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A Small Resident Community of Bottlenose Dolphins, *Tursiops truncatus,* in Texas: Monitoring Recommendations

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A small community of bottlenose dolphins (*Tursiops truncatus*) in western Galveston Bay, Texas, was first studied in 1990 with subsequent study from 1995 through 2001. These animals showed strong site fidelity with seasonal variation in habitat use. From 1997 to 2001, three methods of assessing dolphin occurrence and abundance in this location were compared for efficiency and accuracy: photoidentification (photo-ID) for occurrence patterns and counts of individual animals; capture–recapture analyses from photo-ID data for abundance estimates; and line transect surveys for dolphin density estimates. Our line transect data were thought to be positively biased and that method is not recommended for this location. Counts of animals with site fidelity were consistent with abundance estimates of all dolphins using the bay from capture–recapture analysis. Resident animal counts ranged from 28 to 34 in different survey years. Abundance estimates for all dolphins using the bay, including nonresident animals, ranged from 28 to 38. Specific recommendations are made for long-term low-level monitoring of dolphins in this study area. These guidelines may be useful to researchers studying similar small coastal dolphin communities when appropriately modified and applied to their research sites.

Wells et al. (1987) define a community of coastal bottlenose dolphins (*Tursiops truncatus*) as being composed of resident animals that are relatively discrete from dolphins in adjacent waters. Recent studies have provided evidence that fits this definition for bottlenose dolphins that inhabit the southwestern end of the Galveston Bay Estuary System in the Western Gulf of Mexico (Maze and Würsig, 1999). This community of dolphins, which occurs in and around the San Luis Pass/Chocolate Bay (SLP/CB) region of West Galveston Bay, appears to be relatively discrete from the bottlenose dolphins occurring in the adjacent Gulf and the northeastern end of the Galveston Bay Estuary System.

Other bottlenose dolphin studies demonstrated that habitats protected from open oceans may attract small populations with site fidelity and limited movement patterns (Wells et al., 1987). This does not necessarily mean that all members of the community are present at all times (Würsig and Harris, 1990). Dolphins may roam, most commonly subadults (Wilson et al., 1999) and males (Wells et al., 1987; Lynn, 1995), and there can be varying degrees of site fidelity, resulting in resident and semiresident animals (Weller and Würsig, 2004). Data from a 1995–1996 study in SLP/CB showed evidence of dolphins with site fidelity, as well as seasonal variation in dolphin use of subareas (Maze and Würsig, 1999).

In this article, we report on a study designed to more clearly characterize residency patterns of SLP/CB dolphins and to make recommendations for monitoring dolphin occurrence patterns and abundance in this small area. Our specific objectives were to 1) further define the residency status of individuals in the community of bottlenose dolphins with site fidelity for SLP/CB, 2) verify that dolphin density varies seasonally within SLP/CB, and 3) compare three methods for monitoring dolphin use of this area and to make monitoring recommendations on the basis of this comparison. These three methods were counts of individual occurrence in SLP/CB and in the Gulf of Mexico using photoidentification (photo-ID), capture–recapture for abundance estimates of dolphins in SLP/CB, and line transect surveys to estimate dolphin density, both in SLP/CB and the Gulf of Mexico.

MATERIALS AND METHODS

Boat surveys.—From March 1997 through Feb. 1998, one to three surveys per week were conducted from a 4.9 or 5.8 m outboard boat. We designated this the 'intensive survey year.' Subsequent 'low-level' surveys were conducted once or twice per month from March 1998 through Nov. 1999. Annual warm month (May through Oct.) surveys were accomplished in 2000 (four surveys) and 2001 (seven surveys).

