Biological Sciences

SITE FIDELITY AND MOVEMENT OF BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) ON FLORIDA'S EAST COAST: ATLANTIC OCEAN AND INDIAN RIVER LAGOON ESTUARY

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ABSTRACT: *This study examined the site fidelity, group size, and seasonality of dolphins* (Tursiops truncatus) *in the Atlantic Ocean along Florida's east-central coast, and evaluated dolphin movements between the coastal waters and the adjacent Indian River Lagoon Estuary (IRL). Dolphin sightings occurred in each month surveyed (2|2006–8|2008); of 221 photo-identified dolphins, 185 (83.7%) were seen ≤2 times. Low sighting frequencies suggest an extended geographic range beyond the 80 km latitudinal study area, or transience. Twenty-five dolphins seen during exploratory surveys (10|2002–10|2005) were re-sighted, indicating some level of longer-term residency for particular individuals. Increases in relative abundance in winter and spring indicate that at least some of the population may be migratory. Group size averaged 6.0 (SD = 7.8), and most frequently contained two individuals (22.8%). Calves were present in 88 of 167 (52.6%) groups encountered. Four dolphins that exhibited year-round site fidelity to the estuary were observed once in the ocean within 1 km of an inlet. One female and a dependent calf, which were first observed in the ocean, immigrated into the estuary. The limited movement between the coastal Atlantic and the IRL populations supports discrete management units, with low potential for disease transmission.*

Key Words: Dolphin, *Tursiops truncatus*, Atlantic Ocean, Indian River Lagoon, photo-identification, site fidelity, stock

BOTTLENOSE dolphins (*Tursiops truncatus*) are distributed in a continuous spatial pattern along the U.S. eastern seaboard from New Jersey to Florida. The population structure consists of a complex mosaic of stocks defined in seven management units, including two on the east coast of Florida (northern and central) (Waring et al., 2009). Conversely, on the west coast of Florida, over 18 dolphins stocks have been identified in embayments and coastal areas of the Gulf of Mexico (Waring et al., 2009). The stable, long-term residence patterns observed there suggests that dolphin communities (''distinct assem-

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blages of dolphins that inhabit similar ranges and that interact more with each other than with adjacent assemblages''; Wells, 1986) exist as functional units of unique ecosystems, and are managed as such under the Marine Mammal Protection Act. Similar communities are considered to be present along the Atlantic coast (Waring et al., 2009), but are poorly documented.

Atlantic coastal bottlenose dolphin populations generally occur within 7.5 km of shore (Torres et al., 2003), and in some areas have been observed to be year-round residents, seasonal residents, and migratory or transient (Barco et al., 1999). Satellite tag telemetry studies have provided evidence for a seasonal migration of dolphins between the North Carolina and northern Florida management units (NMFS, Southeast Fisheries Science Center, unpublished data). Genetic evidence exists for differentiating dolphins inhabiting the nearshore, coastal waters of northern Florida, from dolphins in the adjacent, inland estuarine waters (Caldwell, 2001), and those sampled in the central Florida management unit (NMFS, 2001). However, the spatial extent of coastal dolphins occurring in the central Florida management unit, as well as their site fidelity, and the degree of overlap between the bordering estuarine population(s) remains uncertain.

The Indian River Lagoon (IRL) is a 250 km linear estuary located on the east central coast of Florida. The IRL is connected to the Atlantic Ocean via five inlets and the Canaveral Lock. Long-term, year-round, multi-generational resident dolphins have been observed in the estuary (Odell and Asper, 1990; Mazzoil et al., 2005; Howells et al., 2009), and at least three distinct communities have been identified within the system (Mazzoil et al., 2008a). Two rehabilitated and radio-tracked dolphins that stranded in the IRL did not leave the system (Mazzoil et al., 2008b), providing limited evidence for separation between the IRL Estuary and Atlantic Ocean populations. However, movement patterns through the inlets have not been studied. This paper describes the site fidelity, group size, and seasonality of photo-identified dolphins in the Atlantic Ocean, and evaluates dolphin movement between the coastal and estuarine habitats. Knowledge of distribution will serve to refine stock structure on a national (Atlantic seaboard) and regional (Florida) scale relevant to the conservation and management of dolphins in U.S. waters (Hohn, 1997).

