THE SOCIAL STRUCTURE, BEHAVIOR, AND OCCURRENCE OF BOTTLENOSE DOLPHINS IN RELATION TO SHRIMP TRAWLERS IN SOUTHPORT, NORTH CAROLINA

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ABSTRACT

Bottlenose dolphins use a wide diversity of feeding tactics, and can be quite flexible in their use. Numerous researchers have described associations of dolphins with shrimp trawlers. Trawler foraging is characterized by bottlenose dolphins feeding on organisms stirred up by an actively trawling shrimp boat, bycatch, and/or fish attracted to non-working shrimp trawlers. This study analyzed data collected from boat-based photo-identification surveys conducted from 1998-2003 in the Southport, North Carolina area, where there is an active shrimp fishery in the summer and fall. Based on findings from two recent studies, the following hypotheses were tested: (1) separate, non-interacting communities of trawler and non-trawler dolphins occur, (2) trawler dolphins spend more time socializing and less time feeding than do non-trawler dolphins, (3) trawler dolphins are seasonal in their occurrence and (4) trawler dolphins occur in larger group sizes than non-trawler dolphins. Data from 99 sightings were analyzed (40 trawler sightings and 59 non-trawler sightings). Trawler dolphins were defined as any dolphin seen at least once with a trawler, and non-trawler dolphins were those never seen with a trawler. Of 51 dolphins sighted three or more times in the Southport area, 45 were trawler dolphins and 6 were non-trawler dolphins. Associations between trawler (T) and non-trawler (NT) dolphins were significantly different from those within both NT and T groups ($p<0.0001$), and within group associations (T-T and NT-NT) were significantly higher than between group associations (NT-T; $p<0.0001$). T animals had significantly different activity budgets than NT animals ($p<0.0001$); when not with trawlers, T dolphins spent more time socializing than did NT dolphins. In addition, NT dolphins spent more time traveling than did T dolphins, which could be at least partially due to their increased need to search for food. Sightings of trawler dolphins were highly seasonal, occurring only in the summer and fall ($p=0.0033$), and larger group sizes ($p=0.0020$, $F=10.07$) occurred with trawlers. Non-trawler dolphin sightings occurred primarily in winter in Southport, but year round in other portions of the Wilmington study area. Results support the hypotheses that separate, non-interacting groups of trawler and non-trawler dolphins occur in Southport, NC and that these groups differ in their activity budgets and seasonal patterns of occurrence.

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INTRODUCTION

Ecological variables, such as food availability and predators, strongly influence the behavior of many cetacean species (Reynolds *et al.* 2000). Bottlenose dolphins (*Tursiops truncatus*) use a wide diversity of feeding tactics, and can be quite flexible in their use (Connor 2001, Heithaus and Dill 2002). For example, bottlenose dolphins are known to take advantage of human activities to gain access to easily obtainable sources of food (Fertl 2002). Such interactions can be mutually beneficial to both dolphins and fishermen. For example, in Mauritania, dolphins used a distinctive dive (surging roll) as a signal to the coastal mullet fishermen to cast their nets over the fish, which the dolphins chased in their direction (Pryor *et al.* 1990, Connor *et al.* 2000). The net was thought to confuse the fish, which in turn made it easier for the dolphins to catch them (Pryor *et al.* 1990); this practice may decrease the amount of energy expended by dolphins while foraging (Fertl and Leatherwood 1997).

In other cases, dolphins may benefit at the expense of humans. For example, in the Indian River lagoon, some bottlenose dolphins were found to eat the baitfish from crab pots (Noke and Odell 2002). The dolphins tipped the crab pots over to gain access to the bait-well door, which is flush to the sediment and secured with a bungee (Noke and Odell 2002). This behavior resulted in the dolphins getting baitfish but also in the crab pots being destroyed (Noke and Odell 2002). Fisheries interactions can also be detrimental to both dolphins and humans, such as when dolphins become entangled in fishing gear (Waerebeek *et al.* 1990, Fertl and Leatherwood 1997, Wells and Scott 2002). During the height of the gillnet season (Oct-Nov) in 1997-1998, 10 of the 18 dolphins that stranded in southeastern North Carolina were killed in monofilament gillnets (Friedlaender *et al.* 2001).

Numerous researchers have described associations of dolphins with shrimp trawlers. Trawler foraging is characterized by bottlenose dolphins feeding on organisms stirred up by an actively trawling shrimp boat, bycatch, and/or fish attracted to non-working shrimp trawlers (Gruber 1981, Corkeron *et al.* 1990, Fertl and Leatherwood 1997, Reynolds *et al.* 2000). The Southport, NC area hosts a large shrimp fishery in the summer and fall. This fishery lands approximately 1,000,000 pounds of shrimp per year (National Marine Fisheries Service 2002). My study examined how this fishery may affect the occurrence, behavior, and social structure of bottlenose dolphins in Southport, North Carolina. The following hypotheses (described in more detail below) were addressed:

1. Association patterns of dolphins in Southport, North Carolina are affected by the presence of shrimp trawlers.

    Prediction: There are distinct groups of "trawler" and "non-trawler" dolphins in Southport, North Carolina, and these two groups do not associate with one another.

