Tour operator data illustrate long term dusky dolphin (*Lagenorhynchus obscurus*) occurrence patterns near Kaikoura, New Zealand

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ABSTRACT

In Kaikoura, New Zealand, dusky dolphins (*Lagenorhynchus obscurus*), also termed "duskies", support a thriving tourism industry. The dolphin tour operator Encounter Kaikoura has been collecting dusky group locations using GPS coordinates since October 1995. These data describe the first group of dolphins encountered each tour, which is not a full indication of the location of all dolphin groups in the Kaikoura area. However, as the longest continuous record of dusky sightings near Kaikoura, the Encounter Kaikoura dataset provides a unique opportunity to assess dusky occurrence patterns over several temporal scales. Despite variance across seasons and years, there is a recurring seasonal pattern. In summer, duskies occur in near-shore shallow waters, frequently close to the Kaikoura Canyon head. In winter, dolphins occur farther offshore, often associated with the deeper waters of the Kaikoura Canyon axis and widely scattered throughout the study area. This onshore/offshore pattern is stable across the 12 years. The dusky dolphins' distribution along shore, particularly during summer months, changes during the study period. There is a greater incidence of duskies in the southernmost regions of the study area during the late 1990's than in later years. The dolphins' affinity for the Kaikoura Canyon may reflect a strategy to maximize access to prey; duskies in Kaikoura feed at night on the Deep Scattering Layer as it rises to the surface. We are presently investigating the role of predators such as killer whales, prey availability and human activities on dusky dolphin daytime occurrence patterns. Because of it's greater than 10 year duration and ability to collect information at times when researchers are not in the field, the Encounter Kaikoura data are a valuable asset to these ongoing studies.

KEY WORDS: WHALEWATCHING, DUSKY DOLPHIN, NEW ZEALAND, MONITORING, DISTRIBUTION

INTRODUCTION

Dusky dolphins (*Lagenorhynchus obscurus*), also termed "duskies", are small, coastal to semi-pelagic dolphins found in New Zealand's near-shore waters (Würsig *et al*., 1997). In Kaikoura, New Zealand, duskies are both ecologically and economically important. As upper level predators capable of consuming large amounts of prey, dolphins may influence ecosystem function (Kenney *et al*., 1997). Their year-round presence and acrobatic displays have allowed a dolphin tourism industry to develop and prosper (Barr and Slooten, 1999; Duprey, 2007). Conservationists and tour operators alike have a vested interest in duskies continuing to thrive in Kaikoura.

New Zealand's Department of Conservation, the agency responsible for managing marine mammals in New Zealand waters, lists '…to better understand…key habitat requirements' as a key objective for dusky dolphin management (Suisted and Neale, 2004). Marine mammal habitat use patterns are commonly related to abiotic factors such as bottom depth (Bräger *et al*., 2003; Yen *et al*., 2004), distance from shore (Elwen and Best, 2004; Parra et al., 2006) and sea surface temperature (Neumann, 2001). These factors may directly influence habitat selection or serve as a proxy for prey availability measures (Neumann, 2001; Würsig and Würsig, 1980). Cetacean habitat selection may be further influenced by attempts to avoid anthropogenic disturbance (Bejder *et al*., 2006b; Lusseau, 2004; Lusseau 2005).

Cetaceans exhibit habitat preferences based at least in part on water depth. In shallow areas, small differences in depth (on the order of 10m) influence habitat selection by bottlenose dolphins (*Tursiops truncatus*) in the Sado Estuary, Portugal (Harzen, 1998) and Hector's dolphins (*Cephalorhynchus hectori*) inhabiting New Zealand's near shore waters (Bräger *et al*., 2003). At larger scales , cetaceans are often associated with bathymetric features such as submarine canyons, shallow banks, and continental shelf breaks (Yen *et al*., 2004). Bathymetric preferences may reflect efforts to improve foraging success (Benoit-Bird and Au, 2003; Elwen and Best, 2004a; Yen *et al*., 2004) or avoid disturbances such as predation (Constantine *et al.*, 1998; Heithaus and Dill, 2006; Weir, 2007; Würsig and Würsig, 1980). At night, Hawaiian spinner dolphins (*Stenella longirostris*) feed in deep water on mesopelagic fishes and squid of the rising Deep Scattering Layer (Benoit-Bird and Au, 2003). In Shark Bay, Western Australia, during seasons of higher tiger shark (*Galeocerdo cuvier*) abundance, Indian Ocean bottlenose dolphins (*Tursiops aduncus*) prefer deep-water channels where they can more easily escape attack (Heithaus and Dill, 2006).

