Study of Bottlenose Dolphin Occurrence in St. Andrew Bay, Florida and Coastal Waters Near the Naval Surface Warfare Center, Panama City Division Testing Range

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Brian Balmer[1], Brian Quigley[1], Todd Speakman[1], Gina Ylitalo[2], Eric Zolman[1], and Lori Schwacke[1]

[1]National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, 331 Fort Johnson Road, Charleston, SC 29412 USA

[2]National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112 USA

Introduction

Common bottlenose dolphins (*Tursiops truncatus*; hereafter dolphins) inhabit the bays, sounds, and estuaries (BSEs), and coastal waters of the Florida Panhandle (reviewed in Waring et al., 2015). Currently, the National Marine Fisheries Service (NMFS) has delineated one coastal (Northern Coastal Stock) and seven BSE dolphin stocks within the nearshore waters of the Florida Panhandle (Waring et al., 2015). Two of these BSE stocks, Choctawhatchee Bay and Apalachicola Bay, have been the focus of 1-2 year studies using photo-identification (photo-id) surveys to estimate seasonal dolphin abundance and gain insight into stock structure (Conn et al., 2011; Tyson et al., 2011; respectively). The St. Joseph Bay BSE Stock, subject of the only long-term study of dolphins in the Florida Panhandle, has been studied since 2004 to determine seasonal abundance and distribution patterns (Balmer et al., 2008), assess dolphin health (Schwacke et al., 2010), and identify contaminant levels (Balmer et al., 2015; Wilson et al., 2012). Although these studies provide valuable information for BSE stock assessment in the Florida Panhandle, little is known about the distribution and movement patterns of dolphins that are part of the Northern Coastal Stock, with hypothesized boundaries extending from the Big Bend region of Florida (84°W longitude) to the Mississippi River Delta (Waring et al., 2015). During spring and fall, seasonal influxes of dolphins into the St. Joseph Bay region have been observed in which abundance increased 2-3 fold (Balmer et al., 2008). Additionally, extended movements of several individuals have been identified [St. Joseph Bay to Destin, FL (~ 100 km) and Mississippi Sound (~300 km)] (Balmer et al., accepted), suggesting that the Northern Coastal Stock may seasonally co-occur with BSE stocks, and coastal dolphins have ranging patterns significantly greater than BSE dolphins.

The Naval Surface Warfare Center, Panama City Division (NSWC PCD) Testing Range is located in the nearshore and offshore waters of the Florida Panhandle and Alabama, extending from the coast to over 220 km seaward, and inclusive of St. Andrew Bay, FL. Limited data exist on the St. Andrew Bay BSE Stock and adjacent Northern Coastal Stock. Blaylock and Hoggard (1994) conducted aerial line transect surveys in the fall of 1992 and 1993 and estimated the abundance of the St. Andrew Bay BSE Stock to be 124 (59 – 259; 95% CI). Bouveroux et al., (2014) conducted photo-id surveys in a limited portion of the St. Andrew Bay BSE Stock's boundaries and estimated abundance ranging from 89 (71 – 161; 95% CI) in March – May 2004 to 183 (169 – 208; 95% CI) in June – July 2007. There is no current abundance estimate encompassing the entire St. Andrew Bay BSE Stock. Furthermore, it is unknown if the Northern Coastal Stock follows a similar pattern to what is observed in the St. Joseph Bay region with seasonal influxes into St. Andrew Bay.

Marine mammal photo-id surveys have been used extensively to estimate abundance via capture-recapture (CR), closed and robust population models (Thompson et al., 1998). When photo-id, CR methods are used, the four assumptions of closed, CR models (Seber, 1982) can be reasonably met if each primary period is completed in a short period of time, dorsal fin markings are not lost on recapture, and full survey coverage of the study area allows for capture homogeneity (Read et al., 2003). The robust design model uses characteristics of closed population models to estimate abundance and open population models to calculate survival and emigration (Kendall et al., 1997; Pollock, 1982). This model has been applied to nearshore bottlenose dolphins to estimate seasonal abundance (primary sessions) in a study area by conducting multiple, short-term photo-id surveys (secondary sessions) and accounting for variations in capture probabilities using aspects of an open population model (e.g. Balmer et al., 2013; Speakman et al., 2010; Wilson et al., 1999).

Photo-id surveys have also been used to identify habitat use and distribution patterns of marine mammals (Hammond, 1990). Habitat selection by small cetaceans has generally been investigated by examining the relationship between distribution patterns and environmental parameters (e.g. Bräger et al., 2003; De Segura et al., 2008). Environmental factors used to assess cetacean habitat include distance from shore, temperature, salinity, and water depth (e.g. Miller and Baltz 2010; Torres et al., 2003). Although these abiotic factors have been correlated with dolphin distribution, prey distribution is more likely the principal causative factor influencing dolphin habitat selection (Heithaus and Dill 2002; Gannon and Waples 2004; Torres et al., 2008). In the coastal waters of the southeastern U.S., dolphin distribution has been linked to water temperature and prey availability (Barco et al., 1999; Torres et al., 2005). Photo-id surveys to identify dolphin density and distribution patterns in conjunction with spatial habitat mapping are a valuable tool to quantify dolphin habitat use (Smith et al., 2013). For example, in Florida Bay, FL, dolphin surveys, prey distribution mapping, and spatial analyses were used to link fine-scale benthic habitat types to different types of dolphin foraging (Torres and Read, 2009).

The goals of this study were to determine abundance, habitat use, and distribution patterns of bottlenose dolphins in St. Andrew Bay and adjacent coastal waters in the NSWC PCD Testing Range over two seasons. During fall in the St. Joseph Bay region, the observed 2 to 3 fold increase in abundance was attributed to Northern Coastal Stock dolphins entering St. Joseph Bay waters. St. Joseph Bay summer abundance was low and animals sighted during this season were suggested to be representative of the BSE Stock. Thus, the seasons selected for surveying in St. Andrew Bay were July 2015 (summer) and October 2015 (fall) to determine abundance for the BSE Stock and provide insight into abundance and movements of Northern Coastal Stock dolphins. Specific study objectives were:

(1) Identify which marine mammal species occur seasonally within St. Andrew Bay and coastal waters (<3 km from shoreline);
(2) Calculate seasonal resighting rates for individual dolphins and develop a site fidelity index for dolphins in this region to provide baseline data for future studies to assess long-term residence;
(3) Determine distribution patterns for dolphins within and between St. Andrew Bay and coastal waters;
(4) Estimate seasonal abundance across the two primary sessions (July and October 2015) and;
(5) Correlate dolphin presence with particular environmental parameters (e.g. water depth, water temperature, water salinity) and broad habitat types (e.g. shallow bay, channel, sea grass bed, surf zone, open water).

Methods

Study Area

St. Andrew Bay is a shallow estuarine tidal embayment (Grady, 1981) consisting of four bays [West Bay (WEB), North Bay (NOB), East Bay (EAB), and St. Andrew Bay (SAB) proper], located in northwest Florida on the northeastern shore of the Gulf of Mexico (Fig. 1A). This embayment is unique among Gulf coast estuaries in that the waters are relatively deep and clear as it receives very little freshwater input and sedimentation (Brim and Handley, 2002). Mean depth in SAB is approximately 5 m, while WEB, NOB, and EAB are generally shallower (2 m) (Ichiye and Jones, 1960). Salinity is approximately 30 parts per thousand (ppt) but can occasionally drop below 10 ppt in proximity to freshwater input and away from the Gulf (Ichiye and Jones, 1960). The primary source of freshwater, with an average discharge of 15.3 m^3/s, is Econfina Creek (reviewed in Brim and Handley, 2002) that flows into Deer Point Lake and empties into NOB at Deer Point Dam (Fig.1A). St. Andrew Bay is characterized by a diurnal tidal cycle with a mean range of 0.4 m (Salsman et al., 1966). Seagrasses, primarily shoal grass *(Halodule wrightii)* and turtle grass *(Thalassia testudinum)*, are found throughout St. Andrew Bay (Grady, 1981).

The St. Andrew Bay photo-id study area includes the estuarine waters of SAB, NOB, WEB, and EAB (Fig. 1A). The survey area also includes Gulf coastal (CST) waters directly adjacent to the estuary (CSTC) and extending approximately 3 km offshore (CST3K) from northwest of Crooked Island Sound (northern boundary of the St. Joseph Bay BSE Stock) to Gulf of Mexico waters across from WEB.

Capture-recapture Photo-identification Surveys

CR photo-id surveys were conducted during summer (July) and fall (October) of 2015. For BSE waters, contour transects (i.e. transects following a particular geographic feature) were followed either 500 m from the shoreline or along the 1 m depth contour (Fig. 1A). The total distance of all survey transects for the BSE and CST waters were 200 km and 52 km, respectively.

Following the robust-design (Pollock 1982), survey effort was temporally divided into primary periods. Within each primary period, three secondary sessions were completed, in which all transects were surveyed. Once a secondary session was completed, survey effort was ceased for $\geq$ 1 day to allow for sufficient population mixing (reviewed in Rosel et al., 2011). The BSE and CST transects were separated into two distinct survey areas to optimize survey effort, and allow for calculation of separate abundance estimates for each area as well as a cumulative estimate for the study area as a whole. All transects were surveyed a total of six times (six secondary sessions) across the two primary periods (July and October 2015). All surveys were conducted in a Beaufort Sea State (BSS) of 3 or less to optimize sighting conditions.

The survey vessel was a 6.3 m, center-console, Zodiac rigid-hulled inflatable boat (RhIB) with twin 90-hp Yamaha four stroke outboard engines. Survey speed was maintained at approximately 30 km/h while searching for dolphins. At least three observers were required, and each observer covered 60° of the 180° forward of the vessel beam. During each survey, a sighting was recorded when any dolphin was encountered. Sighting data were recorded onto a data sheet that included time, geographic location (GPS coordinates), total number of dolphins, group behavior(s), and various observational and environmental parameters (reviewed in Melancon et al., 2011). A Canon EOS-1Dx with a 100 - 400 mm telephoto lens (or comparable digital camera) was used to capture dorsal fin images of each individual in the group. Effort was made to photograph all dolphins within a sighting (full photo coverage) without regard to distinctiveness. Circumstances that could preclude full coverage included: 1) prolonged adverse reactions by one or more dolphins in the group; 2) sighting duration > 45 minutes; and 3) adverse weather conditions.

All digital photographs were downloaded and sorted using protocols discussed in Speakman et al. (2010). A standardized approach was used to grade photograph quality and dorsal fin distinctiveness (Urian et al., 2014). Photographic quality of the best left and/or right side dorsal fin image was graded based upon the focus, contrast, angle, dorsal fin visibility, and proportion of the dorsal fin within the image frame. Digital dorsal fin images with a Q-1 (excellent) or Q-2 (good) quality grade were included in data analyses; images with a Q-3 (poor) grade were excluded. A distinctiveness rating (D1-very distinctive, D2-moderately distinctive, D3-not distinctive) was given to each identified individual, as agreed upon by two experienced investigators. Photographs and associated sighting data were entered into FinBase (Adams et al., 2006), a customized Microsoft Access (Microsoft Corporation, Redmond, WA, USA) database. Dorsal fin images were also incorporated into the Digital Analysis to Recognize Whale Images on a Network (DARWIN) Program, which utilizes image processing algorithms to identify dorsal fins that have the same or similar dorsal fin features (Roberts et al., 2000). The St. Andrew Bay project is the first to use DARWIN in conjunction with FinBase for dorsal fin matching and the incorporation of both of these programs has formed the foundation of an enhanced and more efficient matching process that will be applied to other bottlenose dolphin photo-id projects in the southeastern U.S.

