Occurrence, distribution and density of marine mammals in Camp Lejeune

Final Report for Task Order Number X049

July 1, 2012

Andrew J. Read, Kim W. Urian, Bethany Roberts & Danielle M. Waples,

Division of Marine Science and Conservation

Nicholas School of the Environment

Duke University Marine Laboratory

Duke University

Beaufort, NC 28516

M. Louise Burt and Charles G.M. Paxton

Centre for Research into Ecological and Environmental Modeling

University of St Andrews

St Andrews, Fife

KY16 9LZ

Scotland

United Kingdom

This work was performed through funding from Marine Corps Base Camp Lejeune under the Department of the Navy, Naval Facilities Engineering Command, Mid-Atlantic Biological Resources Contract No. N62470-08-D-1008, Task Order 0049, managed by Tetra Tech.

Abstract

This report describes development of the first phase of a monitoring program designed to provide quantitative information on the seasonal occurrence, distribution and density of marine mammals in estuarine and coastal waters around Camp Lejeune. The work consisted of three components: (1) coastal line transect surveys, designed to provide estimates of the density of marine mammals and sea turtles in near-shore ocean waters; (2) photo-identification surveys to document patterns of residency by individual dolphins; and (3) passive acoustic monitoring of the occurrence and distribution of bottlenose dolphins in the New River. We conducted eleven shipboard surveys in coastal waters in and around the N1/BT3 Impact Area from August 2010 to November 2011. We combined data from all surveys to produce estimates of abundance for the entire study period. The estimated number of bottlenose dolphins was 221 (CV=52%; 95% CI 83 – 592) and the estimated number of spotted dolphins was 93 (CV=71%; 95% CI 25 – 337). Using strip transect methods, we estimated the average number of loggerhead turtles as 38 (CV=56%; 95% CI 13 – 110). We conducted photographic surveys for bottlenose dolphins in the New River on 19 days between October 2010 and November 2011. We recorded 54 sightings throughout the Intracoastal Waterway and New River, with some groups seen as far upriver as Morgan Bay. The mean size of dolphin groups was 7.4 (SD = 7.9) and encounters ranged from single animals to a group of 40 dolphins. Dolphins were present throughout the year; the minimum water temperature recorded at a dolphin sighting was 5.6°C in January; the maximum was 28.5°C in June. We obtained 3,508 digital images of dolphin dorsal fins and, from these images, we identified 56 individual marked dolphins. We matched 32 of these dolphins to our DUML/UNCW photo-identification catalog but none to dolphins photographed during our coastal surveys. Dolphins from both the Northern North Carolina Estuarine Stock and Southern North Carolina Estuarine Stock were present in the New River, which appears to be an area of mixing. The frequency of re-sightings varied considerably; two dolphins were photographed in four separate months, but 35 were identified only once. The population of dolphins in the New River was very open, as we continued to identify new individuals throughout the study. Finally, we deployed bottlenose dolphin click detectors (C-PODs) at four sites in the New River from November 2010 to December 2011. The C-PODs recorded for 9099 hours in the Inlet, 8545 hours in Stone Bay, 7642 hours in Farnell Bay and 6061 hours in Morgan Bay. Dolphins were detected at least daily at all four sites, but were not present continuously at any site. Dolphins occurred most frequently at the Inlet (22% of recorded effort), then in Morgan (8%) and Stone Bays (8%) and least frequently in Farnell Bay (4%). We ground-truthed the occurrence of echolocation click detections from three C-PODs with digital acoustic recordings made from a DMON, an autonomous digital acoustic monitoring device. The C-PODs performed well at detecting dolphin echolocation and produced very few false positive records. However, all three C-POD units performed conservatively, failing to detect some echolocation events, and therefore underestimated the occurrence of dolphins.

General Introduction

This report describes development of the first phase of a monitoring program designed to provide quantitative information on the seasonal occurrence, distribution and density of marine mammals in estuarine and coastal waters around Camp Lejeune. The work consisted of three components: (1) coastal line transect surveys, designed to provide estimates of the density of marine mammals and sea turtles in near-shore ocean waters; (2) photo-identification surveys to document patterns of residence by individual dolphins; and (3) passive acoustic monitoring of the occurrence and distribution of bottlenose dolphins (*Tursiops truncatus*) in the New River. The work conducted under each component is described separately below.

We employed an approach that incorporated three complementary research modalities. The line transect surveys provide robust estimates of density, and thus abundance, of marine mammals and sea turtles in areas of open water. This is the approach typically used to estimate the abundance of dolphins in coastal waters by the National Marine Fisheries Service in its stock assessment program (Waring *et al*. 2011). This component of the work represents a continuing partnership between researchers at Duke University and the Centre for Research into Ecological and Environmental Modeling at the University of St. Andrews, who have developed many of the methods employed in the analysis of these data. The photo-identification surveys provide information of patterns of residency and stock structure – with this approach we are able to determine whether or not the same dolphins are present in the area over extended periods. Finally, the passive acoustics program provides continuous information on the occurrence of dolphins that complements the snapshots obtained by the photo-identification surveys. Importantly, this method generates data during periods of darkness and poor weather, when traditional visual surveys are not possible.

We view this work as the first step in a long-term monitoring program that will provide information on the distribution, occurrence and abundance of marine mammals and sea turtles in Camp Lejeune. The results reported here provide the first quantitative estimates of these parameters for Camp Lejeune and, importantly, allow us to refine our research approaches and hypotheses as we move forward with the monitoring program. We will build on the results of this first phase of research in the second phase of monitoring, scheduled to begin later this year.

Component 1: Coastal Line Transect Surveys

We conducted standardized line transect vessel surveys in coastal waters in and around the N1/BT3 Impact Area near Marine Corps Base Camp Lejeune from August 2010 to November 2011 (Figure 1.1). The objective of these surveys was to estimate the abundance of marine mammals and sea turtles in the region. During these surveys we detected spotted dolphins (*Stenella frontalis*), bottlenose dolphins and loggerhead turtles (*Caretta caretta*), albeit in small numbers. We used conventional distance sampling methods (Buckland *et al*. 2001) to estimate the abundance of dolphins and strip transect methods (Buckland *et al*. 2001) to estimate the abundance of sea turtles.

Survey Methods

We attempted to conduct a coastal survey each month, weather permitting, with each survey covering four of the eight line transects aligned northwest–southeast across the region (Figure 1.1). The region of interest, in which we estimated density, extended offshore beyond the seaward end of each transect by approximately 4.6 km and covered an area of 1,116 km^2.

We conducted visual surveys for cetaceans and sea turtles from two survey platforms. Most surveys were conducted from the F/V *Sensation*, a 16-m offshore fishing vessel, but we also used the R/V *Cetus*, a modified 12-m offshore fishing vessel. The homeport of both vessels was Beaufort, NC, approximately 1.5 hours transit from the study area. We conducted all surveys at a speed of approximately 10 knots. Throughout, we employed the same survey methods, vessels, observers and analytical approaches as those used to estimate the abundance of marine mammals and sea turtles in waters further offshore in Onslow Bay for NAVFAC Atlantic as part of our Undersea Warfare Training Range (USWTR)/Atlantic Fleet Active Sonar Training (AFAST) monitoring work. This allowed us to use data from the offshore surveys to parameterize the models we used to estimate density (see below), which was particularly important given the low number of sightings we recorded during the coastal surveys off Camp Lejeune.

We made observations from the flying bridge (5.0m and 4.2m above waterline for the *Sensation* and *Cetus*, respectively) by naked eye and 7x50 binoculars. All marine mammal observers received training in survey methods and species identification at the Duke University Marine Laboratory. Two observers (one port and one starboard) scanned constantly from straight ahead to 90˚ abeam either side of the trackline. A center observer monitored the trackline, coordinated with the vessel skipper and acted as data recorder. Observations were conducted following standard distance sampling/line transect methods for cetaceans (Buckland *et al*. 2001). When we detected marine mammals or sea turtles, the observers recorded the species, group size, sighting angle and radial distance or reticle reading (from the binoculars) to the observed animals. In cases where the radial distance was obtained from a reticle reading, we assumed a constant eye height of 5m and 0.00497 radians per reticle. We generated estimates of perpendicular distance from the sighting angle and radial distance. In sightings of dolphins each observer estimated group size independently and individual estimates were averaged at the end of the survey to generate an overall estimate of group size.

We recorded environmental conditions (weather, sea state, depth and sea surface temperature) at the beginning and end of each transect and every 30 minutes or whenever sighting conditions changed. Sighting and environmental data were entered into an at-sea data collection system (Vis-Survey, developed by Dr. Lance Garrison, NOAA/SEFSC) linked with an onboard GPS.

Analytical Methods

We implemented conventional distance sampling methods (Buckland *et al*. 2001) in the program Distance (Thomas *et al*. 2009) to estimate density (D) and abundance (N) as follows:

$$\hat{D} = \frac{n}{2L\hat{\mu}}\hat{E}[s] \qquad \hat{N} = A\hat{D}$$

where A is the area, n is the number of detected groups, $\hat{\mu}$ is the estimated effective search half-width (ESW), L is the distance covered along the trackline and $\hat{E}[s]$ is the expected group size. The ESW is obtained from a detection function model fitted to the distribution of perpendicular distances, as described below. The expected group size is usually obtained from a regression of probability of detection (obtained from the fitted detection function model) against the logarithm of group size, but here the detection function was fitted to sightings from other surveys (see below), so the average group size of sightings within the region of interest was used convert group abundance to animal abundance. The variance of the encounter rate (n/L) was estimated using the method developed by Innes *et al*. (2002) using the R2 form of the estimator as in Fewster *et al*. (2009) and is the default estimator in Distance (Thomas *et al*. 2009). The confidence intervals (CI) were obtained using 95% log-normal CI with Satterwaite's correction (Buckland *et al*. 2001).

Estimation of Detection Probabilities

In conventional line transect sampling, the probability of detection depends only on the perpendicular distance of the sighting to the transect (y) and at zero perpendicular distance the probability of detection is assumed to be one (denoted by $g(0)=1$). Both a hazard-rate ($1-\exp(-y/\sigma)^{-b}$) and a half-normal form ($\exp(-y^2/2\sigma^2)$) were considered as suitable forms for the detection function (σ is the scale parameter and b is a shape parameter) and we used Akaike's Information Criterion (AIC) to choose the most appropriate form for the data (Buckland *et al*. 2001). We incorporated the effects of covariates, other than perpendicular distance, into the detection function model by setting the scale parameter in the model to be an exponential function of the covariates (Marques 2001). Thus, the probability of detection becomes a multivariate function, $g(y,v)$, representing the probability of detection at perpendicular distance y and covariates v ($v = v_1,..,v_Q$ where Q is the number of covariates). The scale term, σ, has the form:

$$\sigma_k = \exp\left(\beta_0 + \sum_{q=1}^{Q}(\beta_q v_{kq})\right)$$

and β_0 and β_q (q=1,…,Q) are parameters to be estimated. With this formulation, it is assumed that the covariates may affect the rate at which detection probability decreases as a function of distance, but not the shape of the detection function. The covariates considered for inclusion were Beaufort sea state (BSS) and group size (size). A forward, stepwise selection procedure was used to decide which covariates to include in the model, with a minimum AIC inclusion criterion.

There were not enough sightings from the surveys conducted near Camp Lejeune to fit a detection function for each species, so both dolphin species were considered together and sightings data were augmented with dolphin sightings collected during the Onslow Bay USWTR/AFAST surveys from August 2007 to October 2010 (Burt and Paxton, 2012). These surveys were undertaken close to the region of interest here, although further offshore (Figure 1.2), using the same vessels. We used a strip transect approach to estimate turtle abundance (Buckland *et al*. 2001); sightings were considered as coming from narrow strip transects and detection within the strip was assumed to be certain.

Results

The data include eleven surveys conducted from August 2010 to November 2011 in which a total of 880 km were covered on search effort (Table 1.1). Overall, we observed relatively few marine mammals or sea turtles during these surveys. We detected three species while on effort (Table 1.1 and Figure 1.3); bottlenose dolphins (7 groups), spotted dolphins (3 groups) and 4 turtles (all singletons). The group sizes of dolphins ranged from 2 to 14 animals.

Bottlenose and Spotted Dolphins

We used an additional 121 sightings of dolphin groups from the AFAST surveys in Onslow Bay to fit the detection function. Most groups of dolphins were seen close to the trackline (Figure 1.4) and so, as in Burt and Paxton (2012), the perpendicular distances were binned into intervals of 100m to avoid a spike in the detection function and truncated at 300m to avoid a long tail for the perpendicular distance distribution. The selected model used the half normal form of the detection function and included covariates of Beaufort sea state and group size (Table 1.2). The ESW was estimated to be 158m (CV=7.6%; Figure 1.5) and the average group size was 9.75 animals (CV=17%). The abundance estimate for all dolphins considered together for the time period of the survey was 314 animals (CV=41%; 95% CI 141 – 697) (Table 1.3). We also generated estimates separately for both species (Table 1.3); the abundance of bottlenose dolphins was estimated to be 221 animals (CV=52%; 95% CI 83 – 592) and the abundance of spotted dolphins was estimated to be 93 animals (CV=71%; 95% CI 25-337).

Loggerhead Sea Turtles

Turtles were assumed to have constant and certain detectability within a strip with a half-width of 50m (Figure 1.4). All turtles detected were singletons; the resulting abundance over the time period of the surveys was 38 animals (CV=56%; 95% CI 15 – 110).

Figure 1.1. Schematic of the survey region in coastal waters offshore Camp Lejeune, NC. Eight 12-nm survey transects (black lines) extend perpendicularly from the beach. The abundance of dolphins and sea turtles was estimated for the area enclosed within the light grey box.

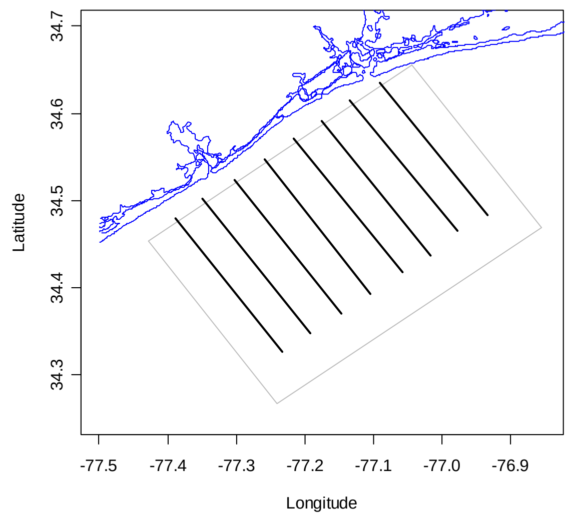

Figure 1.2. The location of the coastal survey area located near Camp Lejeune, in relation to the USWTR/AFAST survey region located further offshore in Onslow Bay.

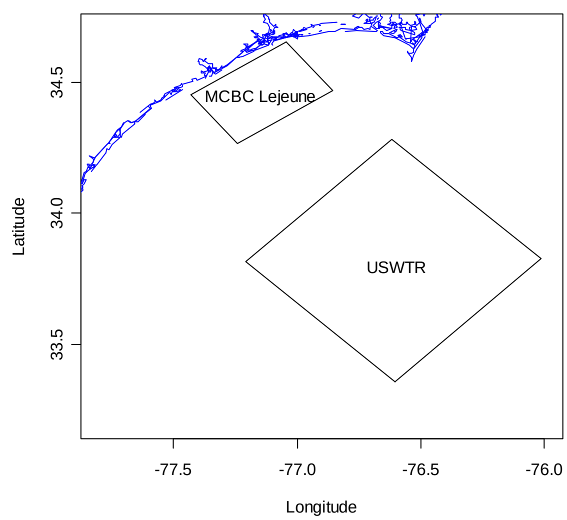

Figure 1.3. Location of sightings of spotted dolphins, bottlenose dolphins and loggerhead turtles made during coastal surveys off Camp Lejeune.