METHODS—*Survey area and survey coverage*—The Atlantic Ocean was surveyed from 27°53′N to 27°08′N (Fig. 1). The north-south or south-north survey route allowed for visual scanning for dolphins from the track to the beach (1.5 km) and to at least 3 km offshore. The survey route encompassed three inlets, originated from Ft. Pierce Inlet and extended 2 km north of Sebastian Inlet (45 km) or 2 km south of St. Lucie Inlet (35 km).

OCT 2002–OCT 2005. Exploratory photographic surveys, which represented unequal temporal and spatial effort, were randomly conducted from Sebastian to St. Lucie inlets, with one survey reaching as far south as Jupiter Inlet.

FEB 2006–AUG 2008. Systematic photographic surveys of dolphins were conducted once monthly; two days were required each month to completely evaluate the entire area. Surveys were conducted on consecutive days to the extent possible; selected days required a Beaufort wind force scale of ≤ 2 to ensure consistent sighting conditions.

FIG. 1. Map of the study area in the nearshore, coastal waters of the Atlantic Ocean (indicated by dotted line) and the adjacent Indian River Lagoon Estuary (in white) in east-central Florida.

Photographic procedures and analyses—A 6.7 m in length vessel with a 2.2 m elevated helm station/viewing deck, operated at a speed of 10–12 km/h was used for surveys. Data collection and photographic protocols have been described previously (Mazzoil et al., 2005). Data were archived and analyzed in a customized Microsoft Access database. Laboratory computer-based analyses of digital images were described previously (Mazzoil et al., 2004), as was the selection criteria for prototype images used to identify and match each dorsal fin (Mazzoil et al., 2008a). To determine whether estuarine dolphins occurred in ocean waters, images of distinct dolphins were first compared to all dolphins identified in the IRL from 1996–2006 (n=704) (Murdoch et al., 2008). If a distinctly marked dolphin could not be matched to an existing image, it was added to the catalog as a newly identified individual.

Site fidelity and group size—Data collected from 2006–2008 were summarized by the following parameters: number of dolphins identified, monthly rate of discovery, individual sighting frequencies, group size frequency, and percentage and size of groups with or without calves (defined as two-thirds or less the length of an adult they continually swam beside). Sightings from these surveys were partitioned into two categories: ''on'' effort, which included dolphins encountered while actively searching along the survey route where attempts were made to photograph each individual, and ''off'' effort, which included opportunistic encounters or partial photo coverage during time spent traveling to and from the survey route. Only ''on'' effort systematic survey sightings were included in the analyses of discovery rate, individual sighting frequencies, and group size. Dolphins initially identified in exploratory surveys that were re-sighted during systematic surveys were excluded from the discovery rate, but included in the sighting frequency analysis.

Distribution and relative density—Sightings for every distinct dolphin were plotted in ESRI® ArcMap™ 9.3 based on the GPS coordinates of each encounter. Dolphins were categorized as present in the Atlantic Ocean only, or in the Atlantic Ocean and IRL Estuary. Relative density (the number of dolphins observed per linear km) was determined using 1 km latitudinal increments, designed in ESRI® ArcInfo™, which was layered over the survey area. North-south 1 km linear units were grouped by three, with all surveyed inlets bordered by 1 km in both directions.

Seasonal trends—Seasonal trends in relative abundance were compared between data collected during aerial surveys from 1995–1996 (McClellan, 1996) and photographic surveys conducted from 2006–2008. Seasons were defined as used in aerial surveys: winter (Jan, Feb, Mar), spring (Apr, May, Jun), summer (Jul, Aug, Sep), and fall (Oct, Nov, Dec) for analysis. Aerial surveys were not corrected for visibility bias (Waring et al., 2007). However, to ensure that group size was accurately counted in photo-identification surveys, only ''on'' effort, ''Grade-1'' sightings (Wells et al., 1996) were included.