Line transect data were collected during the intensive survey year. Surveys were conducted

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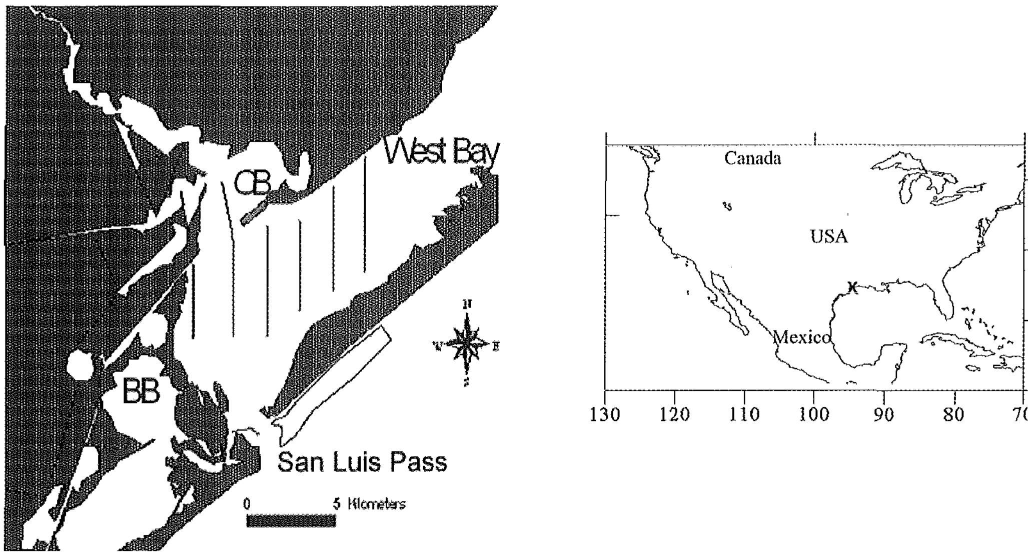

Fig. 1. San Luis Pass/Chocolate Bay transect survey lines in the northwestern Gulf of Mexico and the bay sub-areas of the study site (CB, Chocolate Bay; BB, Bastrop Bay).

along predetermined transect lines with a random start. Transect lines were parallel, but not parallel to shore, in all areas where this could be done, but local topography prevented optimal transect line design in some locations (Fig. 1).

Three observers surveyed by naked eye. The boat driver surveyed 90° left and right of the bow. Observers on each side of the bow surveyed their 90° quadrant, with 10° overlap at the bow. Only groups sighted within 90° of the trackline were included in line transect data (Buckland and Anganuzzi, 1988; Buckland et al., 1993). The line transect survey speed was 22.2 km/hr (12 knots), based on recommendations by Hiby (1985), or our preferred speed of 18.5 km/hr (10 knots) in later low-level surveys. Surveys were conducted in Beaufort sea states ≤3.

Sighting data included time, group size, Global Positioning System location, bearing to the group from the transect line (using range-finding binoculars or a compass), line of sight distance of the group from the boat (estimated by eye), sun position, and the bearing of any glare.

We diverted from the transect line for photo-ID using the 'closing mode' survey procedure (Hiby and Hammond, 1989). Group size for line transect analysis was based on the number of animals in the initial sighting. For analyses based on photo-ID, all animals, including those that later joined the group, were counted for the group size estimate. A group was defined as all animals engaged in similar activity and in close proximity (Weigle, 1990; Defran and Weller, 1999; Karczmarski et al., 2000), usually within less than five body lengths but occasionally as far as 25 body lengths apart.

Neonate dolphins were recognized by small, dark, neonatal folds and uncoordinated surfacings. Approximate ages of calves (up to 2 yr of age) were based on field observations of mothers with their calves over time, as well as the size of the young animals and changes in their fin size and shape.

Dorsal fins were photographed (Würsig and Würsig, 1977; Würsig and Jefferson, 1990) with a Nikon 6006 or a Canon EOS camera and 70–210 mm or 100–300 mm zoom lens on black and white Kodak T-Max ISO 400 film. Once photography was complete or the animals were lost, environmental data were collected and the transect line was continued.