2. Activity budgets of dolphins that associate with shrimp trawlers in Southport, North Carolina differ from those that do not.

    Prediction: Dolphins that forage with shrimp trawlers spend more time socializing and less time feeding than those that do not.

3. Seasonal occurrences of dolphins in Southport, North Carolina are affected by the presence of shrimp trawlers.

Prediction: Trawler dolphins are only seen in Southport, North Carolina in the summer and fall (the shrimp season).

4. Group sizes of dolphins in Southport, North Carolina are affected by the presence of shrimp trawlers.

   Prediction: Larger groups of dolphins occur with shrimp trawlers than without shrimp trawlers.

Hypothesis #1: *Association patterns of dolphins in Southport, North Carolina are affected by the presence of shrimp trawlers.*

Association patterns range from stable to fluid in the few odontocete species that have been studied in detail. At one end of the spectrum are resident killer whales in Prince William Sound, Alaska; British Columbia; and Seattle, Washington. These whales live in very stable groups composed of females and males that remain in the group into which they were born (Baird 2000). Resident killer whales feed on fish, primarily salmon, and show strong seasonal movement patterns associated with their prey (Ford 2002). Sympatric with the resident killer whales are mammal-eating transient whales, which show few seasonal movements (Ford 2002). These two groups are believed to have diverged over time by way of foraging strategies that were learned and passed down from generation to generation (Ford 2002).

Sperm whale (*Physeter macrocephalus*) social structure is more fluid than that of resident killer whales, but long-lasting bonds among females are common (Whitehead 2002). Groups are made up of about 12 females and their young, and also have distinctive vocal repertoires (Whitehead 2002). Females remain in these natal groups for their entire lifetime, while males leave their natal group between ages four and 21, and move into "bachelor herds," which are made up of other males of the same size and age (Whitehead 2002). As males get older, they migrate to more northern latitudes during the non-mating season, and become more solitary (Whitehead 2002).

Even more fluid social relationships are seen in the fission-fusion societies of bottlenose dolphins, where associations can change by the minute, hour and/or day (Connor *et al*. 2000). Wells *et al*. (1987) found that in the resident community of about 100 dolphins in Sarasota Bay, Florida, associations were generally based on sex, age, and reproductive condition. Adult males of usually similar age formed pairs, which were stable over long periods and had the highest coefficients of association of any animals in the community[1] (Wells *et al.* 1987). Females and their calves had the next highest levels of associations. However, these associations were usually only very strong during the first two to five years of the calf's life (when dependent on their mother), after which the coefficients of association declined to varying degrees. Associations among adult females were quite variable, but some groups of females (called female bands) had relatively high association values (Wells *et al.* 1987, Wells 1991).

Smolker *et al.* (1992) found similar results in Shark Bay, Australia. The highest associations were between members of male alliances and then between mother-calf pairs. However, unlike in Sarasota, males frequently formed trios and also formed second-order alliances with other male pairs or trios (Smolker *et al.* 1992). More recently

[1] Coefficients of association (CoA) are a measurement of how often two animals are seen together. They range from 0 to 1, where two animals that were never seen together have a CoA of 0, and two animals that were always seen together have a CoA of 1.

Connor (1999) found that 14 dolphins in Shark Bay formed a super-alliance, which is a very large, labile second-order alliance. Connor (1999) suggested that the large group size of the super-alliance may enable its members to out-compete members of stable alliances. This idea was supported by observations of conflicts between members of the super-alliance and members of stable alliances (Connor 1999).

Most studies of bottlenose dolphins have found low overall levels of association among most adult individuals. In Wilmington, North Carolina, 50.1% of all possible pairwise coefficients of association among 62 individuals seen ten or more times was zero, 45.1 % was between 0.01 and 0.25, and only 0.63% of associations was greater than 0.50 (Koster 2002). In Perth, Australia, among 93 individuals sighted three or more times, only 16% of possible pairings was greater than zero and of these, 68% was less than 0.3 (Waples 1997). Brager *et al.* (1994) found that in Galveston Bay, Texas, the average association values for 35 dolphins (sighted four or more times in each year) were only 0.154 in 1990 and 0.125 in 1991. Finally, Quintana-Rizzo and Wells (2001) found that in Cedar Key, Florida, out of 46 dolphins seen at least 10 times, the majority of associations were between 0 and 0.20, and 30% was high level associations (0.81-1.0). Of these, however, half were mother-calf pairs, which were excluded from calculations of coefficients of associations in the other cited studies (Brager *et al*. 1994, Waples 1997, Koster 2002).