Capture-recapture Photo-identification Survey Data Analyses

<u>Survey Summary</u>

Data were compiled to provide a summary for the 2015 field work within each primary period (July and October), survey area (BSE and CST), across primary periods and survey areas, and cumulatively. Survey data included total hours, total kilometers, on-effort hours, survey kilometers, and time in contact with dolphins. Total hours and total kilometers were the amount of time on-water, including both on-effort (active dolphin surveying) and off-effort (transit between transects). Survey kilometers were the total kilometers on-effort and time in contact were the total hours of dolphin sightings. Sighting data included total number of sightings, dolphins, calves, neonates, mean group size, dolphins photographed, and proportion of dolphins photographed. The total number of sightings were a sum of all sightings for a given primary period, survey area, or cumulatively. The total number of dolphins was based upon the best field estimate (FE) of dolphins sighted. The total number of calves and neonates, mean group size, and number of dolphins photographed were determined using photo-analysis (PA) back at the lab. The proportion of dolphins photographed was determined by dividing the number of dolphins identified using PA by the best FE of dolphins sighted.

<u>Discovery Curve</u>

A discovery curve is a direct count of new, distinctive individuals that were identified during a primary period. These data can be used to provide insight into immigration/emigration, appropriate study area boundaries, and the total photo-id catalog size (reviewed in Wilson et al., 1999). For the CR photo-id surveys, the number of previously identified individuals, number of new individuals, and total number of individuals were determined for each secondary session. For all photo-id effort (CR photo-id and remote biopsy sampling surveys), the number of previously identified individuals, number of new individuals, and total number of individuals in the St. Andrew Bay photo-id catalog were determined for each primary period.

Site Fidelity

The current St. Andrew Bay study includes two primary periods across a 1-year time span that is insufficient to assess year-round and long-term site fidelity. However, these data will provide a framework to fully identify site fidelity of dolphins in the St. Andrew Bay region as subsequent photo-id data are collected. The total number of distinctive dolphins sighted in only one primary period, and in both primary periods, was determined to form a foundation for identifying site fidelity in the St. Andrew Bay study area.

Movement Patterns

To identify movement patterns in the St. Andrew Bay region, the total number of distinctive animals sighted only in BSE waters, only in CST waters, and across both survey areas were determined for each primary period and across both primary periods. In addition, all individuals in the St. Andrew Bay photo-id catalog, across the 2015 field work, were classified by their movement patterns (*i.e.* BSE, CST, or both).

Abundance Estimates

To determine abundance, the current St. Andrew Bay photo-id dataset consisting of two primary periods within one year limits the selection of models to only closed population models. As future primary periods and years of data are collected, robust-design population models will be more appropriate for seasonal abundance and survival estimation. For the 2015 data, a variety of closed population models (e.g. M_o, M_t, M_h, M_{th}) that relaxed one or more of the closed population assumptions were performed in programs MARK and CAPTURE (Rexstad and Burnham, 1992; White et al., 1982). The most suitable model was determined by having (1) the lowest Akaike's information criterion (AIC) values (Burnham and Anderson, 1992), and (2) model parameters thought to be most representative of dolphins along the northern Gulf coast of Florida (i.e. capture probabilities varying over time during and between survey periods).

Abundance estimates from the CR population models were based solely on the number of distinctive animals (D-1 and D-2) sighted during a primary period. The total population size (distinctive and non-distinctive individuals) was estimated as:

$$N_{total} = N_{distinct} / \Theta \quad (1)$$

where N_{total} = estimated total population size, $N_{distinct}$ = CR estimate of distinctive individuals, and Θ = estimated proportion of distinctive individuals in each primary period (Wilson et al., 1999). The delta method was used to extrapolate the closed population model abundance and 95% confidence interval (CI) to that of the total abundance and 95% CI (Wilson et al., 1999).

Habitat Use

To assess habitat use, all waters were classified into one of six habitat types: Bay Channel, Gulf Channel, Open Water, Seagrass, Shallow Bay, and Surf Zone (Fig. 1B). Each habitat type was defined as a shapefile layer using ArcGIS 10.3 (ESRI, Redlands, CA, USA). Bay and Gulf Channel boundaries were determined using the locations of channel markers/buoys. Open Water habitat was defined as all Gulf waters from approximately 1 – 4 km offshore bounded by the CST3K survey transect. Seagrass habitat was defined by using the Florida Fish and Wildlife Research Institute (FWRI) Seagrasses in Florida dataset (http://geodata.myfwc.com/datasets).

Shallow Bay habitat was defined as all estuarine waters not Seagrass or Bay Channel habitats. Surf Zone habitat was defined as all Gulf waters from shoreline to approximately 1 km offshore and bounded by the CSTC survey transect. The area of each habitat type was calculated to determine total available dolphin habitat in the St. Andrew Bay study area. To identify fine-scale habitat preference, a relative density of dolphins per habitat area was calculated by dividing the total number of dolphins sighted in each habitat by the respective habitat area (km^2). Dolphin density was also calculated for each survey area (BSE or CST) and cumulatively by dividing the closed population model abundance for a given primary period by the total area (km^2) for each respective survey area.

To explore relationships between environmental parameters and dolphin presence, the distribution of depth, salinity, and temperature observations from all sightings were examined using box plots (median, quartile, and range), stratified by season (July and October primary periods) and survey area (BSE and CST). The box plots were then compared with the abundance estimate for each season and area. In addition, linear regression was used to examine the association of depth, salinity, and temperature observations with the total number of dolphins for each sighting.

<u>Human Interactions</u>

Dolphins in the St. Andrew Bay region have been exposed to chronic human interactions (HI) in the form of "swim-with" and food provisioning activities (Samuels and Bejder, 2004). Such interactions have likely been the foundation for additional behaviors such as 'patrolling' and depredating that increase the likelihood of severe injuries to dolphins (Powell and Wells, 2011). The NMFS Southeast Region (SERO) has been working on a long-term project to assess the impacts of HI on St. Andrew Bay dolphins. In a joint effort, data were collected during the two primary periods on any HI behaviors observed and dorsal fin identification of any dolphin observed performing these behaviors. HI behaviors included begging, following vessel, accepting food, and patrolling. The total number of HI sightings was determined and these sightings were plotted in ArcMap 10.3 to illustrate areas in which these behaviors occur. In addition, all sightings of HI implicated dolphins were plotted to assess their movements in the St. Andrew Bay region.

<u>Remote Biopsy Sampling</u>

Prior to this field work, little was known about the stock structure and contaminant levels of dolphins in the St. Andrew Bay region. In collaboration with the Southeast Fisheries Science Center (SEFSC) and the Northwest Fisheries Science Center (NWFSC), remote biopsy samples were collected to provide baseline data on genetics and persistent organic pollutants (POPs) in St. Andrew Bay dolphins.

Remote biopsy samples were collected using a Barnett Panzer V crossbow (Barnett Outdoors, LLC, Tarpon Springs, FL, USA). Sample collection and in-field processing have been described previously in Sinclair et al. (2015). Briefly, samples were collected from individual dolphins at a distance of 2 – 10 m, targeting the flank of the animal below the dorsal fin and above the midline (Gorgone et al., 2008). Coincident with sample collection, photographs were taken to identify sampled individuals (reviewed in Urian et al., 2014). The sample obtained consisted of skin and a full-thickness section of blubber approximately 0.7 – 0.8 g in weight. Collected tissue was subsampled for five projects: genetics (skin), POPs (blubber), genomics (skin and blubber), stable isotopes (skin), and hormones (blubber) (Fig. 2). The skin sample for genetic analyses was stored at room temperature in 20% DMSO saturated with NaCl, and was also used to determine sex using methods described by Rosel (2003). The blubber sample used for POP contaminant analyses was stored in a pre-cleaned Teflon vial (Savillex, Eden Prairie, MN, USA), frozen in a liquid N_2 dry shipper in the field, and stored at -80°C in the lab prior to sample analysis. The genomics sample was stored in a 2 ml vial with RNAlater, submerged in ice in the field, and refrigerated for 24 hours. After 24 hours, the RNAlater solution was pipetted out of the vial and the sample was frozen in a liquid N_2 dry shipper. Upon return to lab, the sample was frozen at -80°C prior to sample analysis. Skin and blubber samples for stable isotopes and hormones respectively, were stored in 2 ml cryovials, frozen in a liquid N_2 dry shipper in the field, and stored at -80°C in the lab prior to sample analysis.

Results

Survey Summary

Photo-id survey effort was conducted in the St. Andrew Bay study area during 14 – 21, 27 July and 12 – 18 October 2015 (additional scouting surveys and remote biopsy sampling effort were conducted on 13, 22 – 25, 28 – 29 July and 19 – 23 October which were not included in this survey summary). All BSE and CST transects were completed three times in each primary period, totaling six times across 2015. Cumulatively, 2,050 km were surveyed over 116 on-water hours (Table 1). A total of 162 sightings were recorded during 2015 with 651 dolphins observed, including 74 calves and 3 neonates (Fig. 1C). Mean group size was 4.2 individuals and 95% of all dolphins sighted were photographed (N = 616/651).

Discovery Curve

During CR photo-id surveys, a total of 130 and 95 new, distinctive individuals were identified in July and October 2015, respectively (Fig. 3A). Within secondary sessions (s), the numbers of new individuals sighted were higher than previously identified individuals in s1– s3 (July 2015). In s4 – s6 (October 2015), the number of previously identified individuals increased to higher than the number of new individuals. During all photo-id effort (CR photo-id and remote biopsy sampling surveys), a total of 171 and 75 new, distinctive individuals were identified in July and October 2015, respectively (Fig. 3B). The number of distinctive individuals sighted in both primary periods was 114. The St. Andrew Bay study area (BSE and CST) photo-id catalog consists of 246 distinctive individuals.

Site Fidelity

Of the 246 cataloged individuals, 132 were sighted in only one primary period while 114 were sighted in both primary periods (Fig. 4).

Movement Patterns

Of the 171 distinctive dolphins sighted in July 2015, 141 (83%) and 28 (16%) were sighted exclusively in the BSE or CST waters, respectively, with two (1%) sighted in both areas (Fig. 5A). During October 2015, of the 189 distinctive dolphins sighted, 146 (77%) and 31 (17%) were sighted exclusively in the BSE or CST waters, respectively, with 12 (6%) sighted in both survey areas (Fig. 5B). One hundred and fourteen distinctive dolphins were sighted in both primary periods; 101 (89%) and five (4%) were sighted exclusively in the BSE or CST waters, respectively, with eight (7%) sighted in both areas (Fig. 5C). For the 246 distinctive individuals in the St. Andrew Bay photo-id catalog, 182 (74%) and 49 (20%) were sighted exclusively in BSE or CST waters, respectively, while 15 (6%) were sighted in both survey areas (Fig. 6). None of the individuals sighted in both survey areas (BSE and CST) were observed in BSE subareas EAB, NOB, or WEB (i.e. only in SAB subarea).

