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Distribution and Population Demographics of Common Dolphins (*Delphinus delphis*) in the Gulf St. Vincent, South Australia

Nicole E. Filby,[1*] Mike Bossley,[2] Ken J. Sanderson,[1]
Emmanuelle Martinez,[3] and Karen A. Stockin[3]

[1]School of Biological Sciences, Flinders University, GPO Box 2100, Adelaide, South Australia;
E-mail: nicole.filby@live.vu.edu.au
[2]Whale and Dolphin Conservation Society, P.O. Box 720, Port Adelaide Business Centre, Port Adelaide, South Australia
[3]Coastal-Marine Research Group, Institute of Natural Sciences, Massey University,
Private Bag 102 904, North Shore MSC, New Zealand
[*]Current Address: School of Engineering and Science, Ecology and Sustainability Group, Victoria University,
P.O. Box 14428 (St. Albans Campus), Melbourne, Victoria, Australia (NEF)

Abstract

Within Australian waters, short-beaked common dolphins (*Delphinus delphis*) are exposed to a variety of human-induced impacts, including aquaculture and fisheries. Nonetheless, the occurrence and distribution of common dolphins within these waters remains unknown. Data detailed herein represent the first report of the occurrence and distribution of common dolphins from Australian waters. The density and relative abundance of common dolphins within Gulf St. Vincent (GSV), South Australia, was examined between September 2005 and May 2008 using systematic boat surveys. During 1,850 km of survey effort, a total of 108 independent groups, involving 564 common dolphins, were observed. Group size ranged from 2 to 21 individuals (mean = 5.26, SD = 3.687), with immature dolphins found in larger group sizes. Adults were the most frequent age class observed in this population (60.3%, *n* = 340), with neonates and calves observed most frequently between December and April. Sighting frequency was 3 groups/100 km² travelled, with an encounter rate of 16 common dolphins/100 km². The western longitude and southern latitude sections of GSV were used most frequently by this species, with most groups recorded in water depths of 35 to 40 m (mean = 37.2 m, SD = 1.4), and in areas 21 to 31 km from land (mean = 27.4 km, SD = 2.6). Common dolphin density was estimated to be 0.5 dolphins/100 km^2, with a population estimate of 1,957 dolphins within their preferred habitat (waters deeper than 14 m). Results suggest the GSV is important for this species and that common dolphins use these waters as a nursery area.

Key Words: common dolphin, *Delphinus delphis*, occurrence, demographics, Gulf St. Vincent, South Australia

Introduction

The total distribution of short-beaked common dolphins (*Delphinus delphis*) is somewhat complicated, primarily owing to previous taxonomic confusion between the long-beaked (*D. capensis*) and the short-beaked common dolphin (Jefferson et al., 2009). Short-beaked common dolphins are known to occur over continental shelf and pelagic waters of the Atlantic and Pacific Oceans (Reeves et al., 2002). However, due to reduced prey availability (e.g., Trites et al., 1997; Bearzi et al., 2006, 2008b), environmental change (e.g., Bearzi et al., 2003; Murphy et al., 2006), habitat depredation (e.g., Long et al., 1997; Bearzi et al., 2003; Tornero et al., 2006; Stockin et al., 2007; Lavery et al., 2008), and fisheries by-catch (Kemper & Gibbs, 2001; Bearzi et al., 2003; Bilgmann et al., 2008; Hamer et al., 2008; Stockin & Orams, 2009), short-beaked common dolphins (hereafter referred to as common dolphins) have become locally extirpated in parts of their former range—the Mediterranean Sea (Bearzi et al., 2008a; Natoli et al., 2008) and the Gulf of Vera in southern Spain (Cañadas & Hammond, 2008).

The seasonal abundance and distribution of common dolphins varies worldwide, with some areas reporting transient populations (e.g., Californian coast, Forney & Barlow, 1998; North Atlantic Ocean, Mirimin et al., 2009), while others are described as resident (e.g., eastern Ionian Sea, Bearzi et al., 2008a). Unfortunately, published data available to describe distribution and occurrence of *Delphinus* within the South Pacific is limited (e.g., Kemper et al., 2008; Stockin et al., 2008c). This is especially true of Australian waters where common dolphins have been the focus of few field-based studies (e.g., Bilgmann et al., 2008; Hamer et al., 2008). Currently, occurrence along the South Australian coast is documented only through stranding (Kemper et al., 2005; Ross, 2006) and incidental capture records (Bilgmann et al., 2008; Hamer et al., 2008). Thus, prior to the present study, no density or abundance estimates for common dolphins within Australian waters existed.

While little is known about the demographics of Australian common dolphins, a number of human-induced impacts have been documented for this species. Within South Australian waters, common dolphins are exposed to interactions with fisheries, aquaculture facilities and, in some of the gulf regions, marine pollution (e.g., Edwards et al., 2001; Kemper & Gibbs, 2001; Kemper et al., 2005; Hamer et al., 2008; Lavery et al., 2008). Fisheries interactions are currently considered the most prominent threat for common dolphins, with both direct capture and indirect trophic pathways potentially affected. Fisheries interactions within the Spencer Gulf and eastern Great Australian Bight regions have resulted in the by-catch of common dolphins in the sardine purse seine fishery (Hamer et al., 2008). A recent genetic study revealed common dolphins from these regions form part of a different and considerably isolated population compared with those of southeastern Tasmania (Bilgmann et al., 2008). Furthermore, it is not yet clear how the population structure of common dolphins occurring off southern West Australia, eastern South Australia, and Victoria relate to those of the eastern Great Australian Bight and Tasmania. This lack of knowledge prevents the formation of appropriate conservation measures for common dolphins exposed to high fishing pressure in South Australian waters.