Data analysis.—Photoidentification: We analyzed dorsal fin photographs according to Defran et al. (1990) and Würsig and Jefferson (1990). Searches were made for potential matches in catalogs of fin tracings of previously identified animals from SLP/CB. If no match was found, the animal was designated as new. At least two, preferably three, searches were made by different individuals before an animal was considered to be new.

Occurrence patterns: Occurrence patterns of individuals were cumulative, designating each animal as sighted if it was seen one or more times in a season. Seasons were defined according to Shane (1977): spring = March, April, May; summer = June, July, Aug.; fall = Sept., Oct., Nov.; and winter = Dec., Jan., Feb. Occurrence patterns comprised all individuals sighted with the exception of animals that were seen only in the Gulf of Mexico. We also considered occurrence pattern data from 1990 (Henningsen and Würsig, 1991; Maze and Würsig, 1999) and 1995–1996 surveys (Maze and Würsig, 1999), constituting a span of 12 yr.

Because resident animals regularly return to a specific site, resident designation during the intensive survey year required sightings in three seasons and subsequent presence in two seasons per year. We designated an animal as 'status undetermined' if it was not sighted for three seasons in a row in the intensive survey year or four seasons in a row in low-level surveys. For the subsequent seasonal warm month surveys, resident classification required presence in at least two of these periods. Dolphins absent for more than two consecutive warm month periods would be given a status undetermined classification.

Line transect analysis: Dolphin density was estimated using program DISTANCE (Buckland et al., 1993). Population abundance estimates are recommended with this method primarily when the subject animals' range or use of the study area is known (Hammond, 1987; Wilson et al., 1999). Assumptions for this technique are: 1) all animals on the trackline are detected; 2) animals do not make movements in response to the survey vessel, and none are counted twice; 3) distances and angles are measured accurately; 4) sightings are independent events; 5) the survey area is representative of the entire area; and 6) the probability of detection is a function of perpendicular distance to the trackline (Buckland et al., 1993).

The line transect component of the study area was divided into two subareas for analysis (Fig. 1). The bay section included West Bay, CB, and the SLP bridge areas. The Gulf component was the Gulf of Mexico, just offshore and northeast of SLP.

Densities for the entire area and the two subareas were estimated for the intensive year and by warm (May–Oct.) and cold (Nov.–April) month periods. During May–Sept. sea surface temperatures were 22–36 C, Nov.–March were 11–22 C, and transitional months of Oct. and April were 19–20 C. The inclusion of Oct. and April in respective warm and cold periods corresponds to definitions of warm and cold month periods in other bottlenose dolphin studies (Wilson et al., 1997; Barco et al., 1999; Karczmarski et al., 2000).

Model selection with program DISTANCE was based on Akaike Information Criterion (Buckland et al., 1993). The most consistent model selected was the hazard rate/hermite polynomial model. For consistency, this model was used for data comparison for all regions and time periods.

Capture–recapture analysis: Capture–recapture analysis was based on photo-ID data. Because each sampling 'occasion' must cover the entire study area, some sampling occasions included surveys from more than one day when there had been an incomplete survey. If an animal was captured more than once during the same occasion, this was treated as a single capture.

Assumptions for program CAPTURE include: 1) a 'closed population' with no births, deaths, immigration, or emigration for each sampling period; 2) equal probability of recapture for each animal; 3) marking does not affect 'catch-ability'; 4) no loss of mark occurs; and 5) animals are correctly identified on resighting (Hammond, 1986).

CAPTURE has 11 models from which to select, some combining features of open and closed populations. Model Chao Mth, robust to time and individual heterogeneity (Chao et al., 1992), was selected by CAPTURE most frequently for SLP/CB data, as has commonly been the case in other cetacean studies (Williams et al., 1993; Wilson et al., 1999; Forcada and Aguilar, 2000). Model Chao Mth was used for all comparative analyses because it is considered to be the most appropriate model when it is not possible to ensure equal probability of capture (Wilson et al., 1999).