Distance from shore influences habitat selection of coastal cetacean species (Bräger *et al.*, 2003; Elwen and Best, 2004a; Parra *et al*., 2006). Near-shore waters may offer protection from predation, or provide nursery habitat for cetaceans. Hawaiian spinner dolphins rest in near-shore waters during the day probably due to lower levels of shark predation than in the open sea (Norris and Dohl, 1980). In rougher waters, the surf zone may provide protection from killer whale (*Orcinus orca*) attacks (Constantine *et al*., 1998). Additionally, mothers with calves may select protected near-shore habitat (Elwen and Best, 2004b; Weir, 2007).

There is a growing concern that boat traffic affects marine mammal behavior (Barr and Slooten, 1999; Bejder *et al*., 2006a; Bejder *et al.*, 2006b; Constantine *et al*., 2004; Lusseau, 2004; Yin, 1999). Several studies assess immediate or short-term effects of boat activity on dolphin behavior (e.g. Bejder *et al.*, 1999; Constantine *et al.*, 2004; Lusseau 2003), but few have addressed long-term effects on cetacean habitat selection. In Shark Bay, Western Australia, over a 14 year period, Indian Ocean bottlenose dolphins living in an area exposed to tourism declined in relative abundance with increasing tourism activity; there was no decline in adjacent tourism free areas (Bejder *et al*., 2006b). It is likely that some individuals relocated to the tourism free area. (Bejder *et al*., 2006b). Similarly, bottlenose dolphins off the north coast of New Zealand's South Island spend less time in Milford Sounds when boat traffic levels are high (Lusseau, 2005). For the Kaikoura area, there was speculation in the late 1990's that increased tourism might have caused duskies to shift their preferred habitat south, away from the busy commercial boat ramp (Brown, 2000; Würsig *et al.*, 1997; Yin, 1999).

Research on duskies has been conducted sporadically near Kaikoura since 1984 (Würsig *et al*., 2007), but since October 1995, Encounter Kaikoura (http://www.encounterkaikoura.co.nz) skippers have been recording dusky locations on most good weather days. The Encounter Kaikoura dataset represents the longest continuous all-season record of duskies in the area. It provides a unique opportunity to examine effects of abiotic factors on dusky dolphin long-term occurrence patterns and to explore how these patterns change over time. Because of the long-term collaboration between Texas A&M University and Encounter Kaikoura, the data collection process is standardized and researchers have access to a large dataset that would be difficult to build and maintain without tour operator support. We test the hypotheses that duskies have seasonally specific preferences for depth, distance to the Kaikoura submarine canyon edge, and distance to shore. Further, we test whether dusky dolphin occurrence patterns during summer, when tourist numbers are highest, were consistent between 1995-2000 and 2001-2006.

METHODS

Encounter Kaikoura tourism vessels search for dolphins in an approximately 2,800 km^2 area, which includes about 90 km of coastline and some of the Kaikoura Canyon system (Fig. 1). Tours depart daily at 05:30 AM, 8:30 AM and 12:30 PM; the early tour runs only when tourist numbers are high, between October and April. Boats typically leave the South Bay Harbor (42°25'31" S, 173°40'53" E), in the middle of the permitted area, and head south until dolphins are found. Skippers record GPS coordinates to the nearest one tenth of a minute when they first approach the dolphin group. This dataset is therefore a measure of group closeness to the commercial on-shore boat harbor during tour times, and not a fair indication of location of all dolphin groups in the Kaikoura area. Skippers estimate group size with each GPS location, however the definition of 'group' was not consistent between skippers or years; group size is not discussed in this study. In addition, skippers record the presence of other cetaceans, such as killer whales, in the area.

From October 1995 to November 2006 there are more than 5,000 useable dusky sighting records spread unevenly across years and seasons and 138 instances of killer whales in the permit area. Summer months, with better weather and higher tourist numbers, are best represented with 1,792 records. Winter months are least represented with 755 records. The records were analyzed using ArcGIS 9.1, Arcview 3.3 and SPSS 13. All spatial data, including a shapefile of the NZ coastline (courtesy of Eagle Technology, Wellington, NZ) were projected to the New Zealand Transverse Mercator Projection 2000, which provides the most accurate spatial reference for the study area (Land Information New Zealand, 2001). Data were grouped by season across the twelve year period, defining winter as June 1- August 31, spring as September 1- November 30, summer as December 1- February 29 and fall as March 1- May 31.

