Abundance and site fidelity of bottlenose dolphins in coastal waters near Panama City, Florida

T. Bouveroux[1,2], R.B. Tyson[3] and D.P. Nowacek[3]

Contact e-mail: tbouveroux@gmail.com

ABSTRACT

Dolphin watching and swim-with programmes are popular tourist attractions in Panama City, Florida, USA. Despite this, little is known about the population of dolphins that utilise this area, specifically St. Andrew Bay. To learn more about this population, photo-identification mark-recapture surveys were conducted between March 2004 and July 2007. The main objectives were to estimate the abundance of bottlenose dolphins inhabiting this region during this time period and to examine their patterns of site fidelity. Robust design population models were used to calculate seasonal abundance estimates, which ranged from 89 (CI 95% = 71–161) to 183 (CI 95% = 169–208) dolphins, even though 263 distinctive dolphins were identified during the study. Only 7% of dolphins (n = 18) observed were seen regularly in the study region. In addition, only 12% of dolphins (n = 30) observed had high site fidelity for the study region, while 58% (n = 153) were considered to be transient to the area. This study provides baseline information regarding dolphin abundance and site fidelity in and around St. Andrew Bay that may be used for the conservation and management of this dolphin population.

KEYWORDS: BOTTLENOSE DOLPHIN; ABUNDANCE; PHOTO-ID; SITE FIDELITY; GULF OF MEXICO; MARK-RECAPTURE; NORTHERN HEMISPHERE; NORTH AMERICA

INTRODUCTION

The presence of a bottlenose dolphin (*Tursiops truncatus*) population in St. Andrew Bay near Panama City, Florida, USA, has been well known by tourists for more than 20 years (Samuel and Spradlin, 1995; Colborn, 1999; Samuels and Bejder, 2004). Although illegal as defined by the US Marine Mammal Protection Act (as amended 2007), tourists have been swimming, feeding and interacting with this dolphin population since the 1980s either independently or as participants of swim-with or dolphin watching programmes (Colborn, 1999). Despite the popularity of dolphins in this region for tourism purposes, scientific information regarding the status and/or ecology of this population is lacking. In fact, the only scientific reports on this population include results from aerial surveys conducted in 1993 (Blaylock and Hoggard, 1994) and a few quantitative studies regarding human-dolphin interactions in this region (Samuels and Spradlin, 1995; Colborn, 1999; Samuels and Bejder, 2004).

Between 1999 and 2006, three unusual mortality events (UMEs) occurred along the northwest Gulf coast of the Florida Panhandle (NMFS, 2004; Gaydos 2006). These events appear to have been spatially and temporally correlated with blooms of *Karenia brevis*, a dinoflagellate known to cause red tide, and were associated with the deaths of over 300 dolphins (NMFS, 2004). On 20 April 2010, the *Deepwater Horizon* offshore drilling rig exploded and sank approximately 160 n.miles from Panama City. This event occurred at approximately 1,500m below sea level and discharged approximately 10 million litres of oil per day for 84 days (Mascarelli, 2010). The cumulative effect that these events, combined with anthropogenic stressors such as boating, fishing, and military activities, had on the population of dolphins in this region cannot be fully evaluated because baseline data regarding their abundance and distribution patterns does not exist.[4]

Bottlenose dolphins inhabiting the Gulf of Mexico are managed as eastern, western, and northern Gulf of Mexico 'stocks'. Within the northern Gulf of Mexico stock, a separate management boundary for dolphins inhabiting the bays, sounds and estuaries exists, although portions of the coastal stocks may co-occur with the northern Gulf of Mexico continental shelf stock. However, as noted by the US National Marine Fisheries Service, there is insufficient information available to determine the current status of bottlenose dolphins in St. Andrew Bay, and thus how the total human-caused mortality may engender a decline of the local populations.

Therefore, the objectives of this study were: (1) to estimate the seasonal abundance of bottlenose dolphins in St. Andrew Bay using photo-identification mark-recapture techniques; (2) to create a photo-identification catalogue of distinctive individuals in the region for long-term monitoring purposes; and (3) to characterise dolphin site fidelity patterns in this area.

MATERIALS AND METHODS

Study area

St. Andrew Bay (30°07'N, 85°43'W) is located on the northwest Gulf coast of Florida, USA (Fig. 1). The survey area, of approximately 323 km^2, included St. Andrew Bay and the surrounding near-shore and coastal waters of the

[4] See *http://www.nmfs.noaa.gov*.