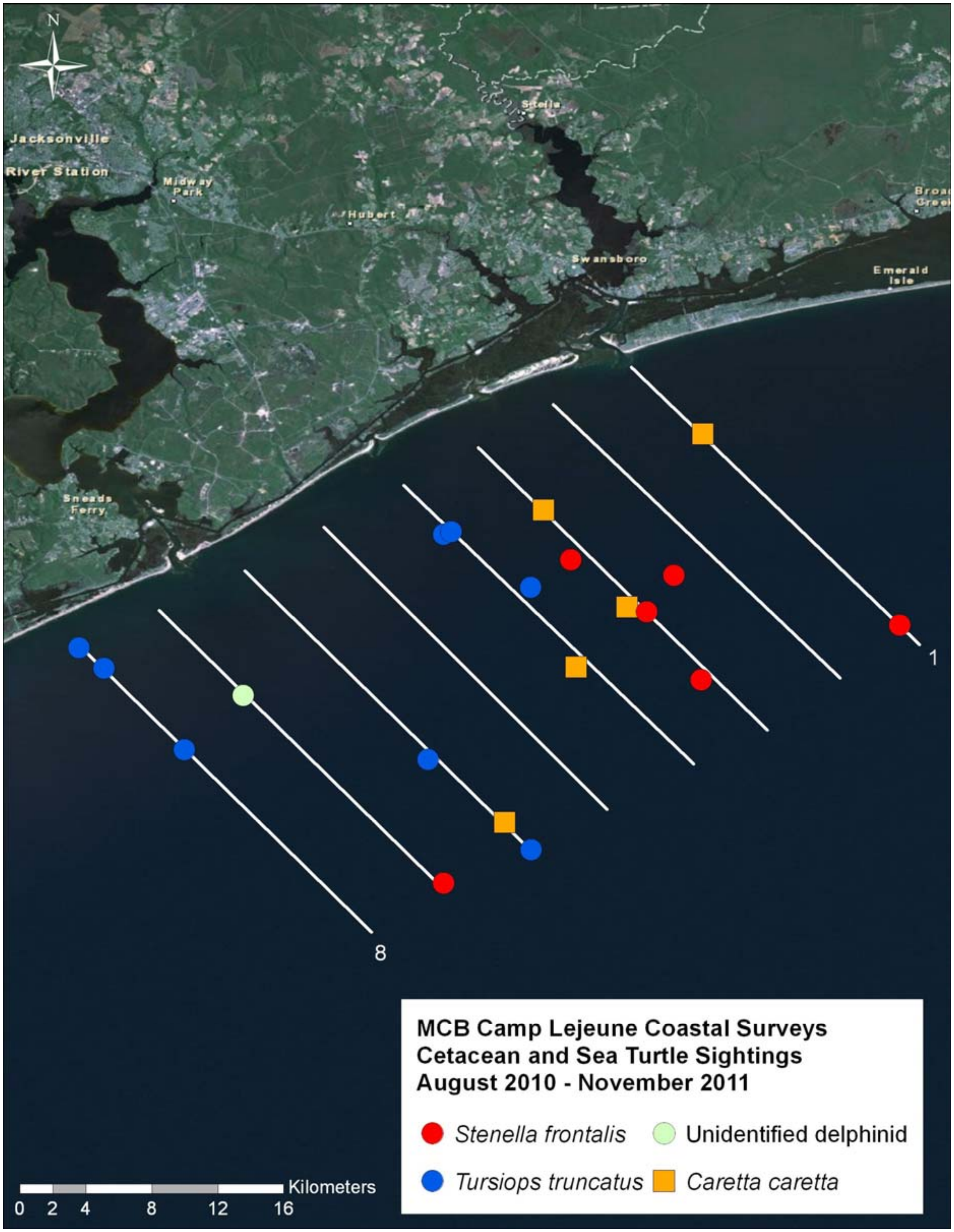

Figure 1.4. Histograms of perpendicular distances of all groups of dolphins and sea turtles sighted during coastal surveys off Camp Lejeune.

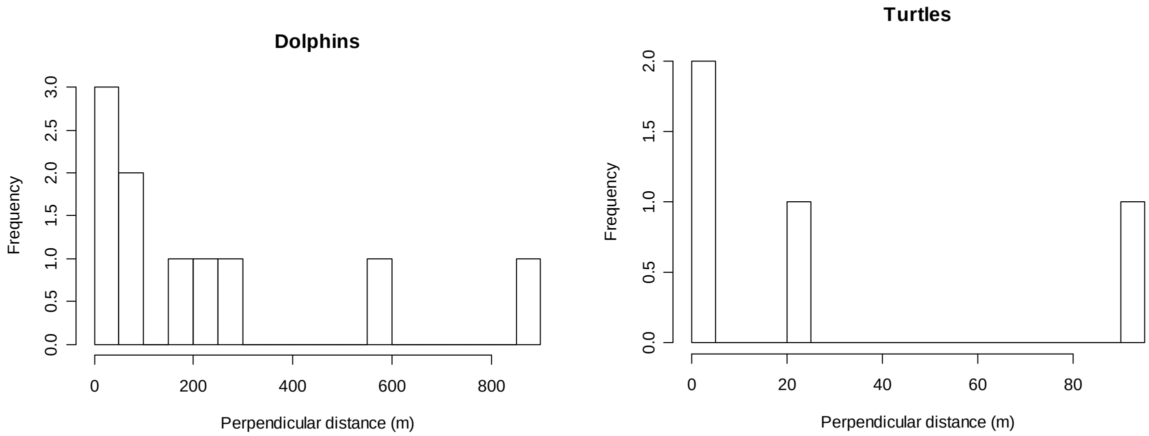

Figure 1.5. Detection function for all dolphins (including USWTR/AFAST sightings) overlaid onto scaled perpendicular distance distribution.

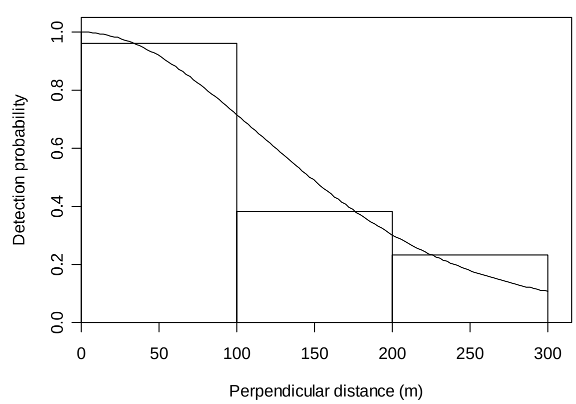

Table 1.1. Summary of the number of transects (k), search effort (L) and number of groups sighted (no truncation) during coastal surveys conducted off Camp Lejeune. Only one transect was completed in September 2010 due to poor weather. Only sightings made while on survey effort are included in this summary.

Year	Month	k	L (km)	Spotted dolphins	Bottlenose dolphins	Loggerhead turtles
2010	August	4	77.8	1		
	September	1	11.9			
	October	4	89.8		2	1
2011	January	4	88.8			
	February	4	88.8			
	April	4	87.9		2	1
	May	4	89.5	1		1
	August	4	89.1	1		
	September	4	79.5		1	
	October	4	90.7			1
	November	4	85.9		2	
Total		41	879.7	3	7	4

Table 1.2. Summary of the detection function (DF) models used to estimate density of dolphins in coastal surveys off Camp Lejeune. The number of sightings includes additional USWTR/AFAST sightings of dolphins from further offshore in Onslow Bay. In the last column, HN indicates a half normal form, BSS is Beaufort sea state and size refers to group size.

Species	Number of sightings before truncation	Truncation distance (m)	Number of sightings after truncation	Number of bins	DF model
Dolphins	131	300	95	3	HN: BSS + size
Turtles	4	50	3	1	Strip

Table 1.3. Estimates of encounter rate (n/L), average group size ($E[s]$), group abundance (N_s), animal abundance (N) and 95% CI of animal abundance. Coefficients of variation are given in parentheses.

Species	n/L (groups/km)	$E[s]$	N_s (groups)	N (animals)	95% CI of N
Dolphins	0.0091 (0.37)	9.75 (0.17)	32 (0.38)	314 (0.41)	141 – 697
Bottlenose	0.0068 (0.45)	9.17 (0.24)	24 (0.46)	221 (0.52)	83 - 592
Spotted	0.0023 (0.70)	11.50 (0.13)	8 (0.70)	93 (0.71)	25 - 337
Turtles	0.0034 (0.56)	1.00 (0.00)	38 (0.56)	38 (0.56)	15 – 110

Component 2: Photo-Identification Surveys

Methods

New River

We conducted photographic surveys for bottlenose dolphins in the New River from two outboard-powered, center-console research boats (R/V *Exocetus* and R/V *Caretta*) operated by the Duke University Marine Laboratory. Researchers on each boat included a skipper, one or two photographers and a data recorder. We recorded survey routes continuously with a GPS and noted any changes in sighting conditions during the course of the survey. We required optimal conditions (Beaufort Sea State 2 or less) to obtain good quality dorsal fin images. At each encounter with dolphins we recorded the position (using the GPS unit), water depth and the approximate number of dolphins. We identified neonatal (newborn) dolphins from the presence of folded dorsal fins and neonatal lines (Thayer *et al*. 2003). We then obtained photographs of the dorsal fin of each dolphin in the group using Nikon digital cameras equipped with 300-mm zoom lenses. We attempted to photograph every dolphin in each encounter.

We used the software program ACDSee PhotoManager 8 to organize digital images of dolphin dorsal fins. We identified each digital image with the date and encounter number. Prior to photo-identification, we graded images of dolphin dorsal fins for photographic quality (PQ) (Appendix 1 and Read *et al*. 2003). The photographic quality score was based on a weighted scale that incorporated: focus and clarity; contrast; angle of the fin to the photographer; and visibility of the fin in the frame. Any image at an oblique angle or that did not show the entire trailing edge of the dorsal fin from the tip to the posterior insertion was excluded from analysis. Excellent quality images received scores from 6-9; good quality images ranged from 10-12; and poor quality images scored 13 and higher.

We also scored the distinctiveness (D) of features, predominantly nicks on the trailing edge, on each dolphin's dorsal fin (Appendix 1 and Read *et al*. 2003). Dolphins with the most distinctive features, evident in even a poor quality photograph, were scored D1; those with intermediate features, with at least two distinguishing features or one major feature, were scored D2; and animals with few or no distinctive characteristics received a score of D3 (see Appendix 1 for a complete description of the criteria used for scoring photographic quality and mark distinctiveness). For the purposes of this study, only animals with the most and intermediate distinctive fins (D1 and D2) were considered "marked."

We used only images of excellent or good photographic quality (scores ≤ PQ12) of marked individuals (D1 and D2) in the photo-identification process. By restricting the data set to excellent and good quality images of distinctively marked individuals, we minimized subjectivity in the matching process and reduced the chance of making incorrect identifications or missing them altogether (Friday *et al*. 2000; Read *et al*. 2003). We sorted images of individual dolphins based on the location of the most prominent feature on their fin, gave each individual a temporary identification number and placed its image in a catalog folder. We pooled images from left and right side photographs because features of the dorsal fin edge are equally visible from either side. We compared each distinctive dolphin to every other marked individual before adding it to the catalog; a second researcher verified every potential match of an individual dolphin from one encounter to another. We then compared each dolphin to the DUML-UNCW photo-identification catalog that includes 2,378 dorsal fin images dating back to 1995. The catalog represents past research effort from inshore and coastal waters extending from the NC/SC border north to Oregon Inlet and Roanoke Sound. To examine the movements and potential stock identity of dolphins observed in the New River we selected a sub-sample of matched dolphins with five or more prior sighting records in the DUML-UNCW catalog (including those made during the present study) and plotted the sighting locations of these animals.

Coastal Waters

In addition, we monitored the use of the N1/BT3 survey area by individual dolphins using the same photo-identification techniques described above. Thus, whenever possible, we obtained photographs for individual photo-identification; we also used these photographs to confirm species identification at each sighting. Due to the configuration of our survey vessels and the difficulty of maneuvering them around groups of dolphins, our photographic coverage of these groups was often incomplete. We obtained digital images of the dorsal fins of bottlenose and spotted dolphins with Canon or Nikon digital SLRs (equipped with 100-300 mm zoom lenses) in 24-bit color at a resolution of 3072 X 2048 pixels and saved in jpg format.

Results

New River

We conducted photographic surveys for bottlenose dolphins in the New River on 19 days between October 2010 and November 2011; we surveyed in every month except August 2011, due to the effects of Hurricane Irene. We surveyed the entire New River, the New River Inlet and the Intracoastal Waterway between Alligator Bay and Bear Island (Figure 2.1). Field hours, numbers of encounters, estimated number of dolphins encountered and number of photographs taken are presented in Table 2.1.

We encountered dolphins on every survey and, in total, recorded 54 sightings of bottlenose dolphins in the New River and adjacent waters (Figure 2.2 and Table 2.1). A detailed summary of each sighting is included as Appendix 2. We sighted dolphins throughout the Intracoastal Waterway and New River, with some groups seen as far upriver as Morgan Bay (Figure 2.2).

The mean size of dolphin groups from our field estimates was 7.4 (SD = 7.9) and our encounters ranged from single animals to a group of 40 dolphins. The largest groups occurred in winter and spring, with smaller groups more common during summer. In general, the largest groups of dolphins were seen near the New River Inlet (Figure 2.2).

We encountered dolphins throughout the year (Figure 2.3), even during one survey in winter when the surface of the water in the northern part of the River was covered by a thin sheen of ice. The minimum water temperature recorded at a dolphin sighting was 5.6°C in January; the maximum was 28.5°C in June. We observed neonates only in the months of November-December and March-April, a bimodal pattern consistent with previous observations of the seasonality of reproduction of bottlenose dolphins in North Carolina (Thayer *et al*. 2003).

During these encounters we obtained 3,508 digital images of dolphin dorsal fins. From these images we identified 56 individual marked (D1 and D2) dolphins. Thumbnail images of these marked dolphins are included as Appendix 4. We matched 32 (57%) of these dolphins to our DUML/UNCW photo-identification catalog; the remaining 24 were new and will be added to the catalog. The frequency of re-sightings varied considerably; two dolphins were photographed in four separate months, but 35 were identified only once. We did not match any of the dolphins photographed in the New River to those we photographed during our coastal surveys in the coastal N1/BT-3 survey area.

We created a discovery curve (Figure 2.4) by plotting the number of newly identified dolphins against sequential survey day to determine whether the population was closed or open. In a closed population, the rate of new identifications declines and reaches a plateau over the course of the study as photographic sampling saturates the number of dolphins available. In an open population, newly identified dolphins are continually added with each subsequent survey. The discovery curve (Figure 2.4) shows that the population of dolphins in the New River was quite open, as we continued to identify new individuals throughout the study. On our last survey (20 November 2011) we identified 29 dolphins, 11 of which were new to the study.

To gain insight into larger patterns of movement and the potential stock identity of dolphins using the New River we examined the previous sighting histories of the 32 dolphins matched to the DUML-UNCW catalog. The number of prior sightings of these dolphins ranged between 1 and 37 per individual. Seventeen of these animals had been seen on five or more occasions. In Figure 2.5 we show examples of sighting histories from bottlenose dolphins that likely belong to the Northern North Carolina Estuarine stock

(NNCES), as defined by the National Marine Fisheries Service (Waring *et al*. 2011). These dolphins range from Pamlico Sound south the New River where they intermingle with dolphins from the Southern North Carolina Estuarine stock, whose range extends south to the South Carolina border (Figure 2.6). It seems clear that estuarine waters of the New River represent an area of overlap between these two stocks (also see Read *et al*. 2003).