Chilvers and Corkeron (2001) were the first to examine the social structure of bottlenose dolphins associated with shrimp trawlers. In their study area of Moreton Bay, Australia, they discovered two separate communities of dolphins, those that fed with shrimp trawlers and those that did not. Members of the two communities did not interact with one another, even though they were sympatric. This finding was unusual because most biological stocks are separated geographically or temporally, not by feeding preferences (Wang 2002). Based on preliminary data (Fleming 2002) I predicted that there are similarly distinct groups of "trawler" and "non-trawler" dolphins in Southport, North Carolina and that these two groups do not associate with one another.

Hypothesis #2: *Activity budgets of dolphins that associate with shrimp trawlers in Southport, North Carolina differ from those that do not.*

Food availability and abundance play a major role in determining the activity budgets of cetaceans. Killer whales in the Johnstone Strait, British Columbia spent more time foraging (38%) and traveling (32%) and less time socializing (12%), resting (15%), and rubbing (3%) during the salmon runs (Nichol and Shackleton 1996). Bottlenose dolphins in the North Adriatic Sea were found to spend most of their time (82%) feeding, which may be due to the very low food availability in this area (Bearzi *et al.* 1999).

Similarly, Shane (1990) found that bottlenose dolphins in Florida spent more time feeding and less time traveling (36% and 48% respectively) than bottlenose dolphins in Texas (21% and 63%). This difference was thought to result from local fish abundance and distribution. In Texas, dolphins feed in channels that concentrate fish, whereas the more open habitat in Florida may have required dolphins to spend more time foraging (Shane 1990). Brager (1993) found that dolphins spent more time feeding in the fall as opposed to the summer in Galveston, Texas, in response to a decrease in prey abundance. When time spent feeding decreased, dolphins spent more time socializing (Brager 1993).

Fishing operations can also affect bottlenose dolphin behaviors by changing food availability and abundance. Gruber (1981) found that in Matagorda Bay, Texas, most of the dolphins' daily activities involved shrimp trawlers. In the mornings, they followed the boats to feed and in the afternoons social activities were seen frequently very near to the trawlers. Shane *et al.* (1986), in the Aransas Pass area of Texas, also found that shrimp boats affected dolphin activities. Dolphins were seen to wait for boats to leave port, after which they would follow the boats to sea and start feeding when the boats started trawling.

Jones and Sayigh (2002) found that dolphins in Southport, North Carolina had different activity and vocal patterns than those in nearby areas, and proposed that these differences could be associated with the fact that many dolphins in the Southport area foraged in association with shrimp trawlers. In particular, Jones and Sayigh (2002) hypothesized that dolphins that associate with shrimp trawlers may be able to spend less time foraging than those that do not (due to the readily available source of food), thus presumably leaving more of their time available for socializing. However, Jones and Sayigh (2002) did not test this hypothesis directly, as their fieldwork was not structured for such a test. This type of influence has been seen in other animals that take advantage of human activities for feeding. Female baboons that had access to refuse (an easy food source) spent only 43% of their time foraging, which was half of the time baboons that did not have access to refuse spent feeding (Bronikowski and Altmann 1996). The baboons that ate refuse also spent more time resting and socializing than those that did not (Bronikowski and Altmann 1996). Therefore, I predicted that dolphins that forage with shrimp trawlers spend more time socializing and less time feeding than those that do not.

Hypothesis #3: *Seasonal occurrences of dolphins in Southport, North Carolina are affected by the presence of shrimp trawlers.*

Most seasonal movements of cetaceans are thought to be due to prey availability and abundance. Sperm whales in Kaikoura, New Zealand had distribution patterns that were positively correlated with the abundance of grouper (Childerhouse *et al*. 1995). Gill (2002) found that blue whales in southern Australia moved seasonally based on krill availability due to upwelling. When krill were abundant in the summer and autumn, numerous blue whales were seen. However, when the upwelling stopped in winter and spring, no blue whales were observed (Gill 2002).

Northern resident killer whale movements in British Columbia were correlated with salmon runs (Nichol and Shackleton 1996). Whales were most abundant in the Johnstone Strait between July and October when salmon migrated through the strait, and no whales were observed after the migration was over. The same whales were then seen around King Island in the spring, which coincided with sockeye and chinook salmon runs. In addition, whales were found to forage in areas with high salmon densities, such as along shorelines and in areas with strong currents (Nichol and Shackleton 1996).

Shrimp trawlers appear to provide an abundance of easily obtainable food. Walter and Becker (1997) estimated that 60,000 seabirds were supported each year by shrimp trawler discards in the Wadden Sea. Additionally, Gruber (1981) found large increases in numbers of bottlenose dolphins in late spring, summer, and fall in Matagorda Bay, Texas, coinciding with times of heavy use of the area by shrimp trawlers, which could be due to the concentrated food source this fishery provides. However, whether the seasonality was due to the trawlers or to prey availability is not known. Shrimp trawlers are also present in Southport, NC, but only in the summer and fall. Thus, I predicted that sightings of trawler dolphins (those seen with a trawler at least once) would be limited to the summer and fall.