[1] *Laboratory of Marine Biology, 1348 Louvain-la-Neuve, Belgium.*
[2] *Present address: Nelson Mandela Metropolitan University, Coastal and Marine Research Institute, PO Box 77000, Port Elizabeth, 6031, South Africa.*
[3] *Duke University Marine Laboratory, Nicholas School of the Environment, Duke University, Beaufort, North Carolina, USA.*

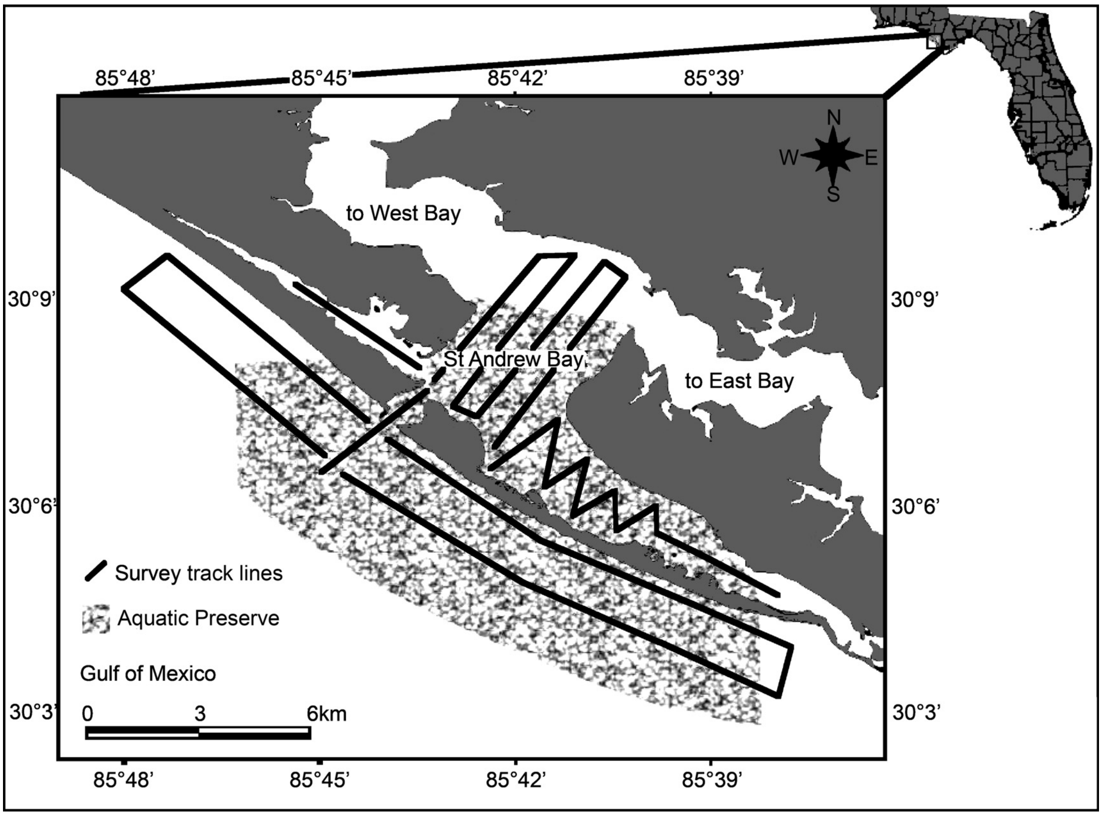

Fig. 1. St. Andrew Bay mark-recapture photo-identification survey region, including survey tracklines and the delimitation of the St Andrew Aquatic Preserve.

northern Gulf of Mexico (Fig. 1). The St. Andrew Aquatic Preserve, which aims to protect, promote and utilise indigenous marine wildlife and habitats by providing food and healthy habitats (Gardner, 1991), was included in the survey area.

Data collection

Seventeen photo-identification primary sampling periods were conducted in the study area between March 2004 and July 2007 from small boats (5–7m) powered by 55–85 horse power outboard engines between. Each photo-identification primary sampling period was 3–5 consecutive days long, which resulted in 77 independent survey days (366 total hours; Table 1).