For occurrence patterns, all photographs with unambiguous animal identifications were used. The selection of optimal photographs for capture–recapture analysis is imperative because of the assumption that marking does not affect catch-ability because some animals are more distinctively marked and easily recognizable than others (Hammond, 1986). To minimize this potential source of bias, all cataloged photographs were graded for quality and reviewed at least twice for consistency.

All noncalf resident animals had marked fins, so there was no need to adjust abundance estimates for unmarked fins. Unmarked calves were not included in any of our resident animal counts.

Because each capture period covered a relatively short time frame, population closure was assumed. Our capture periods included summer (June–Aug.) in 1997 and 1998 and warm months (May–Oct.) in subsequent years. Wilson et al. (1999) used a similar time frame, indicating that it gives a 'good approximation of closure.' Capture–recapture estimates included only animal sightings in the bay subarea in warm months.

Results

Occurrence patterns.—In the intensive survey year (March 1997–Feb. 1998), 155 dolphin groups were observed during 89 surveys. Thirty-four subsequent low-level surveys were completed through 2001, and 80 dolphin groups were observed. Thirteen animals first seen in 1990 continued to show evidence of site fidelity through 2001. Since 1995, a total of 41 animals fulfilled the residency criteria. The status of seven of the 41 was undetermined at the completion of the 2001 surveys, leaving 34 known current residents.

During our 1997–2001 study period, no animal gained resident status other than calves that acquired markings and became recognizable as they aged. One animal (SLP 021) seen from the spring of 1996 through spring of 1997 was not sighted again until Sept. 2000 and was considered 'absent' in that interval; however, it was seen again in 50% of the 2001 surveys. During the last 6 yr of work, the number of animals in the area that fulfilled residency criteria in single years ranged between 28 and 34. There was variability in sighting frequencies for all resident animals during the intensive survey year. Despite this variability, all resident dolphins were seen in at least three of the four seasons except for one, a known male (sex reported by Maze-Foley and Würsig, 2002). During the last 4 yr of our research, there were four sightings of SLP/CB resident animals by researchers outside of our study area in other portions of Galveston Bay and the Gulf of Mexico.

DISTANCE analysis.—Dolphin density in the full study area ranged between 0.94 and 1.01 dolphins/km^2 within the three time frames: the intensive year, warm months, and cold months (Table 1). There were 46 surveys in warm months and 43 surveys in cold months. Gulf of Mexico sightings included a mix of SLP/CB residents and transient animals that are part of the larger Texas coastal bottlenose dolphin population. Sporadic resightings of some of these transient animals have been documented over long time intervals both in the Gulf portions of our study area and further northeast in the Gulf (Beier, 2001), but most were seen on one occasion only. Infrequent dolphin sightings in the bay in cold months generated insufficient data for analysis, so comparison of estimated dolphin densities in the bay section could only be made between the intensive year and the warm season. There was a tendency toward a higher dolphin density in the bay in warm months and in the Gulf in cold months.

Table 1. Estimated dolphin density (dolphins/km^2) from line transect surveys with 95% confidence intervals by region and by year, warm or cold season. Higher densities in the bay in warm months and the Gulf in cold months are indicated in bold.

Area/time	Dolphin density/km^2	(95% Confidence interval)
Total area/full year	0.94	(0.47–1.88)
Total area/warm	1.01	(0.39–2.63)
Total area/cold	1.00	(0.40–2.51)
Gulf/full year	0.93	(0.40–2.19)
Gulf/warm	0.26	(0.08–0.85)
Gulf/cold	**2.09**	(0.65–6.70)
Bay/full year	1.12	(0.40–3.16)
Bay/warm	**1.81**	(0.55–6.01)

Because of our impression that our densities were higher than expected compared with dolphin density estimates in other studies (Mullin et al., 1990; Weigle, 1990), we included one analysis of abundance in warm months in the bay within the known area of dolphin use. The abundance estimate using DISTANCE was 108 dolphins (95% CI = 33–358), whereas photo-ID of resident animals counted a maximum of 30 in the summer of 1997. Nine nonresident animals were also sighted, most seen on one occasion only.