Analyses proceeded in two different phases. First, depth and distance-to-feature measurements were associated with each point. We used bathymetry lines, developed by Lewis and Barnes (1999) with an accuracy of ± 2m and distributed by New Zealand's Institute of Water and Atmospheric Research (NIWA), to create a continuous model of depth at 30m resolution using the Topogrid command in ArcInfo. The Nearest Features extension for ArcView 3.3 (Jenness, 2004) calculated distance-to-feature variables. The 150m isobath poly line, the average depth of the continental shelf break (Garrison, 1999), represents the canyon edge and access to deep water prey preferred by duskies in Kaikoura (Benoit-Bird *et al.*, 2004; Cipriano 1992). When calculating distance to the canyon, all occurrences in waters deeper than 150m were assigned a zero distance. Seasonal means for each factor were calculated, and the distributions compared using the non-parametric Kruskal-Wallis test in SPSS 13.0 (SPSS, 2004). To examine potential effect of unequal samples sizes on our results (Winter= 755, Spring= 1175, Summer= 1792, Fall= 1647), we used all 755 winter points and created five random subsets of 755 samples from each season other than winter. We tested these five subsets as well as the full dataset, and found that means were similar for the random sets and the full data set, allowing us to use the full data set for subsequent tests presented in 'Results'.

In the second phase, areas occupied by duskies were compared using Kernel Home Range (KHR) probability polygons. We used the Animal Movement Extension 2.0 for Arcview 3.3 (Hooge and Eichenlaub, 2000) and ad hoc smoothing parameters to create 50% and 95% KHR's for each season and for summers grouped by year, 1995-2000 and 2001-20006. The program does not recognize that land is not accessible to dolphins and, therefore, the western edges of some KHR's overlapped land. We clipped the KHR's to eliminate this overlap. KHR analysis is further sensitive to the numbers of points used to generate the polygons. Numbers of points used to generate seasonal KHR's were highly unequal, but numbers of points used to generate summer KHR's separated by year were similar (1995-2000= 830, 2001-2006 = 962). Because of clipping and dissimilarity in numbers of points, we can compare only general trends in north- south location and size, but not absolute areas of the KHR's.

RESULTS

Mean depth was deepest during winter (411m) and spring (386m) and shallowest during summer (131m) and fall (165m). Distance to the canyon was farthest during summer (1.58km) and fall (1.23km) and nearest during spring (0.23 km) and winter (0.60km). Distance to shore was farthest for winter (6.32km) and spring (4.51km) occurrences and nearest for summer (1.82km) and fall (2.14km) occurrences. Kruskal-Wallis tests confirmed that seasonal occurrences differed significantly in terms of depth (χ^2=1379, p<0.000, df=3), distance to shore (χ^2=1792, p<0.000, df=3), and distance to canyon (χ^2=1039, p<0.000, df=3). Dolphins exhibited seasonally specific preferences for all three abiotic factors. On average, at all times of year, duskies were closer to the canyon than shore.

There are 138 recorded instances of killer whales in the Kaikoura area. Killer whales were seen in every season (Winter n=6, Spring n=35, Summer n= 58, fall n= 39). Approximately half of the spring sightings occurred during the last two weeks of the springs of 1996, 2000, 2003, and 2004.

KHR analyses showed seasonal differences in shape and size of the 95% and 50% probability polygons. Winter had the largest 95% and 50% KHR (668.41km^2 and 109.59km^2 respectively) while summer sightings were concentrated in much smaller 95% and 50% KHR's (115.31km^2 and 15.07km^2 respectively) (Fig. 2). Spring and fall were intermediate in both size and location. Areas enclosed by 95% KHR's representing summers of 1995-2000 (129.99km^2) and 2001-2006 (114.69km^2) were very similar, but the 95% KHR for summers of 1995-2000 was farther south than in later years (Fig. 3). However, 50% KHR's were in nearly identical locations and occupied roughly the same amount of area (14.01 km^2 for 1995-2000 and 19.01 km ^{2} for 2001-2006). All KHR's included the Kaikoura Canyon head.

DISCUSSION

While there is annual variability, duskies exhibit clear seasonal occurrence patterns. These patterns are evident in depth, distance from shore, distance to canyon and 95% and 50% KHR's. In summer, sightings occur in a relatively small area near shore and are closely associated with the Kaikoura Canyon head; in winter, sightings are spread throughout a larger portion of the study area, are further offshore, and are frequently associated with the canyon axis (Fig. 3). Fall and spring show intermediate patterns. Seasonal occurrences could be influenced by prey availability (Bearzi *et al.*, 1999; Cipriano, 1992; Wilson *et al.*, 1997; Würsig and Würsig, 1980), predator attendance patterns (Heithaus and Dill, 2006; Wirsing, 2007), anthropogenic disturbance (Lusseau, 2005), or factors not captured in this dataset.