We photographed six dolphins that had been previously captured and sampled by researchers at the National Marine Fisheries Service Beaufort Laboratory as part of a health assessment and tagging program. These animals are particularly well marked (see Appendix 4) and have been freeze-branded to facilitate identification. Two of these dolphins (FB724 and FB726, both male) were captured together in July 1995 in Bogue Sound and we have long sighting histories for both individuals (see Figure 2.5). FB403, a female, was captured near Marshallberg, NC in November 1999; FB418 (male) was captured in April 2000 near Beaufort and FB445 (female) and FB460 (male) were captured in April 2006 in Bogue Sound.

Coastal Waters

As noted above, we surveyed 41 tracklines in coastal waters between August 2010 and November 2011. These surveys were conducted in Beaufort Sea State (BSS) 0-4 with most effort in optimal sighting conditions of BSS 1-2. We recorded 15 sightings of dolphins during the reporting period, including off-effort sightings (*e.g.* made during transit between adjacent tracklines) (Table 2.2 and Figure 1.3). A complete summary of all encounters made during these coastal surveys is included as Appendix 3. We made every attempt to photograph all animals encountered and obtained 1,188 digital images during these encounters.

We identified 17 well-marked (D1 and D-2) spotted dolphins and seven bottlenose dolphins from these images. We compared these 24 individuals to our existing catalogs for both species in coastal waters and from previous surveys conducted in the near-shore coastal waters of Onslow Bay from 2001-2003. We made one and possibly two matches to spotted dolphin photographed during our AFAST/USWTR surveys in Onslow Bay in 2010 and 2011 (Figure 2.7). (The second potential match is still being verified). We also routinely compare images of the dorsal fins of stranded cetaceans in North Carolina to our photo-identification catalogs for Onslow Bay, but we have not found any matches to date.

Figure 2.1. Distribution of effort during photo-identification surveys of bottlenose dolphins in the New River and vicinity from October 2010 through November 2011.

Figure 2.2. Distribution of bottlenose dolphin sightings, stratified by group size, in the New River and vicinity made during photo-identification surveys conducted from October 2010 through November 2011.

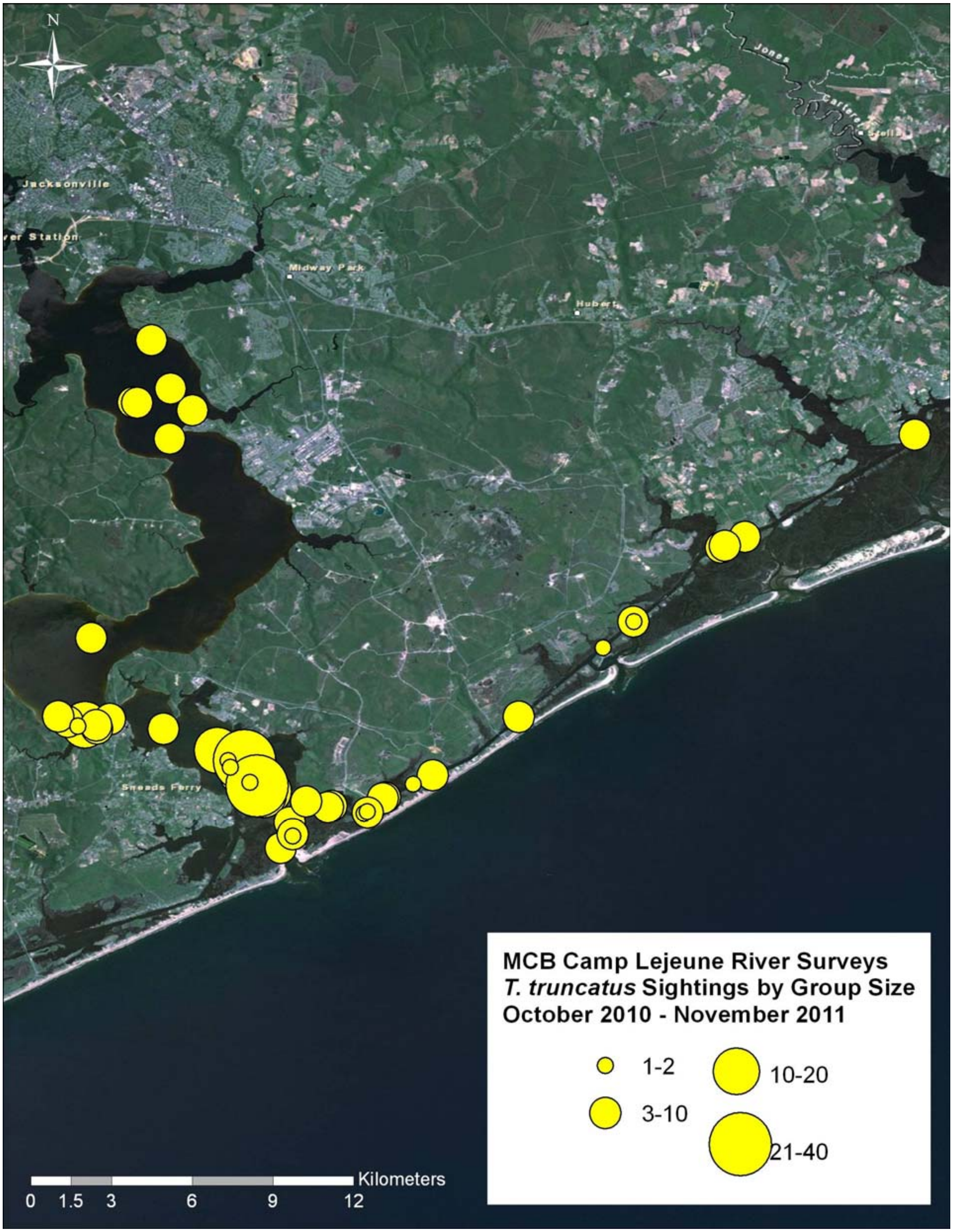

Figure 2.3. Distribution of bottlenose dolphin sightings, stratified by season, in the New River and vicinity made during photo-identification surveys conducted from October 2010 through November 2011.

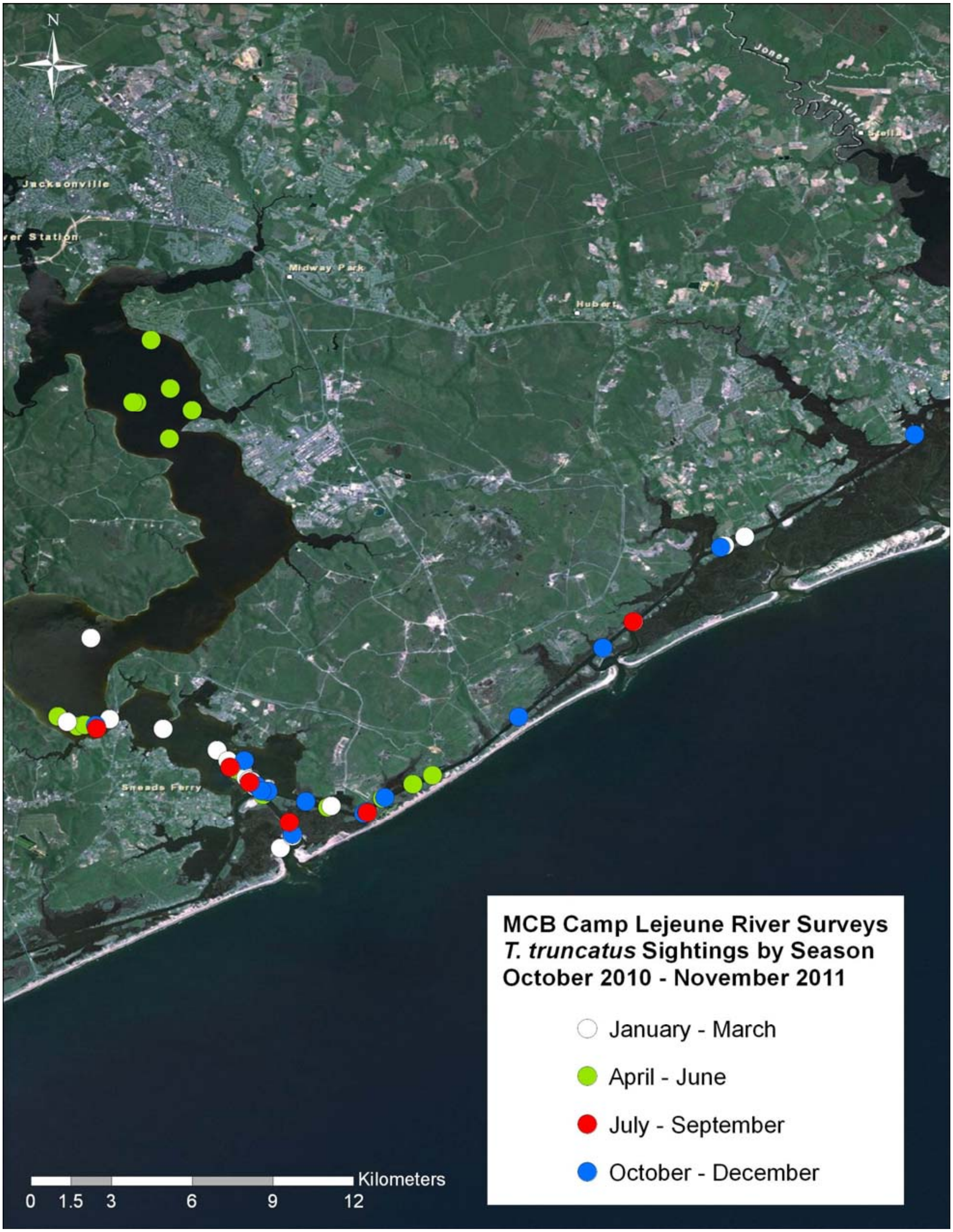

Figure 2.4. Discovery curve for New River photo-identification surveys showing the cumulative number of new identifications of bottlenose dolphins made each day over the course of the survey period, October 2010-November 2011. On two surveys no marked animals were photographed, so those surveys are not included here.

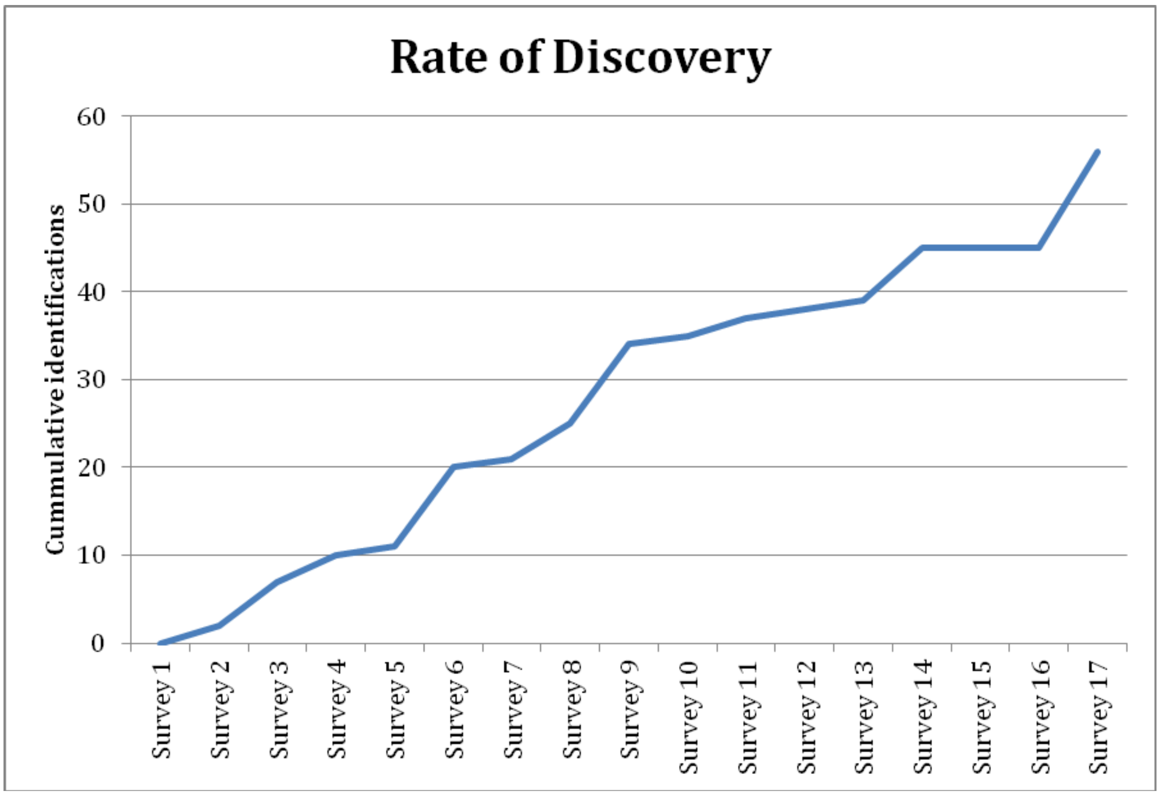

Figure 2.5. Sighting histories of selected bottlenose dolphin photographed in the New River that likely belong to the Northern North Carolina Estuarine Stock. Symbols are of different size to allow observation of overlapping points.

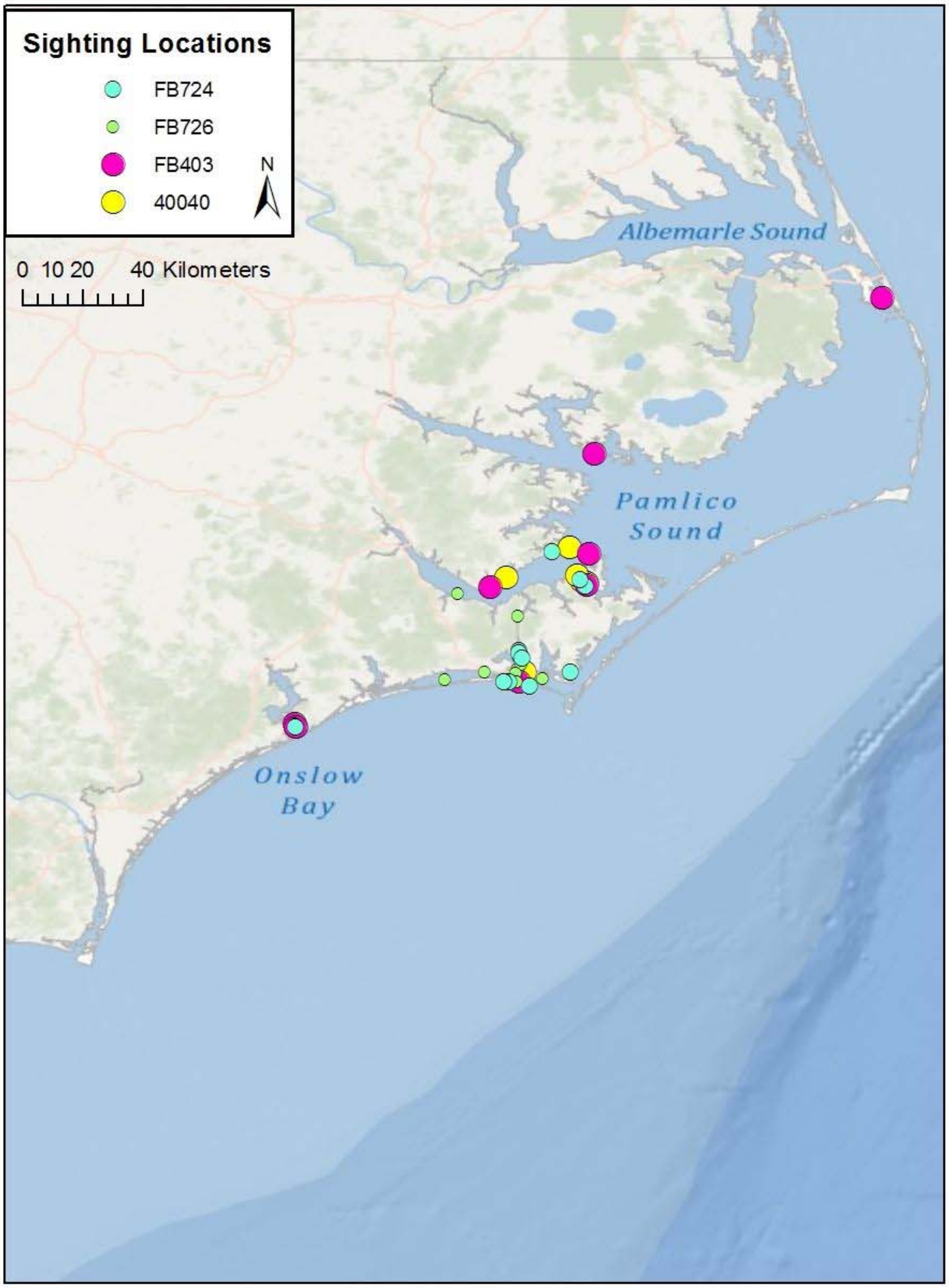

Figure 2.6. Sighting histories of selected bottlenose dolphin photographed in the New River that likely belong to the Southern North Carolina Estuarine Stock. Symbols are of different size to allow observation of overlapping points.