Surveys were carried out in Beaufort sea states of ≤3 and followed predetermined track lines (Fig. 1). When a group of dolphins was sighted, the survey vessel slowly approached the group and ran parallel to their course. The location of each dolphin encounter was recorded with a GPS (*Garmin* GPSMAP 76S). Photographs were taken by one or two photographers using *Canon* EOS 350D cameras equipped with 35–80mm, or 70–300mm zoom lenses. Individual dolphins were identified daily from photographs using unique natural markings, such as nicks and notches along the dorsal fin, as well as tooth rakes marks, scratches, scars and skin lesions along the dorsal fin and peduncle (Würsig and Würsig, 1977; Würsig and Jefferson, 1990). Photographs of dorsal fins were graded on both distinctiveness of the dorsal fin (D) and quality of the photographs (Q) following Urian *et al.* (1999). Only dolphins with sufficient markings (e.g. 3–5 small to medium sized markings, one or two large markings) identified from high-quality pictures (e.g. in focus, unobscured, with the dorsal fin relatively perpendicular to the plane of the photograph) were used in the analyses (Urian *et al.,* 1999; Baird *et al.,* 2001). To minimise subjectivity and the possibility of making incorrect matches or missing matches altogether, poor-quality photographs of non-distinctive animals were not used in the analyses (Read *et al.*, 2003; Tyson *et al.,* 2011). In addition, as many distinctive features as possible were used to confirm matches (Scott and Chivers, 1990; Wilson *et al.*, 1999) and to create our photo-identification catalogue. Finally, a classification system designed by Urian *et al.* (1999) was used to facilitate the comparison of dorsal fins in the photo-identification catalogue. This method allowed us to compare distinctive individuals observed in the study area to one-another as well as to compare distinctive individuals observed in study area to distinctive individuals observed in near-by areas where similar photo-identification catalogues exist (e.g. St. Joseph Bay; Balmer *et al.*, 2008).

Table 1

Summary of mark-recapture photo-ID surveys of bottlenose dolphins in St. Andrew Bay, Florida, between 2004 and 2007.

Months	No. of days surveyed	No. of sampling periods	No. of hours surveyed	No. of sightings
Mar.–May 2004	12	4	71	139
Sep.–Oct. 2005	15	3	69	129
Nov. 2005	15	3	56	156
Jul.–Aug. 2006	15	3	68	186
Jun.–Jul. 2007	20	4	102	192
Total	77	17	366	802

Estimation of population size

Population size was estimated from mark-recapture surveys for multiple time periods (Table 1) using the robust design model (see below). To avoid problems associated with pseudo-replication (Wilson *et al.,* 1999), photo-identification surveys were not conducted every day. Encounter histories of each identified animal were created: days each animal was observed were coded as '1', while days on which each animal was not observed but the study area was surveyed were coded as '0'. Encounter histories of each distinctive individual were used to determine the abundance of dolphins inhabiting the region during each time period using the program *MARK* (White and Burnham, 1999).

The robust design model (Pollock, 1982; Pollock *et al.,* 1990) was preferred to other closed population models for the analysis because the assumptions of geographic (immigration/emigration) and demographic (births/deaths) closure were not upheld during our study period (Cooch and White, 2010). For example, six dolphins that had been freeze-branded during a health study assessment in St. Joseph Bay (located approximately 30 n.miles away) were observed in the study area. In addition to these observations, several mortalities and births were recorded during the study period. Robust design models combine characteristics of both closed and open population models by assuming that the population under study is open to gains (birth and immigration) and losses (death and emigration) between sampling periods, but that it is closed to such gains and losses during sampling periods (see Pine *et al.*, 2003 for a review). For each photo-identification sampling period, the probability of first capture (*p*), the probability of recapture (*c*), and the abundance of dolphins inhabiting the survey region (*N*) was estimated. Five primary sampling periods, each 3–5 consecutive days long (Table 1), were carried out during each field survey period. The abundance of bottlenose dolphins inhabiting the survey region was then estimated for each primary sampling period (N_1, N_2… N_5) (Pollock *et al.,* 1990).