Abundance Estimates

The closed population model M_o had the lowest AIC value and was the most appropriate fit for determining abundance in July and October 2015. Distinctiveness rates (θ) were lower in the BSE waters than the CST waters (Table 2). Probability of capture (p-hat) was higher in the BSE waters than along the CST waters. Based upon overlapping 95% CIs, there was no difference in BSE and CST total abundance (N_{total}) across primary periods (mean; 95% CI) [BSE: Jul-15 (249; 200 – 337, 95% CI), Oct-15 (314; 266 – 392, 95% CI), CST: Jul-15 (189; 75 – 631, 95% CI), Oct-15 (129; 79 – 270, 95% CI)] (Figs.7A and 7B). Total abundance (N_{total}) for 2015 was also generally similar between the Jul-15 and Oct-15 primary periods; 399 (311 – 539, 95% CI) and 407 (346 – 499, 95% CI), respectively (Fig. 7C). Dolphin densities between primary periods and survey areas were likewise comparable (0.96 – 1.48 dolphins/km^2) (Table 2).

Habitat Use

In general, dolphin sighting depths were greater in CST than BSE waters (Fig. 8A). Salinity was more variable across BSE sightings (Fig. 8B), but still relatively high (75th percentile was above 20 ppt) and thus unlikely to influence dolphin distribution. Not surprisingly, variation of water temperatures measured at dolphin sighting locations was driven primarily by season, although within a season there tended to be greater variability in temperature for BSE sightings versus CST sightings (Fig. 8C). A linear regression analysis was performed between dolphin group size and depth, salinity, and temperature. There was no relationship identified between total number of dolphins per sighting and depth or salinity ($P = 0.587$, $R^2 = 0.0015$; $P = 0.8796$, $R^2 = 0.0001$; respectively) (Figs. 9A and 9B). There was a significant negative relationship between dolphin number and temperature ($P = 0.0266$; $R^2 = 0.0244$) with more dolphins sighted in cooler water temperatures (Fig. 8C). The majority of BSE habitat in the St. Andrew Bay study area was classified as Shallow Bay (204.39 km^2) followed by Seagrass (41.97 km^2) and Bay Channel (29.22 km^2) (Fig. 10). In the CST waters, Open Water comprised the majority of habitat (97.41 km^2), followed by Surf Zone (29.22 km^2), and Gulf Channel (1.06 km^2) (Fig. 10). Overall, dolphin density in the St. Andrew Bay study area was highest in Channel (Bay and Gulf) and Seagrass habitat (Fig. 11).

Human Interactions

Of the 215 sightings recorded during the 2015 St. Andrew Bay survey effort, eight sightings (4%) had human interactions (HI). Of these eight sightings, nine individual dolphins were identified as having HI behavior totaling 4% (9/246) of the St. Andrew Bay photo-id catalog. HI behaviors were primarily observed along the CSTC transect, followed by the northeast leg of SAB, and then EAB (Fig. 12). However, the nine HI individuals were also observed in WEB, SAB, and EAB with no apparent HI behavior.

Remote Biopsy Sampling
A total of 51 remote biopsy samples (N = 25, ♂; N = 26, ♀) were collected during 12 field days during the 2015 St. Andrew Bay field work (Jul-15, N =34; Oct-15, N = 17) (Fig. 13). POP analyses were conducted by the NWFSC on 39 samples (N = 23, ♂; N = 16, ♀). POP class concentrations were all higher in males than females (Fig. 14). For males and females, POP concentrations were highest in polychlorinated biphenyls (ΣPCBs) followed closely by dichlorodiphenyl-dichloroethanes (ΣDDTs), then chlordanes (ΣCHLs) and polybrominated diphenyl ethers (ΣPBDEs), and the lowest levels in dieldrin, mirex, and hexachlorobenzene (HCB).

Discussion

The 2015 St. Andrew Bay field project was the first to provide a complete assessment of dolphin abundance, habitat use, and distribution patterns in this region. Based upon the small number of catalog individuals that were sighted in both BSE and CST waters (N = 15/246; 6%) and the limited estuarine waterways into/out of the study area for potential immigration/emigration, the closed population models were likely appropriate for estimating BSE abundance. With the addition of the 2016 survey data, the robust population model will allow for the estimation of temporary immigration/emigration rates, which will provide additional insight for BSE movements. Based upon extended movements of coastal dolphins in the northern Gulf of Mexico (Balmer et al., accepted; Balmer et al., 2008; Balmer et al., 2010), the closed population model assumptions of immigration/emigration were likely violated in the CST and cumulative (BSE and CST) abundance estimates. The extremely large 95% CI for the CST and cumulative abundance estimates likely result from these violations.

Dolphin abundance was similar in both the July and October survey periods with the majority of animals being sighted within the BSE waters. The BSE abundance estimates of 249 (200 – 337; 95% CI) (July) and 314 (266 – 392; 95% CI) (October), and dolphin densities of 0.96 (0.77 – 1.30; 95% CI) (July) and 1.21 (1.02 – 1.51; 95% CI) (October) d/km^2 are generally comparable to other northern Gulf of Mexico BSEs (Waring et al., 2015). Although there was a correlation between dolphin numbers and water temperature, with more dolphins sighted in cooler water temperatures, there was no apparent influx of dolphins during the fall survey period (October) as has been observed in the adjacent St. Joseph Bay BSE (Balmer et al., 2008). Based upon preliminary data analyses of the St. Andrew Bay spring (April) 2016 photo-id surveys in which a greater number of dolphins were observed along the CST, future research is needed to investigate the cues for the hypothesized Northern Coastal Stock entering the St. Andrew Bay study area.

The two primary periods of survey effort within a 1-year time span has provided a foundation for determining seasonal and long-term site fidelity in the St. Andrew Bay study area. A more comprehensive assessment of seasonal and year-round site fidelity will be possible with the inclusion of the 2016 photo-id data. In addition, photo-id catalogs from St. Andrew Bay (2004 – 2007) (Bouveroux et al., 2014) and adjacent St. Joseph Bay (2004 – 2013) (Balmer pers. comm; Balmer et al., 2008) are available in the Gulf of Mexico Dolphin Identification System (GoMDIS), a tool to compare individual project-submitted photo-id catalogs across the northern Gulf of Mexico (Cush and Wells, 2015). The results of both of these studies suggest long-term residency of dolphins in these BSEs with some crossover of individuals between study areas. For example, X02, a 43 year old male dolphin that was captured in Crooked Island Sound during a St. Joseph Bay health assessment in 2005 was resighted in the St. Andrew Bay study area during October 2015. The current St. Andrew Bay photo-id catalog is in the process of being added to GoMDIS and subsequent searches may provide insight into long-term site fidelity of dolphins in the St. Andrew Bay study area and conversely movements across stock boundaries.

Gulf of Mexico BSE dolphins preferentially select for channel (Allen et al., 2001), spoil island (Smith et al., 2013), and seagrass habitats (Barros and Wells, 1998; Rossman et al., 2015). Dolphins in the St. Andrew Bay study area had similar habitat preferences with dolphin density highest in Channel and Seagrass habitat types. Along the east coast of the U.S., Torres et al., (2005) observed that the majority of dolphins sighted along the coast were within 3 km of the shoreline, with a rapid decrease in numbers from 3 km to 34 km offshore. The low density of dolphins in Open Water habitat may indicate a similar distribution of dolphins in the coastal waters of the St. Andrew Bay study area. Future research conducting extended systematic surveys in the coastal waters would provide insight into distribution patterns and habitat use of dolphins in this region.

Samuels and Bejder (2004) identified a minimum of seven distinctive dolphins engaged in HI behaviors during a 6-day study in August 1998. NMFS SERO researchers have been conducting recent surveys in the St. Andrew Bay region and preliminary results suggest that the number of HI dolphins is now several times higher than that observed in 1998. The survey design for the current project is not appropriate for a comprehensive assessment of the number of HI individuals and scale of the human interaction issue in St. Andrew Bay. Thus, the nine HI individuals identified from the current study should be considered a minimum indication of the prevalence of this behavior. However, the extended survey coverage that includes all of the BSE waters within St. Andrew Bay and the adjacent coastal waters provides insight into overall movement patterns of both HI and non-HI individuals. These data, in collaboration with NMFS SERO focal follows, will identify differences in ranging patterns of HI and non-HI dolphins and the impacts of HI behavior in the St. Andrew Bay region.

In 1997, Tyndall Air Force Base (AFB) was added by the Environmental Protection Agency (EPA) to the Superfund program's National Priority List (NPL) as a result of DDT contamination 200 times greater than the EPA's risk-based standards for human and environmental health (EPA, 2007). In 2013, the Air Force, EPA, and state of Florida signed an agreement to remediate the Tyndall AFB NPL site. St. Andrew Bay male dolphins sampled in 2015 had ΣDDT levels (66.19 μg/g lipid; 48.95 – 89.51 95% CI) that are currently the highest in the southeastern U.S. (Balmer et al., 2015; Kucklick et al., 2011). Future research targeting additional remote sampling in the BSE and CST waters of the St. Andrew Bay study area will provide insight into the dolphin health throughout the Tyndall AFB NPL site remediation process.

Acknowledgments
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TABLE LEGEND

Table 1. Photo-identification (photo-id) effort for each survey area [Bay, Sound, and Estuary (BSE) and Coastal (CST)], primary period (Jul-15 and Oct-15), and cumulatively (2015) in the St. Andrew Bay study area. FE = Field Estimate; PA = Photo-Analysis.

Table 2. Closed population (M_o) model abundance and density estimates for each survey area [Bay, Sound, and Estuary (BSE) and Coastal (CST)], primary period (Jul-15 and Oct-15), and cumulatively in the St. Andrew Bay study area.

FIGURE LEGEND

Figure 1. (A) St. Andrew Bay photo-identification (photo-id) study area with survey transects and survey distance (km) [Coastal 3 km offshore (CST3K), Coastal 0.5 km offshore (CSTC), East Bay (EAB), North Bay (NOB), St. Andrew Bay (SAB), and West Bay (WEB)], (B) habitat types, and (C) 2015 sighting distribution.

Figure 2. St. Andrew Bay remote biopsy sampling schematic and project analyses.

Figure 3. Number of distinctive individuals sighted and discovery curve for bottlenose dolphins in the St. Andrew Bay study area during (A) capture-recapture (CR) photo-identification (photo-id) survey secondary sessions and (B) all photo-id effort (CR photo-id and remote biopsy sampling surveys) primary periods.

Figure 4. Number of distinctive individuals sighted in only one primary period or both primary periods (July and October 2015) in the St. Andrew Bay study area.

Figure 5. Number and percent of distinctive individuals that were sighted exclusively in Bay, Sound, and Estuary (BSE) waters, Coastal (CST) waters, or both (BSE/CST) during (A) July 2015, (B) October 2015, and (C) July/October 2015 in the St. Andrew Bay study area.

Figure 6. Number and percent of all distinctive individuals in the St. Andrew Bay photo-id catalog (N = 246) that were sighted exclusively in Bay, Sound, and Estuary (BSE) waters, Coastal (CST) waters or both (BSE/CST).

Figure 7. Total abundance estimates and 95% confidence intervals (CIs) for (A) Bay, Sound, and Estuary (BSE) (B) Coastal (CST) and (C) cumulatively in the St. Andrew Bay study area.

Figure 8. Box plots including median (inner line), quartiles (box) and non-outlier range (whiskers) for (A) depth, (B) salinity, and (C) water temperature observations from dolphin sightings, stratified by primary period and survey area.

Figure 9. Total number of dolphins sighted and (A) depth, (B) salinity, and (C) water temperature in the St. Andrew Bay study area.

