Factors Affecting the Occurrence and Demographics of Common Dolphins (*Delphinus* sp.) in the Hauraki Gulf, New Zealand

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Abstract

The common dolphin (*Delphinus* sp.) is the most frequently observed cetacean species in the Hauraki Gulf, a large shallow body of water on the northeastern coastline of North Island, New Zealand. Herein, we present the first data relating to the occurrence and distribution of common dolphins in this region and assess the possible effects of abiotic parameters on the demographics of this population. The presence of associated marine species is quantified, and differences in the occurrence and demographics of single and multi-species groups are examined. Sightings data were collected between February 2002 and January 2005 during boat-based surveys. We recorded 719 independent encounters with common dolphins, involving 1 to > 300 animals. Dolphin presence was significantly affected by month, latitude and depth. Group size varied significantly by month, season, depth, sea surface temperature (SST) and latitude, and was highly skewed towards smaller groups made up of < 50 animals. Larger aggregations were most frequent during the austral winter when nutrient upwelling typically leads to increased prey availability within the region. Over 70% of groups encountered contained immature animals and 25% of groups included neonates. Calves were observed throughout the year but were most prevalent in the austral summer months of December and January. Month, season, depth, and SST significantly affected group composition. Common dolphins were observed in association with four cetacean and eight avian species, most frequently with the Australasian gannet (*Morus serrator*) and the Bryde's whale (*Balaenoptera brydei*). The distribution of dolphin-only groups differed significantly from that of dolphin-whale groups, with mono-specific groups found on average in waters that were 3.6 m shallower and 3.1°C warmer. The year-round occurrence and social organisation of common dolphins in Hauraki Gulf waters suggest this region is important both as a calving and nursery ground.

Key Words: common dolphin, *Delphinus*, occurrence, demographics, prey, calving, nursery, predation, Hauraki Gulf, New Zealand

Introduction

The range and distribution of any animal population reflects the complex relationships between a variety of environmental and social factors. Many studies have reported relationships between cetacean distribution and abiotic parameters—for example, sea floor profile (Hui, 1979; Selzer & Payne, 1988), thermocline (Reilly, 1990), and sea surface temperature (SST) (Gaskin, 1968; Dohl et al., 1986; Bräger & Schneider, 1998). However, the influence of such factors is often considered to be indirect since prey distribution is also likely to be affected by oceanographic variables. The primary biotic parameters considered to influence cetacean distribution include prey availability (Cockcroft & Peddemors, 1990; Murase et al., 2002; Baumgartner et al., 2003), predation (Corkeron & Connor, 1999; Palomares & Caro, 1999; Clapham, 2001) and competition (Polacheck, 1987; Clapham & Brownell, 1996). New Zealand common dolphins (*Delphinus* sp.) move further inshore during what appears to be the main reproductive season (Bräger & Schneider, 1998; Neumann, 2001). Whether these movements, however, are related solely to reproductive requirements or reflect changes in prey distribution remains unclear.

Common dolphins are generally considered to be mesopelagic (Gaskin, 1992) and are found worldwide in a diversity of temperate, subtropical, and tropical marine habitats (Jefferson et al., 1993; Perrin, 2002). *Delphinus* occurs around much of the New Zealand coastline, especially off the east coast of the North Island (Gaskin,

1968; Bräger & Schneider, 1998). However, their occurrence, especially in southern waters, appears to be restricted by a seasonal influx of cooler water (Webb, 1973). Within New Zealand waters, the southern limit of their distribution is considered to be 44º S near Banks Peninsula in the South Island, with their abundance presumed to increase with decreasing latitude (Gaskin, 1968).

Common dolphins are assumed to be one of the most abundant marine mammals in New Zealand waters and are the most frequently observed cetacean in the Hauraki Gulf (O'Callaghan & Baker, 2002). No population estimates exist for the New Zealand population, however, and there is little published information on their distribution, habitat use, or social organisation. Herein, we present the first data relating to the demographics of common dolphins in the Hauraki Gulf. We examined the occurrence, distribution, and social structure of this species in relation to sea depth

and SST, and we discuss the importance of prey availability, predation, and competition for dolphins in this region. We also examined evidence that the region is important as a calving and/or nursery ground.