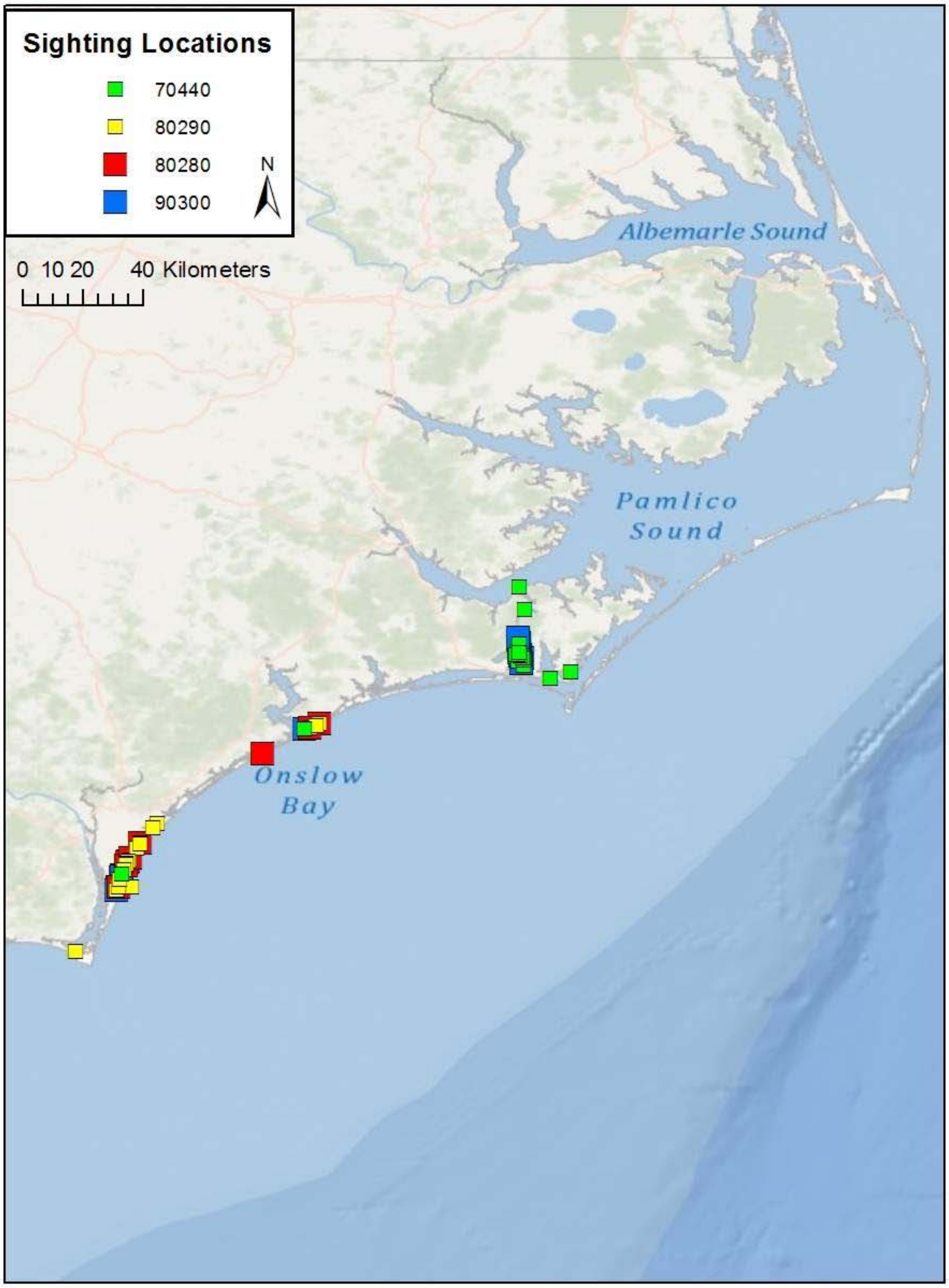

Figure 2.7. Photographic matches of two spotted dolphin photographed in coastal surveys off Camp Lejeune to surveys and during AFAST/USWTR surveys further offshore in Onslow Bay.

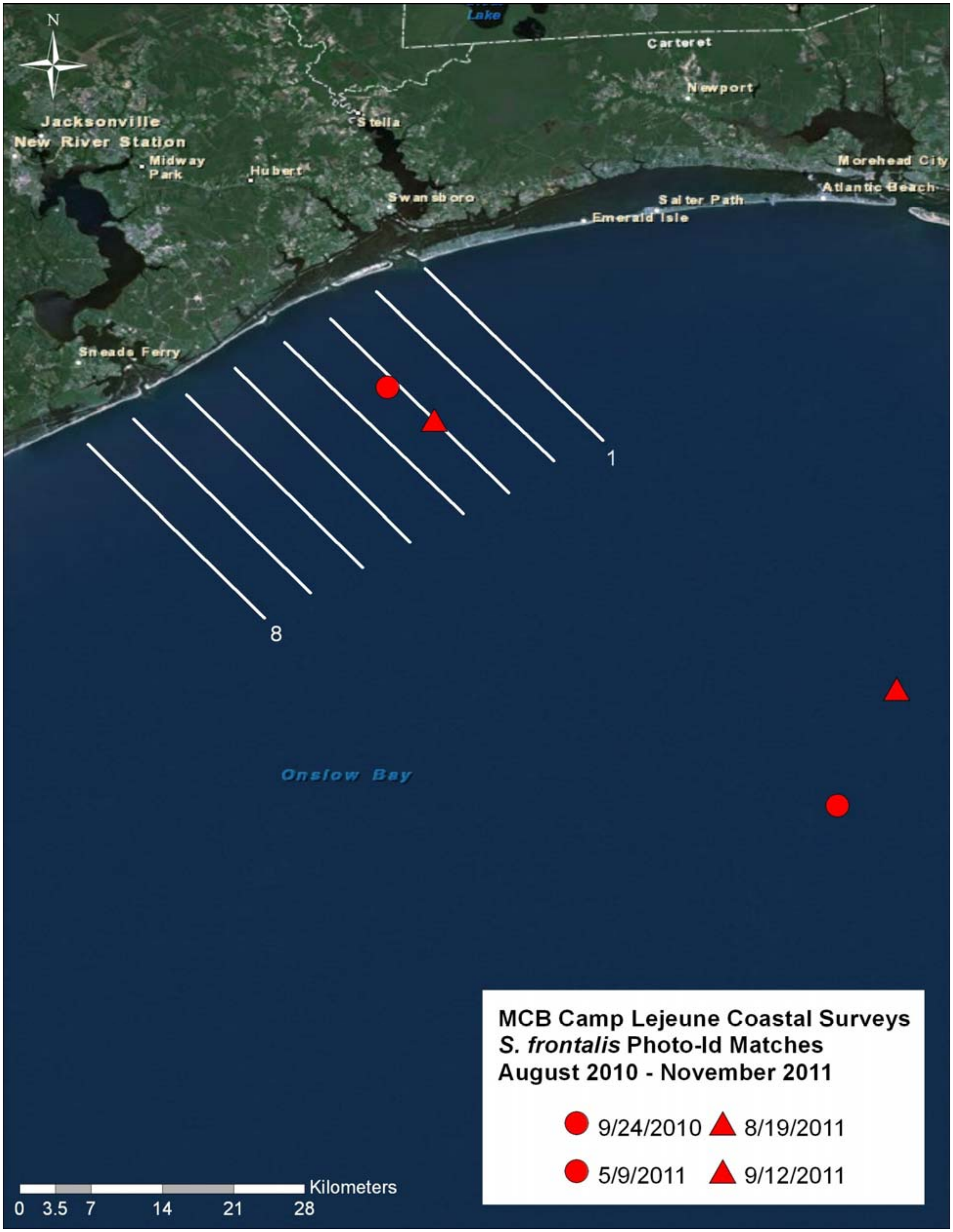

Table 2.1. Summary of effort for bottlenose dolphin photo-identification surveys conducted in the New River and vicinity. No surveys were conducted in August 2011.

Date	Field Hours	Vessel	Sightings	Dolphins	Photos
17-Oct-10	5.0	*Exocetus*	1	3	20
20-Nov-10	7.5	*Exocetus*	2	22	35
30-Dec-10	5.5	*Exocetus*	4	20	139
05-Jan-11	3.8	*Caretta*	5	25	30
30-Jan-11	7.5	*Exocetus*	2	15	69
06-Feb-11	5.0	*Caretta*	3	30	143
11-Feb-11	3.8	*Exocetus*	2	16	74
29-Mar-11	6.5	*Caretta*	5	33	263
06-Apr-11	7.8	*Caretta*	7	66	538
16-May-11	3.0	*Caretta*	1	2	22
20-May-11	7.3	*Caretta*	1	8	131
13-Jun-11	6.8	*Caretta*	1	5	121
14-Jun-11	7.0	*Caretta*	4	14	336
15-Jun-11	7.5	*Caretta*	3	20	448
11-Jul-11	8.5	*Caretta*	4	22	199
02-Sep-11	8.1	*Caretta*	1	1	17
09-Sep-11	6.8	*Caretta*	1	1	0
26-Oct-11	5.7	*Exocetus*	2	5	107
20-Nov-11	6.2	*Caretta*	5	89	816
Totals	**119.3**		**54**	**397**	**3508**

Table 2.2. Summary of effort and dolphin sightings made during line transect surveys in coastal waters off Camp Lejeune. Number of sightings and photos include encounters with dolphins while off effort (*e.g.* transiting from one transect line to the next).

Date	Field Hours	Vessel	Sightings	Dolphins	Photos	Legs Surveyed
18-Aug-10	5.5	*Cetus*	2	22	84	1, 3, 5, 7
09-Sep-10	0.5	*Sensation*	0	0	0	2
21-Oct-10	5.8	*Sensation*	2	22	47	2, 4, 6, 8
14-Jan-11	5.0	*Sensation*	0	0	0	2, 4, 6, 8
17-Feb-11	5.8	*Sensation*	0	0	0	1, 3, 5, 7
14-Apr-11	5.5	*Sensation*	3	22	120	2, 4, 6, 8
09-May-11	9.0	*Sensation*	3	103	709	1, 3, 5, 7
19-Aug-11	5.5	*Sensation*	1	10	139	1, 3, 5, 7
13-Sep-11	6.1	*Sensation*	1	2	4	2, 4, 6, 8
13-Oct-11	7.8	*Sensation*	1	3	0	1, 3, 5, 7
12-Nov-11	5.5	*Sensation*	2	17	85	2, 4, 6, 8
	62		**15**	**201**	**1188**	**41**

Component 3: Passive Acoustic Monitoring

In addition to the photo-identification surveys, we also used passive acoustic monitoring to investigate the occurrence of bottlenose dolphins in the estuary of the New River, North Carolina. The area is used extensively for military training exercises, commercial and recreational fishing, and recreational boating, so there is a considerable degree of anthropogenic noise in these shallow waters. We deployed passive acoustic monitoring systems (see below) at four sites in the New River (Figure 3.1). The Inlet site is situated closest to the mouth of the estuary, where the New River intersects the Atlantic Intracoastal Waterway (ICW). The other deployment sites (Stone Bay, Farnell Bay, and Morgan Bay) were each located 5-10 km apart further upstream. We chose sites in open bays to maximize the monitored area. Given the distance between deployment sites and spatial configuration of the river, we expected no overlap in detections of echolocation clicks at the four sites. Water depths ranged from 3 to 4 m at each site. Tidal activity is highest at the Inlet and minimal at the three other sites.

Methods

Data Collection: C-POD

We deployed Version 1 C-PODs (Figure 3.2a; Chelonia Ltd., Cornwall, United Kingdom) to detect echolocation clicks of bottlenose dolphins in the New River; no other odontocete species occur in the estuary. The C-POD records a continuous summary of echolocation events, but does not record actual sound files. Each C-POD contains a battery pack of 10 alkaline D-cell batteries, a 4 GB memory card, an omni-directional hydrophone and transducer. The C-POD uses a digital time domain waveform analysis to detect cetacean echolocation clicks at a 5μs resolution and 8-bit intensity within a frequency range of 20-160 kHz. The units can operate for a maximum of 6 months depending on the level of echolocation activity and background noise.

We deployed C-PODs at each site in the New River (Figure 3.1) for various periods occurring between 20 November 2010 and 15 December 2011 (Table 3.1). Due to variation in sensitivity among the units (see below), we used the same CPOD unit at each site for the duration of the study. We initially deployed C-PODs on 20 November 2010 in the Inlet and Stone Bay, on 30 January 2011 in Farnell Bay and on 6 April 2011 in Morgan Bay (Table 3.1). We recovered all C-PODs on 15 December 2011. The C-PODs recorded continuously during all deployment periods. Each C-POD was positively buoyant and moored approximately 1.5 m above the seabed between a concrete cinder block and a subsurface buoy. We secured the cinderblocks using a heavy chain to nearby navigation markers to prevent drift. We changed batteries and memory cards of each C-POD every one to three months. Heavy bio-fouling occurred on the C-PODs, especially during late spring through early fall, so we needed to maintain a regular maintenance schedule to ensure optimal functioning.

Data Collection: DMON

We ground-truthed the occurrence of echolocation click detections from the C-PODs with digital acoustic recordings made from a DMON, an autonomous digital acoustic monitoring device (Figure 3.2b; Woods Hole Oceanographic Institution, Woods Hole, MA, USA). The DMON can be configured in a variety of bandwidth settings (Low Frequency (LF) = 10 Hz – 7.5 kHz, Mid-Frequency (MF) = 100 Hz – 50 kHz, High Frequency (HF) = 1 kHz – 160 kHz). The unit contains sensors for detecting depth, 2-axis acceleration/tilt and temperature. The DMON uses a rechargeable Li-Ion battery and a 16 GB memory card and records at an 8-bit resolution. The DMON can hold up to 600 hours of acoustic data at the LF setting, 90 hours at MF and 24 hours at HF.