The following models were used to derive estimates of abundance estimates: (1) the robust design with 'Random Emigration'; (2) the robust design with 'Markovian Emigration'; and (3) the robust design with heterogeneity (M_h; capture probability can vary for individuals). It was hypothesised that the last model would be the most appropriate model for the data set because individual dolphins in this region have been observed begging near boats (Bouveroux and Mallefet, 2008), which creates heterogeneity in capture probabilities of individiuals. This behaviour may be due to years of human interaction in this region (e.g. humans feeding and swimming with the animals) (Samuels and Bejder, 2004). Natural markings were used to identify individuals, thus initial abundance estimates pertained to the population of marked animals only. To expand these estimates to include the unmarked component of the population, the estimates were divided by the proportion of distinctive dolphins in the population (Wilson *et al.*, 1999). This proportion was calculated from the ratio of distinctive (D1 + D2) to total (D1 + D2 + D3) animals in all photographs that exceeded quality thresholds (Williams *et al.,* 1993; Wilson *et al.*, 1999; Read *et al.,* 2003; Tyson *et al.,* 2011). Variances were estimated for each estimate using the delta method and calculated 95% confidence intervals (CI) by multiplying the square root of the variance by 1.96. The standard error distribution (SE) was assumed to be the same as the estimate of the distinctive population estimate (Williams *et al.* 1993).

SITE FIDELITY

A site fidelity index was created following Balmer *et al.* (2008) so that observed side-fidelity patterns could be compared with site-fidelity patterns observed in nearby regions (e.g. St. Joseph Bay). For each sampling period each identified dolphin was placed into one of five categories based on the number of times it was sighted: Category 1 = 1 sighting; Category 2 = 2–10 sightings; Category 3 = 11–20 sightings; Category 4 = 21–30 sightings; and Category 5 = 31+ sightings. Each identified dolphin was further classified based on the number of sampling periods during which it was observed (adapted from Wilson *et al.,* 1997; Quintana-Rizzo and Wells, 2001): Category 1 = 'common', 13–17 capture occasions; Category 2 = 'frequent', 9–12 occasions; Category 3 = 'occasional', 5–8 occasions; and Category 4 'rare', 1–4 occasions.

RESULTS

Photo-identification

Between 2004 and 2007, 263 distinctive bottlenose dolphins were identified in St. Andrew Bay.

Population size

The robust closed capture model with heterogeneity was chosen as the most appropriate model for estimating dolphin abundance in this region because it had the lowest Akaike's Information Criterion (AIC) value (Table 2). With this model, it was estimated that the abundance of dolphins was 126 (SD = 8.75, CI 95% = 113–49) individuals in November 2005 and 133 (SD = 8.67, CI 95% = 121–57) individuals in September–October 2005. The highest estimated abundance, 183 dolphins (SD = 9.46, CI 95% = 169–208), occurred in June 2007 while the lowest abundance, 89 dolphins (SD = 19.34; CI 95% = 71–161) occurred in March–April 2004 (Table 2).

Site fidelity

Distinctive dolphins were observed during each of the 77 photo-identification surveys. Forty-two percent (*n* = 110) of animals were observed only once in the study region, while 7% (*n* = 18) were observed more than 21 times. Two individuals were observed more than 35 times (Fig. 2).

Seventy-five percent of dolphins observed were considered to be in the 'rare' category (*n* = 197), 11% were considered to be in the 'occasional' category (*n* = 29), 7% were considered to be in the 'frequent' category (*n* = 18) and 7% were considered to be in the 'common' category (*n* = 18). Twelve percent of dolphins (*n* = 33) were seen in all four years and thus were considered here to be high site fidelity, while 58% (*n* = 154) were observed during only one year and were therefore defined as transients (Table 3).

The annual variation in the proportion of dolphins observed is seen in Fig. 3. Three quarters of dolphins were seen one to five times. More dolphins were observed five

Table 2

Mean estimates of population size for each sampling period. The standard deviation (SD), 95% confidence interval (CI 95%), and AIC values are included for each model.

Models, robust design	Mar.–May 2004	Sep.–Oct. 2005	Nov. 2005	Jul.–Aug. 2006	Jun.–Jul. 2007
With heterogeneity	89	133	126	125	183
AIC: 4,199.14					
SD	*19.34*	*8.67*	*6.89*	*8.75*	*9.46*
CI 95%	*71–161*	*121–157*	*115–143*	*113–149*	*169–208*
Markovian emigration	67	112	109	105	151
AIC: 4,615.92					
SD	*2.1*	*2.58*	*2.24*	*2.9*	*1.98*
CI 95%	*64–74*	*109–121*	*106–116*	*101–114*	*146–155*
Random emigration	77	115	122	130	154
AIC: 4,722.37					
SD	8.23	4.35	6.80	10.70	3.38
CI 95%	67–104	110–129	113–140	116–159	148–164