Dolphins often choose habitat to match prey patterns (Bearzi *et al*., 1999; Wilson *et al*., 1997). Dusky bathymetric and distance-to-shore preferences may reflect a strategy to maximize access to prey. In Kaikoura, duskies feed at night on the Deep Scattering Layer, a community of fish and invertebrates that rises towards the surface at night (Benoit-Bird *et al.*, 2004; Cipriano, 1992). If prey availability influences dusky occurrence patterns, duskies should have a strong association with deep water year round. During all seasons, on average, duskies were found closer to deep water than to shore and, all 50% and 95% KHR's overlap with the Kaikoura canyon head (Fig. 2). Further, dusky dolphins' shift offshore in winter may reflect changing patterns of prey availability (Cipriano, 1992). Studies of fish communities about 150km southwest of Kaikoura reveal a winter shift offshore into deeper water for many species, including the arrow squid, *Nototodarus sloanii* (Beentjes *et al.*, 2002), an important dusky prey item (Cipriano, 1992). In winter, duskies may be following squid and other prey offshore.

The level of predation risk from killer whales may also influence dusky dolphin occurrence patterns. When killer whales are present, duskies often swim rapidly towards shore and continue alongshore (Cipriano, 1992; Weir, 2007), presumably using the shallow waters as a predation refuge (Constantine *et al.,* 1998; Norris and Dohl, 1980; Würsig and Würsig, 1980). Dusky preference for near shore shallow waters in summer and fall may be the long-term consequence of a killer whale avoidance strategy. Of 138 killer whale sightings recorded by Encounter Kaikoura skippers, 97 are reported in summer and fall (December-May) when duskies are found closest to shore. About one-half of spring sightings occurred during the last two weeks of spring of four years. During times of year when killer whale attendance is typically high, duskies may choose habitat to minimize detection or capture by predators rather than solely matching patterns of prey availability, a pattern which has been documented in bottlenose dolphins (*Tursiops aduncus*) and dugongs (*Dugong dugong*) in Western Australia (reviewed in Wirsing, 2007).

Seasonal changes in occurrence patterns may also be influenced by changes in dolphin demographics not captured in these data. Summer groups contain calves and exhibit predictable daily activity and onshore/offshore movement patterns. The sheltered waters of Goose Bay, near the Kaikoura Canyon head, are important to nursery groups (Weir, 2007). On a daily basis, mothers may balance the need for protected waters for their calves (Elwen and Best, 2004b) and access to deep-water food for themselves. Winter groups contain no infants and may value habitat features differently. For dolphins without calves, the offshore waters of the canyon may be more attractive.

In summer, dolphins occurred in approximately the same core areas (50% KHRs) across the study period (Fig. 3), reinforcing the importance of the Kaikoura Canyon head and nearby shallow waters. However, the 95% KHR's reflect that the tour boats made significantly more trips to the southernmost portion of the study area during the summers of 1995-2000 than in later years (Fig. 3). During the late 1990's it was therefore speculated that increased tourism pressure might cause the dolphins to shift their preferred habitat south away from port (Brown, 2000; Würsig *et al.*, 1997; Yin, 1999). Since that time, tourism has not decreased, but the boats no longer need to make as many trips to the southernmost extent of the study area to find dolphins. Currently, there is no definitive explanation for these changes. Inter-annual variation, potentially related to changes in prey habitat use and abundance, may be mainly responsible for the alongshore shifts.

The Encounter Kaikoura data set does not include information regarding number of boats and boat behavior, so we can not directly examine the effects of tourism on duskies in Kaikoura. In several near-shore areas where dolphins number in the hundreds, groups exposed to tourism activity have shown relocation out of high traffic areas (Bejder *et al*., 2006; Lusseau, 2005), and significant changes in activity budget (Constantine 2004; Lusseau, 2003; Lusseau, 2004). However, duskies in Kaikoura may be buffered against these effects. Approximately 1,900 duskies of a population of over 12,000 individuals are present in Kaikoura at any one time (Markowitz, 2004), and the tour boats preferentially target large groups (this dataset, unpublished), thus effectively diluting tourism interaction experienced by individual dolphins. While duskies primarily rest and socialize during the day (Barr and Slooten, 1999; Markowitz, 2004) the two activity states which have been shown to be most vulnerable to disturbance in bottlenose dolphins (Constantine *et al.,* 2004; Lusseau, 2003), Encounter Kaikoura voluntarily respects a midday rest period of 11:30- 13:30 from December 1 to March 31 and does not visit dolphins when they are most likely to be resting (Barr and Slooten, 1999; Duprey, 2007). It is encouraging that after nearly 20 years of dolphin tourism in Kaikoura, duskies still seem to be thriving. They have maintained preferred habitat close to the commercial boat ramp, summer core habitat has not greatly changed over the 12 year dataset, and dolphins are still present in large numbers year round.