Materials and Methods

Study Site
The Hauraki Gulf (Figure 1) is a shallow (60 m maximum depth), semi-enclosed body of temperate water (Manighetti & Carter, 1999), extending from Bream Head to Cape Colville at the northern tip of the Coromandel Peninsula on the east coast of North Island, New Zealand (Latitude: 36º 10' to 37º 10' S; Longitude: 174º 40' to 175º 30' E). Influenced by the subtropical East Auckland Current (EAUC), the Hauraki Gulf is an extremely productive region (Booth & Sondergaard, 1989), exhibiting a high diversity
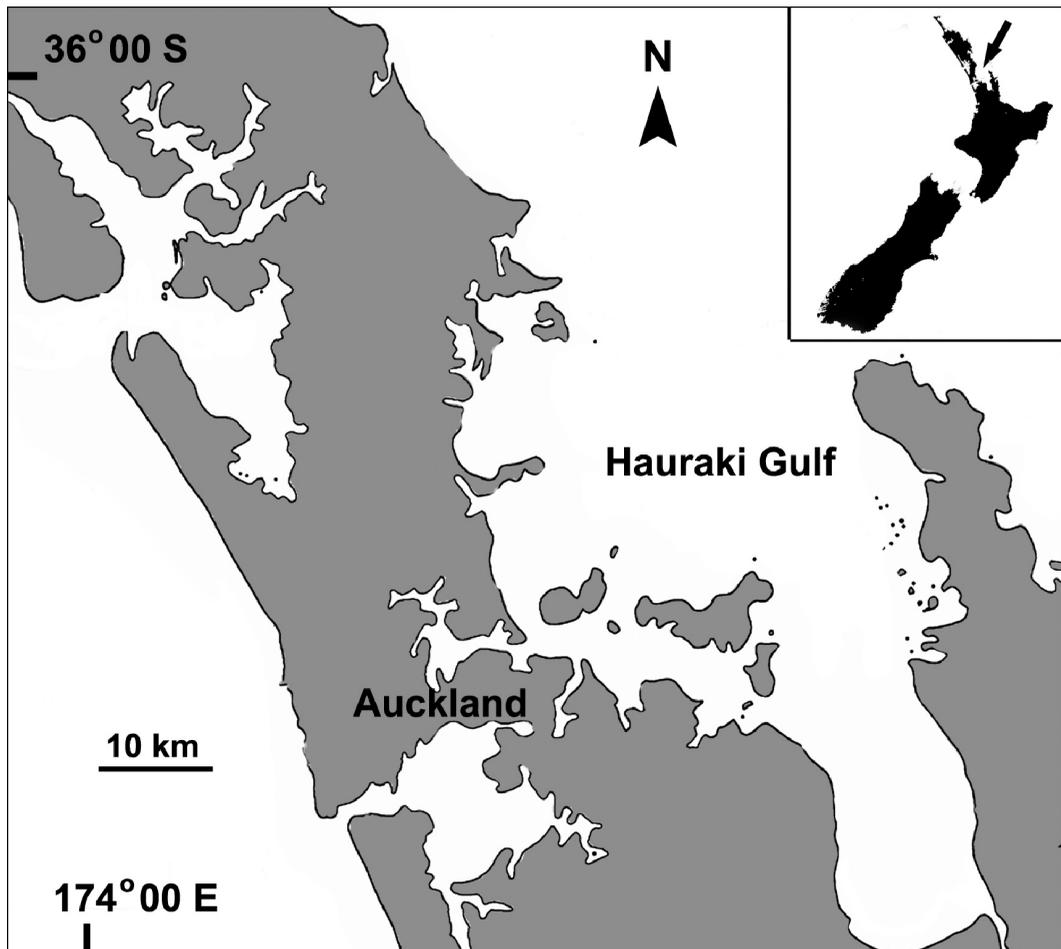

Figure 1. Map showing location of the Hauraki Gulf, New Zealand

of biological fauna. Winds also have a strong influence on the circulatory patterns and productivity of this marine ecosystem. In late austral winter and spring, upwellings produced by prevailing westerly winds result in high levels of nutrient availability associated with some of the highest spring chlorophyll-a levels on the New Zealand continental shelf (Chang et al., 2003). In the austral summer, easterly winds dominate, leading to downwellings and the movement of warm, nutrient-poor waters towards the coast (Proctor & Greig, 1989).

Data Collection
Observations of dolphins were conducted from *Aihe*, a 5.5-m centre-console, inflatable boat fitted with a 90-hp four-stroke outboard engine, and *Dolphin Explorer*, a 20-m catamaran powered by twin 350-hp power diesel engines. Observer eye height for the two vessels was 0.5 m and 5 m, respectively. Since platform height is known to affect the detectability of cetaceans at sea, survey conditions were assessed in relation to the observational platform used (Hammond et al., 2002). Owing to the lower eye height of *Aihe*, and consequent reduced detectability of cetaceans, only surveys conducted in good visibility (≥ 1 km) and in $\leq$ Beaufort 2 were used in the analysis. Data collected from onboard *Dolphin Explorer* were included when visibility was good (≥ 1 km) and in Beaufort 4 or less. The survey speeds varied between platforms and ranged from 5 to 15 kts.

Observations were conducted by experienced observers using a continuous scanning methodology (Mann, 1999), by naked-eye and with binoculars (Bushnell 8×42 magnification). Sighting cues used to detect dolphins include splashing and/ or silhouettes of porpoising animals, water disturbance due to surface activity of animals, sighting of dorsal fins, and/or the presence of key indicator species within the area, namely the Australasian gannet (*Morus serrator*) and Bryde's whale (*Balaenoptera brydei*). Both of these species are known to associate with common dolphins within this region (O'Callaghan & Baker, 2002).