The aerial survey study area was arbitrarily divided into zones according to 20 minute latitude lines (McClellan, 1996). Zone 2 (27°50′N to 27°30′N) and zone 3 (27°30′N to 27°10′N) were aligned to correspond with photographic coverage in 1 km latitude units 2–43 (Sebastian Inlet to 3 km north of Ft. Pierce Inlet) and 45–81 (3 km north of Ft. Pierce Inlet to St. Lucie Inlet), respectively.

RESULTS—*Survey and photographic coverage*—2002–2005: Dolphin sightings occurred in 10 of 15 d. Random exploratory surveys totaled 99 h, with 47 h spent searching for dolphins. One hundred thirty-eight dolphins were photographed in 27 encounters, and approximately 1,750 digital images were sorted, analyzed, and archived.

2006–2008: Dolphins sightings occurred in 51 of 53 d and in all months surveyed (n=33). Surveys could not be conducted in Mar 2006, Mar 2007, and May 2007; partial surveys were carried out in Jan 2007 and Mar 2008, due to

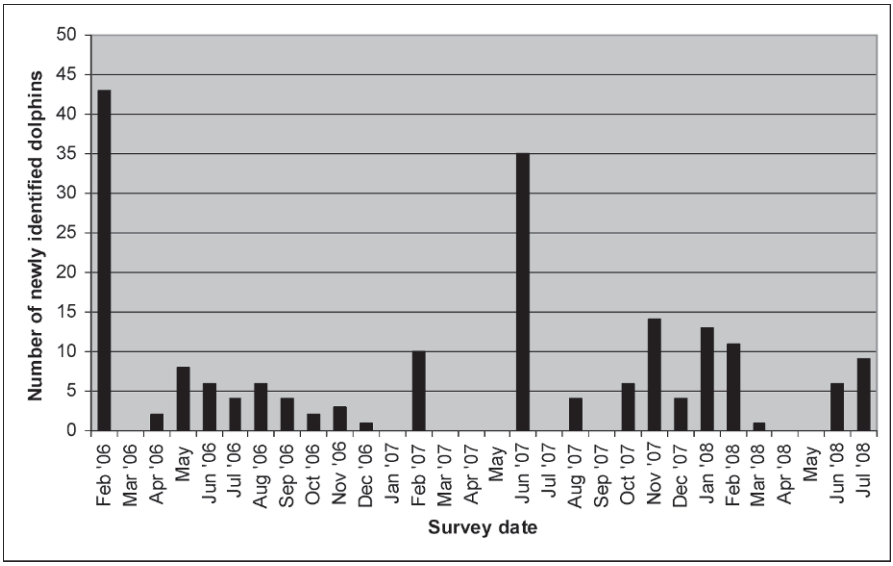

FIG. 2. The discovery rate for individual dolphins in the Atlantic Ocean identified from 2006 to 2008.

limiting factors such as weather (rain) and wave height (≥3 on the Beaufort wind force scale). Systematic surveys totaled 650 h, with 392 h spent searching for dolphins ("on" survey). During "on" surveys, 1,007 dolphins were photographed in 167 encounters, and 51 dolphins were photographed in five encounters while "off" survey. Approximately 52,500 digital images were sorted, analyzed, and archived.

Site fidelity—During the 2006–2008 systematic surveys, 221 distinct dolphins were photographically identified. This includes 25 of 48 dolphins (52%) initially identified during exploratory surveys that were re-sighted during systematic surveys. Additionally, 196 distinct dolphins were photographically identified. The rate at which new dolphins were added to the photographic catalog showed the expected high rate of discovery during the initial survey in February 2006, then fell sharply and did not rise significantly until June 2007 (Fig. 2). Sighting frequencies for individual dolphins identified (n=221) averaged 1.7 (SD = 1.3) and ranged from 1 to 9 (Fig. 3). The highest sighting frequencies were one to three (92.3%), with most dolphins photographed only once.