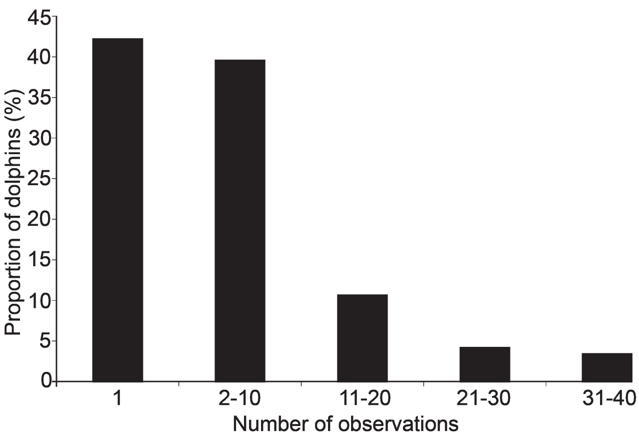

Fig. 2. Proportion of individuals observed in the study area based on their total number of observations.

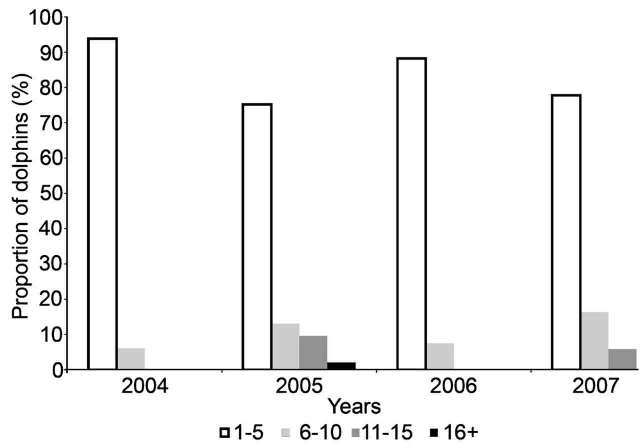

Fig. 3. The proportion of dolphins observed each study year and the number of times they were observed.

times or more during the autumn of 2005 (24.7%, *n* = 65) and summer of 2007 (22.2%, *n* = 58) than during any other season.

DISCUSSION

The highest and lowest abundance of dolphins were estimated during June 2007 and April–May 2004, respectively. Similar fluctuations have been reported in coastal waters of Texas (Shane, 1980), the Gulf of California (Ballance, 1990), Ireland (Rogan *et al.,* 2000), Scotland (Wilson *et al.,* 1997; Culloch, 2004) and Louisiana (Hubard *et al.,* 2004). Fluctuations in dolphin abundance have been attributed to spatial variations in local conditions, which result in certain areas being more suitable for mating, foraging, or predator avoidance (Wells *et al.,* 1980; Rogan *et al.,* 2000; Culloch, 2004). Balmer *et al.* (2008) found that bottlenose dolphins in St. Joseph Bay were also seasonally variable in abundance. They recorded the highest abundance of dolphins in May 2005 and the lowest in July 2005.

Table 3

The number and percentage of distinctive dolphins observed during the study.

	One year	Two years	Three years	Four years
No. of dolphins sighted	154	47	29	33
% of dolphins sighted	58.55	17.87	11.02	12.54

While confident conclusions regarding seasonal variations in dolphin abundance in St. Andrew Bay cannot be made because the region was surveyed only once each season, the abundance of dolphins did appear to fluctuate seasonally, which is similar to patterns of dolphin abundance observed in other regions (Shane, 1980; Ballance, 1990; Wilson *et al.,* 1997; Rogan *et al.,* 2000; Culloch, 2004; Hubard *et al.,* 2004). The results presented here are the opposite of those found in St. Joseph Bay, which had a lower abundance rate in June and a higher abundance in April and May 2004 (Balmer *et al.,* 2008). This difference may be explained by movements of dolphins between St. Joseph Bay and St. Andrew Bay. Indeed, of the 263 dolphins identified, six had previously been freeze-branded by researchers in St. Joseph Bay in April and July 2005 (Balmer *et al.,* 2008). In addition, a comparison of both photo-identification catalogues (St. Joseph Bay versus St. Andrew Bay) revealed that 69 individuals were observed in both study areas.