CONCLUSIONS

The Encounter Kaikoura dataset describes strong seasonal patterns that are consistent across years, despite inter-annual variation. Seasonal preferences for water depth and distance to shore may reflect a strategy to maximize access to deep water prey while balancing the need for near-shore predation refuges. Further investigations of prey patterns, predator patterns, human disturbance and other factors are needed to clarify inter-annual and seasonal patterns. Encounter Kaikoura skippers are continuing to collect data and develop the dataset in collaboration with researchers from Texas A&M University. These continued efforts will help us to better understand long-term dusky dolphin occurrence patterns.

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REFERENCES

Barr, K. and Slooten, E. 1999. Effects of tourism on dusky dolphins at Kaikoura. *Conservation Advisory Science Notes* no. 229, Department of Conservation Wellington.

Bearzi, G. Politi, E., di Sciara, N. G. 1999. Diurnal behavior of free-ranging bottlenose dolphins in the Kvarneric (northern Adriatic Sea). *Marine Mammal Science* 15 (4): 1065-1097

Beentjes, M. P., Bull, B., Hurst, R. J. and Bagley, N. W. 2002. Demersal fish assemblages along the continental shelf and upper slope of the east coast of the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 36(1): 197-223.

Bejder, L., Samuels, A., Whitehead, H. and Gales, N. 2006a. Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal Behaviour 72*: 1149-1158.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C. and Krutzen, M. 2006b. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology* 20:1791-1798.

Benoit-Bird, K. J. and Au, W. W. L. 2003. Prey dynamics affect foraging by a pelagic predator (*Stenella longirostris*) over a range of spatial and temporal scales. *Behavioral Ecology and Sociobiology* 53:364-373.

Benoit-Bird, K. J., Würsig, B. and McFadden, C. J. 2004. Dusky dolphin (*Lagenorhynchus obscurus*) foraging in two different habitats: active acoustic detection of dolphins and their prey. *Marine Mammal Science* 20(2): 215-231.

Bräger, S., Harraway, J. A. and Manly, B. F. J. 2003. Habitat selection in a coastal dolphin species (*Cephalorhynchus hectori*). *Marine Biology* 143(2): 233-244.

Brown, N.C, 2000. The dusky dolphin, *Lagenrhynchus* [sic] *obscurus*, off Kaikoura, New Zealand: A long term comparison of behaviour and habitat use. Masters Thesis, University of Auckland, Auckland, New Zealand.

Cipriano, F. 1992. *Behavior and occurrence patterns, feeding ecology, and life history of dusky dolphins (Lagenorhynchus obscurus) off Kaikoura, New Zealand.* Doctoral Thesis University of Arizona. 216pp.

Constantine, R., Visser, I., Buurman, D., Buurman, R. and McFadden, B. 1998. Killer whale (*Orcinus orca*) predation on dusky dolphins (*Lagenorhynchus obscurus*) in Kaikoura, New Zealand. *Marine Mammal Science.* 14(2): 324-330.

Constantine, R., Brunton, D. H. and Dennis, T. 2004. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation* 117: 299-307

Duprey, N. M. T. 2007. Dusky dolphin (*Lagenorhynchus obscurus*) behavior and human interactions: implications for tourism and aquaculture. Masters Thesis, Texas A&M University, College Station, USA.

Elwen, S. H. and Best, P. B. 2004a. Environmental factors influencing the distribution of southern right whales (*Eubalaena australis*) on the south coast of South Africa I: broad scale patterns. *Marine Mammal Science.* 20(3): 567-582.

Elwen, S. H. and Best, P. B. 2004b. Environmental factors influencing the distribution of southern right whales (*Eubalaena australis*) on the south coast of South Africa II: within bay distribution. *Marine Mammal Science* 20:583-601.

Garrison, T. 1999. *Oceanography: an invitation to marine science* (Third ed.). Wadsworth Publishing Company. Belmont, CA, 552pp.

Harzen, S.. 1998. Habitat use by the bottlenose dolphin (*Tursiops truncatus*) in the Sado estuary, Portugal. *Aquatic Mammals* 24:117-128.

Heithaus, M. R. and Dill, L. M. 2006. Does tiger shark predation risk influence foraging habitat use by bottlenose dolphins at multiple spatial scales? *Oikos.* 114(2): 257-264.

Hooge, P. N. and Eichenlaub, B. 2000. Animal Movement Extension to Arcview ver. 2.0. Anchorage, AK, USA: Alaska Science Center- Biological Science Office, U.S. Geological Survey.

Kenney, R. D., Scott, G. P., Thompson, T. J. and Winn, H. E. 1997. Estimates of prey consumption and trophic impacts of cetaceans in the USA northeast continental shelf ecosystem. *Journal of Northwest Atlantic Fishery Science.* 22: 155-171.

Land Information New Zealand. 2001. New Zealand Transverse Mercator Projection. Land Information Fact Sheet. http://www.linz.govt.nz/docs/miscellaneous/nztm.pdf.