To understand the potential effects of anthropogenic threats facing common dolphins in South Australian waters, insight into the ecology and demographics of this species is required. Herein, the distribution and density of common dolphins occurring within Gulf St. Vincent (GSV), a large inlet of water on the coast of South Australia, is assessed for the first time. Using boat-based surveys, the importance of GSV waters for common dolphins using density estimates was documented. Furthermore, the role of abiotic factors (e.g., water depth, sea surface temperature [SST], latitude, longitude, diel, and month) in determining common dolphin distribution, group size, and group composition was investigated. Data presented herein refer only to the short-beaked form since only this species of *Delphinus* has been reliably documented to occur within South Australian waters (Bell et al., 2002; Bilgmann et al., 2008).

Materials and Methods

Study Site

This study was conducted in Gulf St. Vincent (Figure 1), a large (7,000 km²) inlet of water on the coast of South Australia (35° 1' 0" S, 138° 4' 0" E) (Nunes & Lennon, 1986). A shallow (maximum depth 45 m), tidal inverse estuary, GSV is considered a productive ecosystem exhibiting high biodiversity (De Silva Samarasinghe, 1998). Bordered by the Yorke Peninsula to the west and the Fleurieu Peninsula to the southeast, and with Kangaroo Island across the opening to the Southern Ocean on the southwest, GSV offers a relatively sheltered environment. Investigator Strait and Backstairs Passage connect GSV to the eastern Southern Ocean and continental shelf (Petrusevics, 1993). The upper gulf reaches are characterised by shallow, mostly hyper-saline waters which exhibit a greater water temperature range compared with the southern, deeper waters of the region (Shepherd & Sprigg, 1976; De Silva Samarasinghe et al., 2003). Similar to other South Australian gulfs (e.g., Spencer Gulf), GSV is substantially more saline than the surrounding shelf waters, with non-tidal circulation and various metal contamination hotspots (e.g., Bye, 1976; De Silva Samarasinghe, 1998; Lavery et al., 2008).

Data Collection

Data were collected in GSV during systematic boat surveys onboard *Silverback*, an Arvor 6.2 m diesel inboard boat, fitted with a 90-hp engine. Due to logistical and environmental constraints, the study area encompassed the lower to middle section of GSV since northern regions of the gulf were either too shallow (on the western side) or frequently closed (on the eastern side) for military purposes (Berggy, 1996). As such, the resulting survey site fell within the following area: 138° 2' E, 34° 40' S; 138° 2' E, 35° 15' S; 138° 25' E, 35° 15' S; and 138° 25' E, 34° 40' S (Figure 1).

Following Hammond et al. (2002), the study area within GSV was subsequently divided into nine grids, each with a total distance of 85.75 to 86.12 km (Figure 1). Grid size was limited by distances that could be covered by the research vessel during a single survey during daylight hours. Grids were randomly surveyed throughout the study area and used instead of traditional line-transects to maximise on-effort distance covered. Search-effort was conducted at 12 to 14 kts in good conditions (≤ Beaufort 3, ≥ 1 km visibility) only (Hammond et al., 2002). If the sea state increased above Beaufort 3, or if the weather conditions deteriorated, the survey was terminated to prevent sighting rates being negatively affected (Notarbartolo di Sciara et al., 1993; Chilvers et al., 2003).