The detection probability graph for the intensive survey year data in all SLP/CB subareas as a function of perpendicular distance of dolphin group sightings from the transect line had a 'spike' of sightings near the transect line (Fig. 2). An ideal sighting curve has a well-defined shoulder without a spike.

Seasonal movement patterns.—Seasonal movement patterns of resident dolphins into the bay areas in warm months and the Gulf in cold months were apparent from the line transect densities. A second analysis was done to determine the sighting frequency of individual resident dolphins per survey per unit effort in the intensive survey year (Table 2). In colder

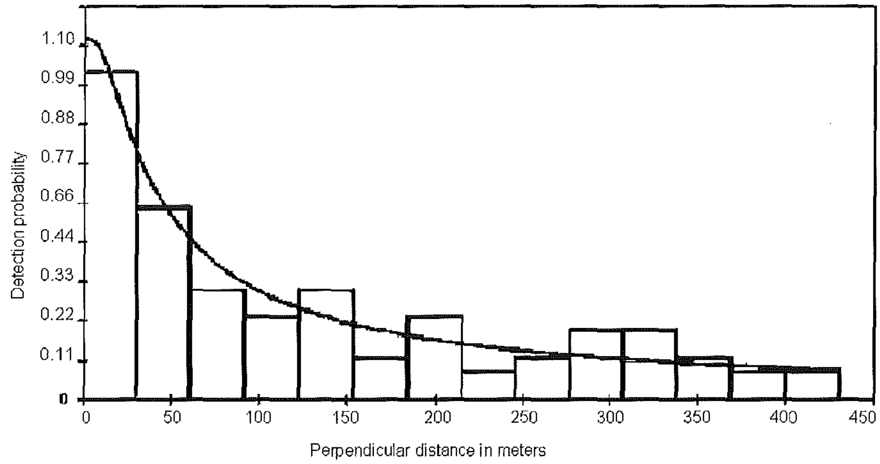

Fig. 2. Detection probability function bottlenose dolphin sightings during line transect surveys in all San Luis Pass/Chocolate Bay sub-areas.

months, there were higher sighting frequencies of resident dolphins in the Gulf than in the bay (Wald test, $P = 0.007$, Freeman, 1987).

CAPTURE analysis.—CAPTURE analysis estimates of dolphin abundance in the bay in each study year in warm months ranged from a low of 28 (95% CI = 26–71) for analysis of three surveys in 1998 to a high of 38 (95% CI = 33–55) for four surveys in 2000 (Table 3). Confidence intervals decreased when four, instead of three, surveys per year were included.

Discussion

Occurrence patterns.—The occurrence patterns of bottlenose dolphins in SLP/CB showed clear evidence of a community of resident animals. Although recognizing that varying degrees of individual site fidelity occur (Bearzi et al., 1997; Quintana-Rizzo and Wells, 2001), we found our method of evaluating resident status for animals in this community to be practical and effective for this specific location.

Table 2. Sighting rates of resident SLP/CB dolphins (dolphins/km of survey effort) in the bay and the gulf in warm and cold months in the intensive survey year (March 1997–Feb. 1998). Higher sighting frequencies in the bay in warm months and the Gulf in cold months are indicated in bold.

	Individual animal sightings per survey per km			
Season/region	**Warm/ bay**	Warm/ Gulf	Cold/ bay	**Cold/ Gulf**
Animals/km	**0.417**	0.015	0.015	**0.503**
P Value	0.08			0.007

Despite the addition of new calves in SLP/CB, the community size appeared relatively stable. Approximately 30 animals may represent the optimal carrying capacity for this area (Lynn and Würsig, 2002). As in other bottlenose dolphin communities, males, beginning at a young age, may roam from the resident range (Wells et al., 1987; Lynn, 1995; Wilson et al., 1999).

