were confident that within this range, all surface activities could be identified accurately. Beyond this limit, the sample may be biased towards the most visible surface activities and so observations were terminated when the pod had moved > 2 km offshore. Because measuring distance offshore is highly subjective, the actual distance of the "2-km limit" may have varied with each observer. Observations were always terminated when observers were no longer confident that they were seeing all surface behaviours.

To minimise bias towards active pods, observers were instructed to choose the pod closest to them and to remain with this pod, even if there were other more active pods in the area. The primary role of the land-based observers was to collect a set of control data of whale behaviour in the absence of moving vessels as part of a larger study. Thus, observations were terminated when a moving vessel approached within a 5-km radius of the focal pod.

Plankton samples was taken on 6 October 2005 at 37° 04' 57" S, 150° 00' 19" E and on 14 October 2005 at 37° 05' 34" S, 149° 59' 43" E. Samples were collected by towing a 300-µm mesh net for 2 min at 3.5/h less than 1 m below the surface close to where whales had been observed feeding. The samples were preserved in 10% formaldehyde in unbuffered seawater.

On 1 October 2005, a faecal sample was scooped out of the water with a clean plastic container. Once the faecal matter had settled to the bottom, excess water was decanted off and the sample was preserved in 70% alcohol. Total DNA was purified from the faecal matter using a faecal DNA extraction kit (Bio101). The total DNA was then tested for the presence of krill DNA using the PCR method described by Jarman et al. (2002).

Statistical analyses were performed using *SPSS for Windows*, Version 14.0 (SPSS Inc., Chicago).

Results

Vessel-based observations were made during 98 whale-watching trips over 89 d and included 30 trips over 27 d from 21 September to 7 November 2002, 31 trips over 28 d from 21 September to 8 November 2003, and 37 trips over 34 d from 24 September to 4 November 2005 (Table 1). The duration of observations ranged from 5 to 115 min (Table 2). The length of the vessel-based observations depended on the movements of the whale-watching vessel, while the length of land observations was dependent on the pod's movements (i.e., observations were terminated if the pod moved > 2 km from the observation site) and the intrusion of moving vessels into the observation zone.

Humpback whales were observed feeding on 24 whale-watching trips on 22 separate days (i.e., 24.5% of the total trips made during the study period). The frequency of these feeding observations varied between years: 7% of trips ($n = 30$) in 2002, 10% of trips ($n = 31$) in 2003, and 49% of trips ($n = 37$) in 2005. The total number of feeding

Table 1. Summary of effort, including observation frequency of humpback whales both from whale-watching vessels and land-based observation sites

	Whale-watching vessels	Land-based observation sites	Total
Days of observations	89	64	153
Total pods observed	217	144	361
Feeding pods observed	41	20	61
Total hours of behavioural observations	121	46	167

pods observed from the whale-watching vessels was 41 out of a total of 217 pods (i.e., 19%). Rigorous behavioural data were collected for 40 of these feeding pods. All feeding pods were within 16 km from shore (the whale-watching vessels rarely went further out to sea than this) (Figure 1).

In 64 days of land-based observations, the total number of feeding pods observed from both sites combined was 20 out of a total of 144 pods (i.e., 14%) (Table 1). From the combined observations, feeding pods contained one to six whales, but the majority (55%) comprised two individuals (mean = 2.5) (Table 2). The average depth of water where the whales were feeding was 61 m, and the deepest was 86 m (Table 2). Whales were at or near the surface most of the time, however. For 96% of the observation time, the interval between surface behaviours was less than 1 min (n = 7,814). Because individual whales could not be identified confidently each time they surfaced, dive duration was not established for individuals. Whales in a pod typically moved in a synchronized manner, however, and so were usually below surface and above surface at approximately the same time.

Feeding whales typically lunged laterally through the surface of the water with their mouths agape at an approximately 45° angle and their ventral pleats fully extended. Occasionally, whales lunged sideways just below the surface. Often, individuals from the same pod moved in a synchronized manner, frequently changing direction and sometimes moving in small circles (usually about one to two body lengths in radius). Whales often lunged simultaneously and in close proximity to one another. Feeding lunges were typically followed by a blow (i.e., exhalation at the surface) and then a peduncle arch or a slip under (i.e., when the whale slips back beneath the surface).