Lewis K. B. and Barnes, P. L. 1999. Kaikoura Canyon, New Zealand: active conduit from near-shore sediment zones to trench-axis channel. *Marine Geology* 162:39-69.

Lusseau, D. 2003. Effects of tour boats on the behavior of bottlenose dolphins: using Markov chains to model anthropogenic impacts. *Conservation Biology* 17(6): 1785-1793.

Lusseau, D. 2004. The hidden cost of tourism: detecting long-term effects of tourism using behavioral information. *Ecology and Society* 9 (1):2 [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art2

Lusseau, D. 2005. Residency patterns of bottlenose dolphins *Tursiops* spp in Milford Sound, New Zealand, is related to boat traffic. Marine Ecology Progress Series 295:265-272.

Markowitz, T. 2004. Social organisation of the New Zealand dusky dolphin. Doctoral Thesis. Texas AandM University. 278 pp.

Neumann, D. R. 2001. Seasonal movements of short-beaked common dolphins (*Delphinus delphis*) in the north-western Bay of Plenty, New Zealand: influence of sea surface temperature and El Nino/La Nina. *New Zealand Journal of Marine and Freshwater Research.* 35(2): 371-374.

Norris, K. S. and Dohl, T.P. 1980. The behavior of the Hawaiian spinner dolphin, *Stenella longirostris*. *Fishery Bulletin* 77(4): 821-849.

Parra, G., Schick, R. and Corkeron, P. 2006. Spatial distribution and environmental correlates of Australian snub-fin and Indo-Pacific humpback dolphins. *Ecography.* 29(3): 396-406.

SPSS. (2004). SPSS Base 13.0 for Windows User's Guide. Chicago, IL: SPSS Inc.

Suisted, R. and Neale, D. 2004. *Department of Conservation marine mammal action plan 2005-2010*. Wellington, New Zealand: Department of Conservation. 89pp.

Weir, J. S. 2007. *Dusky dolphin nursery groups off Kaikoura, New Zealand.* Texas A and M University. 65pp.

Wilson, B., Thompson, P.M. and Hammond, P. S. 1997. Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *Journal of Applied Ecology* 34(6): 1365-1374.

Wirsing, A. 2007. Seascapes of fear: evaluating sublethal predator effects experienced and generated by marine mammals. Marine Mammal Science 24 (1): 1-15.

Würsig, B., Cipriano, F., Slooten, E., Constantine, R., Barr, K. and Yin, S. 1997. Dusky dolphins (*Lagenorhynchus obscurus)* off New Zealand: status of present knowledge. *Rep. Int. Whal. Commn.* 47: 715-722.

Würsig, B., Duprey, N. M. T. and Weir, J. S. 2007. Dusky dolphins (*Lagenorhynchus obscurus)* in New Zealand waters: status of present knowledge and research goals. *DOC Rsearch and Development Series* no. 270, Department of Conservation, Wellington.

Würsig, B. and Würsig, M. 1980. Behavior and ecology of the dusky dolphin, *Lagenorhynchus obscurus*, in the south Atlantic. *Fishery Bulletin.* 77(4): 871-890.

Yen, P. P. W., Sydeman, W. J. and Hyrenbach, K. D. 2004. Marine bird and cetacean associations with bathymetric habitats and shallow-water topographies: implications for trophic transfer and conservation. *Journal of Marine Systems.* 50(1-2): 79-99.