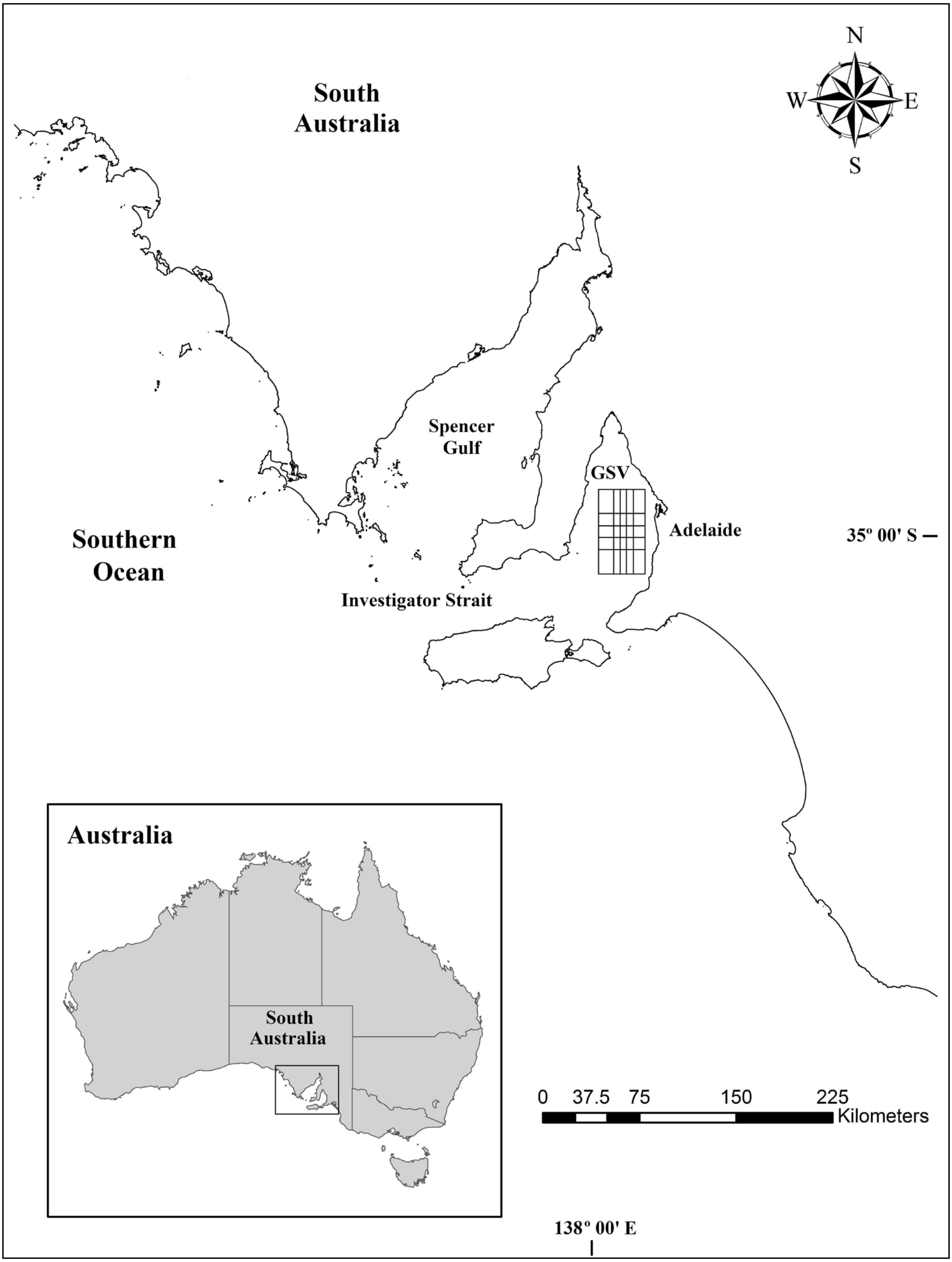

Figure 1. Study location and survey grid locations within Gulf St. Vincent (GSV), South Australia

During each survey, the boat travelled along the outside boundary of the grid, with one to four observers (inclusive of the primary observer) continuously scanning 180° of the horizon in front of the research vessel (Frantzis & Herzing, 2002). Observations of seabirds were used in addition to surface activity of dolphins (i.e., jumping and splashing) to detect dolphin schools (Stockin et al., 2008b). Observers could view approximately 250 m to either side of the boat, resulting in the survey track width of approximately 0.5 km. Responsive movement of dolphins towards boats (Goold, 1996; Tregenza et al., 1997; Kemper et al., 2008) suggests that even if observers missed dolphins on the outer edge of the track-line, the probability of detection increased as dolphins approached to bow-ride.

Once dolphins were detected, the boat gradually slowed to approximately 2 to 4 kts, with alterations in speed or course kept to a minimum to avoid disturbance (Stockin et al., 2008a). During each independent encounter, the start time, species identification, GPS location, water depth, SST, sea state, visibility, and dolphin(s) distance from the boat were recorded. Group size and composition of dolphins, behaviour, and presence of any associating species (i.e., bottlenose dolphin [*Tursiops* sp.] or flesh-footed shearwater [*Puffinis carneipes*]) were recorded. GPS coordinates of dolphin groups were recorded using a Navman TRACKER 5500. Water depth (m) was recorded using a Navman FISH 4500. SST was acquired from the Australian Government's Bureau of Meteorology (www.bom.gov.au/nmoc/archives/SST). Following completion of the sighting information, the survey track-line was rejoined in a convergent course to avoid pseudoreplication of the same animals (Forcada & Hammond, 1998; Bearzi et al., 2005). To minimise potential disturbance, time spent with dolphin groups was kept to a minimum.

A group was defined as any group of dolphins observed in apparent association, moving in the same direction and usually engaged in the same activity (Shane, 1990). Members of a group usually remained within approximately 100 m of each other and comprised one or more different age classes (Cribb et al., 2008). Group size was estimated independently by at least two observers during each sighting and based on the minimum number of dolphins counted. Group size was later categorised as ≤ 10 dolphins *vs* > 11 dolphins prior to analysis. Age class was defined using categories based on size and independence (Table 1) according to Neumann & Orams (2005) and Stockin et al. (2008b). Additionally, group composition was categorised broadly as adults-only groups *vs* groups containing immature dolphins, with *immature* defined as all individuals that did not appear physically mature (*ca.* < 1.8 m).