Once within 400 m of a group of dolphins, the boat would slow to an approach speed (~ 5 kts). At this point, environmental parameters (i.e., water depth, SST, sea state, visibility, and weather) and data relating to group size and composition were recorded. The boat would then travel slowly parallel to the course of moving animals or proceed closer towards static groups, approaching slightly to the rear of the group in a slow and continuous manoeuvre. Once the boat was within approximately 200 m of the animals, the start time and location for the encounter were recorded using a handheld GARMIN GPS 12.

Data Analysis
We investigated spatial, diurnal and seasonal patterns in occurrence; relative abundance; group size and composition; and determined relationships with environmental variables (i.e., water depth, SST, season, and tidal phase), controlling for other confounding or additional explanatory variables (e.g., latitude, longitude, platform, sea state). We also analysed the depth and SST at which dolphins occurred in relation to month, season, time of day, and group size.

Sightings Per Unit Effort (SPUE) was calculated as the number of common dolphin sightings per 60 min of search effort. For the purposes of analyses, group size was categorised at two resolutions. Group size on a fine scale was classified as 1-10, 11-20, 21-30, 31-50, 51-100, 101-200, and 200+ animals. On a broad scale, two categories were defined: ≤ 50 or > 50 animals. A *group* was defined as any number of dolphins engaged in a similar behaviour, moving in a similar direction, and within five body lengths of any other dolphin (Fertl, 1994). Group composition was also analysed at two resolutions based on the age classes present. First, the youngest component within a group was classified as either neonates, calves, juveniles, or adults. *Neonates* were defined as small calves which exhibited diagnostic features indicative of newborns (e.g., the presence of dorso-ventral foetal folds); *calves* were defined as animals that were approximately $\leq$ one-half the length of an adult and were consistently observed in association with an adult animal (Fertl, 1994); *juveniles* were defined as animals approximately two-thirds the size of an adult animal and frequently observed swimming in association with an adult animal but not in the infant position, suggesting that they were weaned (Mann et al., 2000). *Adults* were defined as all animals not included in the prior classifications. No attempt was made to classify subadults in the field since intraspecific size variation made it impossible to confidently discriminate between small adults and large subadults. Secondly, group composition was categorised on a broad scale as adults-only *vs* groups containing immature animals. Immatures were defined as all animals that that did not appear fully grown (*ca* < 1.8 m).

The survey was not specifically designed to examine patterns in dolphin occurrence, thus, the full suite of environmental variables was not measured throughout the surveys. To generate absence data for common dolphins, we used those sighting records where only other species of cetacean were observed.

Latitude, longitude, field year, month, and time-of-day were all considered as explanatory variables (although they may, of course, represent proxies of environmental variation). Observations were

restricted to daylight hours. For analysis of presence, all except year were treated as continuous variables in binomial Generalised Additive Models (GAMs). Clearly, month is not a continuous variable, but treating it as such allows seasonal patterns to be visualised more readily (e.g., see Smith et al., 2005). For other analyses, some grouping was necessary. Diel patterns were investigated by assigning each observation to a 2-h time period within the sequence 0600-0759 h, 0800-0959, through to 1800-2000. Seasonal analyses were based on the austral seasons as follows: spring (September to November), summer (December to February), autumn (March to May), and winter (June to August).

SST, depth, tidal and sea state, visibility, and weather were recorded at the start of each cetacean encounter. SSTs recorded at sea were later calibrated against temperature data collected from Leigh Marine Laboratory (36° 16' S, 174° 48' E). Data exploration showed that SST was strongly correlated to month. To avoid including two highly collinear explanatory variables in the GAMs, we de-seasonalised the SST data by fitting a Gaussian Generalised Linear Model (GLM) to SST using month as a nominal explanatory variable. This model explained 83.4% of variation in SST. Residual values (i.e., de-seasonalised SST) were used as an explanatory variable in subsequent GAM analysis.

Water depth (m) was recorded to one decimal place, using an onboard depth sounder. Tidal patterns were examined based on the time of each sighting categorised as from -6 h to +6 h before high tide. For the GAMs, tidal state was also decomposed into two separate categorical variables, expressing the absolute number of hours from high tide (0 to 6) and the direction of tidal flow (-1, 0, +1). Sea state (Beaufort scale), visibility (on a scale of 1 to 4), weather (on a scale of 1 to 4), and platform identity were included in the GAMs as "nuisance variables," which could have affected detectability of dolphins.

Statistical analysis was carried out using *Minitab*, Version 14 (Minitab Inc.) for the majority of analyses and *Brodgar,* Version 2.5.1 (Highland Statistics Ltd.; see www.brodgar.com) for GAMs. The distributions of continuous response variables (SPUE, SST, depth) were initially tested for normality and homogeneity using Anderson-Darling & Bartlett's and Levene's tests, respectively (Zar, 1996). In most cases, data were non-normal, so for comparisons we used the nonparametric Kruskal-Wallis test and Pearson χ^2 tests for categorical data sets (group size and composition).

For analysis of presence using binomial GAMs, explanatory variables were fitted in different combinations (variously as smoothers, linear

terms, and factors) and the best model selected based on the Akaike Information Criterion (AIC), the significance of individual explanatory variables (nonsignificant terms were dropped, even if their inclusion reduced the AIC), and examination of plots of residuals to ensure that no trends remained.