Generally, the presence of the whale-watching vessel did not appear to influence feeding behaviour. On approach, whales often frequently changed direction, which resembled avoidance behaviour; however, once the whales started lunge-feeding, it became clear that the frequent changes in direction were more likely a foraging strategy than a response to the whale-watching vessel. Whales would often lunge close to the vessel. Forty-two percent (n = 564) of feeding lunges were performed less than 100 m from the vessel, and 57% of these lunges were performed less than 50 m from the vessel.

During the majority of whale-watching trips, the approach and movements of the vessel while watching the whales complied with the NSW whale-watching regulations. On 16 of 24 whale-watching trips, the vessel was either sitting idle or

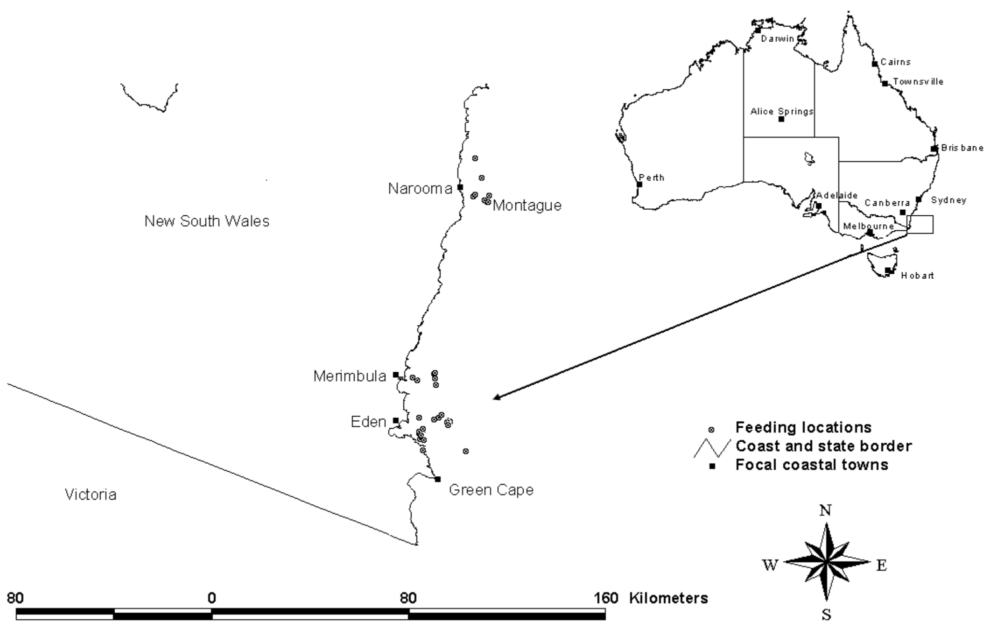

Figure 1. Map showing the geographical location of all feeding humpback whale pods observed from whale-watching vessels during the 2002, 2003, and 2005 study seasons

Table 2. Summary of observations of all feeding humpback whale pods observed from whale-watching vessels and land-based observation sites during the 2002, 2003, 2004, and 2005 study seasons

	Minimum	Maximum	Mean	SE	*n*
Pod size	1.0	6.0	2.5	0.2	60
Number of lunges (per observation)	1.0	75.0	16.0	2.5	60
Feeding lunge frequency (per min/per whale)	0.02	9.1	0.9	0.2	60
Feeding frequency (per min/per whale)	0.01	1.8	0.4	0.1	60
Observation time (min)	5.0	100.0	32.0	3.0	60
Water depth (m)	26.0	86.0	61.0	2.5	39

moving at a no-wake speed parallel to the whales at 100 m or greater separation, which is consistent with the regulations. During the other eight whale-watching trips, the vessel approached closer than the 100-m approach limit and/or traveled into the whales' path.