Coastal bottlenose dolphins may be year-round residents, such as those observed in the Moray Firth, Scotland (Culloch, 2004) and in Sarasota Bay, Florida, USA (Barros and Wells, 1998). Re-sighting data in St. Andrew Bay suggests that a small community of dolphins with high site fidelity inhabit the region, but a large number of transient dolphins also frequent the area. These transient dolphins reveal important movements into and out of the study area. They may come from areas such as St. Joseph Bay, West Bay or East Bay (which are directly connected to St. Andrew Bay) which were not surveyed in this study (Fig. 1).

It is possible that these results may be biased by individual home ranges that extend beyond the limits of the study area and/or by the limited sampling periods occurring during multiple seasons and years. It is unlikely that an individual's home range would coincide exactly with the selected boundaries of the study area. Therefore, such biases may have resulted in an underestimation of the proportion of dolphins inhabiting St. Andrew Bay during the study and thus the estimates of abundance.

The previous estimates of dolphin abundance in this region were based on aerial surveys conducted in 1993 (Blaylock and Hoggard, 1994), thus the effect of UMEs on this population cannot be assessed. Moreover, sources of pollution may be present in this marine ecosystem and may accumulate in the bodies of these dolphins (i.e. heavy metals, organochlorines; Wells *et al.,* 2004) because they are located in a region with intensive human activities. As dolphins are top predators and can concentrate pollutants that accumulate in the environment (Shoham-Frider *et al.,* 2009), they may accumulate high concentrations of anthropogenic chemicals such as PCB and DDT, whose metabolites can be harmful for bottlenose dolphin health (Schwacke *et al.,* 2002). For example, an increased exposure of dolphins to anthropogenic compounds may reduce their immune function (Lahvis *et al.,* 1995) or may impact their reproduction (Wells *et al.,* 2005). These deleterious effects may subsequently result in declining dolphin abundance.

Future mark-recapture surveys should include West Bay and East Bay during each season to improve our understanding of seasonal fluctuations in dolphin abundance in St. Andrew Bay. Moreover, continued year-round monitoring of this dolphin population, (subjected as it is to human and environmental pressures, e.g. tourism, military, fishing, yachting, and harbour activities, red tide and oil spills), is needed to detect possible declines in dolphin abundance (Bejder *et al.,* 2006).

ACKNOWLEDGEMENTS

We thank Denis and Nathalie Richard for logistical support, Sarah Lessire, Stephanie Nowacek, Rudy Renard, Kim Urian, Brian Balmer and Sanna Kuningas for their assistance with data collection and analysis. This research was conducted under NMFS General Authorisation No. 1,055–1,732 issued by the NOAA Fisheries Department. Funding was obtained through donations from the Delphus Foundation, the Foundation Léopold III for the Exploration and the Conservation of Nature and French Community of Belgium. Canon Belgium provided the photography equipment.

REFERENCES

Baird, R.W., Gorgone, A.M., Ligon, A.D. and Hooker, S.K. 2001. Mark-recapture abundance estimation of bottlenose dolphins (*Tursiops truncatus*) around Maui and Lanai, Hawaii during the winter of 2000/2001. Report prepared under contract 40JGNF0-00262 to the Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA.

Ballance, L.T. 1990. Residence patterns, group organisation, and surfacing associations of bottlenose dolphins in Kino Bay, Gulf of California, Mexico. pp.267–83. *In*: Leatherwood, S. and Reeves, R.R. (eds). *The Bottlenose Dolphin*. Academic Press, San Diego, CA.

Balmer, B.C., Wells, R.S., Nowacek, S.M., Nowacek, D.P., Schwacke, L.H., McLellan, W.A., Scharf, F.S., Rowles, T.K., Hansen, L.J., Spradlin, T.R. and Pabst, D.A. 2008. Seasonal abundance and distribution patterns of common bottlenose dolphins (*Tursiops truncatus*) near St. Joseph Bay, Florida, USA. *J. Cetacean Res. Manage.* 10(2): 157–68.

Barros, N.B. and Wells, R.S. 1998. Prey and feeding patterns of resident bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *J. Mammal.* 79(3): 1,045–59.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J. and Flaherty, C. 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conserv. Biol.* 20(6): 1,791–98.