Data Analysis

The relative density of common dolphins in GSV initially was calculated by determining Sighting Frequencies (SF) (i.e., number of groups encountered per km² travelled) and Encounter Rates (ER) (i.e., number of individual dolphins encountered per km² travelled). SF and ER were calculated using the ratio $n/\mathrm{L} \times 100$ where n is the number of dolphins or groups and L is the number of km spent on-effort (Cockcroft & Peddemors, 1990; Forcada & Hammond, 1998; Bearzi et al., 2005). SF and ER were calculated for month, each latitude and longitude region, and for the entire study area (Gannier & West, 2005). A density estimate for common dolphins in GSV also was derived (total number of dolphins encountered divided by the km^2 spent on-effort [924.88 km^2]). Since no common dolphins were observed in waters less than 14 m during the present study, a population estimate was only calculated for areas where waters exceeded 14 m. This population estimate was derived by multiplying the density estimate by the area in which waters were deeper than 14 m within GSV (i.e., 3,915 km^2).

Biasing effects, such as dolphins approaching the boats and an unknown probability of detection, are likely to be severe in sighting conditions less than optimal (Gannier & West, 2005). As such, only data obtained in sea states of Beaufort ≤ 3 were analysed. To account for uneven survey effort across the months, means were taken of the number of dolphins encountered per month.

Table 1. Definitions of age categories used to assess common dolphin groups within Gulf St. Vincent (GSV), South Australia (modified from Stockin et al., 2008c)

Age class	Definition
Adult	Apparently fully grown individuals (> 1.8 m) in length with the ability to be independent of all other group members
Juvenile	Approximately two-thirds the length of an adult and did not travel in typical echelon position with an adult individual
Calf	Approximately half the length of an adult and did not travel in typical echelon or nursing position with any accompanying adult
Neonate	Young calves that still showed foetal folds, presence of a floppy dorsal fin, extreme buoyancy, or always positioned in close relation to an adult (presumed to be its mother); these dolphins were also of typical newborn size, 80 to 120 cm, and when surfacing, lifted the whole head above water.

Latitude was categorised into three classes: North (34° 40' S - 34° 51' S), Middle (34° 52' S - 3° 03' S), and South (35° 04' - 35° 15' S). Similar assignments were made for longitude classes: East (138° 02' E - 138° 09' E), Central (138° 10' E - 138° 17' E), and West (138° 18' E - 138° 25' E), following Døhl et al. (1986). Time of day, season, latitude, longitude, water depth, and age class were grouped as categorical data for analyses, following Stockin et al. (2008c). 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). Diel patterns were investigated by assigning each observation to a 1-h time period within the sequence 0700-0759 h, 0800-0859 h, through to 1600-1659 h.

Using *SPSS 17*, nonparametric Kruskal-Wallis tests were applied since these data revealed a non-normal distribution. Spatial and diurnal patterns in occurrence, relative abundance, group size, and composition were investigated, along with relationships with environmental variables (i.e., water depth and SST), controlling for other confounding or additional explanatory variables (e.g., latitude, longitude, and sea state). The depth and SST at which dolphins occurred was compared by month, time of day, and group size.

Table 2. Monthly analysis of common dolphin sightings (September 2005 to May 2008) in GSV, South Australia

Month	Mean number of dolphins sighted	On-effort distance (km)	SF
September	2.0	85.93	2.33
November	22.0	85.98	2.47
December	35.5	85.93	4.13
January	17.7	71.49	2.48
February	15.8	79.12	2.00
March	19.6	85.89	2.28
April	37.5	85.84	4.37
May	10.0	85.75	1.12

Results

Survey Effort

Data were collected between September 2005 and May 2008 during 27 independent boat-based surveys conducted between 0630 and 1730 h (Central Standard Time). The study area encompassed 2,592 km^2, with an on-effort distance travelled of 1,850 km (mean = 77.5 km/survey). A total of 108 independent common dolphin groups were recorded, with 564 individuals encountered. More than half (51.4%) of the surveys were conducted in sea states of Beaufort 1, with clear visibility (5 km+ view) recorded during 80% of surveys. Uncontrollable circumstances (e.g., weather) resulted in unequal survey effort between grids, with the greatest effort occurring during February to March and the lowest coverage during September and May. No surveys were undertaken during the austral winter months or in the month of October (Table 2).

Occurrence varied by month, with SF highest in April (4.37) and December (4.13) and lowest in May (1.12) (Table 2). SF and ER varied by latitude and longitude (Table 3), with southern latitudes exhibiting the highest SF (17.9) and ER (30.3) and northern latitudes having the lowest SF (1.9) and ER (14.7). The western longitude area had the highest overall SF (5.4) and ER (32.0). A SF and ER of 3 common dolphin groups/100 km^2 and 16 dolphins/100 km^2, respectively, was calculated for the study area as a whole. This equated to a density estimate of 0.5 dolphins/km^2 and the population estimate (based on waters deeper than 14 m) of 1,957 common dolphins.