There are several possible reasons, other than death, that previous resident animals were no longer found in the study area. First, varying degrees of site fidelity could have been a factor, as suggested by the recent sighting in CB of an animal that had not been sighted in the area for 3 yr. Based on fin size, shape, and growth, this animal was thought to be young in 1997 and could possibly have been a male that temporarily moved. Some of the nonresident dolphins sighted in the bay were seen in SLP/CB repeatedly for short times, and some also were seen with the resident animals in the Gulf. These animals may have been intermittently using SLP/CB as a preferred site or could be males that were born in this location and periodically return. Second, it is possible that animals that had exhibited site fidelity for SLP/CB may have simply moved to another area. Third, an animal might have become unrecognizable after developing significant new marks and could have been incorrectly considered absent from the area. A great deal of effort was made to avoid this error, but fin changes could have occurred that were extreme.

DISTANCE analysis.—As previously noted, our dolphin density estimates, ranging from 0.94 to

TABLE 3. Estimated dolphin abundance from capture–recapture analyses with 95% confidence intervals for all animals that came into SLP/CB for each study year in warm months.

Survey months	June to Aug. 1997	June to Aug. 1998	May to Oct. 1999	June to Sept. 2000	May to Oct. 2001
Community size estimate	29	28	30	38	32
(95% Confidence interval)	(29–33)	(26–71)	(28–42)	(33–55)	(29–47)
Number of surveys	16	3	6	4	6

1.01 dolphins/km^2, appear positively biased compared with bottlenose dolphin estimates in other locations. Mullin et al. (1990) reported dolphin density estimates from aerial strip transect surveys in the northern Texas coastal portion of the Gulf ranging from 0.11 dolphins/km^2 in the fall to 0.18 dolphins/km^2 in the spring, although they thought their results were negatively biased. Additionally, our abundance estimate of 108 animals, using line transect data in the bay, is clearly high compared with our photo-ID data. With 6 yr of direct animal counts using photo-ID and 5 yr of capture–recapture estimates, we are confident that the community size is approximately 28–34 dolphins.

In designing transect lines, it is helpful to take into account known animal movement and behavior patterns that may predominate in particular areas. At the time that our surveys were designed, there had been only one previous year-long study of the SLP/CB animals (Maze and Würsig, 1999), and long-term behavioral patterns of these animals were not established. We ultimately found that some specific areas have a recurring high number of resident dolphins. Chocolate Bay was the preferred subarea for the dolphins in the warmer months but with nonuniform distribution and concentrations at the entrance. The SLP bridge area was also one of their preferred feeding sites. Higher concentrations of bottlenose dolphins in passes and along shorelines, as well as low densities of animals in open bays, have been described in other studies (Shane, 1990; D. W. Weller, pers. comm.). Wilson et al. (1997) noted a tendency for bottlenose dolphins to concentrate in areas with deep and narrow channels, particularly where there were strong tidal flows and steep slopes that may facilitate prey capture, as is the case at SLP. The deep channels at the intersection of the Intracoastal Waterway and the CB-dredged channels also may have been a factor in the dolphins' apparent preference for this area.

Although West Bay was most appropriate for transect lines, the area is large and the animals do not spend much time there, so no animal was sighted 'on effort' in this subarea for the entire year. In the Gulf, the need to run survey lines parallel to shore because of sand bars and surf also created the potential for lines to run through high animal density areas because resident animals were seen more commonly closer to shore. The nonrandom distribution of animals with transect lines that turned out to be through, rather than across, areas of high animal density is likely an important factor in the apparent overestimation of dolphin densities.