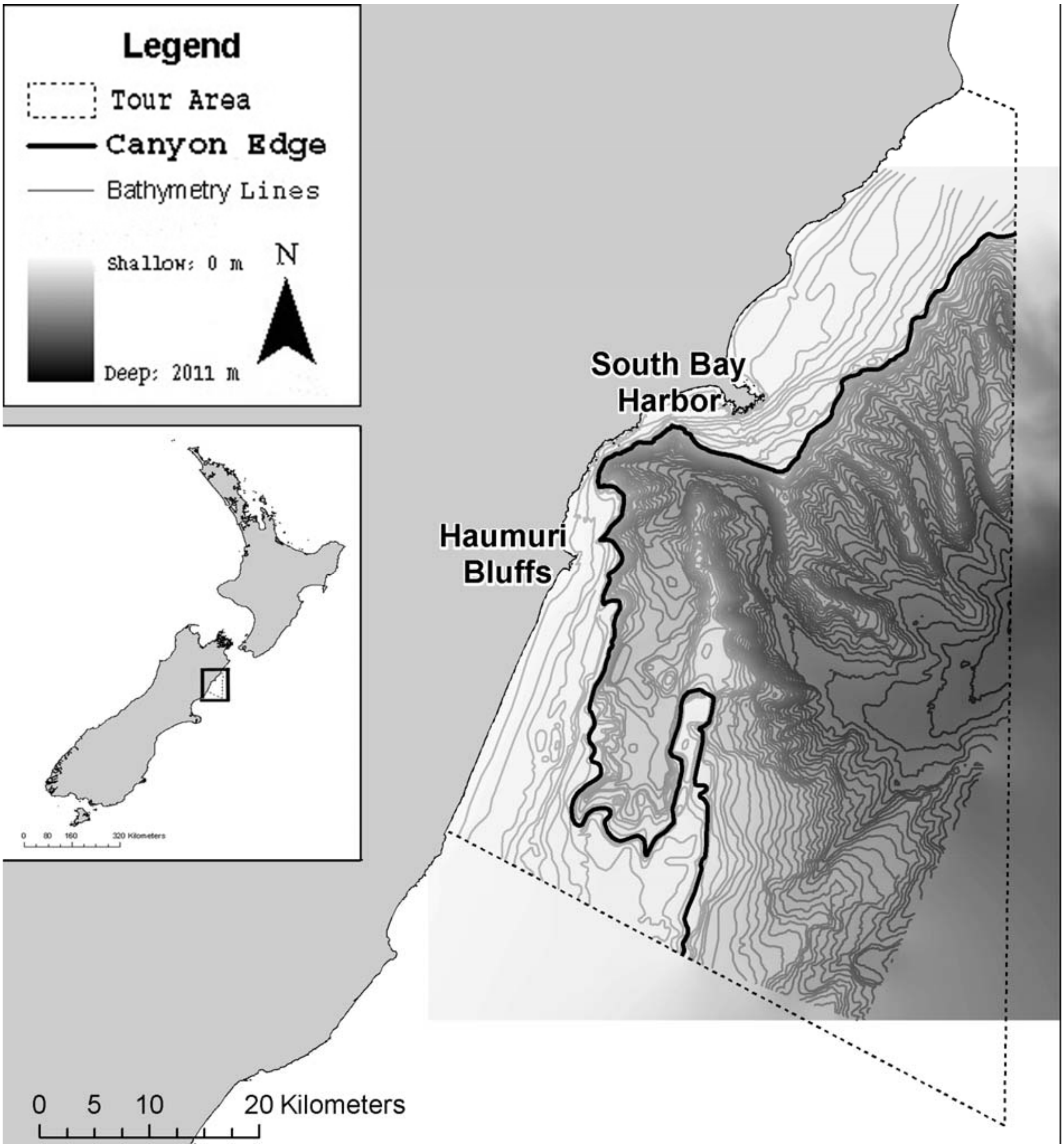

Figure 1: *The area in which tour boats focus their searches is outlined by a dotted line. The commercial dolphin watching permit sets the north and south boundaries, but does not define an offshore limit. The Canyon Edge is marked at 150 m depth. Detailed bathymetric data exist for most of this area. The South Bay Harbor, where all of the dolphin tour boats launch, and Haumuri Bluffs, an important southern landmark for the skippers, are noted on the map.*