Results

Survey Effort

Data were collected between February 2002 and January 2005 during 506 boat-based surveys. A total of 141 and 578 independent common dolphin encounters were recorded from onboard *Aihe* and *Dolphin Explorer*, respectively. Uncontrollable circumstances (e.g., weather) resulted in unequal survey effort between platforms. Effort was greatest during April and autumn and lowest in September and spring. SPUE varied by month, season, and in relation to platform (Table 1). When data from both platforms were combined, SPUE was highest in winter (0.61) and lowest in spring (0.31) (Table 2).

Dolphin Presence in Relation to Abiotic Parameters

Common dolphins were sighted over sea depths ranging from 7.0 to 52.0 m (mean = 38.3, SD = 9.3) from *Aihe* and over sea depths between 8.9 and 54.8 m (mean = 39.5, SD = 7.4) from *Dolphin Explorer*. The median sea depth over which dolphins were located varied significantly between diel categories from both platforms (Kruskal-Wallis: h = 50.9, df = 4, $p < 0.001$), with dolphins located in the deepest waters between 1400 and 1600 h (median = 43.9, SD = 9.4) and the shallowest waters between 0800 and 1000 h (median = 33.2, SD = 9.8). Median water depth of sightings varied significantly by month from both platforms (Kruskal-Wallis: h = 35.19, df = 11, $p < 0.001$), with shallower depths used more during the summer months of December to February and deepest depths used more during May. Seasonally, there was a significant difference in the median depth in which common dolphins were observed (Kruskal-Wallis: h = 9.81, df = 3, $p = 0.020$), ranging from 40.0 m in austral summer ($n = 195$, SD = 0.70) to 42.1 m in autumn ($n = 231$, SD = 7.08).

Common dolphins were located from *Dolphin Explorer* in waters with SST ranging from 12.5 to 25.6°C (mean = 18.47, SD = 2.89) and in waters of 12.0 to 24.9°C (mean = 17.95, SD = 3.30) from *Aihe*. Median SSTs for dolphin encounters varied significantly between time-of-day categories from both platforms (Kruskal-Wallis: h = 35.47, df = 4, $p < 0.001$), with dolphins located in warmest and coolest waters between 1600 and 1800 h (median = 21.9, SD = 1.6) and 1000 and

Table 1. Monthly analysis of common dolphin sightings (February 2002 to January 2005) in the Hauraki Gulf, New Zealand

| Month | Number of sightings | | Sighting rates (SPUE) | | |
	Aihe	*Dolphin Explorer*	*Aihe*	*Dolphin Explorer*	Combined
Jan	16	58	0.35	0.51	0.47
Feb	20	42	0.81	0.69	0.72
March	2	76	0.48	0.54	0.53
April	7	63	0.27	0.44	0.41
May	4	63	0.64	0.47	0.48
June	9	54	0.82	0.56	0.59
July	15	63	1.36	0.52	0.59
Aug	29	40	0.67	0.62	0.64
Sep	8	17	0.33	0.28	0.29
Oct	15	35	0.44	0.39	0.41
Nov	8	18	0.50	0.19	0.23
Dec	8	49	0.48	0.34	0.38
Total	141	578	Mean = 0.59	Mean = 0.46	Mean = 0.48
			SE = 0.09	SE = 0.04	SE = 0.04

Table 2. Seasonal analysis of common dolphin sightings (February 2002 to January 2005) in the Hauraki Gulf, New Zealand

| Austral season | Number of sightings | | Sighting rates (SPUE) | | |
	Aihe	*Dolphin Explorer*	*Aihe*	*Dolphin Explorer*	Combined
Spring	31	70	0.42	0.28	0.31
Summer	44	149	0.51	0.47	0.48
Autumn	13	202	0.36	0.48	0.47
Winter	53	157	0.81	0.56	0.61
Total	141	578			

1200 h (median = 18.3, SD = 1.6), respectively. The median SST at which dolphins were observed varied significantly by month (Kruskal-Wallis: h = 515.76, df = 11, $p < 0.001$) with coolest and warmest waters apparent during August (median = 14.0, SD = 0.81) and January (median = 21.8, SD = 1.61), respectively. As expected, median SST ranged seasonally from 14.8°C ($n = 190$, SD = 1.49) in the austral winter to 21.2°C ($n = 163$, SD = 0.12) in the austral summer (Kruskal-Wallis: h = 458.17, df = 3, $p < 0.001$).

The optimal GAM for common dolphin presence was as follows:

Presence ~ 1 + s(Month, df = 8.4) + s(Latitude, df = 4.8) + s(Depth, df = 2.1) + residual SST

where s indicates a smoother with degrees of freedom (df). This model explained 13.2% of the deviance in dolphin presence ($n = 779$). Adding sea state, time of day, longitude, platform identity, visibility, weather, or state of tide did not improve the model. Residual (deseasonalised) SST had a positive (and linear) effect on dolphin presence ($p = 0.0017$). Effects of month ($p < 0.0001$), latitude ($p = 0.0021$), and depth ($p = 0.0033$) were also all significant. Partial plots of the smoothers indicate that sightings

of common dolphins were highest around February and between July and August (Figure 2) at approximately 36° 40' S (Figure 3) and in the deeper waters of the Hauraki Gulf (Figure 4).