The mean feeding lunge frequency per pod was 0.9 per min (SE = 0.18) and the maximum was 9.1 per min (Table 2). Because an individual sampling protocol was not used in this study, we could not establish an actual lunge frequency for individual whales, but instead calculated "feeding lunge frequency (per min/per whale)" by dividing the lunge frequency per pod by the number of whales in the pod. For mother/calf pods, the calf was excluded from the analysis because only the mother and/or escort performed feeding lunges. The mean feeding frequency per whale (Table 2) was 0.37/min (SE = 0.05). There was no significant difference in feeding lunge frequency if a vessel was present or not (Table 3), and vessel proximity did not affect the feeding lunge frequency (Table 4).

Most pods (73%) were still feeding when the whale-watching vessel left the area, and the remaining 11 pods had stopped feeding > 5 min before the vessel left. The termination of feeding behaviour by six of these pods (15 % of all feeding pods) was likely in response to the whale-watching vessel. Two pods stopped feeding and approached the vessel to < 5 m, apparently to investigate it. Four pods stopped feeding when the vessel was traveling less than 50 m from the pod, and they may have been disturbed by the vessel's proximity. On one of these occasions, the vessel traveled through the baitfish ball that the whale was feeding on. On another occasion, when the vessel approached within 70 m, the pod stopped feeding, and both mother and calf began fluke slapping and peduncle slapping.

Seventy-six percent (n = 625) of the intervals between each feeding lunge (FLI) were < 60 s. These were not calculated for individuals and so the high number of FLIs < 60 s can in part be attributed to pods of more than one whale lunging either simultaneously or only a few seconds apart. Even so, 52% of FLIs were between 6 and 60 s. Long FLIs (> 5 min) were rare, occurring in 26 out of 625 FLIs (i.e., 4%). The presence of the whale-watching vessel probably contributed to the break in feeding lunges on at least nine of these 26 occasions. On six occasions, the whales came close to the vessel, often circling before heading further away to feed. On the other three occasions, the vessel was still moving towards the pod and was within 50 to 80 m of it. On two of these occasions, the vessel had cut into the path of the whales at 80 m.

Although there was no difference in mean FLI in the presence or absence of a vessel (Table 3), mean FLI was significantly longer when the vessel's movements were not consistent with whale-watching regulations (Table 4). A potential

Table 3. Differences in humpback whale feeding lunge frequency and mean feeding lunge interval in the presence and absence of vessels

		n	Mean	Mean rank	SE	Test statistics	
Feeding lunge frequency (per min/per whale)	Vessel present	40	0.3	28.8	0.1	Mann-Whitney U	330.00
						Wilcoxon W	1,105.00
	Vessel absent	20	0.4	34.0	0.1	Z	-1.10
						Asymp. Sig. (2-tailed)	0.27
Mean feeding lunge interval(s)	Vessel present	39	94	30	14	Mann-Whitney U	336.00
						Wilcoxon W	526.00
	Vessel absent	19	67	28	11	Z	-0.56
						Asymp. Sig. (2-tailed)	0.57

Table 4. Mann-Whitney U analysis of differences in humpback whale feeding lunge frequency and mean feeding lunge interval when the movements of the whale-watching vessel were and were not consistent with NSW whale-watching regulations; * significant at 0.05 probability level.

	Vessel movements	*n*	Mean	Mean rank	SE	Test statistics	
Feeding lunge frequency (per min/per whale)	Consistent	29	0.4	21.6	0.1	Mann-Whitney U	127.00
						Wilcoxon W	193.00
	Not consistent	11	0.7	17.6	0.1	Z	-0.98
						Asymp. Sig. (2-tailed)	0.34
Mean feeding lunge interval(s)	Consistent	28	81	17	17	Mann-Whitney U	81.00
						Wilcoxon W	487.00
	Not consistent	11	127	27	24	Z	-2.28
						Asymp. Sig. (2-tailed)	0.02*

confounding factor in these analyses is uncontrolled variation in pod size. A full factorial general linear model of vessel movement (fixed factor—consistent or inconsistent with regulations) with pod size (random factor) was used for variance estimation by the restricted maximum likelihood method. The results showed essentially no contribution by pod size (~ 0) to the variance in mean FLI and only 4.5% contribution to the variance from the interaction between pod size and vessel movement. On five of the 11 occasions that the vessels' movements were not consistent with the regulations, the pod had a break in feeding longer than 5 min.