Figure 10. Total area (km^2) and percentage of available habitat in the St. Andrew Bay study area.

Figure 11. Density (total dolphins sighted/km^2) and percentage of dolphin habitat use in (A) July 2015, (B) October 2015, and (C) 2015 cumulatively in the St. Andrew Bay study area.

Figure 12. Sighting locations of human interaction (HI) and non-HI behavior for the nine identified HI dolphins in the St. Andrew Bay study area.

Figure 13. St. Andrew Bay study area remote biopsy sampling locations during 2015.

Figure 14. Concentrations (µg/g lipid; geometric mean, 95% CI) of seven classes of persistent organic pollutants (POPs) measured in remote biopsy blubber samples from bottlenose dolphins sampled in the St. Andrew Bay study area (N = 23, ♂; N = 16, ♀).

Jul-15	Sp.	Total Hours	On-effort Hours	Total KM	Survey KM	Time in Contact (hrs)	Total Sightings (#)	Total Dolphins (FE) (#)	Total Calves (PA) (#)	Total Neonates (PA) (#)	Mean Group Size (PA) (#)	Dolphins Photographed (#)	Proportion Photographed
BSE	*T.t.*	48	27	848	659	14	66	213	22	1	3.4	205	0.96
CST	*T.t.*	12	8	208	173	3	16	42	9	1	2.6	38	0.90
TOTAL	*T.t.*	60	35	1056	832	17	82	255	31	2	3.3	243	0.95

Oct-15	Sp.	Total Hours	On-effort Hours	Total KM	Survey KM	Time in Contact (hrs)	Total Sightings (#)	Total Dolphins (FE) (#)	Total Calves (PA) (#)	Total Neonates (PA) (#)	Mean Group Size (PA) (#)	Dolphins Photographed (#)	Proportion photographed
BSE	*T.t.*	43	25	763	575	14	64	328	32	1	5.3	314	0.96
CST	*T.t.*	13	8	231	182	4	16	68	11	0	4.3	59	0.87
TOTAL	*T.t.*	56	33	994	757	18	80	396	43	1	5.1	373	0.94

2015	Sp.	Total Hours	On-effort Hours	Total KM	Survey KM	Time in Contact (hrs)	Total Sightings (#)	Total Dolphins (FE) (#)	Total Calves (PA) (#)	Total Neonates (PA) (#)	Mean Group Size (PA) (#)	Dolphins Photographed (#)	Proportion photographed
BSE	*T.t.*	91	52	1611	1234	28	130	541	54	2	4.4	519	0.96
CST	*T.t.*	25	16	439	355	7	32	110	20	1	3.4	97	0.88
TOTAL	*T.t.*	116	68	2050	1589	35	162	651	74	3	4.2	616	0.95

Table 1.

BSE

Primary Period	$N_{distinct}$	θ	p-hat	N_{model}	SE (N_{model})	N_{total}	95% CI (N_{total})	BSE Habitat (km^2)	Density (N_{total}/km^2)	95% CI (N_{total}/km2)
Jul-15 (1)	102	0.69	0.26	172	20.69	249	200 - 337	259	0.96	0.77 - 1.30
Oct-15 (2)	145	0.71	0.29	223	19.34	314	266 - 392	259	1.21	1.02 - 1.51

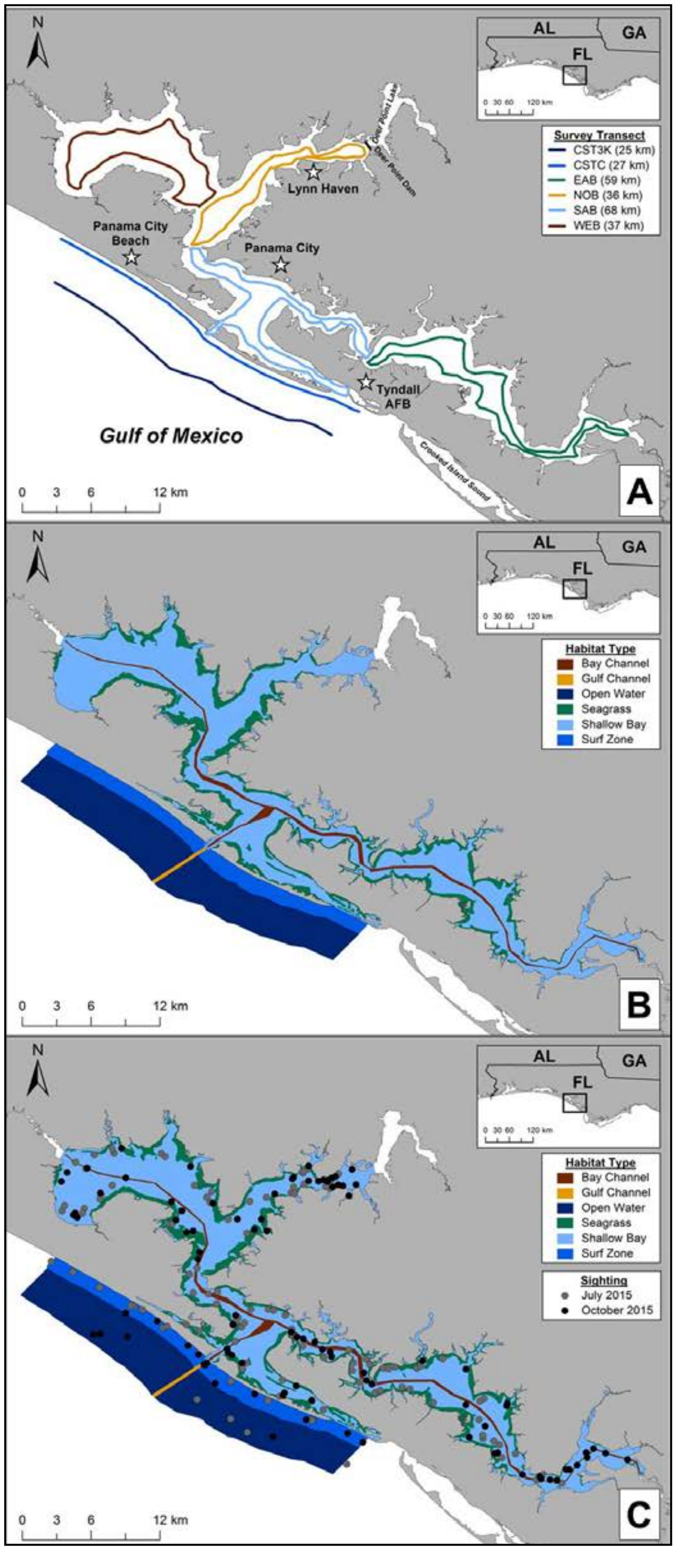
CST

Primary Period	$N_{distinct}$	θ	p-hat	N_{model}	SE (N_{model})	N_{total}	95% CI (N_{total})	CST Habitat (km^2)	Density (N_{total}/km^2)	95% CI (N_{total}/km2)
Jul-15 (1)	30	0.84	0.07	159	100.42	189	75 - 631	128	1.48	0.59 - 4.93
Oct-15 (2)	43	0.85	0.15	110	32.93	129	79 - 270	128	1.01	0.62 - 2.11

ALL

Primary Period	$N_{distinct}$	θ	p-hat	N_{model}	SE (N_{model})	N_{total}	95% CI (N_{total})	Total Habitat (km^2)	Density (N_{total}/km^2)	95% CI (N_{total}/km2)
Jul-15 (1)	130	0.71	0.10	283	37.57	399	311 - 539	387	1.03	0.80 - 1.39
Oct-15 (2)	176	0.73	0.14	297	24.84	407	346 - 499	387	1.05	0.89 - 1.29

Table 2.



AL
GA
FL
Survey Transect
CST3K (25 km)
CSTC (27 km)
EAB (59 km)
NOB (36 km)
SAB (68 km)
WEB (37 km)
Lynn Haven
Panama City Beach
Panama City
Tyndall AFB
Deer Point Lake
Deer Point Dam
Crooked Island Sound
Gulf of Mexico
0 3 6 12 km
A
Habitat Type
Bay Channel
Gulf Channel
Open Water
Seagrass
Shallow Bay
Surf Zone
B
Sighting
July 2015
October 2015
C

Figure 1.