Group size—The average group size was 6.0 (SD = 7.8), with a range of 1 to 52. The most frequently observed groups contained two individuals (22.8%), followed by groups of one (17.4%) (Table 1). Calves were present in 88 of 167 (52.6%) groups encountered. Groups that contained at least one calf were larger ($\bar{x}$ = 8.5, SD = 8.7) than groups without calves ($\bar{x}$ = 3.1, SD = 5.5) (Table 2). Groups containing calves were encountered relatively equally throughout the year.

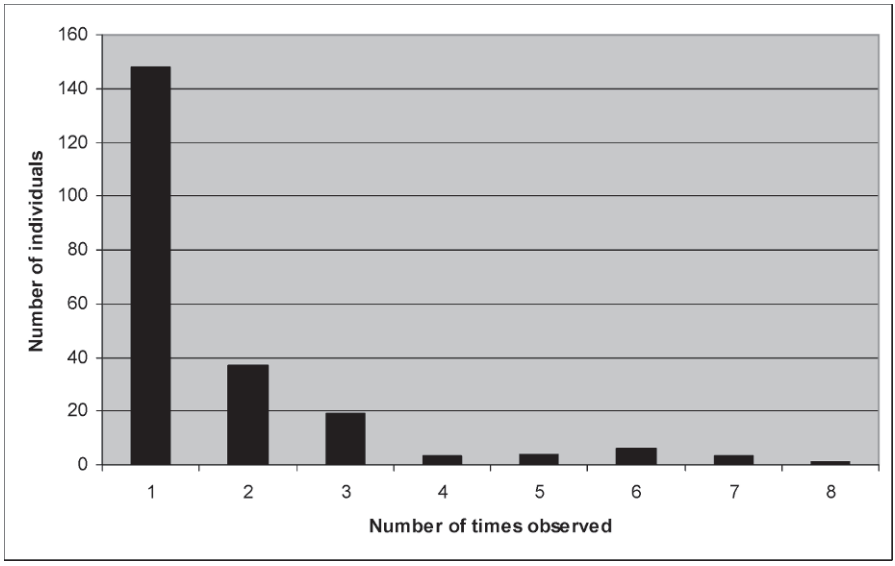

FIG. 3. Sighting frequencies for individual dolphins identified in the Atlantic Ocean from 2006 to 2008.

TABLE 1. Group size frequency for bottlenose dolphins sighted in the Atlantic Ocean study area, from 2006 to 2008.

Total dolphins	No. of groups	Percentage
1	29	18.0%
2	38	23.6%
3	20	12.4%
4	20	12.4%
5	8	5.0%
6	11	6.8%
7	8	5.0%
8	2	1.2%
9	4	2.5%
10	4	2.5%
11	1	0.6%
12	1	0.6%
14	4	2.5%
15	3	1.9%
16	2	1.2%
19	2	1.2%
21	1	0.6%
22	2	1.2%
24,27,31,32,40,43,52	1	0.6%
	167	100.0%

TABLE 2. Bottlenose dolphin group composition observed by season and by presence of calves in the Atlantic Ocean from 2006 to 2008.

	Calf Groups			Non-Calf Groups		
Season	Number of Groups	Mean Group Size	SD	Number of Groups	Mean Group Size	SD
Winter	24	10.5	10.1	31	4.2	8.5
Spring	22	8.5	11.1	9	2.0	1.4
Summer	24	5.8	4.1	26	2.6	1.2
Fall	18	9.7	7.5	13	2.3	1.8

Distribution and relative density—The vast majority (97.2%, or 215 of 221) of distinct dolphins observed in the Atlantic Ocean were classified as Atlantic Ocean only. Four dolphins that exhibit long-term (≥10 y), year-round, site fidelity to the IRL were observed once along the Atlantic coastline at the mouth of an inlet. One dolphin that was observed during Atlantic Ocean exploratory surveys (3/2004) was re-sighted in the IRL in the Ft. Pierce Inlet channel (4/2006). One female dolphin with a dependent calf, which were not previously identified in the IRL (1996–2006) and first observed in the Atlantic Ocean (2/2006), immigrated into the estuary (6/2007). All subsequent re-sightings of this pair were within the IRL Estuary.