Hypothesis #4: *Group sizes of dolphins in Southport, North Carolina are affected by the presence of shrimp trawlers.*

A variety of factors can influence group size in cetaceans. The most commonly cited benefit to group living is protection from predators. This can result from the dilution effect (reduction in the attack rate per individual), the confusion effect (decreased ability of predators to track an individual in a group), and from increased predator detection (Connor 2000). Acevedo-Gutierrez (2002) found in Isla del Coco in the south Pacific that when sharks were present, group sizes of dolphins increased from a mean of four to a mean of five to nine individuals (depending on activity). Also, as group size increased, incidences of dolphins chasing sharks away increased (Acevedo-Gutierrez 2002).

However, being in a large group can also incur costs, primarily related to food availability. Less food is available per individual, which means the group may have to travel farther to find food (Connor 2000). Group living can also increase the amount of intra-specific food competition (Connor 2000), which is thought to be one of the main reasons why baleen whales do not form stable groups (Tershy 1992).

To overcome some of these costs, bottlenose dolphins may engage in bout feeding, in which group size decreases during feeding and then increases when not feeding (Connor 2000). Bearzi *et al.* (1999) observed bout feeding in bottlenose dolphins in the North Adriatic Sea; group sizes were significantly smaller when feeding than when socializing. Waples (1997) also found that group sizes were larger during socializing than while feeding in Perth, Australia.

However, if the food source is stable and abundant these costs can be mitigated and large groups may be maintained. For example, among banded mongoose in Queen Elizabeth National Park, Uganda, those that fed at garbage dumps had larger and denser groups than those that did not (Gilchrist and Otali 2002). In Moreton Bay, Australia, Chilvers and Corkeron (2001) found that group sizes were larger when dolphins were with trawlers than not with trawlers (7.5 and 3.5 respectively, $p<0.001$), regardless of whether or not the dolphins were feeding. In addition, Jefferson (2000) found that group sizes of Indo-Pacific dolphins were related to the presence of fishing vessels. Average group size with no fishing vessels present was 3.3 dolphins, but increased to 4.0 with shrimp trawlers and to 9.6 with pair trawlers (two trawlers with a net between them). Conversely, Bearzi *et al.* (1999) found smaller groups associating with trawlers in the Adriatic Sea; they suggested that this could be due to the fact that feeding with trawlers in their area was opportunistic rather than an established behavior pattern (Bearzi *et al.* 1999).

Since shrimp trawlers in Southport, North Carolina appear to provide a concentrated source of food, I predicted that larger groups of dolphins would occur with trawlers than without shrimp trawlers.

METHODS

Field methods

This study utilized data collected between 10/24/95 and 10/19/2003 in the Wilmington-Southport, NC area. The study area extended from the tip of Battery Island (Cape Fear River), out Bald Head Island Inlet to the southeastern tip of Bald Head Island, and west past Oak Island to Lockwood Folly Inlet (Figure 1). In addition, data were also collected in areas north of Southport, including a portion of the Intracoastal Waterway from Topsail Island in the north to Snow's Cut in the south, plus the Cape Fear River, and approximately 3km offshore from New Topsail Inlet to Carolina Beach (Figure 1). Boat-based surveys were conducted in this area by trained graduate and undergraduate students working under Dr. Laela Sayigh at the University of North Carolina at Wilmington.[2] While under way, vessel tracks were recorded using a Garmin 12XL Global Positioning System (GPS). When dolphins were sighted, a data sheet was filled out, following the protocol described by Urian and Wells (1996). A descriptive location of the sighting was noted as well as the specific latitude and longitude, which was also recorded on the GPS. Environmental conditions were collected, as was tidal state, beginning and end times of the sighting, and the activities of the animals (Urian and Wells 1996). Activities included travel, feed/probable feed, mill, social, and with boat (See Appendix A for definitions). Minimum, maximum, and best estimates of group size and of the number of calves present were also made.

During a sighting, every effort was made to photograph all animals present. A Nikon N 90s autofocus camera with a 70-300 mm telephoto lens was used to take photos

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[2] General Authorization #7 (1995-2000) and # 972-1601-00 (2000-2005) issued to Dr. Laela Sayigh