Dolphin Presence in Relation to Abiotic Parameters

Common dolphins were sighted in water depths ranging from 14.0 to 39.6 m (mean = 31.46, SD = 6.4; Figure 2). The median water depth in

Table 3. Sighting Frequencies (SF) and Encounter Rates (ER) of common dolphins by latitude and longitude regions (September 2005 to May 2008) in GSV, South Australia

Study grid	Mean dolphins	Mean sightings	Mean distance travelled (km)	SF per 100 km^2	ER per 100 km^2
North (latitude)	12.7	1.6	86.0	1.9	14.7
Middle (latitude)	23.7	4.8	86.0	5.5	27.5
South (latitude)	26.0	15.3	85.8	17.9	30.3
West (longitude)	27.4	4.7	85.8	5.4	32.0
Central (longitude)	19.7	4.0	85.9	4.6	22.9
East (longitude)	15.2	3.1	86.0	3.5	17.7
Total study area	187.0	35.2	1,162.3	3.0	16.1

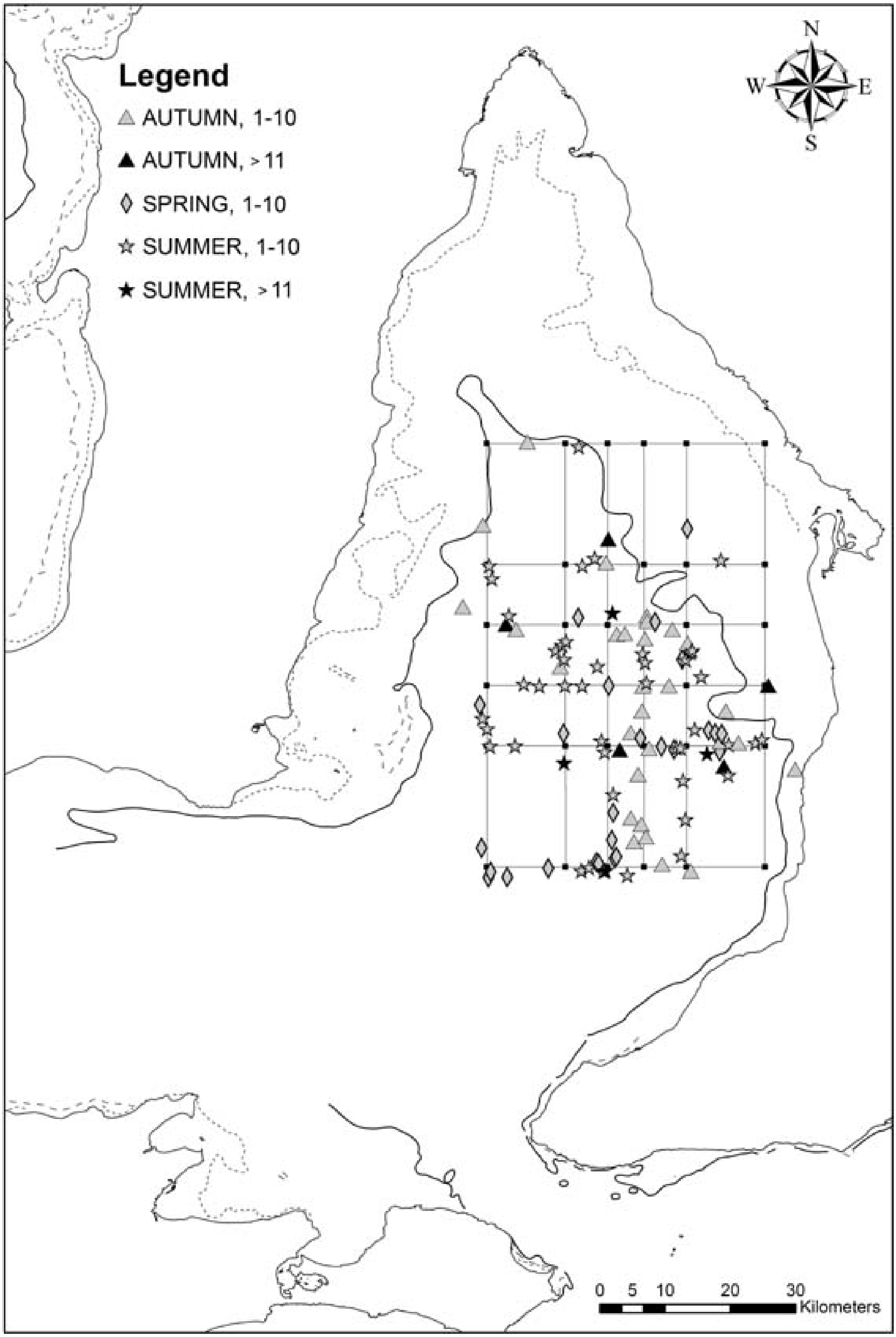

Figure 2. Grid locations and sightings of common dolphin groups by season and group size within GSV, South Australia; bathymetry lines: solid line equals 20 m, dashed line equals 10 m, and dotted line equals 5 m.

which dolphins were located did not vary significantly between diel categories (Kruskal-Wallis: h = 9.119, df = 8, $p = 0.332$) or by month (Kruskal-Wallis: h = 10.715, df = 7, $p = 0.152$).

Common dolphins were located in waters ranging from 14.8 to 23.3° C (mean = 20.42, SD = 1.84). The median SST at dolphin sightings varied significantly by month (Kruskal-Wallis: h = 85.85, df = 7, $p < 0.000$), with coolest and warmest waters apparent during September (median = 14.8, SD = 0.14) and March (median = 22.25, SD = 0.61), respectively. However, dolphin encounters did not vary diurnally (Kruskal-Wallis: h = 8.14, df = 8, $p = 0.420$).