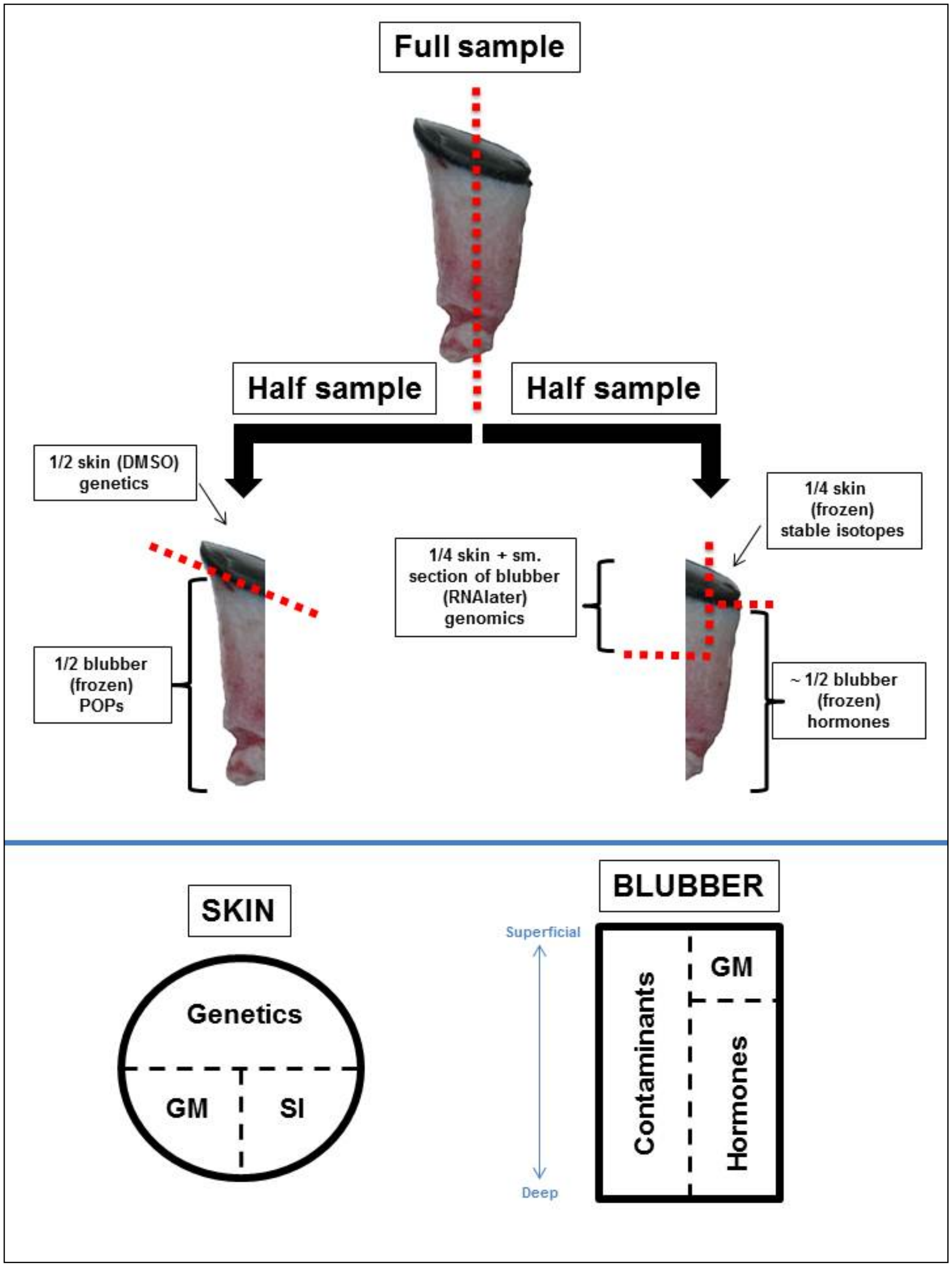
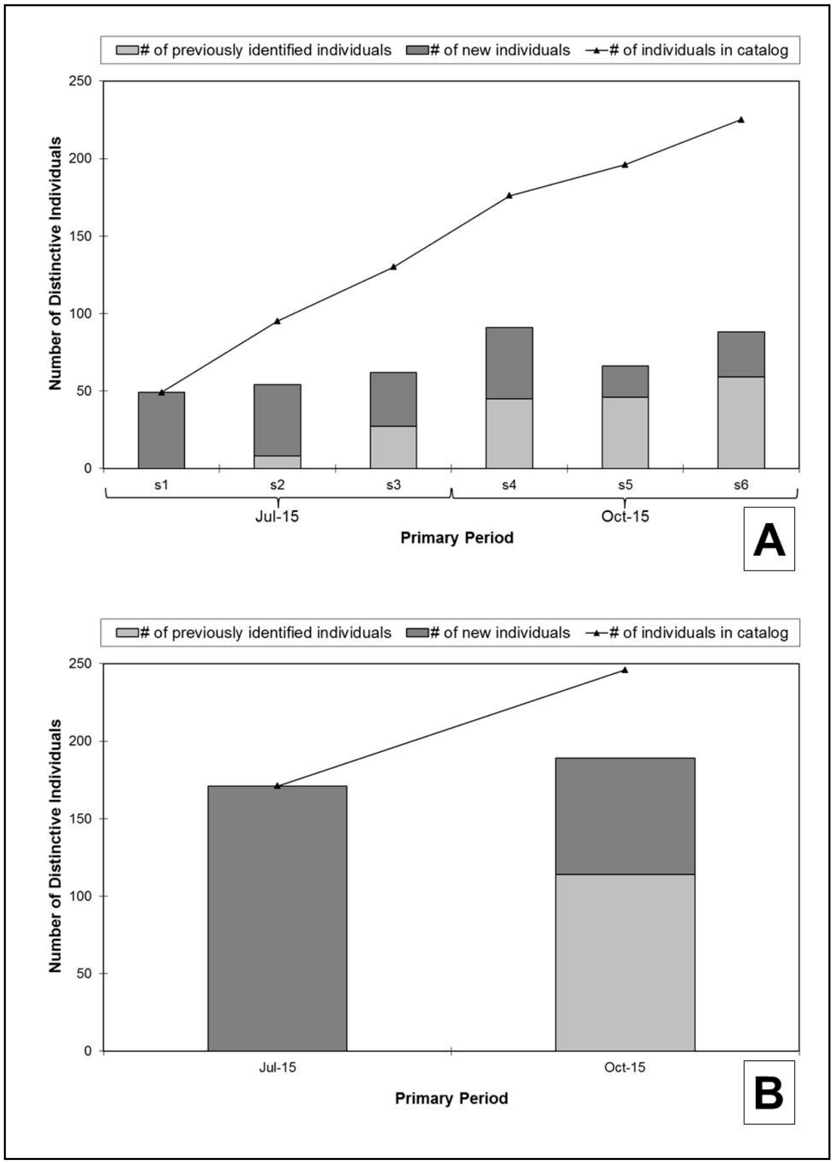

Full sample
Half sample
Half sample
1/2 skin (DMSO) genetics
1/2 blubber (frozen) POPs
1/4 skin + sm. section of blubber (RNAlater) genomics
1/4 skin (frozen) stable isotopes
~ 1/2 blubber (frozen) hormones
SKIN
Genetics
GM
SI
BLUBBER
Superficial
Deep
Contaminants
GM
Hormones

Figure 2.



# of previously identified individuals
# of new individuals
# of individuals in catalog
Number of Distinctive Individuals
250
200
150
100
50
0
s1
s2
s3
s4
s5
s6
Jul-15
Oct-15
Primary Period
A
# of previously identified individuals
# of new individuals
# of individuals in catalog
Number of Distinctive Individuals
250
200
150
100
50
0
Jul-15
Oct-15
Primary Period
B

Figure 3.

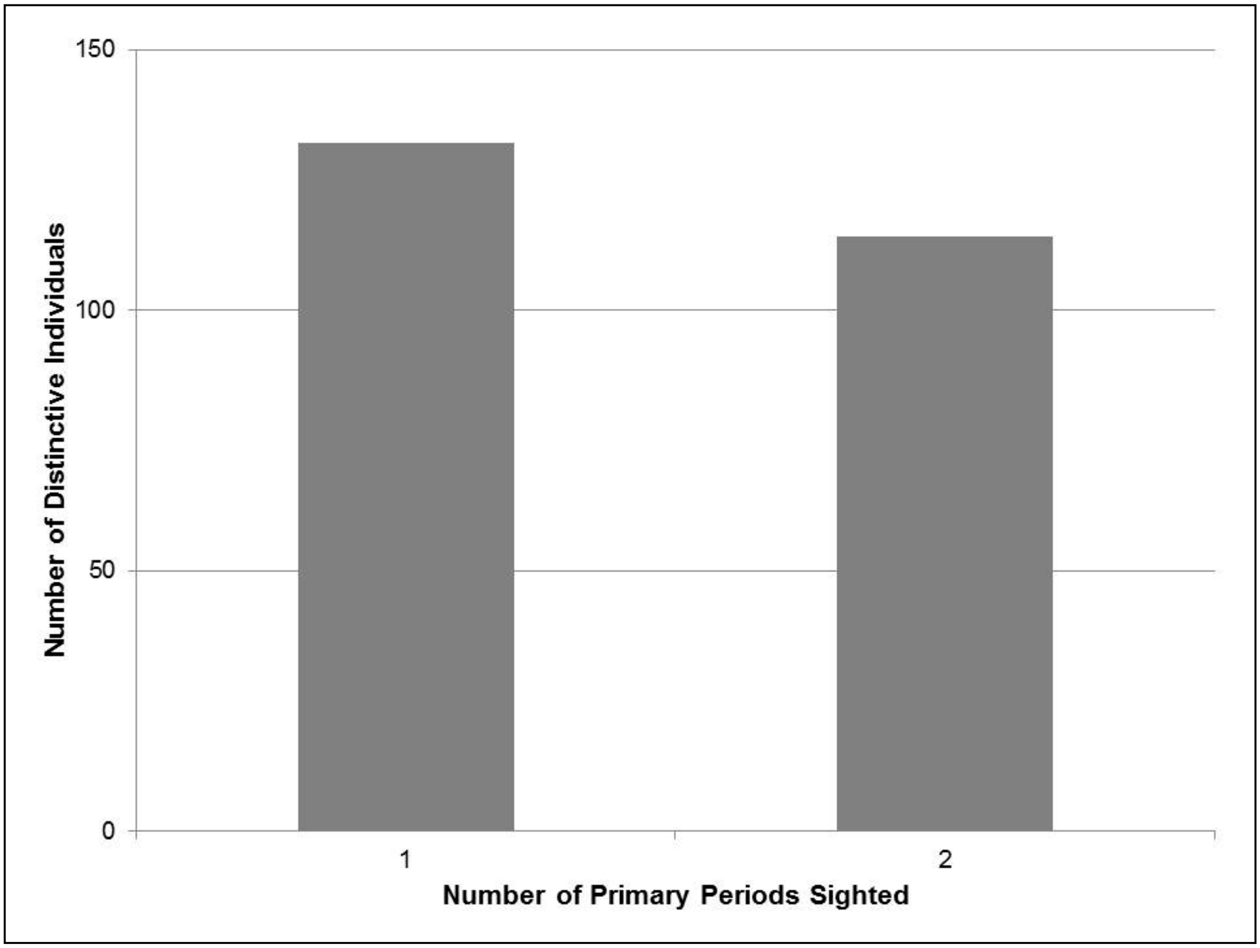

150
100
50
0
Number of Distinctive Individuals
1
2
Number of Primary Periods Sighted

Figure 4.

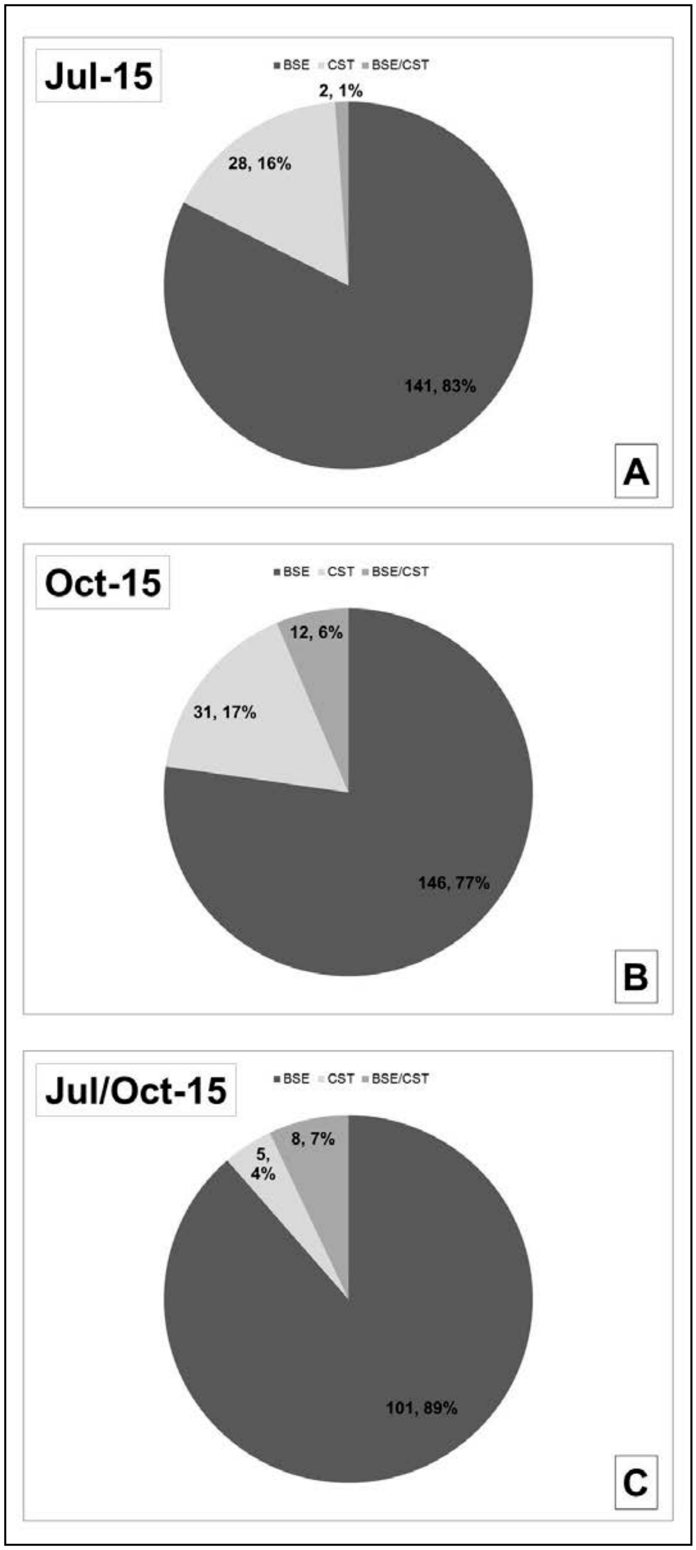

Jul-15
BSE
CST
BSE/CST
2, 1%
28, 16%
141, 83%
A
Oct-15
BSE
CST
BSE/CST
12, 6%
31, 17%
146, 77%
B
Jul/Oct-15
BSE
CST
BSE/CST
8, 7%
5,
4%
101, 89%
C

Figure 5.