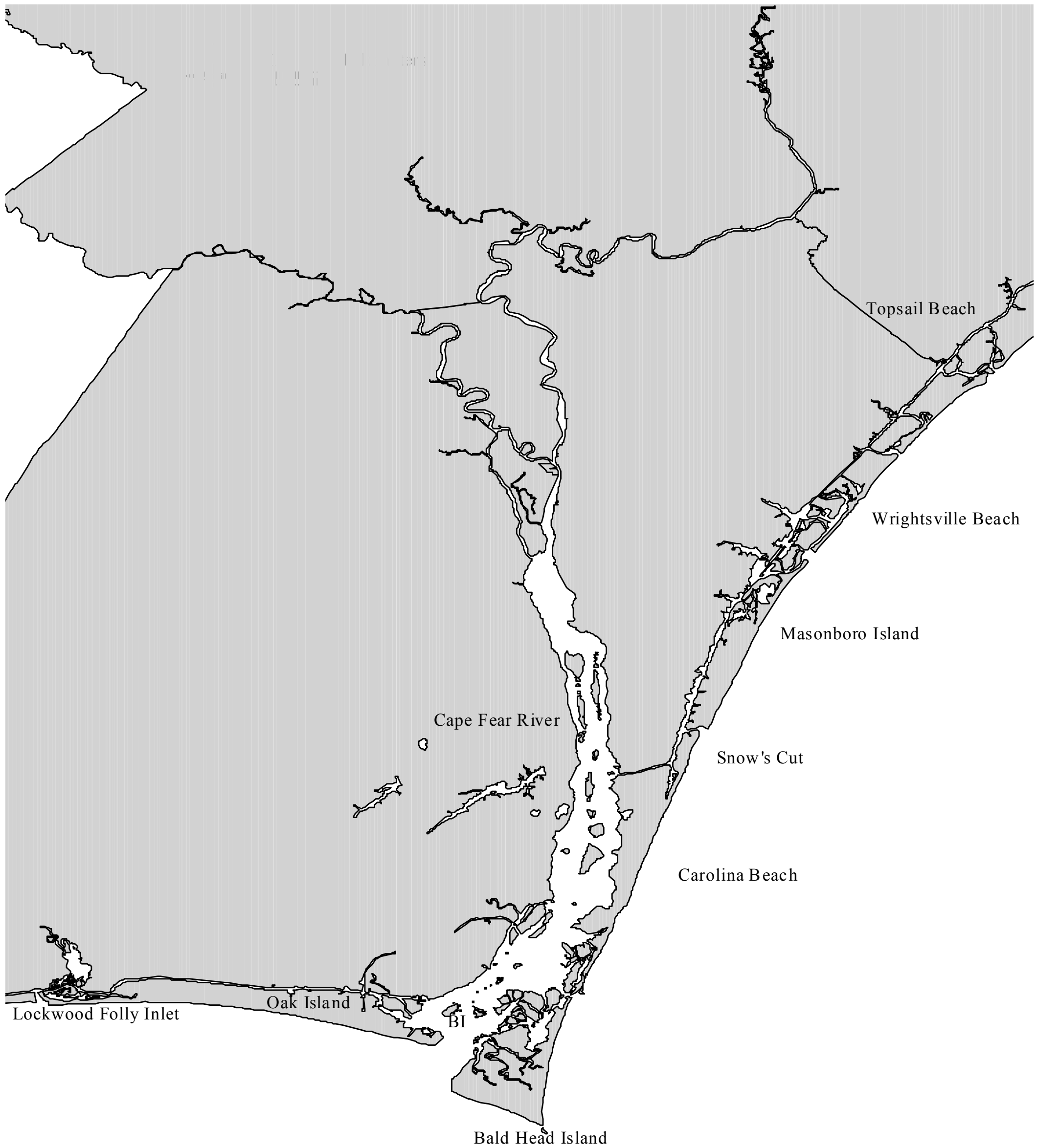

Figure 1. Wilmington, NC study area. The Southport study area extended from the tip of Battery Island (BI), out Bald Head Island Inlet, to the southeastern tip of Bald Head Island, and west past Oak Island to Lockwood Folly Inlet. The rest of the Wilmington study area included the Intracoastal Waterway from Topsail Beach in the north to Snow's Cut in the south, plus the Cape Fear River, and approximately three miles offshore from New Topsail Inlet to Carolina Beach.

of the animals' dorsal fins, which may have natural nicks and notches on them that can be used to identify individual animals (Wursig and Wursig 1977). However, in many sightings it was not possible to photograph all or even any of the animals, due to poor weather conditions or the dolphins being difficult to approach. In addition, some dolphins do not have sufficient markings on the fin to enable individual identification.

To quantify activity budgets, observational data were collected at 4-minute intervals throughout a subset of sightings. Sightings lasted as long as we were able to stay with the dolphins (before losing them or having to leave because of weather or low light). Verbal comments were recorded into a microphone, plugged into a Panasonic AG-7400 videocassette recorder, which also simultaneously recorded underwater sounds produced by the dolphins. Previous studies by Dr. Sayigh and some of her students have utilized both 3-minute and 5-minute sampling intervals. While 3-minute intervals maximized data collection, 5-minute intervals allowed better accuracy (since researchers were also carrying out other tasks during the observations, such as photo-identification). The 4-minute interval was chosen to provide a balance between these two objectives. For each 4-minute point sample, group size was assessed, and predominant group activity sampling was used to access the activity of the group (Mann 2000). Predominant group activity sampling estimated what activity the majority (50% or more) of the animals in a group were engaged in (Mann 2000). Activity budget data were supplemented with data collected by Jones and Sayigh (2002), in cases where presence or absence of a shrimp trawler was noted. Jones and Sayigh (2002) used a 3-minute sampling interval and also assessed activities using predominant group activity sampling (Mann 2000).