Group Size in Relation to Abiotic Parameters

Common dolphins were observed in small groups ranging from 2 to 21 dolphins (mean = 5.26, SD = 3.687), with results highly skewed towards groups containing ≤ 10 dolphins ($n = 99$), accounting for 91.7% of independent encounters. Group size exhibited no diel variation ($\chi^2 = 8.039$, df = 8, $p = 0.430$), with largest group sizes encountered during 1200-1259 h ($n = 3$) and smallest group sizes observed between 1100-1159 h ($n = 24$). Group size did not vary significantly by month ($\chi^2 = 8.719$, df = 7, $p = 0.273$), although larger groups (> 11 dolphins) were not observed in the months of September, November, January, nor May. Generally, small group sizes (≤ 10 dolphins) were present throughout the year, although they were most prevalent during November ($n = 24$).

Variation in the water depths over which different group sizes were found was not significant (Kruskal-Wallis: h = 0.14, df = 1, $p = 0.907$). Typically, larger groups containing > 11 dolphins were recorded in deeper waters (median = 31.5, SD = 56.4, $n = 99$; Figure 2). The mean SST at which different group sizes were observed was insignificant (Kruskal-Wallis: h = 3.26, df = 1, $p = 0.071$), with both group size categories observed in similar water temperatures: 1 to 10 dolphins (mean = 20.23, SD = 1.9) and 11 to 21 dolphins (mean = 20, SD = 5.3).

No effect of latitude on group size was observed (Kruskal-Wallis: h = 54.42, df = 1, $p = 0.934$). Group size was largest in the northern latitude section of GSV (mean = 7.2, SD = 5.5) but did not vary significantly with longitude (Kruskal-Wallis: h = 0.320, df = 1, $p = 0.582$). Largest group sizes were observed in the western longitude sections of GSV (mean = 5.5, SD = 3.9).

Group Composition in Relation to Abiotic Factors

Over 85% of observed groups included immature dolphins ($n = 224$), with over 50% of groups containing calves ($n = 56$). Groups containing neonates ($n = 10$) accounted for almost 20% of the groups with calves that were encountered. Neonates were most frequently recorded in the months of February ($n = 3$), March ($n = 2$), and April ($n = 2$), accounting for 37.5%, 25.0%, and 12.5%, respectively, of the total number of observed groups containing newborns. Adults were the most frequent age class in this population (60.3%), with neonates (mean = 8.6, SD = 6.3) and calves (mean = 6.9, SD = 4.3) encountered in larger group sizes compared with adults only (mean = 5.3, SD = 3.7) and groups whose youngest component were juveniles (mean = 5.7, SD = 4).

Adults, juveniles, and calves were recorded during all daylight hours, while neonates were observed in 50% of the diel classes surveyed. Adults and juveniles occurred during all months surveyed, while calves were observed in all months surveyed except for September. Neonates were only observed in December and between February and May. While the frequency of immature groups did not vary diurnally ($\chi^2 = 2.027$, df = 8, $p = 0.980$), the occurrence of immature dolphins did vary significantly by month ($\chi^2 = 32.69$, df = 7, $p < 0.05$). During February, 24% of groups ($n = 54$) contained immature dolphins, with greater than 50% of all dolphins observed being classified as immature. Groups containing immature dolphins were least often encountered in September, when they accounted for 0.3% of observed groups ($n = 1$).

The water depths at which dolphins were located did not vary with the presence of immature dolphins (Kruskal-Wallis: h = 0.136, df = 1, $p = 0.712$), with no significant difference in SST observed among age classes (Kruskal-Wallis: h = 1.476, df = 3, $p = 0.688$) or between groups containing immature *vs* mature dolphins only (Kruskal-Wallis: h = 0.47, df = 1, $p = 0.828$).

Discussion

Herein, the distribution and abundance of common dolphins in South Australian waters is reported for the first time. Common dolphins were observed in all months surveyed, although seasonality was evident, with more encounters and larger groups sighted during November to April. While typically associated with deeper waters, short-beaked common dolphins in GSV were only found in water depths < 40 m and typically in smaller groups (< 20 dolphins).

Density

The SF and ER for common dolphins in GSV was 0.03 sightings/km and 0.16 dolphins/km, respectively. This is similar to the 0.02 sightings/km reported for common dolphins in the Mediterranean Sea prior to the latter population decline (0.004 sightings/km; Bearzi et al., 2005). Politi et al. (1994) and Frantzis & Herzing (2002) reported SF of 0.021 sighting/km and 0.043 sightings/km in the Mediterranean Sea and north Ionian Sea, respectively. However, these indices included combined estimates for common and bottlenose dolphins (*Tursiops truncatus*). In comparison, the SF calculated for common dolphins within GSV appears to be reasonably high. High prey availability in GSV offers a plausible explanation. Alternatively, the gulf provides shallow, protected waters that offer refuge from deep-water predators for this species (Mann et al., 2000).

A density estimate of 0.5 dolphins/km^2 reported herein indicates that common dolphins are abundant in GSV. This is further supported by the density estimate of 0.16 dolphins/km^2 recorded for the Alboran Sea, which was considered high (Forcada & Hammond, 1998). However, the significance of the GSV estimate remains unclear since this represents the first estimate of common dolphin numbers for Australian waters. The population estimate of 1,957 common dolphins should be regarded with caution since it assumes that common dolphins are distributed evenly throughout GSV in waters > 14 m deep. While this is unlikely, it represents at least an approximation of common dolphins occurring within these waters. However, the use of GSV and any potential movements between neighboring regions, such as Spencer Gulf (an adjacent inlet 40 km west of GSV), remain unclear. Additionally, the impact of seasonality and the estimates reported herein remain unknown.