Blaylock, R.A. and Hoggard, W. 1994. Preliminary estimates of bottlenose dolphin abundance in southern US Atlantic and Gulf of Mexico continental shelf waters. *NOAA Tech. Mem.* NMFS-SEFSC-356, 10pp.

Bouveroux, T. and Mallefet, J. 2008. Behavioural syndromes or when dolphins show some individual differences in their behaviours: preliminary study. Abstracts of the 22nd Annual Conference of the European Cetacean Society, 10–12 March 2008, Egmond aan Zee, The Netherlands. [Available from: *http://www.europeancetaceansociety.eu*]

Colborn, K. 1999. Interactions between humans and bottlenose dolphins (*Tursiops truncatus*), near Panama City, Florida, MSc thesis, Duke University, Durham. 45pp.

Cooch, E. and White, G.C. 2006. *Program MARK: a Gentle Introduction*. 652pp. [Available at: *http://www.phidot.org/software/mark/docs/book/*].

Culloch, R.M. 2004. Mark recapture abundance estimates and distribution of bottlenose dolphins (*Tursiops truncatus*) using the southern coastline of the outer Moray Firth, NE Scotland. Master's thesis. University of Wales, Bangor.

DeMaster, D.P. 1984. Review of techniques used to estimate the average age at attainment of sexual maturity in marine mammals. *Rep. int. Whal. Commn (special issue)* 6: 175–79.

Gardner, T. 1991. St. Andrews State Park: Aquatic Preserve Management Plan. Florida Department of Natural Resources. 102pp.

Gaydos, J.K. 2006. Bottlenose Dolphins and Brevetoxins: A Coordinated Research and Response Plan. NOAA Technical Memorandum NMFS-OPR-32. 46pp.

Hubard, C.W., Maze-Foley, K., Mullin, K.D. and Schroeder, W.W. 2004. Seasonal abundance and site fidelity of bottlenose dolphins (*Tursiops truncatus*) in Mississippi Sound. *Aquat. Mamm.* 30: 299–310.

Lahvis, G.P., Wells, R.S., Kuehl, D.W., Stewart, J.L., Rhinehart, H.L. and Via, C.S. 1995. Decreased lymphocyte responses in free-ranging bottlenose dolphins (*Tursiops truncatus*) are associated with increased concentrations of PCBs and DDT in peripheral blood. *Environ. Health Perspect.* 103: 67–72.

Mascarelli, A. 2010. Deepwater horizon: after the oil. *Nature* 467: 22–4.

NMFS. 2004. Interim report on the bottlenose dolphin (*Tursiops truncatus*) unusual mortality even along the panhandle of Florida. 36pp. [Available from: NMFS, Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL 33149 and at *http://www.nmfs.noaa.gov/pr/health/mmume/event2004.htm*].

Nowacek, S.M. 1999. The effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. Master's thesis, University of California, Santa Cruz.

Nowacek, S.M., Wells, R.S. and Solow, A.R. 2001. Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Mar. Mammal Sci.* 17: 673–88.

Pine, W.E., Pollock, K.H., Hightower, J.E., Kwak, T.J. and Rice, J.A. 2003. A review of tagging methods for estimating fish population size and components of mortality. *Fisheries* 28(10); 10–23.

Pollock, K.H. 1982. A capture-recapture design robust to unequal probability of capture. *J. Wildl. Manage.* 46: 757–60.

Pollock, K.P., Nichols, J.D., Brownie, C. and Hines, J.E. 1990. Statistical inference for capture-recapture experiments. *Wildl. Monogr.* 107: 1–97.

Quintana-Rizzo, E. and Wells, R.S. 2001. Resighting and association patterns of bottlenose dolphins (*Tursiops truncatus*) in the Cedar Keys, Florida: insights into social organization. *Can. J. Zool.* 79: 447–56.

Read, A.J., Urian, K.W., Wilson, B. and Waples, D.M. 2003. Abundance of bottlenose dolphins in the bays, sounds and esturies of North Carolina. *Mar. Mammal Sci.* 19(1): 59–73.

Rogan, E., Ingram, S., Holmes, B. and O'Flanagan, C. 2000. A survey of bottlenose dolphins (*Tursiops truncatus*) in the Shannon estuary. Marine Institute, Marine Resource Series No.9. 46pp.

Samuels, A. and Bejder, L. 2004. Chronic interaction between humans and free-ranging bottlenose dolphins near Panama City Beach, Florida, USA. *J. Cetacean Res. Manage.* 6(1): 69–78.