We deployed the DMON adjacent to C-PODs in Stone Bay, Farnell Bay, and Morgan Bay (Figure 3.1) for one to four days per deployment during February, May and June 2011 (Table 3.1). We did not deploy the DMON at the Inlet due to the difficulty of mooring equipment in this area of high tidal currents and shifting sand. We deployed the DMON at a distance of approximately 5-10m from each C-POD using a separate mooring system. We obtained continuous acoustic recordings of the DMON configured to record at the MF bandwidth. We chose this frequency bandwidth to ensure that bottlenose dolphin clicks would be detected (Au 1993) and to maximize the DMON's battery life and memory capacity during each deployment.

Analysis of C-POD Records

We processed all C-POD data with the manufacturer's software, CPOD.exe v. 2.026, which uses a proprietary algorithm, the 'KERNO classifier' to identify coherent click trains in the data. Click trains are series of more than four similar clicks having successively similar inter-click intervals. All clicks not identified as part of a click train by the KERNO classifier were discarded. Each click train is automatically assigned to one of four quality categories, 'Hi,' 'Moderate,' 'Low,' or 'Doubtful,' that represents the confidence level of the train classification as coming from a real train source and not arising by chance from unrelated sound sources such as snapping shrimp. Click trains are also automatically given one of four species classes: 'NBHF' (narrow band high frequency clicks, such as those produced by porpoises), 'Other cet' (all non-NBHF dolphins), 'Sonars' (boat sonars) and 'unclassed'. Bottlenose dolphins are the only cetacean present in this area, so we did not apply filter settings in addition to the quality category assignments. All trains assigned as 'Other cet' were exported, a category that should contain detections of all delphinid species (Nick Tregenza, Chelonia, Ltd., personal communication).

We used Detection Positive Minutes (DPMs) to indicate the presence of bottlenose dolphins. DPMs are minutes of C-POD recordings that contained at least one echolocation click train, indicating the presence of at least a single dolphin. We included only Hi, Moderate and Low detections in the analysis; all Doubtful detections were discarded. The inclusion of these three categories of DPMs was based on our comparison of the C-POD with the DMON (see below). The number of Doubtful DPMs was low and each was individually evaluated when corresponding DMON data were available. All of the Doubtful DPMs we evaluated were determined to be false detections.

To determine the presence of dolphins on a monthly basis at each site, we used only days with 24 hours of continuous data; we excluded partial days of recordings due to C-POD servicing or malfunctions. We then binned DPMs by hour and normalized them for effort. We determined monthly presence as the percentage of total hours of presence divided by the number of hours of recording effort per each month.
To assess presence on an hourly basis, we used only hours of recordings containing 60 minutes of continuous data; we discarded partial hours of recordings containing less than 60 minutes of continuous data. We binned DPMs by hour and normalized them for effort. We assigned each hour to one of three photoperiods: day, night and twilight. Twilight was defined as the time between the beginning of nautical twilight and sunrise and the time between sunset and the end of nautical twilight; day was time between sunrise and sunset; and night was time between the end and beginning of nautical twilight. Hours encompassing both day/night and twilight times were included in the photoperiod that encompassed the most minutes in the hour. Local sunrise and sunset times were taken from the U.S. Naval Observatory website (http://aa.usno.navy.mil). We assessed hourly presence as the total number of minutes of presence divided by the total minutes of recording effort during each hour.

We exported all click train details for Hi, Moderate, and Low detections at all sites. This export included a unique identification number assigned to each click train and the inter-click intervals (ICI) of all clicks within each train. Inter-click interval can be used to assess dolphin behavior; specifically, we assumed that ICIs of less than 10 msec were foraging buzzes (Elliott *et al*. 2011). Only ICIs of less than 200 msec were evaluated, as ICIs occurring above 200 msec comprised less than 2% of the total number of ICIs. We compiled total numbers of click trains and ICIs for each C-POD and normalized these by sampling effort. Total click trains and ICIs were determined as a percentage of total numbers of click trains or ICIs per total hours of recording effort per each deployment site.

Analysis of DMON Recordings

An experienced analyst (Bethany Roberts) performed a comprehensive manual analysis of all DMON digital acoustic recordings using Raven Pro 1.4 (Bioacoustics Research Program, Ithaca, NY). All acoustic data were analyzed in one-minute spectrogram segments (Frequency range = 100 Hz – 50 kHz, Window = Hann, FFT = 512, Overlap [%] = 85). Each one-minute segment was marked as either containing dolphin echolocation clicks or with clicks absent. We used minutes with echolocation clicks to identify the presence of dolphins; we did not use whistles because the C-POD records only the presence of echolocation clicks. The analyst operated in a 'blind' fashion - without knowledge of the presence or absence of clicks from the corresponding C-POD deployment. Noise due to boats, chain links and weather occurred in parts of each DMON recording; minutes with a sufficient amount of noise to mask echolocation clicks were discarded and no comparison with the corresponding C-POD deployment was made.

Evaluating C-POD Detections with DMON Digital Acoustic Recordings

To evaluate the reliability of the C-PODs in detecting bottlenose dolphin echolocation, we compared all C-POD DPMs with the results of the manual evaluation of echolocation clicks for the corresponding DMON recording. We conducted comparisons for each individual C-POD and the corresponding DMON recording to determine how detections varied among individual C-PODs. C-POD DPMs were determined to be either a true or a false detection after determining whether the corresponding DMON recording contained the presence or absence of echolocation clicks. All C-POD quality category DPMs were analyzed and the following comparisons were conducted for evaluating the C-POD's ability to accurately detect true echolocation events.

We evaluated all C-POD records to determine when: (1) the C-POD correctly detected echolocation; and (2) the C-POD falsely detected echolocation. Each DPM was marked as being either a true positive (TP), defined as a C-POD DPM that corresponded in time with the presence of an echolocation event in the DMON acoustic recording, or a false positive (FP), defined as a C-POD DPM for which no echolocation event occurred in the corresponding time in the DMON acoustic recording. We only marked C-POD DPMs as FP after the analyst was unable to identify echolocation events ten minutes before and ten minutes after the reported C-POD detection time, to reduce the effect of any inconsistencies in the time records due to time drift occurring between the two acoustic units.

We also evaluated all C-POD records to determine when: (1) the C-POD correctly did not report an echolocation event; and (2) the C-POD failed to correctly detect the presence of dolphin echolocation. We defined a true negative (TN) as a minute when the C-POD correctly did not report a DPM when no echolocation events occurred in the DMON acoustic recording and a false negative (FN) as a minute when the C-POD failed to report a DPM when an echolocation event was identified in the DMON acoustic recording.

We used total numbers of TP, FP, TN, and FN to determine corresponding rates for each C-POD (Table 3.2). We also used these calculations to determine specificity, sensitivity, positive and negative predictive value and accuracy of detections for each C-POD (Table 3.2).

Results

C-PODs recorded for 9099 hours in the Inlet, 8545 hours in Stone Bay, 7642 hours in Farnell Bay and 6061 hours in Morgan Bay (Table 3.1). Short gaps occurred within the record due to servicing the C-PODs and/or occasional malfunctions throughout the study period.

Dolphin Behavior

Bottlenose dolphin click trains were detected at all four sites (Figure 3.3 and Table 3.1). The duration of inter-click intervals (ICI) showed a wide range (0.8 to 1932 msec), although the vast majority (98%) of all ICIs were below 200 msec at all sites. ICI patterns exhibited a bimodal distribution at all sites (Figure 3.4). The first peak of ICI duration was at less than 5 msec at all sites, likely resulting from feeding buzzes in which successive clicks occur in rapid succession as a dolphin closes on prey (Elliott *et al*. 2011). The second peak in duration varied from site to site (Figure 3.4), perhaps reflecting different foraging strategies employed in each area.

Spatial and Temporal Distribution of Dolphins

Bottlenose dolphins were detected at all deployment sites throughout the study (Figure 3.5). This finding is consistent with our sightings of dolphins at the Inlet, Stone Bay and Morgan Bay from the photo-identification surveys (see above). Dolphins were detected at least once every day at all four sites (Inlet = 372 d, Stone Bay = 348 d, Farnell Bay = 311 d, Morgan Bay = 249 d). Dolphins used the entire River on a daily basis, but they were not present continuously at any site, as indicated by the distribution of DPMs at each site (Figure 3.5). Dolphins occurred most frequently at the Inlet (22% of recorded effort), then in Morgan (8%) and Stone Bays (8%) and least frequently in Farnell Bay (4%).

Dolphin occurrence, as reflected by mean values of DPM per day, varied significantly among sites and seasons (Figure 3.5, Tables 3.3 and 3.4). The most striking pattern is that dolphins were present much more frequently at the Inlet than any other site during every season. In winter, DPM per day did not vary significantly among Stone Bay, Farnell Bay, and Morgan Bay. Farnell Bay showed significantly lower mean DPM per day during spring and during summer than at all other sites. During autumn, Morgan Bay showed significantly lower mean DPM per day than all other sites.

Mean DPM per day also varied significantly among seasons at each site (Figure 3.5 and Table 3.4). Interestingly, dolphin occurrence was lowest at the Inlet during summer. At Stone Bay, mean DPM per day was significantly lower during winter than all other seasons and significantly higher during summer. In Farnell Bay, mean DPM per day was significantly higher during winter and spring than during summer and autumn. In Morgan Bay, mean DPM per day was significantly lower in autumn than any other season and significantly higher during spring.

Dolphin click trains were detected throughout the day and night, but diel patterns varied significantly from site to site and across seasons (Table 3.5). In summer, there was a significant increase in mean DPM during day at all four sites. At both the Inlet and Farnell Bay, there was a significant increase in mean DPM during the night in winter. In autumn, Stone Bay, Farnell Bay and Morgan Bay showed a significant increase in DPM during daylight and the Inlet showed a significantly higher mean DPM during the night hours. During spring, significantly higher mean DPM occurred during the night at the Inlet. In contrast, significantly higher mean DPM occurred during the day at Stone Bay and Morgan Bay during spring.

Evaluation of C-POD detections

The DMON recorded for 86 hours in Stone Bay from 6 to 11 February 2011, 92 hours in Farnell Bay from 16 to 20 May 2011, and 26 hours in Morgan Bay from 14 to 15 June 2011 (Table 3.1). The DMON reached maximum recording capacity in Stone and Farnell Bays, but we retrieved the unit from Morgan Bay before it reached capacity due to unfavorable weather conditions. Ambient and anthropogenic noise levels were high at all sites because the unit was deployed in shallow areas with frequent boat traffic, so we discarded portions of each deployment. Consequently, 2573 minutes were used for analysis in Stone Bay, 5381 minutes were used in Farnell Bay and 1431 minutes used in Morgan Bay (Table 3.1); we used these recordings to carry out our ground-truthing study. The number of C-POD detections corresponding to discarded DMON recording periods was minimal.

Bottlenose dolphin echolocation clicks were successfully recorded concurrently by both C-PODs and the DMON during all three deployments (Figure 3.6 and Table 3.6). The number of true detections (TP, TN) was substantially higher than the number of false detections (FP, FN) at all sites, except for Farnell Bay, where number of FPs exceeded the number of TPs (Table 3.7).

The C-PODs performed fairly well in detecting dolphin click trains and provided only a small number of false detections, although there was a high degree of variation among individual C-PODs (Tables 3.7 and 3.8). In Stone Bay, 401 DPMs, from 810 minutes with verified presence from the DMON, were correctly identified by the C-POD as having echolocation present (TPR = 50%). There were only 14 DPMs, from 1763 minutes with absence verified by the DMON, in which the C-POD identified echolocation when none was present (FPR = 0.8%). In Farnell Bay, 74 DPMs, from 388 minutes with verified presence, were correctly determined by the C-POD as having echolocation present (TPR = 19%). There were 183 DPMs, from 4993 minutes with verified absence, in which the C-POD identified echolocation when none was present (FPR = 4%). In Morgan Bay, 83 DPMs, from 481 minutes with verified presence, were correctly determined as having echolocation present (TPR = 17%). There were 5 DPMs, out of 950 minutes with verified absence, in which the C-POD identified echolocation when none was present (FPR = 0.5%). It was not always possible to identify the source of false detections, although anthropogenic (*e.g.* noise from the mooring chain) and ambient noise likely contributed to these errors. In Stone Bay and Morgan Bay, all FPs occurred in the Low quality category. At Farnell Bay, FPs occurred both in the Moderate and Low quality categories, with most in the latter (n = 181).

The C-PODs performed well at not reporting the presence of dolphin click trains when they did not occur, but they performed conservatively, resulting in a relatively low number of detections when echolocation was truly present (Tables 3.7 and 3.8). In Stone Bay, the absence of dolphin echolocation was recorded in1749 out of 1763 minutes of recording (TNR = 99%), but the C-POD failed to detect echolocation in 409 out of 810 minutes when it actually occurred (FNR = 50%). In Farnell Bay, the corresponding figures were 4810 out of 4993 minutes of absence (TNR = 96%) and 314 of 388 minutes with verified presence (FNR = 81%). In Morgan Bay, there were 945 from 950 minutes with verified absence, (TNR = 99%) and 398 out of 481 minutes with verified echolocation that the C-POD failed to detect (FNR = 83%).

Variation in sensitivity (equivalent to TPR) was high among individual C-PODs (Table 3.8). The C-POD in Stone Bay showed higher sensitivity (50%) than the units in Farnell (19%) and Morgan Bays (17%). Specificity (equivalent to TNR) was high for all C-PODs with little variation among units (Table 3.8). All C-PODs exhibited relatively high values of specificity: Morgan Bay (99%); Stone Bay (99%); and Farnell Bay (96%). Accuracy was high for all C-PODs, but this too varied among units (Table 3.8). Accuracy was highest in Farnell Bay (91%), due to the high number of TNs detected by this C-POD. Accuracy of C-PODs in Stone (84%) and Morgan Bays (72%) showed relatively high rates, but slightly lower than that in Farnell Bay.

Positive predictive value (PPV) was high for both C-PODs in Stone Bay (97%) and Morgan Bay (94%), but considerably lower in Farnell Bay (29%) (Table 3.8). The values of PPV exhibited by these C-PODs indicate a high probability that the C-PODs correctly identified bottlenose dolphin echolocation when they detected a click train, but was also dependent on dolphin prevalence. Negative predictive value (NPV) was high at all sites (Table 3.8), with the highest value in Farnell Bay (94%), with lower values in Stone Bay (81%) and even lower values in Morgan Bay (70%). The NPV values exhibited by these C-PODs indicate how likely the C-PODs were to correctly identify an absence when no detection was reported (*i.e*. to 'detect' an absence) and indicate that the C-PODs rarely misclassified a true absence of dolphin echolocation.

Figure 3.1. Map of the New River, North Carolina, indicating locations of the four C-POD deployment sites and three DMON deployment sites.