Group Size in Relation to Abiotic Parameters
Group size ranged from solitary animals ($n = 2$) to 100+ animals ($n = 62$) (mean = 48.1, SD = 64.9). Common dolphins were predominantly observed in smaller groups, with results highly skewed towards groups containing ≤ 50 animals ($n = 511$). The most frequently observed group size involved 21 to 30 animals, which was observed in 22.2% of dolphin encounters ($n = 149$). Group size exhibited no diel or tidal variation but did vary significantly by month (Pearson $\chi^2 = 24.956$, df = 11, $p = 0.009$) and season (Pearson $\chi^2 = 9.001$, df = 3, $p = 0.029$). Groups containing > 50 animals were observed more frequently than expected during the months of July, August, October, and November and during the spring and winter seasons.

Smallest groups (≤ 10 animals) were most frequently recorded in March ($n = 17$) and least often observed during May ($n = 1$), accounting for 16.3% and < 1% of the total number of encounters
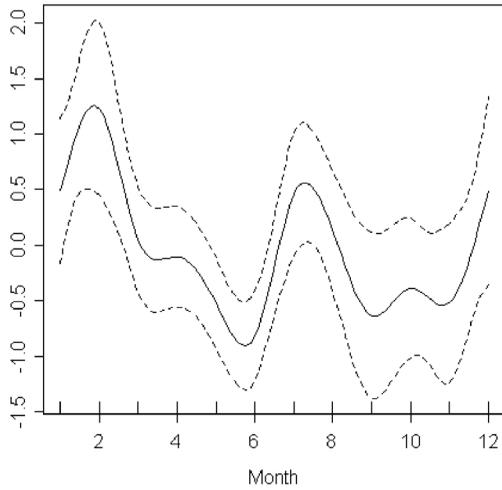
Figure 2. The fitted smoother curve (with the dotted lines indicating 95% confidence limits) depicting the partial effect of month on common dolphin occurrence in the Hauraki Gulf, New Zealand (i.e., the effect of month once other effects in the model have been taken into account); the X-axis refers to month—January equals one through 12 for December. The Y-axis values indicate the strength and direction of the effect.
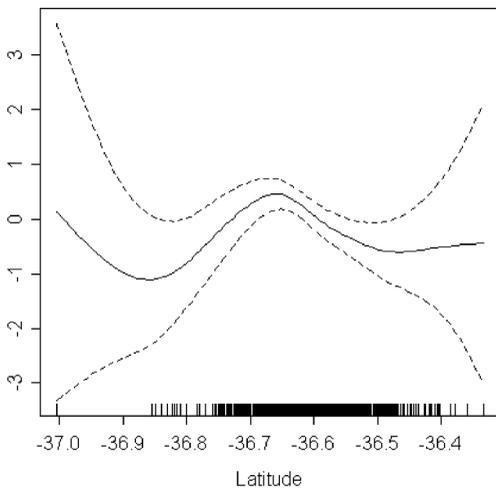

Figure 3. The fitted smoother curve (with the dotted lines indicating 95% confidence limits) depicting the partial effect of latitude on common dolphin occurrence in the Hauraki Gulf, New Zealand; latitude values are shown in decimal degrees. The markings above the X-axis, the so-called rug-plot, indicate variation in the number of data points along the X-axis (i.e., in this case, most data were collected between 36.45° and 36.75° S).
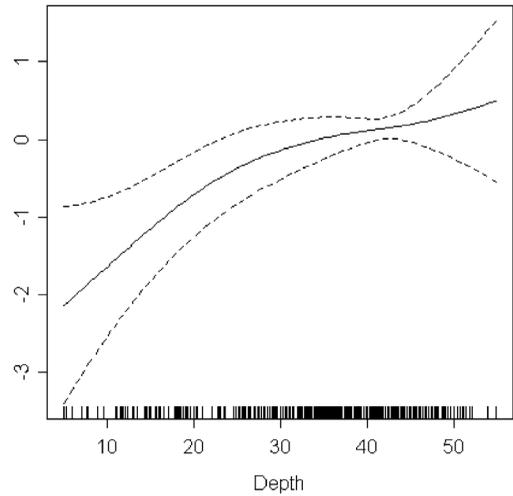

Figure 4. The fitted smoother curve (with the dotted lines indicating 95% confidence limits) depicting the partial effect of depth (m) on common dolphin occurrence in the Hauraki Gulf, New Zealand

observed during each month, respectively. Generally, small groups were present throughout the year but were most frequent during winter ($n = 38$), accounting for 24.2% of the total number of observed groups during June to August. Large aggregations (> 100 animals) were also most frequent during the winter, although dolphin occurrence was highest during autumn ($n = 218$), accounting for 32.5% of total sightings.