The highest density of dolphins was found in areas containing or surrounding Ft. Pierce and Sebastian Inlets, respectively (Fig. 4). More dolphin sightings occurred from Ft. Pierce to St. Lucie Inlets in the earlier aerial survey data (n = 63 of 69) (McClellan, 1996). Conversely, more dolphins were sighted from Ft. Pierce to Sebastian Inlets (300 of 480) in the photo-identification data reported here.

Seasonality—Higher numbers of dolphins occurred in the combined aerial and photo-identification data sets in the winter (n = 180) and spring (n = 189) than in summer (n = 111) or fall (n = 69) (Fig. 5).

DISCUSSION—*Distribution*—This study provides evidence for spatial separation and a minimal degree of movement between dolphins observed in the nearshore coastal waters of the Atlantic Ocean (NMFS central Florida management unit), and dolphins occurring in the adjacent Indian River Lagoon Estuary. The movements of four, long-term resident IRL estuarine dolphins and one Atlantic Ocean dolphin into adjoining waters were restricted to the junction of the estuary and ocean. Similarly, dolphins seen predominately in the nearshore Atlantic Ocean in Charleston, South Carolina that were sighted in the adjacent inland estuaries appear to have restricted movement within the harbor or harbor mouth, and some were following shrimp boats (Speakman et al., 2006). Resident dolphins found in the inshore waters near Hilton Head, South Carolina, were also not sighted in the adjacent Atlantic Ocean (Gubbins, 2002). In Jacksonville, Florida (NMFS northern

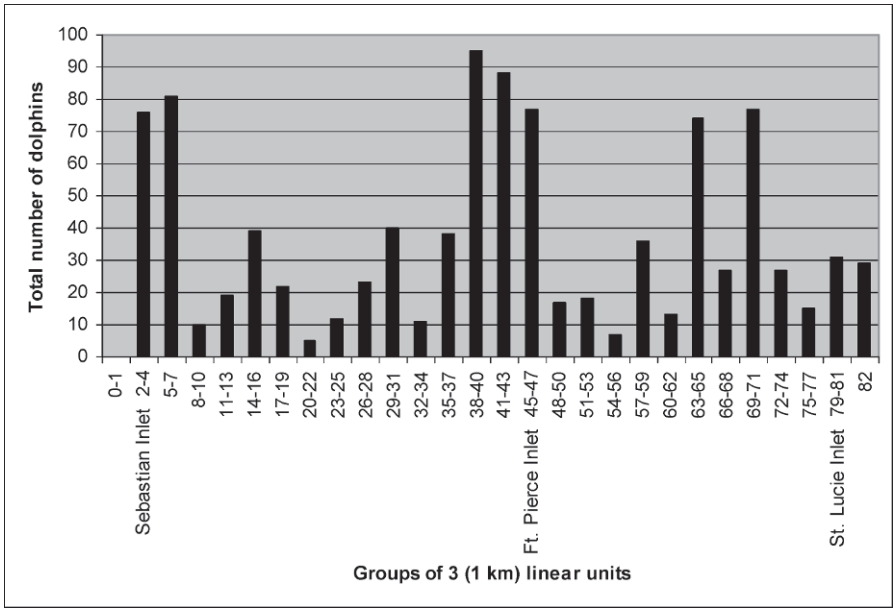

FIG. 4. The relative density of dolphins along the nearshore, coastal Atlantic Ocean waters from Sebastian to St. Lucie inlets, from 2006 to 2008.