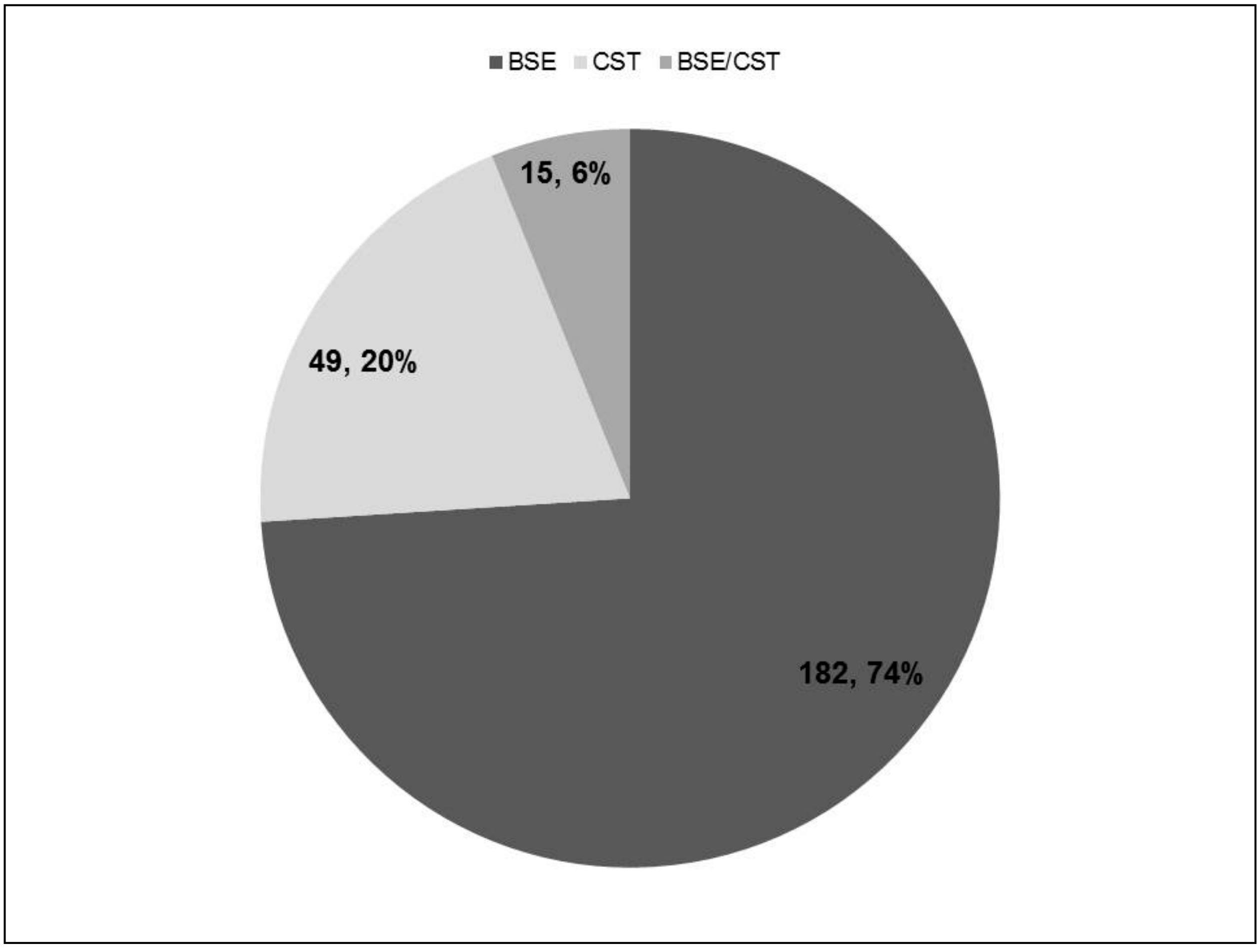


Figure 6.

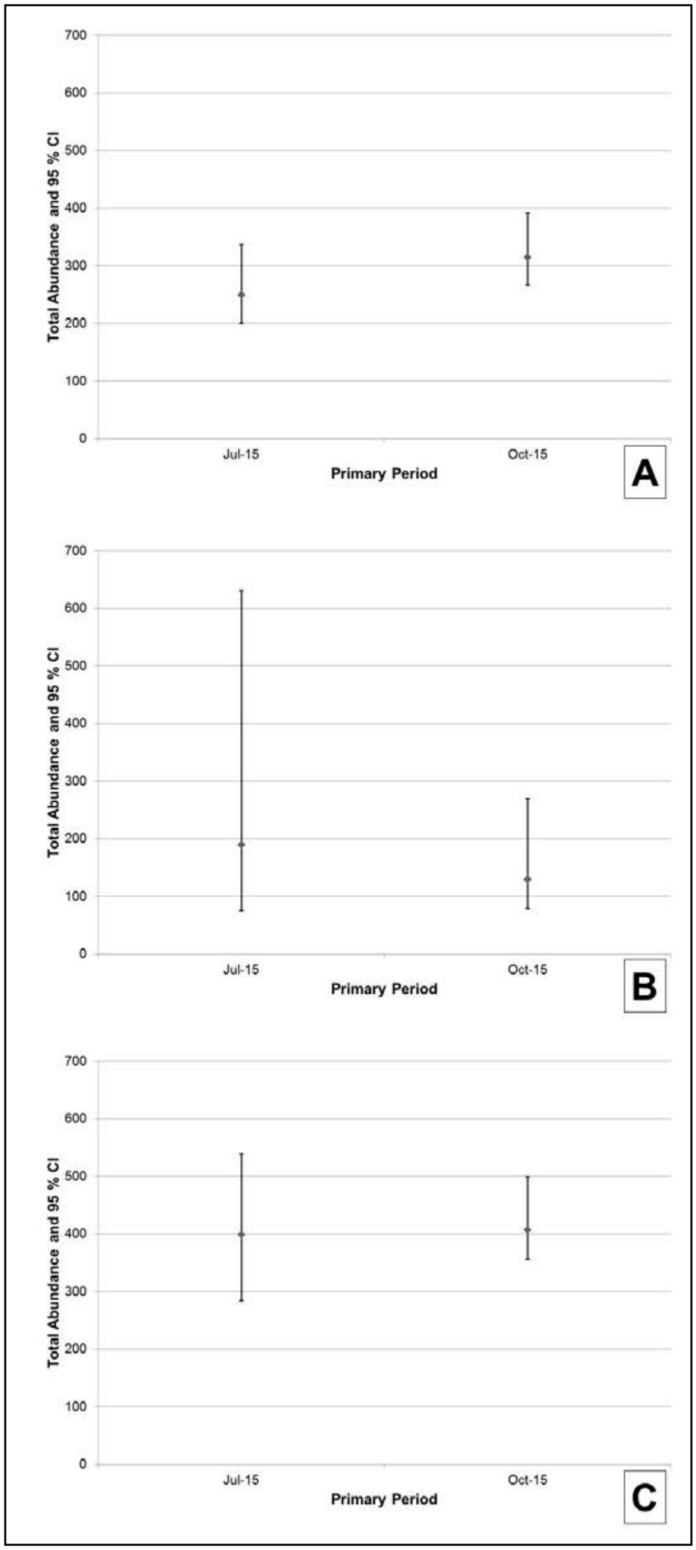
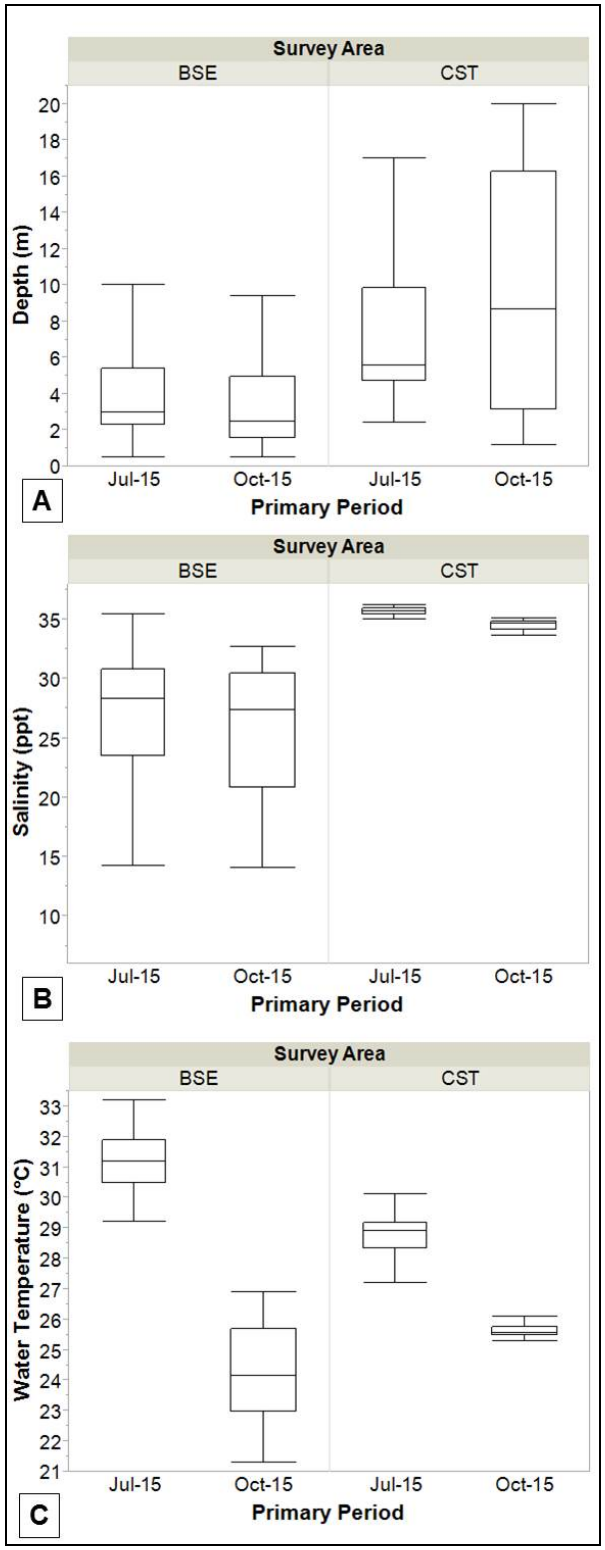
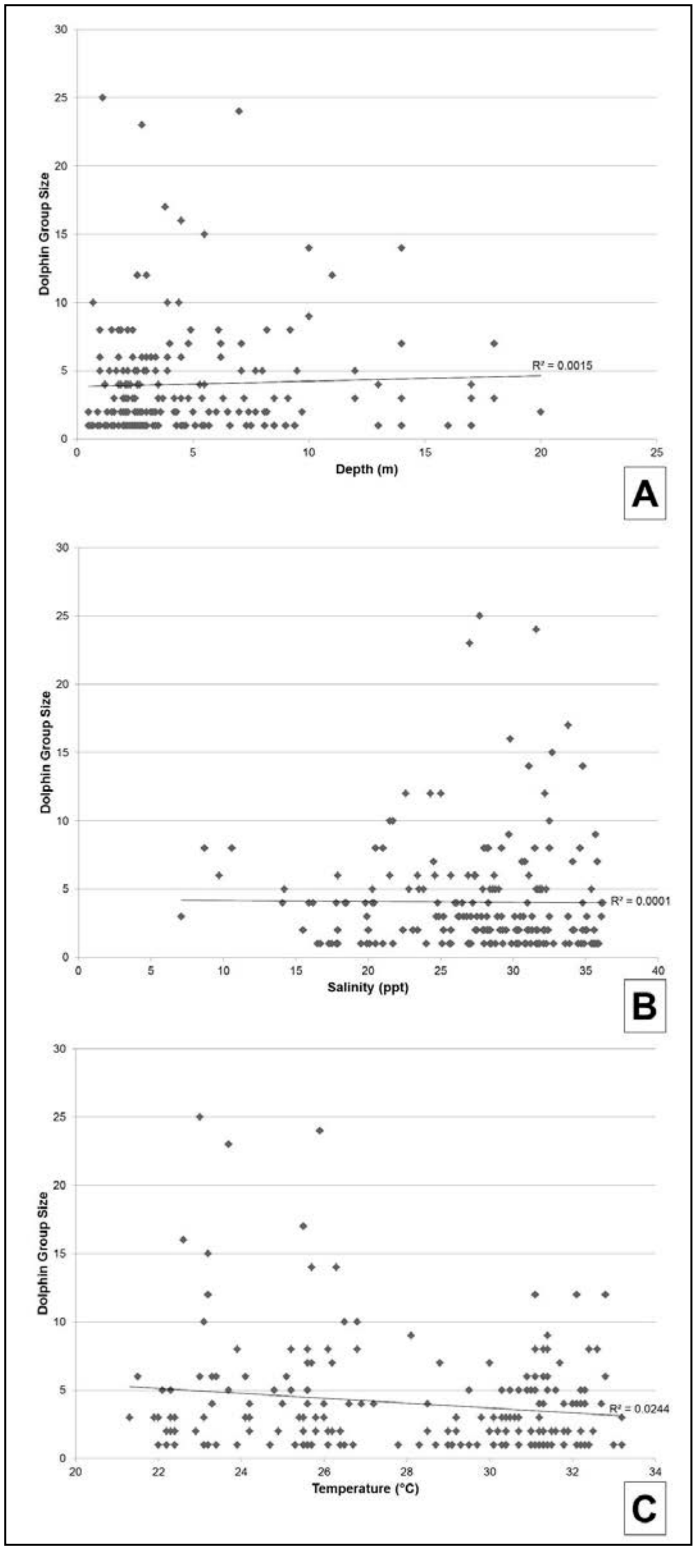