Variation in the water depths over which different group sizes were found was marginally non-significant (Kruskal-Wallis: h = 12.11, df = 6, $p = 0.059$), with groups containing ≤ 10 animals exhibiting preference for the shallowest waters (median = 40.7 m, SD = 7.3, $n = 101$). Groups containing ≤ 30 animals were predominantly observed in shallower waters ($n = 370$, median = 40.8, SD = 8.1), while larger groups containing > 100 animals were most frequently recorded in deeper waters ($n = 59$, median = 42.3, SD = 5.6).

Significant variation was observed in the average SST at which different sized groups were observed for both narrow- (Kruskal-Wallis: h = 12.29, df = 1, $p < 0.001$) and broad-scale (Kruskal-Wallis: h = 33.59, df = 6, $p < 0.001$) group size categories. Large aggregations (> 200 dolphins) were recorded in coolest waters ($n = 20$, median = 15.6, SD = 2.4), and groups of 31 to 50 animals ($n = 114$, mean = 19.3, SD = 2.9) were observed in the warmest waters. Groups containing > 50 animals were generally found in waters 1.4°C cooler than groups of ≤ 50 dolphins. This likely represents a seasonal effect considering that larger

group sizes were observed more frequently during the winter months.

No effect of latitude on group size was observed using either narrow- (Kruskal-Wallis: h = 8.49, df = 6, p = 0.205) or broad-scale (Kruskal-Wallis: h = 2.68, df = 1, p = 0.102) group size categories. However, group size did vary significantly with longitude for both narrow- (Kruskal-Wallis: h = 20.33, df = 6, p = 0.002) and broad-scale (Kruskal-Wallis: h = 18.36, df = 5, p = 0.003) categories.

Group Composition in Relation to Abiotic Factors
Analyses were performed only on data from groups for which we were confident of being able to detect calves and/or neonates should they be present (n = 638). Over 70% of observed groups included immature animals (n = 464), with almost half of these (n = 279) including calves and many (n = 69) including neonates. Groups containing neonates accounted for almost 25% of the groups with calves that were encountered. Neonates were most frequently recorded in the summer months of December (n = 21) and January (n = 17), accounting for 30% and 25%, respectively, of the total number of observed groups containing newborns.

Each age class was observed at all hours of the day and all tidal states, and during all months, seasons, and field years. The relative frequency of occurrence of groups containing immature animals (in relation to all groups) did not vary diurnally (Pearson χ^2 = 6.596, df = 4, p = 0.159) or with the state of the tide (Pearson χ^2 = 11.184, df = 12, p = 0.513). However, the occurrence of immature animals varied by month (Pearson χ^2 = 32.69, df = 11, p = 0.001) and season (Pearson χ^2 = 10.431, df = 3, p = 0.015), with over 80% of observed groups in February (n = 48) and March (n = 61) and during the summer (n = 146) containing immature animals. Groups containing immature animals were least often encountered in June when they accounted for 52% of observed groups (n = 26). No difference was found in the occurrence of groups with immature animals between field years.

Water depths in which dolphins were located varied among different age classes (Kruskal-Wallis: h = 9.89, df = 3, p = 0.042) but not with the presence of immature animals. Typically, neonates were observed in water depths less than 20 m. A significant difference in SST was also observed, both among age classes (Kruskal-Wallis: h = 18.89, df = 3, p < 0.001) and between groups containing immature *vs* mature animals only (Kruskal-Wallis: h = 7.96, df = 1, p = 0.005), with groups containing immature animals being relatively more frequent in warmer waters.

Associated Species
Common dolphins were observed in association with four cetacean and eight avian species: Bryde's whales, bottlenose dolphins (*Tursiops truncatus*), killer whales (*Orcinus orca*), striped dolphins (*Stenella coeruleoalba*), Australasian gannets, flesh-footed shearwaters (*Puffinus carneipes*), Buller's shearwaters (*Puffinus bulleri*), sooty shearwaters (*Puffinus griseus*), grey-faced petrels (*Pterodroma macroptera*), black-backed gulls (*Larus dominicanus*), white-fronted terns (*Sterna striata*), and blue penguins (*Eudyptula minor*). Associations were most frequently observed with Bryde's whales (n = 195) and Australasian gannets (n = 467), accounting for 27.1% and 65.0% of associations, respectively.

Distribution of dolphin-only (i.e., common dolphins only) *vs* dolphin-whale (i.e., common dolphins with Bryde's whale[s]) groups differed significantly, with mono-specific groups generally occurring in waters of higher latitudes (Kruskal-Wallis: h = 14.54, df = 1, p < 0.001) and at lower longitudes (Kruskal-Wallis: h = 30.86, df = 1, p < 0.001). Dolphin group size varied significantly between mono- and poly-specific aggregations (χ^2 = 67.178, df = 6, p < 0.001), while the presence of Bryde's whales was unrelated to the occurrence of immature common dolphins (χ^2 = 0.093, df = 1, p = 0.760). Depth and SST varied significantly between single and multi-species groups (Kruskal-Wallis: h = 62.05, df = 1, p < 0.001 and h = 53.23, df = 1, p < 0.001, respectively), with dolphin-whale groups being observed on average in waters 3.6 m deeper and approximately 3.1°C cooler than reported for dolphin-only groups.