Data Analyses

To determine whether there are two distinct, non-associating groups of "trawler" and "non-trawler" dolphins in Southport, North Carolina, dorsal fin photos were compared to archived pictures in the UNCW dorsal fin catalog, which contains photos from approximately 300 known animals in the Wilmington and Southport, North Carolina area. Coefficients of association (CoA's) were calculated for all dolphins sighted three or more times in Southport. CoA's were calculated in the computer software package SOCPROG (Whitehead 1999), using the Half-Weight Index (Cairns and Schwager 1987, Bejder *et al.* 1998, Ginsberg and Young 1992), which is the most commonly used measure of association for studies of dolphin social structure (Bejder *et al.* 1998). The formula used was $CoA=x/0.5(N_a+N_b)$, where x was the number of times animal A and animal B were sighted together, N_a was the total number of times animal A was sighted, and N_b was the total number of times animal B was sighted. Following the definitions used by Chilvers and Corkeron (2001), trawler dolphins were defined as those sighted at least once with a trawler, and non-trawler dolphins were those never sighted with a trawler. For simplicity, trawler dolphins will be referred to by the abbreviation "T" and non-trawler dolphins will be referred to as "NT."

Association values were compared to a random distribution by permuting the observed data set 20,000 times using a Monte Carlo randomization method in SOCPROG. The mean and standard deviation of the observed CoA's were then compared to the randomly derived values in SOCPROG. If the observed standard deviation is significantly greater than the randomly derived value, this is indicative of preferred associations. All pairwise CoA's were then divided into three groups: T-T associations, NT-NT associations, and T-NT associations. T-T and NT-NT associations were also compared to random distributions using the Monte Carlo method.

Mantel tests (in SOCPROG) were used to determine if T-NT associations differed from T-T and NT-NT associations. This test reports t-values with infinite degrees of freedom, which are equivalent to z-values. Standardized lagged association rates (SLAR), which reflect the stability of associations, were also calculated in SOCPROG for both T-T and NT-NT associations. These calculations yield probabilities that two animals will still be associated at various time lags in the future. Associations are preferred over time if they stay above the null, which is an estimate of lagged association rates resulting from completely random associations (Whitehead 1995). Several models representing different social structures were fit to the SLAR's in order to determine which model had the best fit. To determine this, the Akaike's Information Criterion (AIC) was calculated for each model (Ottensmeyer and Whitehead 2003). The model with the lowest AIC value was considered the best fit. Finally, a cluster analysis was used to visually display the associations among individuals.

To determine whether dolphins that forage with shrimp trawlers spend more time socializing and less time feeding than those that do not, activity budgets (% time spent in each activity) of T and NT dolphins were compared using a log linear model with repeated measures (developed by Dr. Jim Blum of the UNCW Mathematics and Statistics Department). Repeated measures accounted for the fact that observations at 4-minute intervals were not independent of one another within a sighting. Sightings were divided into those that contained NT animals, those that contained T animals while not with a trawler, and those that contained T animals while with a trawler. Activity budgets of these three groups were compared. Since T dolphins primarily feed while with trawlers, this analysis provided insights into the activities of T dolphins when not with trawlers.

To examine seasonality of sightings of T and NT dolphins, chi-square tests were used. Seasons were defined as follows: fall- September to November; winter- December to February; spring- March to May; and summer- June to August. The observed numbers of sightings in each season were compared to expected numbers based on survey effort. Expected values were calculated by determining the proportion of surveys that occurred in each season, and multiplying this proportion by the total number of trawler or non-trawler sightings. The rationale behind this approach is that if the number of sightings is not affected by season, the proportion of observed sightings of dolphins in each season should correspond closely to the proportion of survey effort in each season. For this analysis, sightings that occurred without trawlers were divided as to whether they contained dolphins identified as T or NT, and all sightings of T animals (with and without trawlers) were then combined.

In order to determine whether larger groups of dolphins occur with shrimp trawlers, group size data were analyzed in two ways. First, sightings with and without trawlers were compared using an ANOVA, in the statistical software package JMPIN, to determine if it is strictly the presence of a trawler that affects group size. Second, sightings were divided into three categories, T dolphins with trawlers, T dolphins without a trawler, and NT dolphins, and group sizes were again compared with an ANOVA. The latter analysis examined whether T dolphins occurred in larger groups than NT dolphins regardless of whether a trawler was present.

Finally, the distributions of T and NT dolphin sightings in Southport and the rest of the Wilmington study area were plotted in Arcview-GIS 3.2, in order to visualize the amount of spatial overlap between the two groups. In addition, the percentages of sightings in Southport versus more northern portions of the Wilmington study area (Figure 1) were calculated for T and NT dolphins in order to assess the relative importance of the Southport area versus other portions of the Wilmington study area to these two groups of dolphins.