Distribution

Common dolphin numbers were highest from December to April, indicating that the majority of dolphins use GSV primarily during the summer months. Nonetheless, opportunistic observations of common dolphins in GSV between 1993 and 2004 indicate that common dolphins also occur at least in the months of October through May (Kemper et al., 2008). As such, it is plausible that common dolphins are resident year-round in GSV as has previously been described for other populations of common dolphins inhabiting similar water temperatures (Reilly, 1990; Stockin et al., 2008c). Alternatively, it is equally possible that at least some GSV individuals move into adjacent areas (e.g., Spencer Gulf) during the winter months, where prey resources are in higher abundance. It is within these waters that common dolphins are incidentally caught in the purse seine fishery for sardines (*Sardinops sagax*) (Hamer et al., 2008).

Common dolphins were encountered most frequently in southern areas of the gulf and least frequently in the shallowest waters of GSV. In Spencer Gulf, Svane (2005) observed bottlenose (*T. aduncus*) and common dolphins more frequently in the northern part of the Gulf. These apparent differences between two closely located gulfs may relate to the size, salinity, bathymetry, and/or circulation differences between Spencer Gulf and GSV (Lavery et al., 2008). Common dolphins in GSV may be concentrated in the southern areas because water depths are greater, prey species are more abundant, or because southern areas of the gulf are in closer proximity to the open ocean (Gygax, 2002). Alternatively, habitat partitioning with bottlenose dolphins may explain the absence of common dolphins within waters < 14 m. Bearzi (2005) reported habitat partitioning between common and bottlenose dolphins occurring off Santa Monica, California. Brito et al. (2009) also reported spatial segregation between common and bottlenose dolphins off the west-central coast of Portugal. Common dolphin distribution has previously been discussed in relation to competitive exclusion by conspecifics, including spinner (*Stenella longirostris*) and spotted (*S. attenuata*) dolphins by Smith & Worthy (2006).

Common dolphins were encountered most frequently in the central and western longitude sections of the gulf and at distances of 4.2 to 30.8 km from land. This is similar to Neumann (2001), who reported distances of 2 to 32 km from shore for common dolphins off the Bay of Plenty, New Zealand. The largest group sizes were found on the western side of GSV, with smallest group sizes occurring on the eastern side. De Silva Samarasinghe (1998) suggested that clockwise circulation of GSV carries low salinity water northwards into the gulf along the western side, and high salinity water southwards back to the shelf along the eastern and central parts of the gulf. The low salinity water entering from the western side may affect prey abundance and/or diversity in this section of the gulf. Alternatively, higher levels of pollution and boat traffic associated with the city of Adelaide (34° 55' 44" S, 138° 36' 04" E) (Lavery et al., 2008; Australian Bureau of Statistics, 2009) may potentially explain why common dolphins spend less time on the eastern side of GSV.

Water Depth

Common dolphins were encountered in GSV in waters depths ranging from 14.0 to 39.6 m. This is comparable with Stockin et al. (2008c) who reported a mean water depth of 38.3 m for common dolphins in the Hauraki Gulf, New Zealand. Generally, such depths are considered relatively shallow for short-beaked common dolphins, which typically are found in waters ranging hundreds to thousands of meters in depth (e.g., Gaskin, 1992; Smith & Whitehead, 1999; Frantzis & Herzing, 2002). As such, common dolphins observed in GSV appear to be at the extreme end of their water depth range. Reasons for this remain unclear, although, as previously discussed, shallower waters may provide greater protection from predation.

Prey abundance and distribution can be influenced by numerous factors, including current and temperature gradients (Ballance et al., 2006). Cold, highly oxygenated water is usually the most productive, especially where cold water at depth is brought up to the surface by upwelling. Continental-shelf break upwelling off South Australia is confined to southwest of Kangaroo Island near GSV's opening to the Southern Ocean. Waters in this region are nutrient rich (McClatchie et al., 2006; Middleton & Bye, 2007); thus, prey species of common dolphins are likely to be found in greater proportions in these waters. A similar trend was observed in the western Atlantic Ocean (Jefferson et al., 2009) and in the southwestern Mediterranean (Forcada & Hammond, 1998), where common dolphins inhabited areas that were characterised by upwelling-modified waters. These findings are further supported by Findlay et al. (1992) who suggest that the distribution of cetaceans is determined indirectly by principal prey.