700
600
500
400
300
200
100
0
Total Abundance and 95 % CI
Jul-15
Oct-15
Primary Period
A
B
C

Figure 7.



Survey Area
BSE
CST
Depth (m)
20
18
16
14
12
10
8
6
4
2
0
Jul-15
Oct-15
Jul-15
Oct-15
A
Primary Period
Survey Area
BSE
CST
Salinity (ppt)
35
30
25
20
15
10
Jul-15
Oct-15
Jul-15
Oct-15
B
Primary Period
Survey Area
BSE
CST
Water Temperature (°C)
33
32
31
30
29
28
27
26
25
24
23
22
21
Jul-15
Oct-15
Jul-15
Oct-15
C
Primary Period

Figure 8.



Dolphin Group Size
Depth (m)
R² = 0.0015
A
Dolphin Group Size
Salinity (ppt)
R² = 0.0001
B
Dolphin Group Size
Temperature (°C)
R² = 0.0244
C

Figure 9.

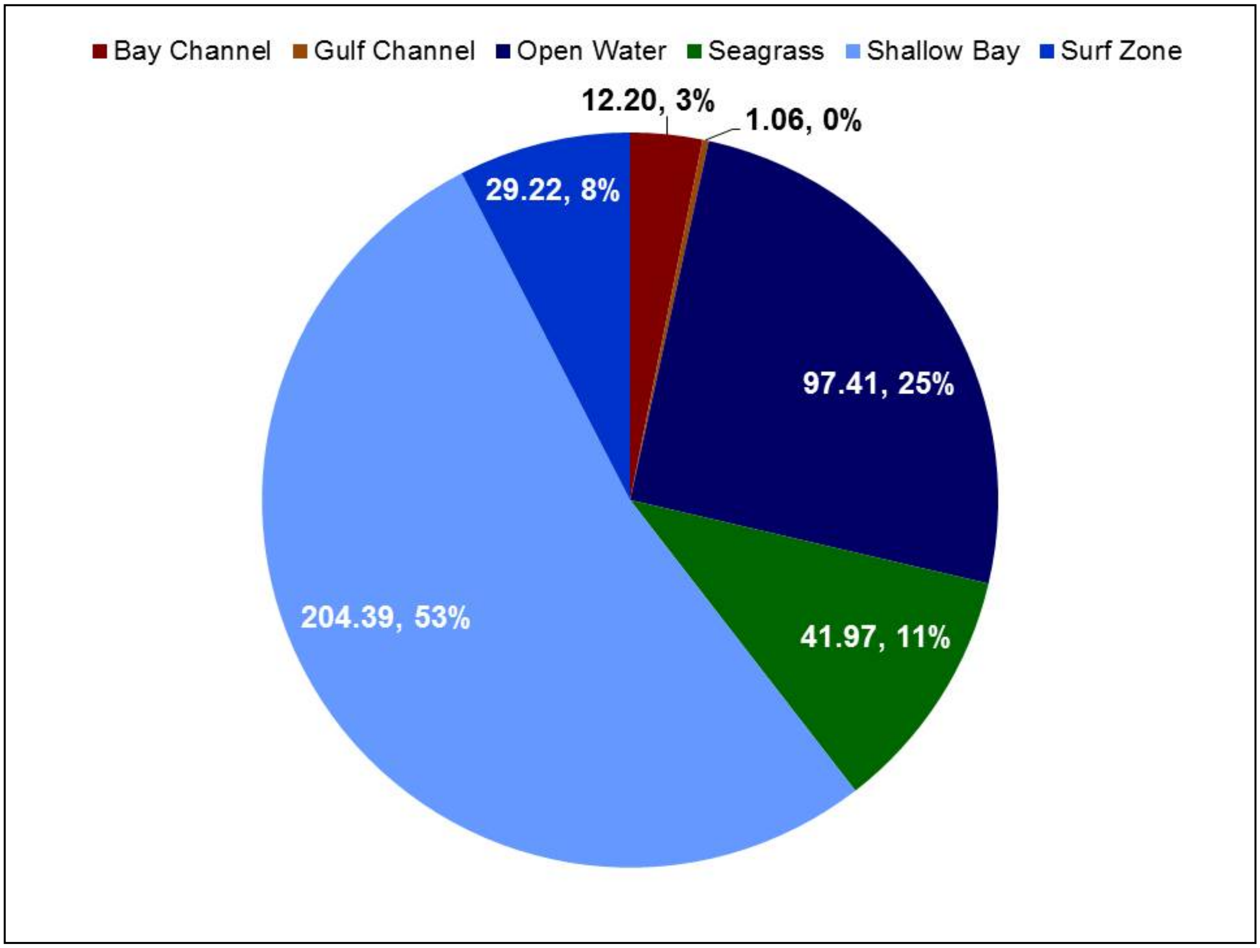
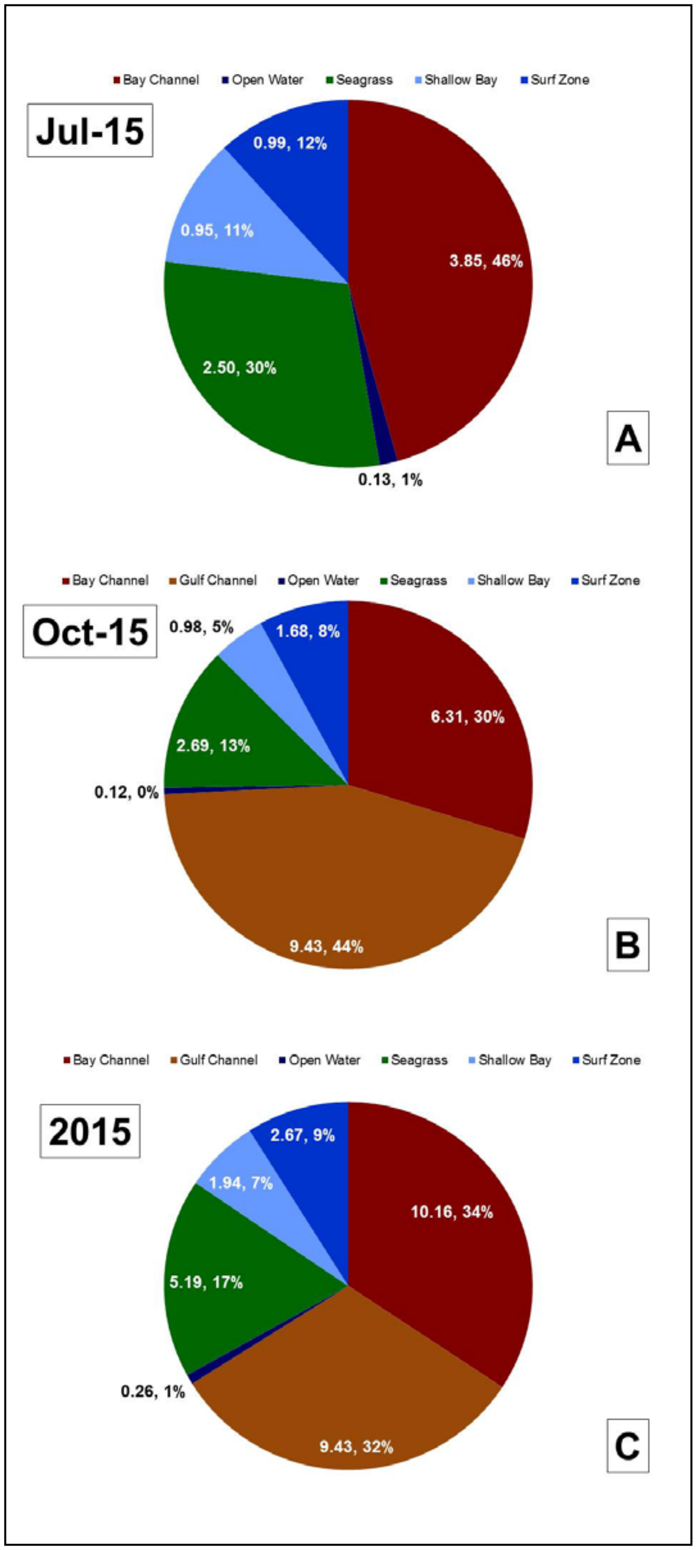

Bay Channel
Gulf Channel
Open Water
Seagrass
Shallow Bay
Surf Zone
12.20, 3%
1.06, 0%
29.22, 8%
97.41, 25%
204.39, 53%
41.97, 11%

Figure 10.