RESULTS

The Southport data set included 99 sightings from 7/2/98 to 6/24/03. A total of 1810 dolphins were encountered based on field estimates (this number includes resights); out of these, 249 dolphins were identified. Of these identifiable animals, 51 were sighted three or more times; 45 were T dolphins (seen with a trawler at least once) and 6 were NT dolphins (never seen with a trawler). Of the 99 sightings, 40 were with trawlers and 59 were not with trawlers. The non-trawler sightings were further broken down with respect to whether they contained T dolphins (11 sightings) or NT dolphins (10 sightings). No dolphins were identified in 38 of the 59 non-trawler sightings; thus, these could not be classified as containing T or NT dolphins. After dolphins were designated as T or NT based on their sightings in the Southport area, sightings of these dolphins in other portions of the Wilmington study area between 10/24/95 and 10/19/2003 were added to the data set.

The mean coefficient of association for all 51 dolphins (1275 pairwise associations) was 0.13 (SD=0.07). The mean T-T CoA (990 pairwise associations) was

0.17 (SD =0.07). Almost half of T-T associations (49.6%, 491 pairwise associations) were equal to zero (Figure 2). Of the remaining 419 pairwise associations, 32% (317 pairs) were between 0.21-0.40, and only 10.3% (102 pairs) were greater than 0.40 (Figure 2). The mean NT-NT CoA (15 pairwise associations) was 0.24 (SD=0.13). The majority of NT associations (40.0%, 6 pairs) were in the 0.01-0.20 range, and 13.3% (2 pairs) were greater than 0.40 (Figure 2). The mean T-NT CoA (270 pairwise associations) was 0.01 (SD=0.03). The majority of T-NT associations (93.3%, 252 pairs) were equal to zero (Figure 2). The 18 non-zero associations (7%) were due to three animals, 10030, 60020, and FB703, which were seen once with a trawler. However, these animals were never seen interacting with other T animals, and interacted only with NT animals. A cluster analysis places these three T animals within the NT group (Figure 3).

Associations within both NT and T groups were significantly higher than between group associations ($t=-5.168$, $p<0.0001$). The mean and standard deviation of the observed associations of all 51 animals were significantly different from random (mean: $p<0.0001$; SD: $p<0.0001$), as were associations involving only T dolphins (mean: $p=0.00035$; SD: $p=0.0002$), and associations involving only NT dolphins (mean: $p=0.00015$; SD: $p<0.0001$).

The SLAR's of T dolphins indicated preferred associations until approximately day 800 out of an 1800-day sampling period (Figure 4). SLAR's then fell below the null with some fluctuations. The model that best fit these data was "Rapid disassociation and casual acquaintances," which describes short-lived associations (Whitehead 1999). Non-trawler dolphins maintained preferred associations over the duration of the study that were well above the null level representing random associations (Figure 5). Several