Discussion

Both the occurrence and group characteristics of common dolphins in the Hauraki Gulf differ from that previously reported for this species in New Zealand waters (Gaskin, 1972; Würsig et al., 1997; Bräger & Schneider, 1998; Neumann, 2001). In the Hauraki Gulf, dolphins were observed year-round, although seasonality was evident in relative abundance and in group size and composition. While typically found in deeper waters, common dolphins in the Hauraki Gulf were frequently observed in water depths < 20 m and typically found in smaller groups (< 30 animals), often containing neonates and/or calves. There are a number of potential explanations for this, which may be non-exclusive, including the role of inter-specific interactions, particularly distribution and abundance of prey resources, predation, competition, and the requirement for suitable breeding and calving conditions.

Prey Availability, Oceanographic Factors, and Climate

Seasonal trends in the occurrence and distribution of *Delphinus* are commonly observed worldwide, especially in temperate populations (e.g., Bräger & Schneider, 1998; Goold, 1998). However, this is not the case for all populations. For example, in the eastern tropical Pacific, short-beaked common dolphins (*D. delphis*) occupy upwelling-modified habitats year-round, neither varying in their occurrence or distribution (Reilly, 1990). Off the northwestern Bay of Plenty, New Zealand, Neumann (2001) reported seasonal movements of common dolphins that correlated with SST and El Niño and La Niña Southern Oscillation patterns. He suggested that offshore shifts of dolphins observed during the winter months were most likely a consequence of prey movement (i.e., an indirect rather than direct effect of SST).

Independent of the intrinsic factors known to govern local population distributions (e.g., reproductive rates) (Lack, 1954), marine mammal populations are influenced by oceanographic and other climatic factors, particularly insofar as they determine the distribution, local abundance, and availability of prey. Prey are affected by the ocean climate, which can vary considerably at different spatial and temporal scales (Redfern et al., 2006). Patterns of distribution and habitat use of cetaceans are related to short-term oceanic conditions such as upwelling (Reilly & Fiedler, 1994; Keiper et al., 2005). Additionally, marine mammal prey can be subject to medium-term changes in the oceanographic conditions (e.g., El Niño/La Niña) (Neumann, 2001). Both seasonal and interannual habitat variability, therefore, may affect marine mammal occurrence and distribution as a consequence of varying prey availability (Murase et al., 2002; Keiper et al., 2005).

The main ocean current affecting the Hauraki Gulf, the EAUC, is a strong but variable southeastward flow off the shelf-edge on the northeast and east coast of the North Island (Stanton & Sutton, 2003). The changing pattern of Hauraki Gulf water temperatures and the influence of the EAUC undoubtedly affect the distribution and abundance of animal communities in this region (Stanton & Sutton, 2003). Primary productivity within the Hauraki Gulf and the consequent abundance of potential prey species within the region may explain the year-round occurrence of common dolphins in this region.

While dietary studies of New Zealand common dolphins remain scarce, Neumann & Orams (2003) previously used underwater video footage to identify species taken during foraging bouts, resulting in the identification of six potential prey species: jack mackerel, kahawai (*Arripis trutta*),

yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus lineatus*), parore (*Girella tricuspidata*), and garfish (*Hyporamphus ihi*). The first quantitative insight into the diet of this population, as determined by stomach contents, suggests New Zealand common dolphins feed on both neritic and oceanic prey (Meynier et al., in press). Furthermore, high levels of mixed-species feeding aggregations are evident within the Hauraki Gulf (Burgess, 2006; Wiseman, 2008), suggesting prey availability as a likely factor to explain the year-round occurrence of common dolphins in this region. Stomach contents (e.g., Pascoe, 1986; Silva, 1999; Santos et al., 2004; Meynier et al., 2008) and stable isotopes (e.g., Das et al., 2003) analyses, obtained from other regions suggest that *Delphinus* exhibits a broad diet comprising predominantly pelagic schooling fish and a variety of squid species. Many authors also highlight the importance of the deep scattering layer for feeding common dolphins (e.g., Waring et al., 1990; Overholt & Waring, 1991; Ohizumi et al., 1998), which is consistent for the New Zealand population (Meynier et al., in press).

Predation

The main predatory threats to New Zealand common dolphins are likely posed by killer whales and various shark species. In New Zealand waters, attacks by killer whales have been observed on most small cetaceans (Visser, 1999a), including common, bottlenose, and dusky (*Lagenorhynchus obscurus*) dolphins. In the Hauraki Gulf, common dolphins have occasionally been observed fleeing from killer whales, and the occurrence of fresh wounds indicative of killer whale attacks suggest common dolphins are not exempt from predation in this region (Stockin, unpub. data). Shark species that are capable of dolphin predation and known to occur within the Hauraki Gulf (C. Duffy, pers. comm.) include broadnose sevengill (*Notorhynchus cepedianus*), shortfin mako (*Isurus oxyrinchus*), white (*Carcharodon carcharias*), bronze whaler (*Carcharhinus brachyurus*), blue (*Prionace glauca*), and smooth hammerhead (*Sphyrna zygaena*) sharks. Given the presence of foraging killer whales (Visser, 1999b), and numerous predatory shark species, predation alone is unlikely to be the key factor determining the year-round occurrence of common dolphins in the Hauraki Gulf.