Bay Channel
Open Water
Seagrass
Shallow Bay
Surf Zone
Jul-15
0.99, 12%
0.95, 11%
3.85, 46%
2.50, 30%
0.13, 1%
A
Bay Channel
Gulf Channel
Open Water
Seagrass
Shallow Bay
Surf Zone
Oct-15
0.98, 5%
1.68, 8%
6.31, 30%
2.69, 13%
0.12, 0%
9.43, 44%
B
Bay Channel
Gulf Channel
Open Water
Seagrass
Shallow Bay
Surf Zone
2015
2.67, 9%
1.94, 7%
10.16, 34%
5.19, 17%
0.26, 1%
9.43, 32%
C

Figure 11.

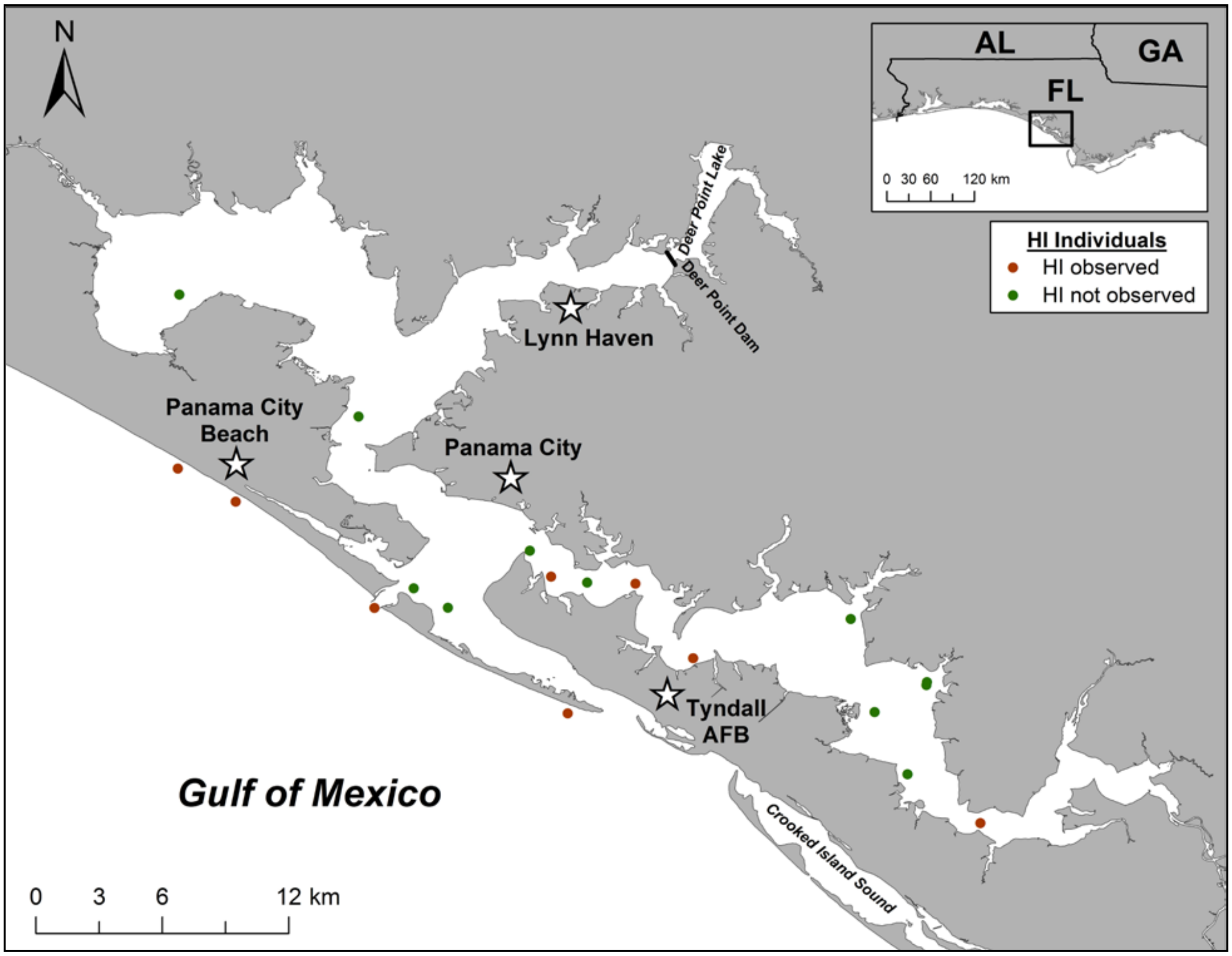

N
AL
GA
FL
0 30 60 120 km
HI Individuals
HI observed
HI not observed
Deer Point Lake
Deer Point Dam
Lynn Haven
Panama City Beach
Panama City
Tyndall AFB
Gulf of Mexico
Crooked Island Sound
0 3 6 12 km

Figure 12.

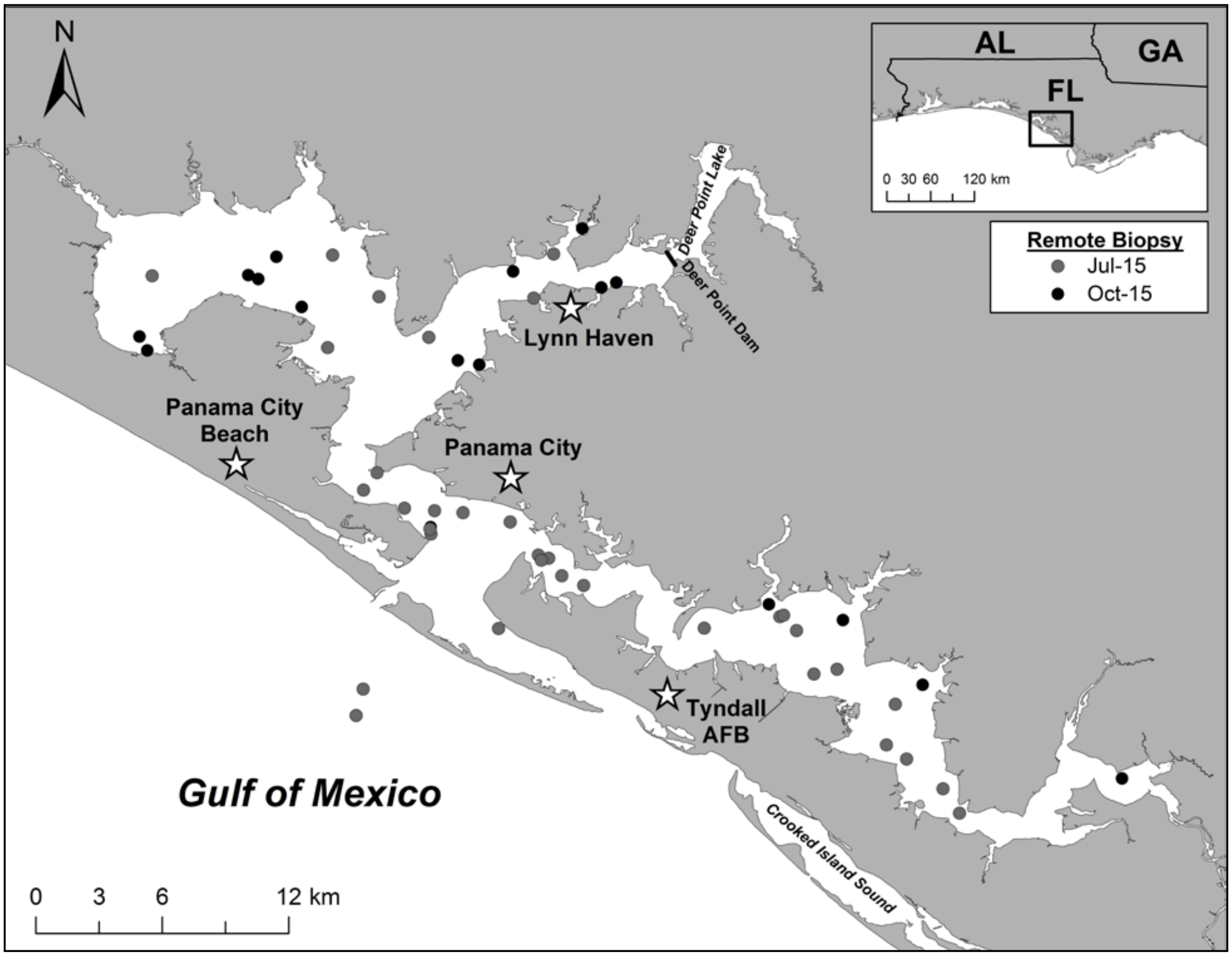

N
AL
GA
FL
0 30 60 120 km
Remote Biopsy
Jul-15
Oct-15
Deer Point Lake
Deer Point Dam
Lynn Haven
Panama City Beach
Panama City
Tyndall AFB
Crooked Island Sound
Gulf of Mexico
0 3 6 12 km

Figure 13.

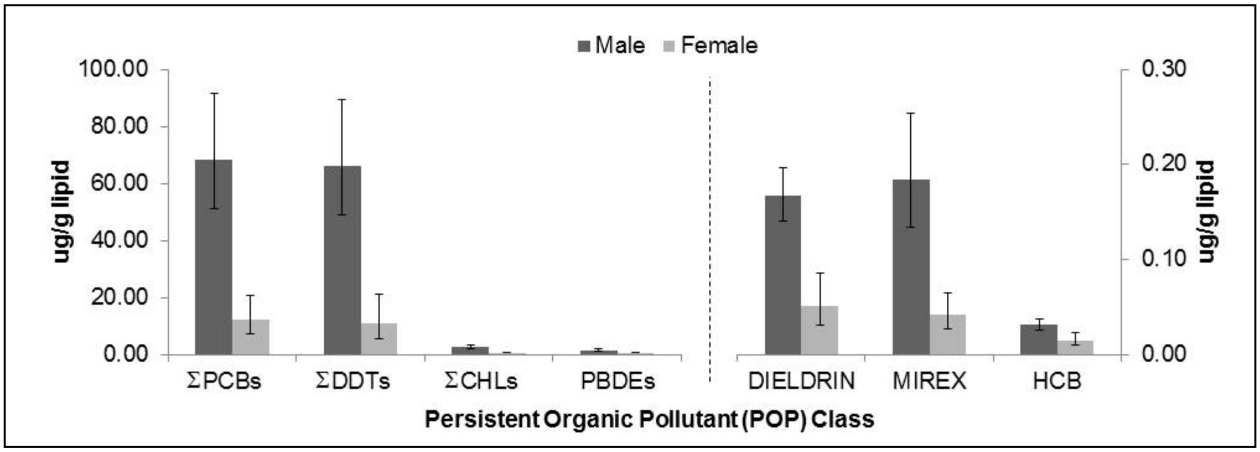

Male
Female
100.00
80.00
60.00
40.00
20.00
0.00
ug/g lipid
0.30
0.20
0.10
0.00
ug/g lipid
ΣPCBs
ΣDDTs
ΣCHLs
PBDEs
DIELDRIN
MIREX
HCB
Persistent Organic Pollutant (POP) Class

Figure 14.