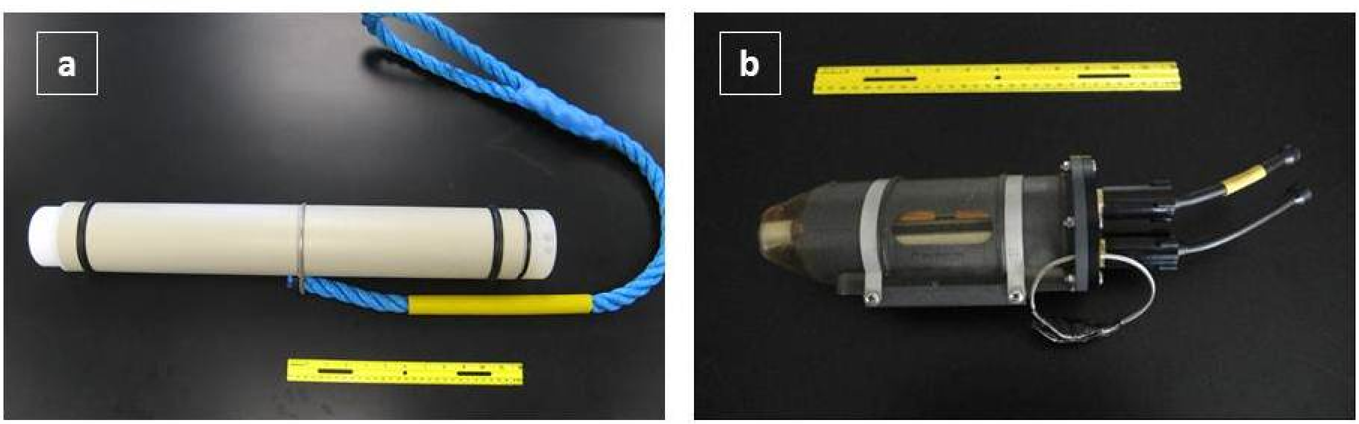

Figure 3.2. Photographs of the passive acoustic monitoring devices used to monitor the occurrence and distribution of bottlenose dolphins in the New River, North Carolina. (a) C-POD – an echolocation click train detector and (b) DMON – a digital, archival acoustic recorder.

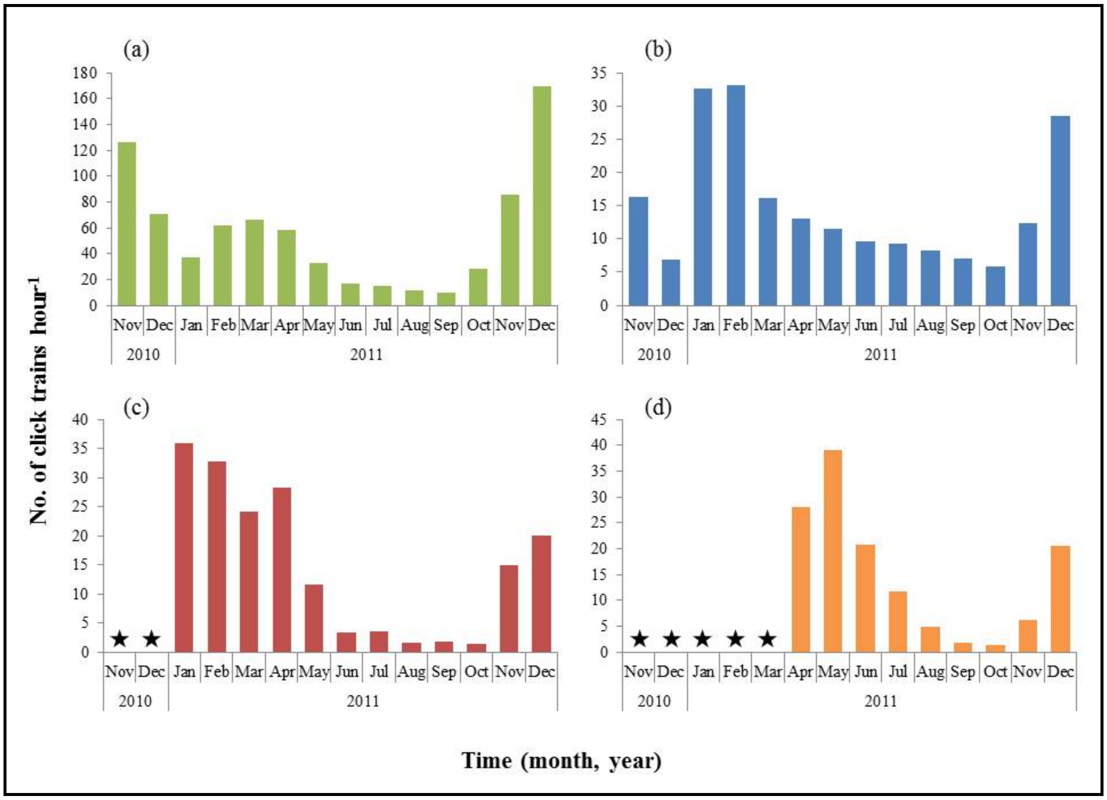

Figure 3.3. Monthly frequency of bottlenose dolphin click train occurrence corrected for effort (total hours operating) detected by C-PODs at: (a) the Inlet; (b) Stone Bay; (c) Farnell Bay; and (d) Morgan Bay. Stars indicate months with no recording effort in Farnell Bay and Morgan Bay. Note that the scales are different for the four sites and that the value for January 2011 in Farnell Bay is based on only one day of effort.

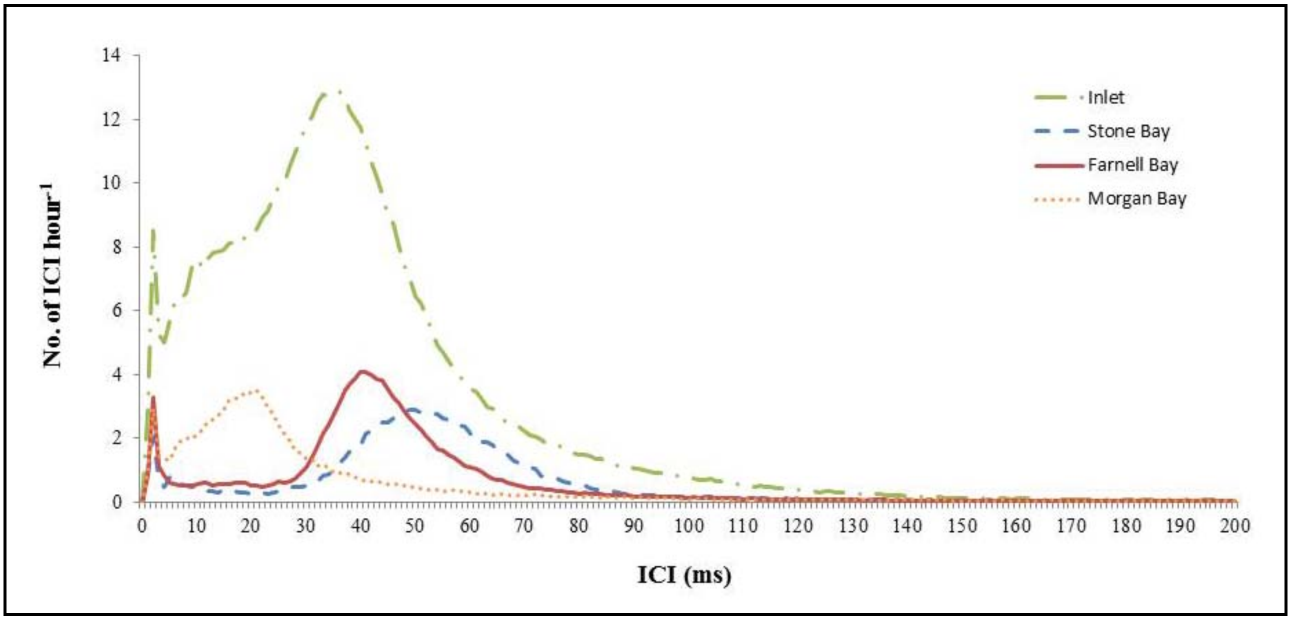

Figure 3.4. Frequency of bottlenose dolphin inter-click intervals (ICI) at four sites in the New River, NC. Only inter-click intervals below 200 msec are shown. Very short inter-click intervals (<10msec) likely represent feeding buzzes.

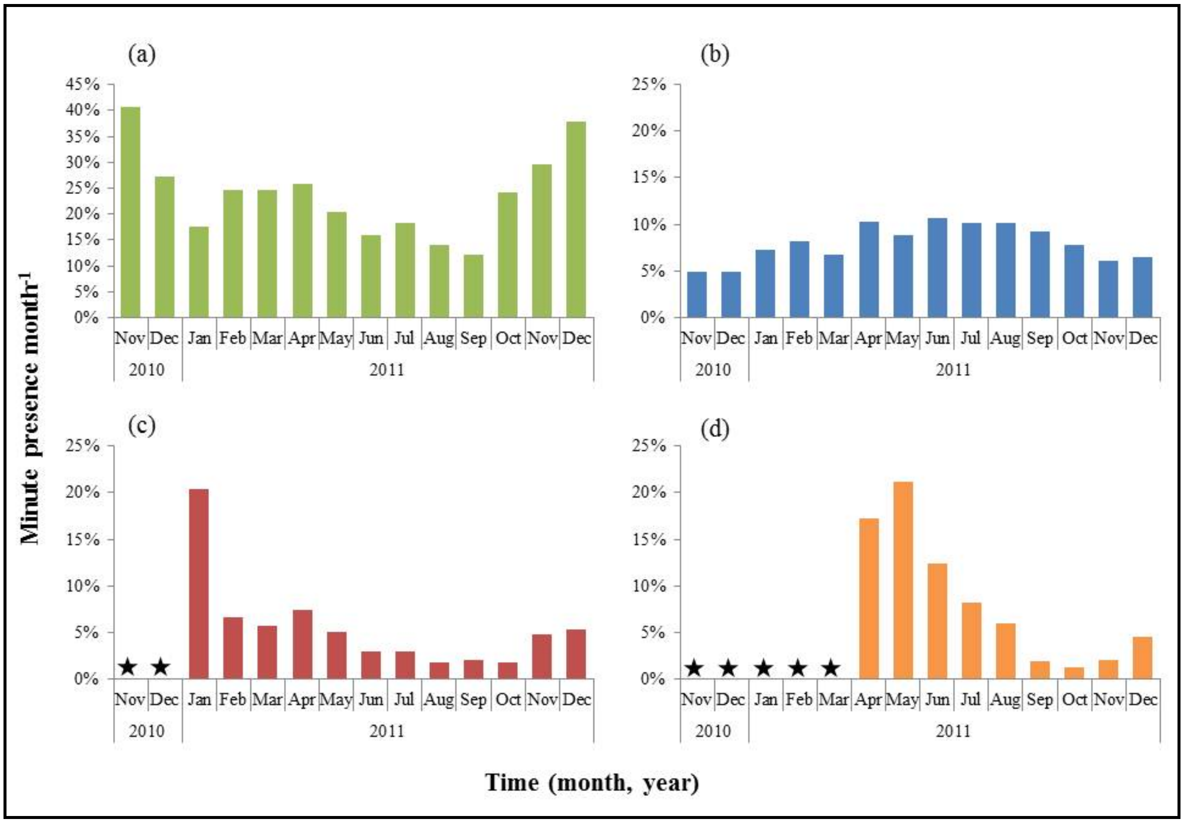

Figure 3.5. Monthly frequency of Detection Positive Minute (DPM) corrected for effort (total minutes operating) of bottlenose dolphin click trains detected by C-PODs at: (a) the Inlet; (b) Stone Ba; (c) Farnell Bay; and (d) Morgan Bay. Stars indicate months with no recording effort in Farnell Bay and Morgan Bay. Note the different scale used for the Inlet and that the value for January 2011 in Farnell Bay is based on only one day of effort.

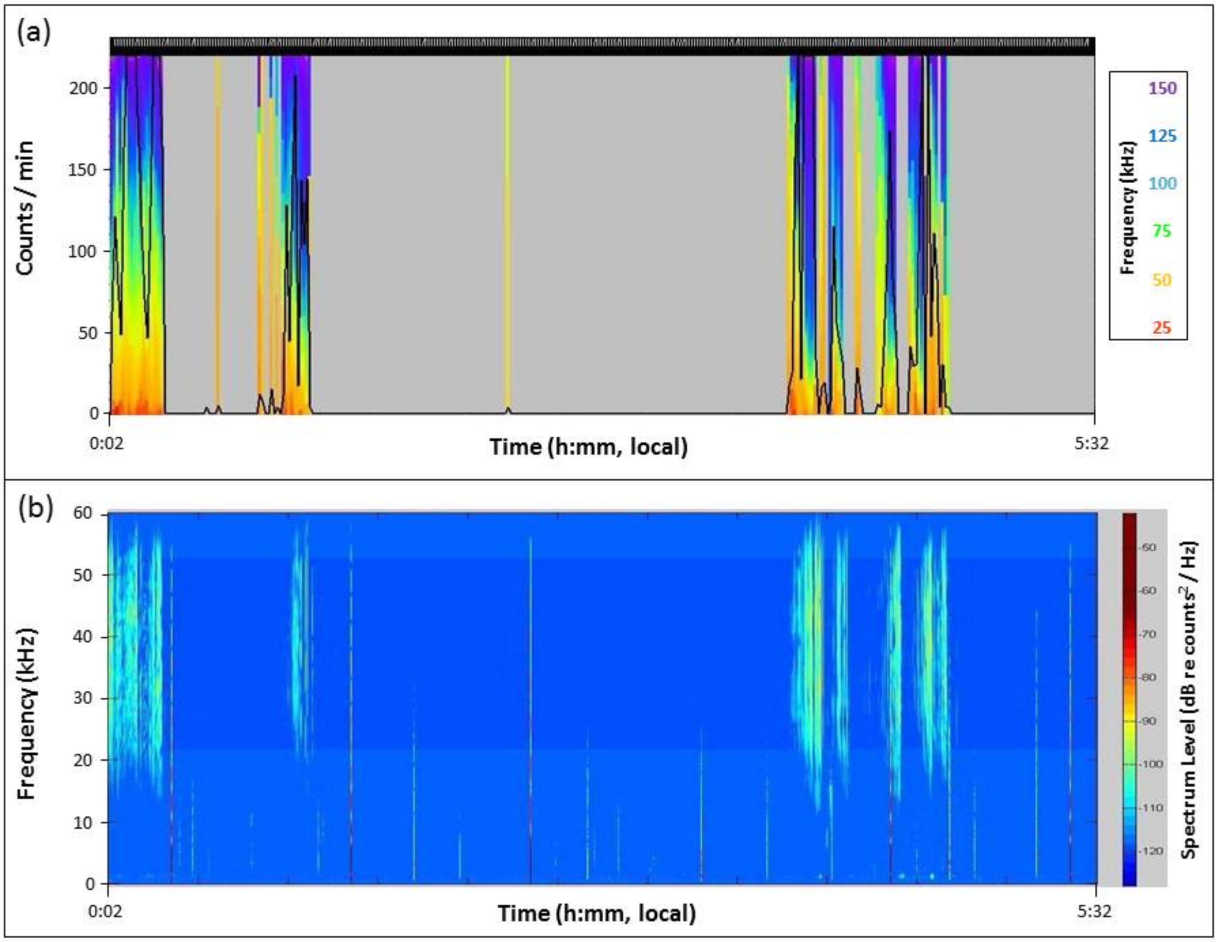

Figure 3.6. Representation of simultaneous recordings made on 7 February 2011 in Stone Bay from (a) C-POD and (b) DMON. (a) The C-POD recording is displayed using the manufacturer's software, CPOD.exe (Chelonia Ltd, UK) and showing Detected Positive Minutes (DPMs) of bottlenose dolphin echolocation. For each DPM, counts of clicks per minute in one-minute bins of quality categories Hi, Moderate and Low detections are shown, with color representing the frequency of clicks. (b) The DMON recording is displayed using Triton v. 1.64 (Scripps Institute of Oceanography, CA, USA) as a LTSA (Long Terms Spectral Average) showing several bouts of bottlenose dolphin echolocation.