Competition and Cooperation

Interspecific competition is known to affect the occurrence and abundance of different species within a habitat, although in sympatric dolphin populations, resource partitioning is often evident (see Bearzi et al., 2005, for a review). Sightings

of striped dolphins in the Hauraki Gulf are rare and typically involve solitary animals among large aggregations of common dolphins (Stockin, unpub. data). Dusky and common dolphins are known to overlap in their distribution further south (e.g., Kaikoura; 42° 25' S, 173° 42' E), although the occurrence of common dolphins in these regions appears to be seasonally restricted (Bräger & Schneider, 1998). Bottlenose dolphins frequently occur within the Hauraki Gulf (Berghan et al., in press); although, given the different dietary preferences of bottlenose dolphins compared to common dolphins (Santos et al., 2004, 2007), interspecific food competition between these species is likely avoided. Direct physical interactions between bottlenose and common dolphins were not observed in the present study, although bottlenose dolphins are reported to interact aggressively with other species elsewhere (Ross & Wilson, 1996; Herzing et al., 2003).

Associations observed during the present study were likely positively biased towards Bryde's whales and Australasian gannets since binoculars were used onboard *Dolphin Explorer* to scan for these indicator species. On the contrary, blue penguin associations are likely to have been underestimated since these flightless, relatively inconspicuous birds were easily disturbed by approaching boats. If any form of competition for prey exists, arguably larger groups would improve foraging capacity and potentially benefit common dolphins in the Hauraki Gulf. However, no evidence of this was found during the present study, thus neither competition or cooperation is likely a primary factor influencing occurrence and demographics of common dolphins in the Hauraki Gulf.

Reproduction
Groups containing neonates, calves, and/or juveniles represent over 70% of the groups encountered during the present study, with calves present in almost half of all dolphin groups recorded. This is relatively high when compared to other populations (e.g., in the Mediterranean Alboran Sea, 46.4% of observed groups contained calves) (Universidad Autonoma de Madrid & Alnitak, 2002). Data presented herein support the hypothesis that the Hauraki Gulf represents a potential calving area as well as an important nursery area for this population (Schaffar-Delaney, 2004). Calves were observed year-round in the Hauraki Gulf, although they were most prevalent during late spring and early summer. The relatively high occurrence of neonates, predominantly through the summer months of December and January, supports the concept of breeding seasonality within this population. Calving peaks reported herein are typical of high latitude populations (Börjesson & Read, 2003) and

appear consistent with previous observations made of this species in New Zealand waters (Bräger & Schneider, 1998; Schaffar-Delaney, 2004). Evidence of similar calving seasonality has also been reported in the eastern North Pacific (Ferrero & Walker, 1995), eastern North Atlantic (Collet & Harrison, 1981; Murphy, 2004), the western North Atlantic (Westgate & Read, 2007), and the Black Sea (Tomlin, 1957).

During the present study, groups containing neonates were typically found in shallower waters representing areas close to shore. Common dolphins observed in New Zealand waters are known to move inshore during what appears to be the main reproductive season (Bräger & Schneider, 1998; Neumann, 2001), and groups containing neonates have previously been observed in shallow waters in this region (Schaffar-Delaney, 2004). However, whether such movements exclusively represent reproductive requirements or are merely secondary to responses to prey availability remains unclear. Parturition has never been observed for this species in the Hauraki Gulf, although it likely occurs given the frequent observations of extremely small neonates lacking basic motor-coordination skills.

Management Implications
There is support within the international community for special consideration to be given for areas that are deemed significant ecosystems or habitats for particular species. For example, under current European legislation, such habitats can be nominated for consideration as Special Areas of Conservation (SACs) under the EU Habitats Directive (92/43/EEC). Within New Zealand, the Hauraki Gulf is already acknowledged as a significant coastal, marine, and island ecosystem and is given special status through the Hauraki Gulf Marine Park Act (2000). However, there is a strong argument for explicit and specific management strategies to be developed and applied for species that rely on this region for important biological processes (i.e., breeding). Herein, we present evidence that common dolphins occur year-round in this area, in contrast to other regions around New Zealand. We also provide evidence to support the hypothesis that common dolphins use this region as a calving and nursery area.

The year-round occurrence and social organisation of common dolphins in Hauraki Gulf waters is probably the result of a combination of factors, including prey availability and the need to meet the energetic demands related to calving and lactation (Bernard & Hohn, 1989; Recchia & Read, 1989). Given the presence of killer whales and sharks within the Hauraki Gulf, the continuous occurrence of common dolphins in these waters is less

likely to relate to predator avoidance. The consistent use of inshore waters by common dolphins is of notable importance given the apparent susceptibility of this population to coastal anthropogenic effects (e.g., pollution and tourism) (Stockin et al., 2007, 2008).

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