Sea Surface Temperature

The SST range for common dolphin sightings in GSV was between 14.8° and 23.3° C (mean = 20.42° C, SD = 1.84° C). This is similar to reports by Stockin et al. (2008c) for common dolphins in the Hauraki Gulf, New Zealand (12.5° to 25.1° C, mean = 19.7° C, ± 1.5° C). The SST at which GSV common dolphins were observed varied significantly by month. Warmest waters were recorded in the month of March, with highest SF observed in April. Neumann & Orams (2005) found that common dolphin movements appeared to be closely linked to SST, with dolphins found relatively close to shore in Mercury Bay, New Zealand, during the warm (18° to 23° C) waters of spring and summer but reported increasingly further offshore as SST dropped in autumn (16° to 18° C). A similar movement pattern was reported in the Irish Sea, where common dolphins also moved further offshore in autumn as the SST decreased (Goold, 1998). It is important to note that factors that concentrate or disperse prey (i.e., SST and water depth) may secondarily affect the distribution and abundance of cetaceans. This is supported by Cockcroft & Peddemors (1990) who report that seasonal fluctuations in the abundance of common dolphins relate to the availability of preferred prey species.

Demographics

These results indicate that GSV may be an important nursery area for common dolphins since over 50% of groups contained calves, with a high percentage of groups encountered in February to April containing neonates. These results are relatively high when compared to the Mediterranean population (Universidad Autonoma de Madrid & Alnitak, 2002), although in line with the Hauraki Gulf, New Zealand, population where 70% of groups encountered contained juveniles, with calves present in almost half of all dolphin groups recorded (Stockin et al., 2008c). The relatively high occurrence of neonates, predominantly through the months of February to April, supports the concept of breeding seasonality within this population. Certainly, the peak in calves reported herein for GSV are typical of the calving seasonality reported for New Zealand (Schaffar-Delaney, 2004; Neumann & Orams, 2005; Stockin et al., 2008c), the Mediterranean (Bearzi et al., 2004), eastern North Pacific (Ferrero & Walker, 1995), eastern North Atlantic (Murphy, 2004), and the western North Atlantic (Westgate & Read, 2007).

Breeding seasonally is thermally efficient for small calves and/or lactating females (Mann et al., 2000). Additionally, food availability may fluctuate sufficiently to favour seasonal births, allowing females to maximise intake when nutritional stress is likely to be greatest. Predator densities may also have an influence on the timing of parturition (Mann, 1999). The main predatory threats to Australian common dolphins are likely posed by killer whales (*Orcinus orca*) and various shark species. Killer whales target the central and southern coasts of mainland Australia, with a seasonal trend in sightings coinciding with prey aggregations (Ling, 1991; Morrice, 2004). Attacks by killer whales in Australian waters have been observed on a number of cetacean species, including common and bottlenose dolphins and young humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus*), and sperm (*Physeter macrocephalus*) whales (Banister et al., 1996; Pitman et al., 2001; Forney & Wade, 2006; Ross, 2006). Shark species that predate on dolphins in Australian waters include tiger (*Galeocerdo cuvier*), hammerhead (*Sphyrna lewini*), white (*Carcharodon carcharias*), bull (*Carcharhinus leucas*), dusky (*C. obscurus*), black tip (*C. brevipinna*), oceanic white tip (*C. longimarius*), bronze whaler (*C. brachyuris*), blue (*Prionace glaura*), and shortfin mako (*Isurus oxyrhynchus*) sharks (Stevens, 1984; Corkeron et al., 1987; Heithaus et al., 2002).

Larger group sizes and groups containing neonates were typically found in the northern, shallowest waters of GSV, further supporting the theory that these sheltered waters may provide refuge for nursing females. Allomaternal care may explain why common dolphin groups containing young were observed in larger group sizes (Mann et al., 2000). Similar findings have been reported in New Zealand, where common dolphins move inshore during what appears to be the main reproductive season (e.g., Bräger & Schneider, 1998; Neumann, 2001; Stockin et al., 2008c). Neonates and calves are certainly more vulnerable than adults, with immature common dolphins stranding more frequently in GSV (C. Kemper, pers. comm., April 2006; Tomo et al., 2006).

Similar group sizes to those reported for GSV were reported for the eastern Ionian Sea, where groups rarely included more than 15 individuals, and with groups greater than 40 never observed (Bearzi et al., 2003). This is remarkably small for short-beaked common dolphins, which typically form larger aggregations (e.g., Bryden et al., 1998; Reeves et al., 2002; Bearzi et al., 2005). For example, Mediterranean common dolphins are predominantly reported in groups of 50 to 70 dolphins, with aggregations of 100 to 600 individuals occasionally recorded (Notarbartolo di Sciara et al., 1993; Cañadas et al., 2002; Frantzis & Herzing, 2002). In the Bay of Plenty, New Zealand, the number of dolphins in each encountered group ranged from 2 to 400 individuals (Neumann & Orams, 2005). The variability in common dolphin group size across different locations may be due to differing environments. For example, Gygax (2002) suggests that group size is positively correlated with openness of habitat for common dolphins and that larger group sizes relate to a larger variety of available prey.

Common dolphins in GSV exhibited seasonal changes in group size, with the largest groups observed during the months of February and March. This coincides with the peak in neonates, again supporting the theory that females likely form nursery schools in this region. In New Zealand, groups containing > 50 dolphins were observed more frequently during the months of July, August, October, and November (Stockin et al., 2008c), thus highlighting the possibility that larger group sizes may also occur in GSV waters during the austral winter. However, owing to survey constraints, such groups may have been missed in the present study. While large aggregations (several thousands) of common dolphins have been reported in offshore open waters off South Australia (Bossley, unpub. data), future research is necessary if comparisons in group size and composition are to be made with those of coastal gulf systems such as GSV reported herein.

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