During nine pod observations, more than one vessel was present. For six of these nine observations, two vessels were watching the pod. On two occasions, there were three vessels and on another, there were four vessels watching the pod. Mean FLI was significantly longer when more than one vessel was watching the pod (Table 5). Ten of the 26 occasions (38%) in which FLI was > 5 min occurred while more than one vessel was watching the pod.

The presence of krill in the upper water column was noted on five occasions during 2005 only. On two of these occasions (6 October 2005 and 14 October 2005), a plankton sample was taken and the krill were identified as *N. australis.* Salps, probably horned or blue salp (*Thalia democratica*) (Iain Suthers, pers. comm.), were noted on six occasions during 2005, but were not seen during 2002 and 2003. During 2005, whales fed on baitfish on six separate occasions. On 7 October 2005, the baitfish were identified by the skipper of the vessel as jack mackerel (*Trachurus declivis*), also known as cowanyoung or horse mackerel, a small surface-schooling pelagic fish abundant in southeastern Australian waters (Williams & Pullen, 1993). Other small schooling fish common to the study area include redbait (*Emmelichthys nitidus*), pilchards (*Sardinops neopilchardus*), sandy sprat or whitebait (*Hyperlophus vittatus*), blue mackerel or slimy mackerel (*Scomber australasicus*), and yellowtail scad (*Trachurus novaezelandiae*) (Kailola et al., 1993; Williams & Pullen, 1993; Young et al., 2001).

On 7 October 2005, whales observed feeding on *T. declivis* were utilizing a slightly different feeding technique from that described above. Whales moved slowly through the water with their mouth open at an approximately 60 to 90° angle so that the upper jaw was extended vertically from the water (Figure 2). The whales skimmed the

Table 5. Mann-Whitney U analysis of differences in humpback whale feeding lunge frequency and mean feeding lunge interval when only one whale-watching vessel was present and when more than one whale-watching vessel was present; * significant at 0.05 probability level.

		n	Mean	Mean rank	SE	Test statistics	
Feeding lunge frequency (per min/per whale)	1 vessel	31	0.4	22.1	0.1	Mann-Whitney U	89.00
						Wilcoxon W	134.00
	> 1 vessel	9	0.2	14.9	0.1	Z	-1.64
						Asymp. Sig. (2-tailed)	0.10
Mean feeding lunge interval(s)	1 vessel	30	82	18	16	Mann-Whitney U	70.00
						Wilcoxon W	535.00
	> 1 vessel	9	132	27	27	Z	-2.17
						Asymp. Sig. (2-tailed)	0.03*

surface of the water column for extended periods (typically 4 to 5 s, maximum 17 s), which is longer than a typical lateral lunge feed during which the mouth is usually open for 2 s. A video-clip taken of a whale feeding in this manner can be seen at www.aquaticmammalsjournal.org/Video/index.htm.

Five of the 41 feeding pods comprised mother/calf pairs. At the time when mother/calf pods migrate through the study area (October through November), the calves are assumed to be between 12 to 16 wks of age. Typically, calves stayed near the mother while she fed, often rising beside her as she lunged with her mouth open (Figure 3a). On 16 October 2005, a calf rose vertically from the water column, opening and closing its mouth in the air with its ventral pleats slightly distended (Figure 3b). The calf appeared to be mimicking its mother's feeding lunges; the calf often displayed this behaviour shortly after the mother had performed a lateral lunge feed. This behaviour was observed 19 times over the 75-min observation period on 16 October 2005. For a video-clip sample of this behaviour, see www.aquaticmammalsjournal.org/Video/index.htm.

Defecation was observed on three occasions—once on 26 September 2005 and twice on 1 October 2005. The faecal sample collected on 1 October contained krill DNA, confirming that the whales had fed on krill recently.