Samuels, A. and Spradlin, T.R. 1995. Quantitative behavioral study of bottlenose dolphins in swim-with-dolphin programs in the United States. *Mar. Mammal Sci.* 11(4): 520–44.

Schwacke, L.H., Voit, E.O., Hansen, L.J., Wells, R.S., Mitchum, G.B., Hohn, A.A. and Fair, P.A. 2002. Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (*Tursiops truncatus*) from the southeast United States coast. *Environ. Toxicol. Chem.* 21(12): 2,752–64.

Scott, M.D. and Chivers, S.J. 1990. Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. pp.387–402. *In*: Leatherwood, S. and Reeves, R.R. (eds). *The Bottlenose Dolphin*. Academic Press, San Diego. 653pp.

Shane, S.H. 1980. Occurrence, movements and distribution of bottlenose dolphins, *Tursiops truncatus*, in southern Texas. *Fish. Bull.* 78: 593–601.

Shoham-Frider, E., Kress, N., Wynne, D., Scheinn, A., Roditielsar, M. and Kerem, D. 2009. Persistent organochlorine pollutants and heavy metals in tissues of common bottlenose dolphin (*Tursiops truncatus*) from the Levantine Basin of the Eastern Mediterranean. *Chemosphere* 77(5): 621–7.

Tyson, R.B., Nowacek, S.M. and Nowacek, D.P. 2011. Community structure and abundance of bottlenose dolphins *Tursiops truncatus* in coastal waters of the northeast Gulf of Mexico. *Mar. Ecol. Prog. Ser.* 438: 253–65.

Urian, K., Hohn, A.A. and Hansen, L.J. 1999. Status of the photo-identification catalog of coastal bottlenose dolphins of the western North Atlantic. Report of a workshop of catalog contributors. NOAA Technical Memorandum NMFS-SEFSC 425. 22pp. [Available from: *http://www.nmfs.gov*].

Wells, R.S., Irvine, A.B. and Scott, M.D. 1980. The social ecology of inshore odontocetes. pp.263–317. *In*: Herman, L.M. (eds). *Cetacean Behaviour: Mechanisms and Functions*. John Wiley & Sons, New York. xiii+463pp.

Wells, R.S., Rhinehart, H.L., Hansen, L.J., Sweeney, J.C., Townsend, F.I., Stone, R., Casper, D., Scott, M.D., Hohn, A.A., Rowles, T.K. and Howard, L. 2004. Bottlenose dolphins as marine ecosystem sentinels: developing a health monitoring system. *EcoHealth* 1(3): 246–54.

Wells, R.S., Scott, M.D. and Irvine, A.B. 1987. The social structure of free-ranging bottlenose dolphins. pp.247–306. *In*: Genoways, H. (eds). *Current Mammalogy*. Plenum Press, New York. 519pp.

Wells, R.S., Tornero, V., Borrell, A., Aguilar, A., Rowles, T.K., Rhinehart, H.L., Hofmann, S., Jarman, W.M., Hohn, A.A. and Sweeney, J.C. 2005. Integrating life history and reproductive success data to examine potential relationships with organochlorine contaminants for bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Sci. Total Environ.* 349(1–3): 106–19.

White, G.C. and Burnham, K.P. 1999. Program MARK: Survival estimation from populations of marked animals. *Bird Study* 46(Supplement): 120–38.

Williams, J.A., Dawson, S.M. and Slooten, E. 1993. The abundance and distribution of bottlenose dolphins (*Tursiops truncatus*) in Doubtful Sound, New Zealand. *Can. J. Zool.* 71: 2,080–88.

Wilson, B., Hammond, P.S. and Thompson, P.M. 1999. Estimating size and assessing trends in a coastal bottlenose dolphin population. *Ecol. Appl.* 9: 288–300.

Wilson, B., Thompson, P.M. and Hammond, P.S. 1997. Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *J. Appl. Ecol.* 34: 1,365–74.

Würsig, B. and Jefferson, T.A. 1990. Methods of photo-identification for small cetaceans. *Rep. int. Whal. Commn (special issue)* 12: 43–52.

Würsig, B. and Würsig, M. 1977. The photographic determination of group size, composition, and stability of coastal porpoises (*Tursiops truncatus*). *Science* 198: 755–56.