For line transect estimates, more sightings than we had are preferred in a number of circumstances, all of which applied to this area. Our number of sightings was small, less than the recommended 60 sightings in each stratum. Our data were spiked, with a predominance of sightings close to the transect line. This finding suggests that animals were not randomly distributed and raises the possibility that the animals were approaching the boat before being sighted and may be 'boat friendly.' Although animals did not appear to regularly approach the boat in the field, the data were consistently spiked in all areas and seasons (e.g., Fig. 2). This has been observed in other small boat-based line transect surveys (Dawson et al., 2000). Highly aggregated populations may result in positive bias of density estimates. Although this is a very small community, over half of the animals were commonly seen together. Group sizes of resident animals ranged from 1 to 22 during the intensive survey year that included the line transect surveys and from 1 to 28 during subsequent low-level surveys.

Other potential sources of error may have been relevant. Seasonal migration of dolphins along the coast may have resulted in periodic nonrandom movement patterns in the Gulf. Negative bias may have occurred because of poor detectability when the animals spent long periods under the water while feeding.

CAPTURE analysis.—Capture–recapture estimates contributed important information beyond the individual occurrence patterns and residency data. Because photography in low-level surveys is unlikely to include all animals present, abundance estimates are useful even for such a small dolphin community. Our abundance estimates of 28 to 38 dolphins are similar to our resident animal counts in different years of 28 to 34. These abundance estimates also took into account those animals that used the bay intermittently that were not part of the designated resident community. We also used these data to evaluate the minimum number of low-level surveys needed to obtain reasonable statistical data for this method. Confidence intervals were smaller when four or more surveys were used.

Recommendations.—This study provided sufficient information to make specific recommendations for conducting low-level monitoring of the SLP/CB dolphin community during years when intensive surveys are not carried out, thus providing continuity of data. Our approach may provide guidance for the development of similar plans, modified appropriately, for other coastal dolphin community study designs. We propose: 1) conduct surveys in warm months, preferably between May and Sept.; 2) a minimum of four surveys, preferably five or more; 3) a minimum of 1 wk between surveys, allowing for turnover of animals present (Forcada and Aguilar, 2000; Lynn and Würsig, 2002); 4) distribute the surveys evenly during survey months to detect animals that may not be present for the entire season; 5) a full survey 'occasion' for capture–recapture estimates must include both CB and the SLP area; 6) a minimum 4 hr per survey; 7) weather conditions should be clear with winds <37 km/hr (20 knots) or a Beaufort sea state ≤ 3; and 8) vessel survey speed of 15–22 km/hr (8–12 knots).

Photographic quality must be graded and optimal for capture–recapture analyses. Annual reviews of photographic catalogs for errors should also be conducted (Forcada and Aguilar, 2000), which is particularly important for newly marked juveniles that are likely to have additional changes in their fin markings.

These two approaches, monitoring for both the presence of resident animals as well as total abundance estimates of all dolphins using the bay, will provide complementary datasets. For example, if the resident animals represent a community component of a metapopulation along the Texas coast, deleterious events resulting in loss of resident animals may not be apparent if monitoring is limited to dolphin abundance estimates. Theoretically, in metapopulations there is a locally stable equilibrium distribution (Harwood and Hall, 1990) such that other animals might take up residence in this area if the previous residents leave or die. Should that occur without recognizing the loss of the long-term resident animals, an opportunity for investigation of the cause of a problem would be missed because abundance estimates alone may not reflect such a loss.

This community of dolphins is unique in the Galveston Bay estuary system because when these dolphins enter SLP into far western Galveston Bay and CB, they become isolated from the larger Texas coastal dolphin population. In East Galveston Bay there are dolphins with apparent site fidelity for that area, but they mix with many other transiently present dolphins that readily enter that portion of the bay through the dredged ship channel. The relative isolation of the SLP/CB dolphins when they are in the bay may become important because CB is fed by waters adjacent to potential pollutants, including chemical plants. For this reason, these animals are being considered as potential environmental biomonitors. In addition, compared with studies done elsewhere, this appears to be an unusually small community. Long-term study of resident coastal dolphins in bays is limited at this time, so we speculate that dolphin communities of this small size may be found commonly as research in other regions continues.

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