Figure 3a. A humpback whale calf rising beside its mother while the mother is lateral lunge-feeding off Merimbula, southeastern NSW, on 16 October 2005 (Photo by W. Reynolds)

Figure 3b. The same calf as in Figure 3a rising vertically out of the water while opening its mouth with ventral pleats partially extended off Merimbula, southeastern NSW, on 16 October 2005 (Photo by W. Reynolds)

Discussion

There are many reports of humpback whales feeding in mid- to low-latitude waters during migration—not only for the Area V population of humpbacks in Australian and New Zealand waters (Dawbin, 1956; Gill et al., 1998; Stockin & Burgess, 2005), but also for the North Pacific (Gendron & Urban, 1993) and North Atlantic Ocean populations (Baraff et al., 1991; Swingle et al., 1993). While most of these reports probably represent opportunistic feeding events, the behaviour was relatively common on the NSW southeastern coast. The NSW southeastern coast may therefore be a significant feeding ground for humpback whales on their southward migration, especially when the oceanographic conditions are optimal for productivity.

Figure 2. A humpback whale with its mouth open at 90° skimming the surface of the water while feeding on baitfish off Narooma, southeastern NSW, on 7 October 2005 (Photo by K. Stamation)

Migration places large energetic demands on the whales, especially on pregnant, lactating, and post-lactating females (Brown & Lockyer, 1984). By the time the whales reach southeastern NSW waters, it has been several months since they left their Antarctic feeding grounds. It thus makes physiological sense that humpback whales use this area as a supplemental feeding ground when they encounter large prey patches. The increase in the number of feeding pods in 2005 may be explained by changes in the EAC system. AVHRR SST (sea surface temperature) data show that during the 2005 study period there was a strong warm current off the shelf that was often 2° C warmer than the currents in the same area during the 2002 and 2003 seasons.

Humpback whales have two main feeding techniques: (1) lateral lunge-feeding (feeding lunges without the use of a bubblenet) and (2) bubblenetting (creating a ring or cloud of bubbles before lunging up through its centre). All pods in this study used the lateral lunge-feeding technique. The use of bubble clouds to trap prey is most common in the North Atlantic when humpbacks feed on small schooling fish; it also has been seen in the North Pacific (Weinrich et al., 1992). In this study, feeding pods commonly consisted of two individuals, which is similar to observations of feeding whales in other areas (Weinrich & Kuhlberg, 1991; Gill et al., 1998). Dolphin (1987a, 1987b) found that dive duration correlated with depth. Pods were typically spending less than one minute below the surface and so prey must have been at or close to the surface layer. This is consistent with observations made by Gill et al. (1998).

In this study, many pods clearly displayed cooperative foraging, which has mostly been documented within fish schools (Weinrich & Kuhlberg, 1991). Foraging in a group may be more efficient with large mobile fish schools as they can be corralled more easily, and some fish may inadvertently swim into the mouth of an adjacent whale while fleeing a neighbouring one (Baker et al., 1982; Whitehead, 1983; Weinrich & Kuhlberg, 1991). Cooperative feeding was observed within both fish schools and krill patches in this study.

This study reports a humpback whale calf imitating its mother's lateral lunge-feeding on the southern breeding migration. Dawbin (1966) described similar displays by southbound calves in Foveaux Strait, New Zealand. Dawbin reported calves swimming with their mouths open through dense plankton swarms and suggested that calves could be consuming substantial amounts of solid food in addition to milk. The calf observed in this study did not appear to be successful in its lunge-feeding technique. The calf was estimated to be between 12 and 16 wks of age and it may have been its first attempts at lateral lunge-feeding. Although the weaning age is typically 10 to 12 mo (Clapham, 2000), unweaned calves have been observed feeding independently at 5 to 6 mo in the western North Atlantic. These calves probably begin learning the bubble cloud feeding technique through mimicry of their mother early in the weaning process (Clapham & Mayo, 1987).

It can be difficult to assess whether feeding whales are responding to the presence of a whale-watching vessel. Although typical avoidance responses in cetaceans are categorized as increased swimming speed and frequent changes in direction (Bauer & Herman, 1986; Baker & Herman, 1989; Bejder et al., 1999; Au & Green, 2000; Nowacek et al., 2001; Williams et al., 2002; Scheidat et al., 2004), both are also characteristic of foraging behaviour. Through a control versus impact comparison (Bejder & Samuels, 2003), we tested vessel effects. Collecting adequate control data sets can be difficult, especially in areas of high vessel traffic; therefore, we found that remote land-based vantage points provided an ideal platform to observe feeding whales in the absence of vessels.