Florida management unit) dolphins displayed behavioral and geographic partitioning between coastal and inshore habitats, and demonstrated significant genetic differences (Caldwell, 2000). Thus, our findings that differentiate dolphins found in the Atlantic Ocean from those in the estuarine waters of the IRL are consistent with other coastal populations and further support designating these populations as separate stocks (Mazzoil et al., 2008a; Waring et al., 2009).

Seasonality—Data were insufficient to determine whether central Florida coastal dolphins comprise part of the Southern Migratory (Winter) Stock, which ranges from South Carolina to northern Florida (Caldwell, 2002; Waring et al., 2009). However, increases in relative abundance in both winter and spring, combined with low sighting frequencies, indicate that at least some of the population is migratory. Dolphins along the Atlantic coast in South Carolina are reported to be transient or short-term visitors (Speakman et al., 2006), similar to patterns presented here. McLellan et al. (2002) demonstrated differences in seasonal distribution using 25-y of stranding data along the entire U.S. Atlantic coast. If migration does occur to central Florida, the region does not appear to be utilized primarily as a calving ground based on the lack of seasonal differences in calf sighting frequency. Future studies, along with genetic sampling and comparison to other photo-identification catalogues along the eastern seaboard (Urian et al., 1999) will contribute to the long-term

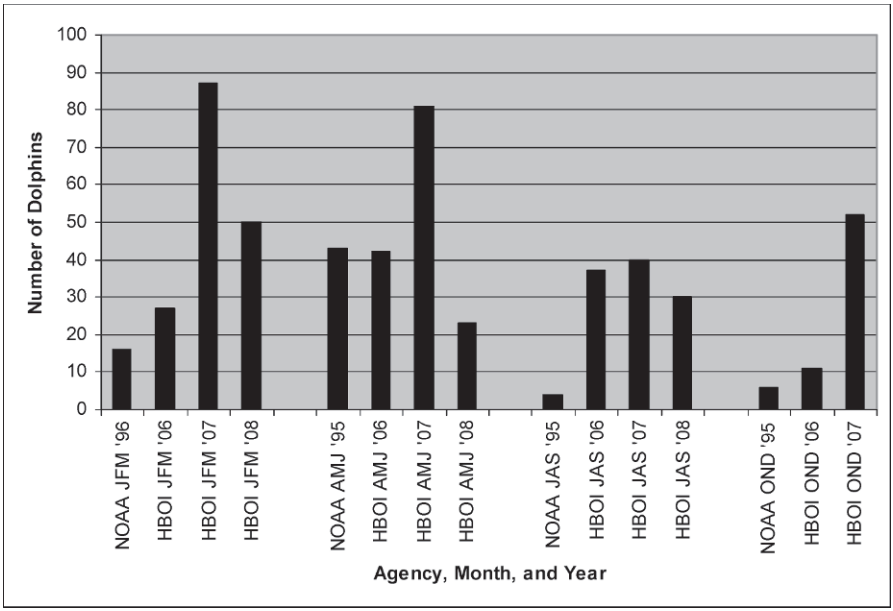

FIG. 5. Seasonal trends in relative abundance of nearshore, coastal Atlantic Ocean dolphins: 1995–1996 aerial surveys (McClellan, 1996) and 2006–2008 vessel based photo-identification surveys (this study).

effort to elucidate the stock structure of the coastal western North Atlantic bottlenose dolphin population (Hohn, 1997).

Group size—The mean group size for coastal dolphins was similar from 1995–1996 and 2006–2008 ($\bar{x}$ = 5.8 and 6.0, respectively), but lower than group sizes reported for coastal dolphins found in northern Florida ($\bar{x}$ = 17.6, Caldwell, 2001). The mean group size was higher than those reported in the IRL Estuary ($\bar{x}$ =1.8, Noke & Odell, 2002; $\bar{x}$ = 4.0, Mazzoil et al., 2005; $\bar{x}$ = 4.1, Kent et al., 2008) and the inland waters in northern Florida ($\bar{x}$ = 4.5, Caldwell, 2001). Evidence from analysis of stomach contents indicates that east-central Florida coastal dolphins have a mixed diet of fish and squid, whereas IRL estuarine dolphins are primarily piscivorous (Barros, 1993). Further, the bulk of the diet of coastal dolphins was comprised of schooling fish and fish associated with beaches and non-vegetated habitats, whereas estuarine dolphins preyed on solitary, seagrass-associated fish species and shrimp. Barros (1993) concluded that these differences were likely related to foraging strategies, wherein coastal dolphins form larger groups to capture fish and squid schools, as found in this study.