Table 3.1. Summary details for C-POD and DMON deployments in the New River, NC. DPM refers to Detection Positive Minutes (see text for definition). DMON total recording effort differs from that of effort used because periods of recording with significant noise were discarded from the analysis.

C-POD

Site	C-POD	Deployment	Total recording effort (h)	Total number of click trains	DPM
Inlet	1031	20 Nov 2010 – 15 Dec 2011	9099	442075	121671
Stone Bay	1034	20 Nov 2010 – 15 Dec 2011	8545	125576	41311
Farnell Bay	1033	30 Jan 2011 – 15 Dec 2011	7642	96194	19225
Morgan Bay	1032	6 Apr 2011 – 15 Dec 2011	6061	86300	30352

DMON

Site	Deployment	Total recording effort (h)	Recording effort used (min)	DPM
Stone Bay	6 –11 Feb 2011	86	2573	810
Farnell Bay	16 – 20 May 2011	92	5381	388
Morgan Bay	14 – 15 Jun 2011	26	1431	481

Table 3.2. Terms and equations of measurements used to evaluate C-POD detections of bottlenose dolphin echolocation click trains in the New River, NC.

Term	Description	Equation
True Positive Rate (TPR), Sensitivity (Se)	Dolphin detected when being present (*i.e.* correct detection)	$TPR = \frac{TP}{Presence} = \frac{TP}{TP + FN}$
False Positive Rate (FPR)	Dolphins detected when not being present (*i.e.* false detection). Type I Error	$FPR = \frac{FP}{Absence} = \frac{FP}{FP + TN}$
True Negative Rate (TNR), Specificity (Sp)	Dolphins not detected when not being present (*i.e.* correct rejection)	$TNR = \frac{TN}{FP + TN} = 1 - FPR$
False Negative Rate (FNR)	Dolphins not detected when being present (*i.e.* a miss). Type II Error	$FNR = \frac{FN}{TP + FN} = 1 - sensitivity$
Accuracy (A)	Measurement of performance to detecting true presence and absence of echolocation	$A = \frac{TP + TN}{TP + TN + FP + FN}$
Positive Predictive Value (PPV)	Probability that a detection is due to a true presence of echolocation (*i.e.* precision)	$PPV = \frac{TP}{TP + FP}$
Negative Predictive Value (NPV)	Probability that no detection is due to a true absence of echolocation	$NPV = \frac{TN}{TN + FN}$

Table 3.3. Summary of Kruskal-Wallis test statistics comparing bottlenose dolphin occurrence, as reflected by mean values of DPM per day, among sites during each season. I = Inlet, SB = Stone Bay, FB = Farnell Bay, MB = Morgan Bay. Note that the winter season for Morgan Bay consisted of only 14 days in December.

	Mean (± standard deviation)				Kruskal-Wallis results			
Season	Inlet	Stone Bay	Farnell Bay	Morgan Bay	X^2	df	*P*	Significant multiple comparison test results
Winter	25.0 (± 10.3) N=102	6.5 (± 5.0) N=101	6.1 (± 4.2) N=41	4.4 (± 3.1) N=14	165.1	3	< 0.001	I > SB, FB, & MB
Spring	23.7 (± 7.0) N=89	8.7 (± 4.0) N=82	6.1 (± 3.3) N=89	19.4 (± 10.9) N=54	208.0	3	< 0.001	I > SB, FB, & MB; SB > FB; MB > SB & FB
Summer	16.1 (± 3.9) N=92	10.4 (± 2.6) N=66	2.5 (± 1.2) N=91	8.9 (± 5.6) N=91	225.3	3	< 0.001	I > SB, FB, & MB; SB > FB & MB; MB > FB
Autumn	24.1 (± 11.1) N=89	7.3 (± 3.1) N=99	2.9 (± 2.6) N=90	1.7 (± 1.6) N=90	270.6	3	< 0.001	I > SB, FB, & MB; SB > FB & MB; FB > MB

Table 3.4. Summary of Kruskal-Wallis statistical test results comparing bottlenose dolphin occurrence, as reflected by mean values of DPM per day, among seasons for all sites. W = winter, Sp = spring, Su = summer, A = autumn. Note that the winter season for Morgan Bay consisted of only 14 days in December.

Site	Mean (± standard deviation)				Kruskal-Wallis results			Significant multiple comparison test results
	Winter	Spring	Summer	Autumn	X^2	df	*P*	
Inlet	25.0 (± 10.3) N=102	23.7 (± 7.0) N=89	16.1 (± 3.9) N=92	24.1 (± 11.1) N=89	69.4	3	< 0.001	W, Sp, & A all > Su
Stone Bay	6.5 (± 5.0) N=101	8.7 (± 4.0) N=82	10.4 (± 2.6) N=66	7.3 (± 3.1) N=99	62.5	3	< 0.001	Sp, Su, & A all > W; Su > Sp & A
Farnell Bay	6.1 (± 4.2) N=41	6.1 (± 3.3) N=89	2.5 (± 1.2) N=91	2.9 (± 2.6) N=90	90.0	3	< 0.001	W & Sp both > Su & A
Morgan Bay	4.4 (± 3.1) N=14	19.4 (± 10.9) N=54	8.9 (± 5.6) N=91	1.7 (± 1.6) N=90	168.6	3	< 0.001	Sp & Su both > W; W, Sp, & Su all > A; Sp > Su

Table 3.5. Summary of Kruskal-Wallis statistical test results comparing bottlenose dolphin occurrence, as reflected by mean values of DPM per day, among day, night and twilight photoperiods from C-POD records for all sites and seasons. D = day, N = night, T = twilight. Note that the winter season for Morgan Bay consisted of only 14 days in December.

		Mean (± standard deviation)			Kruskal-Wallis results			
Season	Site	Twilight	Day	Night	X^2	df	*P*	Significant multiple comparison test results
Winter	Inlet	23.3 (± 13.4)	17.6 (± 7.6)	33.3 (± 15.4)	72.1	2	< 0.001*	N > T & D; T > D
Winter	Stone Bay	6.9 (± 7.7)	6.2 (± 5.4)	8.3 (± 7.9)	6.2	2	0.044*	None
Winter	Farnell Bay	6.0 (± 6.5)	4.3 (± 2.7)	10.6 (± 9.7)	15.8	2	<0.001*	N > T & D
Winter	Morgan Bay	4.5 (± 5.5)	4.4 (± 4.7)	5.9 (± 5.1)	1.0	2	0.599	N/A
Spring	Inlet	21.7 (± 10.8)	16.5 (± 5.2)	36.2 (± 13.2)	131.9	2	< 0.001*	N > T & D; T > D
Spring	Stone Bay	9.2 (± 7.1)	10.8 (± 5.7)	8.0 (± 4.9)	10.0	2	0.007*	D > N
Spring	Farnell Bay	5.7 (± 5.3)	6.4 (± 3.6)	7.5 (± 6.2)	7.6	2	0.023*	D > T
Spring	Morgan Bay	21.4 (± 14.8)	22.2 (± 12.2)	19.1 (± 14.1)	2.4	2	0.308	N/A
Summer	Inlet	16.4 (± 6.1)	19.1 (±6.0)	15.6 (± 9.0)	12.4	2	0.002*	D > T & N
Summer	Stone Bay	10.8 (± 4.9)	12.9 (± 3.4)	9.6 (± 4.3)	24.1	2	<0.001*	D > T & N
Summer	Farnell Bay	3.0 (± 2.3)	4.2 (± 1.9)	1.7 (± 2.0)	77.0	2	< 0.001*	D > T & N; T > N
Summer	Morgan Bay	8.6 (± 5.8)	11.8 (± 6.9)	7.5 (± 7.2)	27.1	2	< 0.001*	D > T & N
Autumn	Inlet	22.6 (± 12.6)	21.2 (± 6.8)	27.7 (± 19.4)	6.8	2	0.033*	N > D
Autumn	Stone Bay	8.9 (± 5.3)	9.2 (± 4.6)	7.1 (± 4.3)	12.6	2	0.002*	D > N; T > N
Autumn	Farnell Bay	3.0 (± 3.4)	3.7 (± 2.6)	3.1 (± 4.2)	19.4	2	<0.001*	D > T & N
Autumn	Morgan Bay	2.2 (± 3.7)	3.0 (± 2.5)	1.2 (± 2.1)	55.3	2	< 0.001*	D > T & N; T > N

Table 3.6. Comparison of bottlenose dolphin presence at Stone Bay, Farnell Bay and Morgan Bay drawn from simultaneous C-POD and DMON recordings at these three sites. DPM = Detection Positive Minutes.

		C-POD		DMON	
Location	Recording effort (min)	DPM	Presence (%)	DPM	Presence (%)
Stone Bay	2573	415	16.13	810	31.48
Farnell Bay	5381	257	4.78	388	7.21
Morgan Bay	1431	88	6.15	481	33.61

Table 3.7. Comparison of simultaneous C-POD and DMON recordings from Stone Bay, Farnell Bay and Morgan Bay. Classifications were based on the performance of C-PODs to correctly identify bottlenose dolphin echolocation presence and absence within each minute evaluated. Minutes presence = minutes containing dolphin echolocation; Minutes absence = minutes containing no dolphin echolocation.

Location	Recording effort (min)	Minutes presence	Minutes absence	True positive	False positive	True negative	False negative
Stone Bay	2573	810	1763	401	14	1749	409
Farnell Bay	5381	388	4993	74	183	4810	314
Morgan Bay	1431	481	950	83	5	945	398

Table 3.8. Summary details of evaluation measurements of C-POD records with simultaneous DMON acoustic records.

Location	True Positive Rate (%)	False Positive Rate (%)	True Negative Rate (%)	False Negative Rate (%)	PPV (%)	NPV (%)	Sensitivity (%)	Specificity (%)	Accuracy (%)
Stone Bay	49.51	0.79	99.21	50.49	96.63	81.05	49.51	99.21	83.56
Farnell Bay	19.07	3.67	96.33	80.93	28.79	93.87	19.07	96.33	90.76
Morgan Bay	17.26	0.53	99.47	82.74	94.92	70.36	17.26	99.47	71.84

General Discussion and Conclusions

Coastal Surveys

We generated the first site-specific estimates of abundance for spotted and bottlenose dolphins and loggerhead turtles in the waters around the N1/BT3 Impact Area near Marine Corps Base Camp Lejeune. Densities and, consequently, the number of encounters were very low, but we were able to augment these sightings with additional data from our surveys to allow us to fit a detection function. The most important finding is that densities of both species of dolphins are quite low. This conclusion is consistent with the results of low density and diversity from our NAVFAC Atlantic surveys further offshore in Onslow Bay (Burt and Paxton 2012).

Two factors could have influenced our estimates of the abundance of dolphins and sea turtles in coastal waters. First, it is possible that dolphins responded to the presence of the survey vessel by approaching it, a behaviour known as responsive movement to the vessel. This would explain why most sightings of dolphins were made close to the trackline (Figure 1.4). If dolphins were, indeed, attracted to the survey vessel then estimates of the ESW will be too small and the resulting estimate of abundance will be biased high. With the data at hand it is difficult to evaluate this possibility in a quantitative manner. Nevertheless, if this is the case, the true values of abundance will actually be lower than the estimates presented here. Second, we estimated the abundance of loggerhead turtles using strip transect methodology and thus assumed that detection of turtles was both constant and certain within a strip with a half-width of 50m. If detection was not certain within this strip, as seems almost certain, then the estimated abundance will be negatively biased. It is possible to evaluate this possibility using models of surfacing (diving) behaviour parameterized using data from turtles equipped with satellite-linked dive recorders. Future work could develop this approach with in situ data of the diving behaviour of loggerhead turtles in Onslow Bay.

In the next phase of our monitoring work, we will estimate the density of dolphins in coastal waters near the N1/BT3 Impact Area off Camp Lejeune by deploying an array of echolocation click detectors. We will combine data on the occurrence of vocalizing marine mammals from these detectors with independent estimates of vocalization rate and group size derived from field observations and measurements of detection range, also derived in the field, to generate estimates of the density of marine mammals. We will use visual surveys to determine the proportion of the two species of dolphins in the area. The visual line transect surveys will also provide a traditional estimate of density, which we will compare with the estimate derived with passive acoustic monitoring.

Photo-Identification

We encountered bottlenose dolphins on every survey in the New River and vicinity, even in the coldest months of the year. This finding is consistent with the results of the C-POD analysis (see below). We sighted dolphins throughout the Intracoastal Waterway and New River, with some groups seen as far upriver as Morgan Bay. We encountered dolphins most frequently near the Inlet and the groups seen there tended to be larger than those in other areas. Thus, we conclude that bottlenose dolphins are present year-round in the New River, with the highest densities occurring at the confluence of the New River and Intracoastal Waterway.

Nevertheless, the population of dolphins in the New River was not comprised of dolphins resident year-round in the area. As shown by the discovery curve (Figure 2.4), the population was quite open reflecting the frequent movement of dolphins into and out of the area. From our initial analysis of the sighting histories of known dolphins, it seems clear that estuarine waters of the New River represent an area of overlap between two stocks of bottlenose dolphins. It appears that there is no dividing line between the NNCES and SNCES stocks, but rather an area of mixing that extends at least from the New River east to Beaufort (Waring *et al*. 2011). Thus dolphins present at any time in the New River could belong to either one of these stocks. We plan to continue analysis of the sighting records of these dolphins to determine whether there are any fine-scale patterns to their seasonal occurrence in the New River. It is also important to note that there was no mixing between these estuarine dolphins and those we observed during the coastal surveys. Dolphins observed in coastal waters likely belong to the Southern Migratory stock, which rarely enters estuarine waters (Waring *et al*. 2011).

We had initially proposed conducting a mark-recapture analysis of photographic identification data to generate an estimate of the abundance of bottlenose dolphins in the New River. Without prior information on seasonal changes in density it was difficult to plan effectively for the surveys required for this work. We were surprised, for example, to encounter such low numbers of dolphins in the New River during three successive survey days in June 2011, when we encountered the same few individuals each day. With the data now at hand from the photo-identification surveys and analysis of CPOD data, we are better positioned to conduct these surveys. In this next phase of work, we will conduct seasonal photographic surveys on three non-consecutive days in each season to allow for sufficient mixing of animals between sampling occasions. We will apply the results of our photographic analyses to mark-recapture models that are best suited for our sampling design and study area, such as Pollock's robust design-which allows for analysis of data from open populations.

Passive Acoustic Monitoring

Our passive acoustic monitoring program revealed a complex picture of dolphin occurrence in the New River in time and space. As noted above, bottlenose dolphins occurred daily throughout the estuary, reaching as far upriver as Morgan Bay, but occurred most frequently near the Inlet. Dolphins were present in the estuary throughout the year, even in the coldest months. Occurrence at the Inlet site was lowest during the summer, although this value of occurrence was higher than all but one seasonal value of occurrence at the other three sites. The C-PODs detected a large number of foraging buzzes at each site, indicating that dolphins feed throughout the estuary.

The C-PODs performed relatively well at detecting dolphin echolocation and, importantly, produced very few false positive records (*i.e.*, indicating the presence of dolphin echolocation when it did not occur). However, all three of the C-POD units we tested performed conservatively, failing to detect some echolocation events, and therefore underestimated the occurrence of dolphins at Stone Bay, Farnell Bay and Morgan Bay and likely at the Inlet as well. It is also important to note that the C-PODs cannot detect the presence of silent dolphins or animals that produce other types of vocalizations, such as whistles or burst-pulse sounds. The true occurrence of echolocation, as verified by the DMON, was significantly higher at all three sites than the values reported by C-PODs. The C-PODs did not appear to miss entire 'bouts' of dolphin echolocation, but may have missed several minutes of echolocation within a bout, likely due to different sensitivities of the three units. The DMON is more sensitive than the C-PODs, perhaps because it is better able to capture faint clicks produced by echolocating dolphins off axis (pointed away from the recorder) or located at a distance from the unit.