Results from this study suggest that FLIs (i.e., the time between successive feeding lunges in a pod) are a more sensitive indicator of disturbance than feeding lunge frequency (i.e., the number of feeding lunges by each whale per minute). Unlike frequency measures, FLIs are sensitive to changes in the timing of feeding behaviour within an observation block and, thus, they are a better estimator of feeding activity. With this measure, the presence of one whale-watching vessel did not significantly change feeding behaviour relative to what it was in the absence of a vessel as long as the vessel was sitting idle or traveling at a no-wake speed at 100 m or greater separation away and parallel to the pod. Even so, a vessel can affect some pods as whales stopped feeding for more than 5 min and approached the idle vessel in 10% of observations ($n = 40$).

The presence of more than one whale-watching vessel consistently impacted on the pod's feeding behaviour, however, with longer intervals between feeding lunges relative to one vessel present. These results are consistent with those of Krieger & Wing (1986), who found that feeding humpbacks seldom responded if the vessel moved into the area at a slow, constant speed and that the reaction of the whales depended on, among other factors, the cumulative effect of more than one vessel.

Likewise, vessels (single or multiple) that moved in a manner inconsistent with current whale-watching regulations significantly increased a pod's FLI. This has important implications for management. We suggest that it is important that commercial operators and recreational vessel users are educated on how to maneuver vessels around feeding whales. The prey of humpback whales form schools or dense patches, which may be disrupted by moving vessels. Skippers need to be aware of the location of prey patches and make every attempt not to drive through and disturb these aggregations. Feeding whales often change their direction of travel, which makes it harder for the skipper to predict where they will surface next. We therefore recommend that operators stay at a conservative distance from all pods (e.g., 300 m) and observe the pod for several surfacings before moving to the 100-m approach limit. The skipper should wait for all members of the pod to surface before maneuvering the vessel to ensure that they do not approach within 100 m.

The commercial operators who participated in this study were very experienced, each having operated in the area for more than 16 y and generally followed the above recommendations. The experience of these operators should be used in developing education programs for new operators and recreational vessel users. It is also recommended that a limit of one whale-watching vessel within 300 m of a feeding pod be set.

Southeastern NSW waters are the only area where migrating humpback whales from the Antarctic Area V are known to feed regularly. Future management of the whale-watching industry should take into consideration the needs of feeding whales. It is important that both commercial whale-watching operators and recreational vessel users are educated on the importance of complying with the whale-watching regulations. If small schooling fish and *N. australis* are considered a significant food resource for humpback whales in this area, then their nutritional requirements may need to be considered in the management of the local small pelagic fisheries (e.g., the jack mackerel fishery) and in any future plans for the exploitation of *N. australis* stocks.

Acknowledgments

The Sustainable Tourism Cooperative Research Centre, an Australian Government initiative, funded this research in collaboration with the New South Wales Department of Environment and Conservation. The authors thank the operators and staff of Cat Balou Cruises, Merimbula Marina, and Narooma Charters for their support of the project. Without their generosity, the project could never have gone ahead. We acknowledge NSW Department of Environment and Conservation staff, in particular Sue Briggs, Craig Dickmann, Stephen Dovey, Ross Constable, and Preston Cope, for their continued support of the project, and staff at the Narooma office for their help in transporting and accommodating volunteers at Montague Island. We are also grateful to all the volunteer observers: Sandy Roadknight, Regan Deale, Peter Harris, Deborah Harcourt, Michael Stone, Xenia Schleuning, and Christina Henschel. We are grateful to Simon Jarman for faecal DNA analysis, Iain Suthers for identification of plankton samples, and Clem Stamation for editing the video clips. We thank Wayne Reynolds for allowing us to use his photographs. Finally, we thank Peter Corkeron for his constructive comments on the manuscript.

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