The most frequently observed group size was similar in both habitats: two individuals (23% and 24%) followed by one individual (17% and 18%) in the ocean and estuary (Mazzoil et al., 2005), respectively. Group size ranged from 1–3 when dolphins were following or engaging in king mackerel (*Scomber-*

omorus cavalla) depredation with fishing vessels off the east coast of Florida (Ft. Pierce to Lake Worth Inlets; Zollett and Read, 2006). Group size associated with feeding habituation from commercial vessels in the IRL Estuary averaged one individual per incident (Noke & Odell, 2002; Noke-Durden, 2005). However, this aberrant behavior may require smaller groups for success.

Group size is thought to reflect predation risk and prey availability, but determining the influence of each factor is difficult. The open coastal habitat (limited structure, deep water, large depth ranges) and small body size of dolphins, considered to increase predation risk, were ''weakly apparent'' in affecting group size of bottlenose dolphins (Gygax, 2002). In the estuary, 32% of distinct dolphins had evidence of shark encounters (Bechdel et al., 2009), but also had smaller group sizes, indicating that other selective pressures may have more influence on group size. Coastal groups that contained ≥ 1 calf were larger than groups without calves, similar to findings in the IRL Estuary (Kent et al., 2008). In both ocean and estuarine habitats, nearly half of all groups contained calves (53% and 55%, respectively). In the context of predation risk and optimal foraging strategies associated with each habitat, these larger calf groups may indicate an elevated importance of shared calf rearing and socialization.

Implications for transmission of infectious disease—Dolphins in the IRL Estuary have been documented to harbor infectious diseases important to ecosystem health such as oral and genital papilloma (Bossart et al., 2005), and lobomycosis (Bossart et al., 2003; Reif et al., 2006). While an environmental component is suspected in their pathogenesis, these infectious diseases may be transmitted by dolphin-to-dolphin contact. Recent health studies have reported an increase in the prevalence of orogenital papilloma in dolphins from the IRL and Charleston, South Carolina estuaries (Bossart et al., 2008), indicating that a large-scale epidemic may be occurring. Further, preliminary data suggest that IRL estuarine dolphins may serve as vectors to disseminate antibiotic resistant bacteria into other environments (Greig et al., 2007) potentially creating a ''superbug'', a new and more drug resistant form of bacteria (Schaefer et al., 2009).

Serologic evidence of morbillivirus infection and an increase in mortality occurred in the IRL Estuary in 1982 (Duignan et al., 1996), and was followed by a major epizootic on the mid-Atlantic coast in 1987–1988 (Geraci, 1989). Epizootics require a sufficient number of susceptible animals, but the magnitude of the outbreak may also be determined by social structure and community interactions that affect transmission rates. An analysis of stranding patterns from the 1987–1988 morbillivirus epizootic indicates complex movements of dolphins along the east coast from New Jersey, where the outbreak originated, to central Florida (McLellan et al., 2002; Geraci, 1989). The mechanisms of maintenance and transfer of morbilliviruses within and between populations are uncertain. Long-finned pilot whales (*Globicephala*

melas) have been hypothesized to contribute to inter-species transmission at sea, based on enzootic infections and their gregarious nature (Duignan et al., 1996). However, based on the data from this study, the potential for disease transmission between the southern IRL Estuary dolphins (Sebastian to St. Lucie Inlets) and the coastal Atlantic population(s) appears to be low in both directions.

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