We have not yet determined the detection range of each C-POD unit. We need this information to understand the significance of the spatial patterns of occurrence described here. We intend to do this in the next phase of our research, by deploying C-PODs and the DMON simultaneously in the vicinity of dolphins in the New River and estimating the distance at which each unit can detect the click trains of echolocating animals. We will need to repeat this exercise in coastal waters, where the propagation qualities of dolphin echolocation will likely be very different, due to the influence of depth and bottom substrate type.

Despite the limitations of the C-PODs, in terms of their archival nature, lack of sensitivity and individual variation, we believe that they hold considerable promise in future monitoring programs. They are robust, relatively inexpensive and easy to use. They are particularly useful in cases where it is important only to know whether or not dolphins (or other echolocating cetaceans) are present.

Acknowledgments

We thank Lynne Williams, Jennifer Dunn, John Wilson, Doug Nowacek, Emily Nys, Faith Purcell, Zach Swaim, Heather Foley, Theresa Ketchner, Dani Crain, Goldie Phillips, Elizabeth McDonald, Corrie Curtice and Reny Tyson for advice and assistance in the field and laboratory. We thank Duane Richardson at USMC Range Control, Camp Lejeune, for making sure we had safe passage in and out of restricted areas of the Base. Captain Dale Britt skippered the F/V *Sensation* and Captain Matt Besch operated the R/V *Cetus*. We thank the Institute of Marine Science, University of North Carolina at Chapel Hill, who generously allowed us to deploy CPODs from their station moorings in the New River and the U.S. Coast Guard, who gave us permission to moor a CPOD on navigation Marker 13 at the Inlet. We thank Mark Hooper and Maria Wise for diving to retrieve the CPOD at Marker 13. Heather Foley prepared many of the figures. Jennifer Dunn managed the finances at Duke University; we thank Jackie Boltz from TetraTech for administrating this contract. Finally, we thank Craig Ten Brink and Bill Rogers, who ensured that we had everything we needed to conduct this work; we are very grateful for their support. No experimentation was conducted on animals during the conduct of this research. Surveys were conducted under U.S. National Marine Fisheries Service General Authorization Numbers 808-1798-2 and 16185, held by Andrew Read.

Literature Cited

Au, WWL. 1993. *The Sonar of Dolphins*. Springer-Verlag, New York. 277 pp.

Buckland ST, DR Anderson, KP Burnham, JL Laake, DL Borchers and L Thomas. 2001. *Introduction to distance sampling: estimating abundance of biological populations.* Oxford University Press, London. 432pp.

Burt ML and GCM Paxton CGM. 2012. Analysis of the UNCW and Duke University aerial and shipboard surveys of the USWTR on the Atlantic Coast of the USA for the period June 2007 to April 2011 (also including the UNCW aerial survey data 1998 – 1999) Unpublished report, CREEM, University of St Andrew

Elliott RG, SM Dawson and S Henderson. 2011. Acoustic monitoring of habitat use by bottlenose dolphins in Doubtful Sound, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 45: 637-649.

Fewster RM, ST Buckland, KP Burnham, DL Borchers, PE Jupp, JL Laake and L Thomas L. 2009. Estimating the encounter rate variance in distance sampling. *Biometrics* 65: 225-236

Friday, N et al. 2000. Measurement of photographic quality and individual distinctiveness for the photographic identification of humpback whales, *Megaptera novaeangliae*. *Marine Mammal Science* 16: 355-374.

Innes S, MP Heide-Jørgensen, JL Laake, KL Laidre, HJ Cleator, P Richard and REA Stewart. 2002. Surveys of belugas and narwhals in the Canadian High Arctic in 1996. *NAMMCO Scientific Publications* 4: 169-190

Marques FFC. 2001. *Estimating wildlife distribution and abundance from line transect surveys conducted from platforms of opportunity.* PhD Thesis. University of St Andrews

Read AJ, KW Urian, B Wilson and DM Waples. 2003. Abundance of bottlenose dolphins in the bays, sounds and estuaries of North Carolina, USA. *Marine Mammal Science* 19: 59-73.

Thayer VG, AJ Read, AS Friedlaender, DR Colby, AA Hohn, WA McLellan, DA Pabst, JL Dearolf, NI Bowles, JR Russell and KA Rittmaster. 2003. Reproductive seasonality of bottlenose dolphins, *Tursiops truncatus*, in North Carolina. *Marine Mammal Science* 19: 617-629.

Thomas L, JL Laake, E Rexstad, S Strindberg, FFC Marques, ST Buckland ST, DL Borchers, DR Anderson, KP Burnham, ML Burt, SL Hedley, JH Pollard, JRB Bishop and TA Marques. 2009. Distance 6.0. **Release 2.** Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Waring GT, E Josephson, K Maze-Foley and PE Rosel, editors. 2011. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments - 2010. NOAA Technical Memorandum NMFS-NE-219, Woods Hole, MA. 598 pp.

Appendix 1
Measurement of Photographic Quality and Dolphin Distinctiveness

Kim Urian

OVERALL PHOTOGRAPHIC QUALITY

- Overall Photographic Quality is based on the quality of the photograph **independent** of the distinctiveness of the fin.

The Overall Photographic Quality score is based on an evaluation and sum of the following characteristics (these scores are absolute values, not a sliding scale):

- **Focus/Clarity**
  Crispness or sharpness of the image. Lack of clarity may be caused by poor focus, excessive enlargement, poor developing or motion blur; for digital images, poor resolution resulting in large pixels.

  Based on the scale: 2 = excellent focus 4 = moderate focus 9 = poor focus, very blurry

- **Contrast**
  Range of tones in the image. Images may display too much contrast or too little. Photographs with too much contrast lose detail as small features wash out to white. Images with too little contrast lose the fin into the background and features lack definition.

  Based on the scale: 1 = ideal contrast 3= either excessive contrast or minimal contrast

- **Angle**
  Angle of the fin to the camera.

  Based on the scale: 1 = perpendicular to camera 2 = slight angle 8 = oblique angle

- **Partial**
  A partial rating is given if so little of the fin is visible that the likelihood of re-identifying the dolphin is compromised on that basis alone. Fins obscured by waves, *Xenobalanus*, or other dolphins, would be evaluated using this rating.

  Based on the scale: 1 = the fin is fully visible, leading & trailing edge 8= the fin is partially obscured

- **Proportion of the frame filled by the fin**
  An estimate of the percentage area the fin occupies relative to the total area of the frame.

  Based on the scale: 1 = greater than 5%; subtle features are visible 5 = less than 1%; fin is very distant

To score Overall Photographic Quality, sum the scores for each characteristic:

6 - 9:	Excellent quality	=> **Q-1**
10–12:	Average quality	=> **Q-2**
>12 :	Poor quality	=> **Q-3**

OVERALL DISTINCTIVENESS

Overall Distinctiveness is based on the amount of information contained on the fin; information content is drawn from leading and trailing edge features, and pattern, marks, and scars.

D-1 - Very distinctive; features evident even in distant or poor quality photograph

D-2 - Average amount of information content: 2 features or 1 major feature are visible on the fin

D-3 - Not distinctive; very little information content in pattern, markings or leading and trailing edge features

Appendix 2.

Detailed Summary of Bottlenose Dolphin Sightings in the New River.

Date	Sighting	Time	Latitude	Longitude	BSS	Depth (m)	Temp (°C)	Group Size	Calves	Neonates	Photos
17-Oct-10	1	0958	34.63536	-77.19746	1			3	1	0	20
20-Nov-10	1	0920	34.60168	-77.23682	1			2	0	0	10
20-Nov-10	2	1004	34.55361	-77.34875	1			20	6	0	24
30-Dec-10	1	1013	34.67303	-77.13257	1			5	0	0	59
30-Dec-10	2	1107	34.57845	-77.26486	1			7	3	0	40
30-Dec-10	3	1432	34.54615	-77.31664	1			2	1	1	10
30-Dec-10	4	1442	34.55153	-77.30960	1			6	3	2	28
05-Jan-11	1	1329	34.63891	-77.18943				4	0	0	0
05-Jan-11	2	1424	34.55662	-77.35476				2	0	0	0
05-Jan-11	3	1449	34.55686	-77.35403	1	3.7	5.6	15	5	0	30
05-Jan-11	4	1553	34.56391	-77.36205				2	0	0	0
05-Jan-11	5	1619	34.61040	-77.22650				2	1	0	0
30-Jan-11	1	1018	34.63591	-77.19614	0	2.2		5	1	0	36
30-Jan-11	2	1512	34.57694	-77.41581	1	4.1		10	1	0	33
06-Feb-11	1	1224	34.55820	-77.35593	2	5.1	8.3	10	2	0	0
06-Feb-11	2	1453	34.56731	-77.36562	2	1.7	8.4	18	4	0	137
06-Feb-11	3	1627	34.53854	-77.34041	2	5.4	8.4	2	0	0	6
11-Feb-11	1	1108	34.55730	-77.35490	1	4.6		8	2	0	41
11-Feb-11	2	1422	34.54872	-77.32749		4.6		8	2	0	33
29-Mar-11	1	1022	34.60490	-77.40780	2	2.9	10	9	1	1	57
29-Mar-11	2	1309	34.57777	-77.40163	0	7.7	11.3	8	3	0	56
29-Mar-11	3	1339	34.57450	-77.38367	2	3.1	10.6	3	0	0	32
29-Mar-11	4	1503	34.55531	-77.35304	2	3.7	10.9	6	3	0	44
29-Mar-11	5	1526	34.53454	-77.34447	2	9.8	10.9	7	2	0	74
06-Apr-11	1	1022	34.55250	-77.35032	1	5.0	13.4	13	2	1	132
06-Apr-11	2	1129	34.56078	-77.35907	2	3.5	13.6	7	0	0	122

06-Apr-11	3	1136	34.55952	-77.35718	2	4.6	13.4	20	2	1	91
06-Apr-11	4	1311	34.57576	-77.40990	1	4.0	15.7	11	1	0	132
06-Apr-11	5	1340	34.57861	-77.41893	1	1.8	16.3	6	3	0	28
06-Apr-11	6	1502	34.68380	-77.39381	3	2.9	16.1	4	2	0	19
06-Apr-11	7	1713	34.55347	-77.34907	1	2.9	15.6	5	2	1	23
16-May-11	1	1220	34.57541	-77.41236	3	4.7	23.2	2	1	0	22
20-May-11	2	1356	34.54821	-77.32874	2			8	0	0	133
13-Jun-11	1	1335	34.67169	-77.38155	1	2.9	29.6	5	1	0	121
14-Jun-11	1	1053	34.68119	-77.37405	1	2.0	27.6	4	1	0	131
14-Jun-11	2	1129	34.70474	-77.38768	1	2.8	27.6	3	0	0	98
14-Jun-11	3	1229	34.68365	-77.39248	1	2.3	28.5	5	1	0	52
14-Jun-11	4	1536	34.55600	-77.30027	1	2.6	26.3	2	0	0	55
15-Jun-11	1	1017	34.55117	-77.31041	1	4.1	24.9	5	1	0	181
15-Jun-11	2	1040	34.55896	-77.29362	1	4.0	24.7	10	1	0	97
15-Jun-11	3	1415	34.68848	-77.38127	3	2.8	27.6	5	1	0	170
11-Jul-11	1	0936	34.57469	-77.40591	0	0.8	28.3	10	2	0	102
11-Jul-11	2	1531	34.54314	-77.34151	2	6.3	28.2	3	1	0	42
11-Jul-11	3	1601	34.54640	-77.31552	2	4.9		6	1	0	39
11-Jul-11	4	1643	34.61042	-77.22670	1	4.8		3	0	0	16
02-Sep-11	1	1434	34.56165	-77.36131	2	0.6	26.2	1	0	0	17
09-Sep-11	1	0930	34.55662	-77.35474	1	3.7	25.9	1	n/a	n/a	0
26-Oct-11	1	1013	34.53918	-77.34041	1	1.0	19.3	3	0	0	41
26-Oct-11	2	1047	34.55372	-77.35098	1	4.6	19	5	0	0	66
20-Nov-11	1	0944	34.55015	-77.33599	1	3.5	14.5	3	0	0	49
20-Nov-11	2	1021	34.56389	-77.35662	1	1.0	14.5	40	6	1	494
20-Nov-11	3	1155	34.57571	-77.40627	1	4.3	14.5	4	1	0	30
20-Nov-11	4	1454	34.55547	-77.35246	1	3.3	15.5	40	7	2	225
20-Nov-11	5	1539	34.54684	-77.31564	1	4.1	15.1	2	1	1	18

Appendix 3.

Detailed Summary of Dolphin and Sea Turtle Sightings in Coastal Waters Near Camp Lejeune.

Date	Sighting	Depth (m)	Temperature (°C)	Time	Latitude	Longitude	Species	Group Size	Calves	Effort
18-Aug-10	1	19.3	29.7	10:37:30	34.35295	-77.19397	*Stenella frontalis*	13	2	On
18-Aug-10	2	16.5	30.0	13:10:26	34.52141	-77.06844	*Stenella frontalis*	9	2	Off
21-Oct-10	1	10.2	22.4	9:45:08	34.47056	-77.37928	*Tursiops truncatus*	13	0	On
21-Oct-10	2	9.1	22.4	10:13:10	34.48174	-77.39299	*Tursiops truncatus*	8	1	On
21-Oct-10	3	20.8	23.4	11:07:56	34.38638	-77.16061	*Caretta caretta*	1	0	On
14-Apr-11	1	18.8	17.3	10:56:55	34.42060	-77.20250	*Tursiops truncatus*	14	1	On
14-Apr-11	2	20.7	17.7	11:46:03	34.37125	-77.14634	*Tursiops truncatus*	4	2	Off
14-Apr-11	3	18.1	17.3	12:33:21	34.47122	-77.12175	*Caretta caretta*	1	2	On
14-Apr-11	4	14.8	17.0	12:58:41	34.54379	-77.19407	*Tursiops truncatus*	4	2	On
9-May-11	1	19.9	21.1	11:33:00	34.4643	-77.0536	*Stenella frontalis*	6	2	On
9-May-11	2	17.7	21.4	11:59:02	34.5042	-77.094	*Caretta caretta*	1	2	Off
9-May-11	3	16.6	21.6	12:10:01	34.5301	-77.1248	*Stenella frontalis*	88	1	Off
9-May-11	4	15.4	22.0	13:58:02	34.5988	-77.0526	*Caretta caretta*	1	2	On
9-May-11	5	20.8	22.0	14:39:00	34.4941	-76.9452	*Stenella frontalis*	9	2	Off
19-Aug-11	1	18.5	29.1	10:50:21	34.50152	-77.08335	*Stenella frontalis*	10	0	On
13-Sep-11	1	15.5	28.0	9:33:48	34.42613	-77.33546	*Tursiops truncatus*	2	1	On
13-Oct-11	1	15.0	22.8	9:31:55	34.45587	-77.30344	Unidentified Delphinid	3	2	Off
13-Oct-11	2	16.5	23.6	12:26:08	34.55736	-77.13945	*Caretta caretta*	1	2	On
12-Nov-11	1	15.9	17.6	11:47:24	34.54542	-77.18998	*Tursiops truncatus*	14	1	On
12-Nov-11	2	15.9	17.7	12:18:44	34.51499	-77.14668	*Tursiops truncatus*	3	2	On

Appendix 4.

Thumbnail Images of Bottlenose Dolphin Dorsal Fins Photographed in the New River