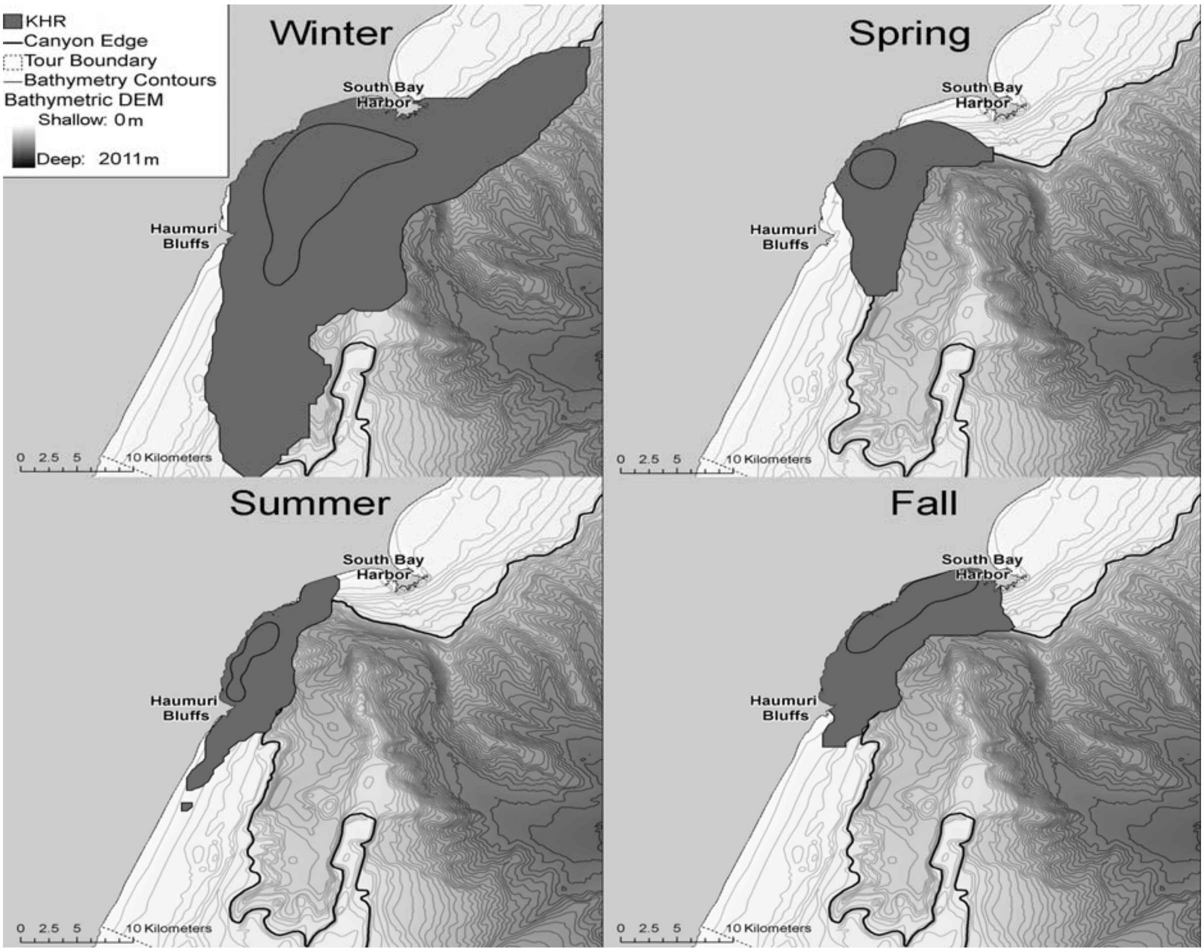

Figure 2: *The seasonal KHR's are displayed in separate panes. The outer edge of the KHR represents the 95% KHR, the outline nested inside illustrates the extent of the 50% KHR. In winter, duskies are difficult to find and are not often in similar areas from day to day. This variability is reflected in the largest 50% and 95% KHR's. In summer, duskies are highly predictable, often occurring very close to shore between the South Bay Harbor and Haumuri bluffs. This is reflected by the smallest 50% and 95% KHR's.*

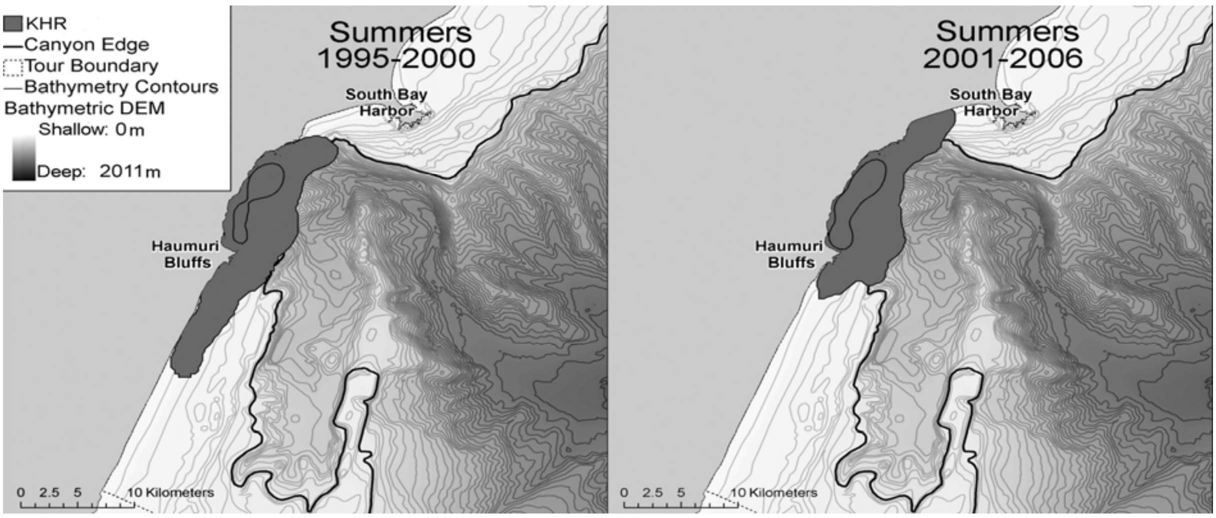

Figure 3: 95% KHR's illustrate that the boats had to make more trips in the southernmost part of the tour area to see dolphins in the late 1990's than in later years. However, 50% KHR's are comparable in area and location between the first and second half of the dataset, indicating that for the most part, the summer tours have been focusing on the same core areas since the 1990's.