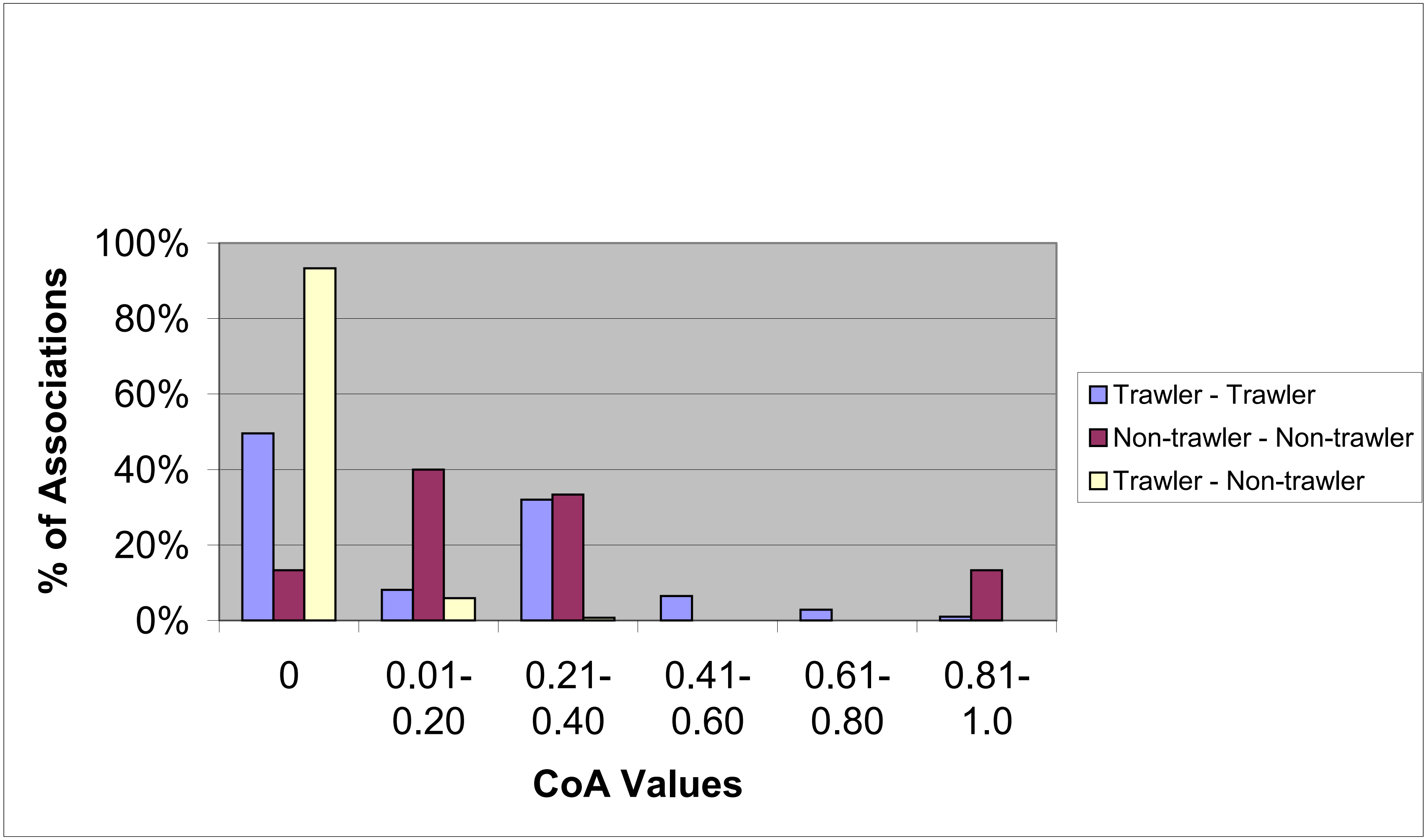

Figure 2. Percentage of trawler-to-trawler (T-T), non-trawler-to-non-trawler (NT-NT), and trawler-to-non-trawler (T-NT) dolphin associations in various CoA ranges.

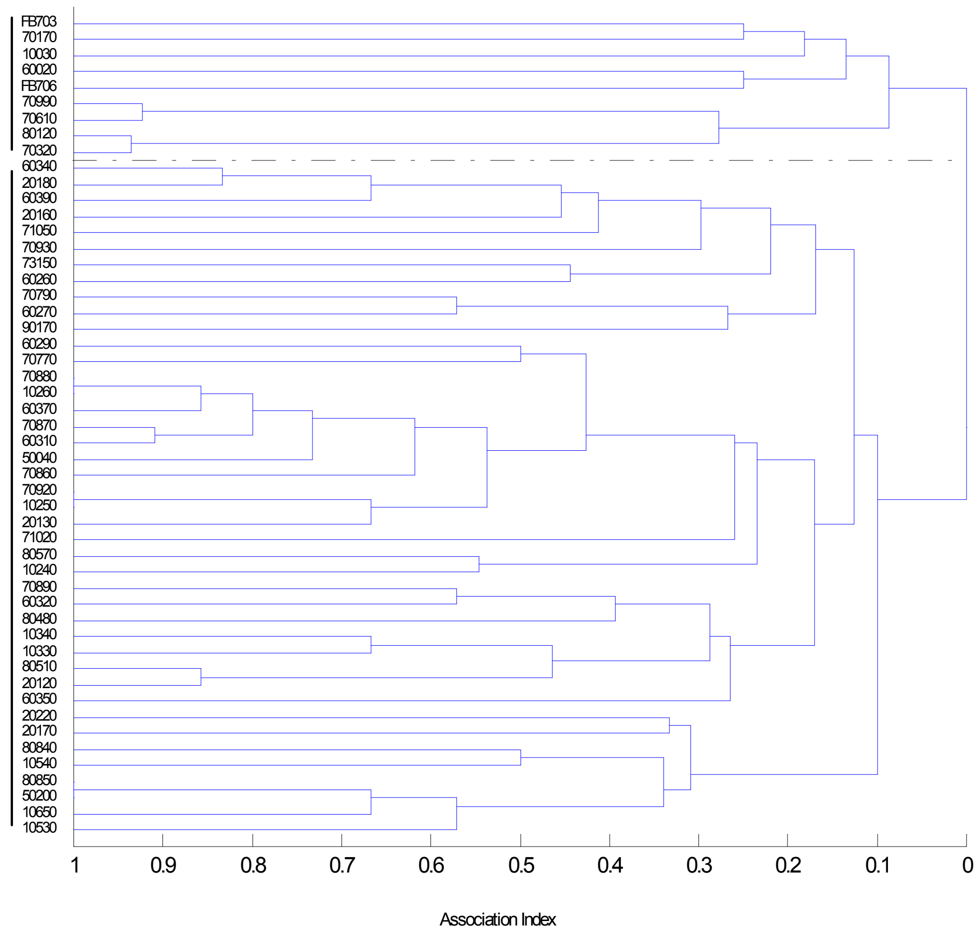

Figure 3. Cluster analysis of associations. A break is visible between dolphins 70320 and 60340. Of the nine dolphins in the upper group, six are non-trawler dolphins, and the other three (10030, 60020, and FB703) are dolphins sighted once with a trawler. The lower group consists entirely of trawler dolphins.

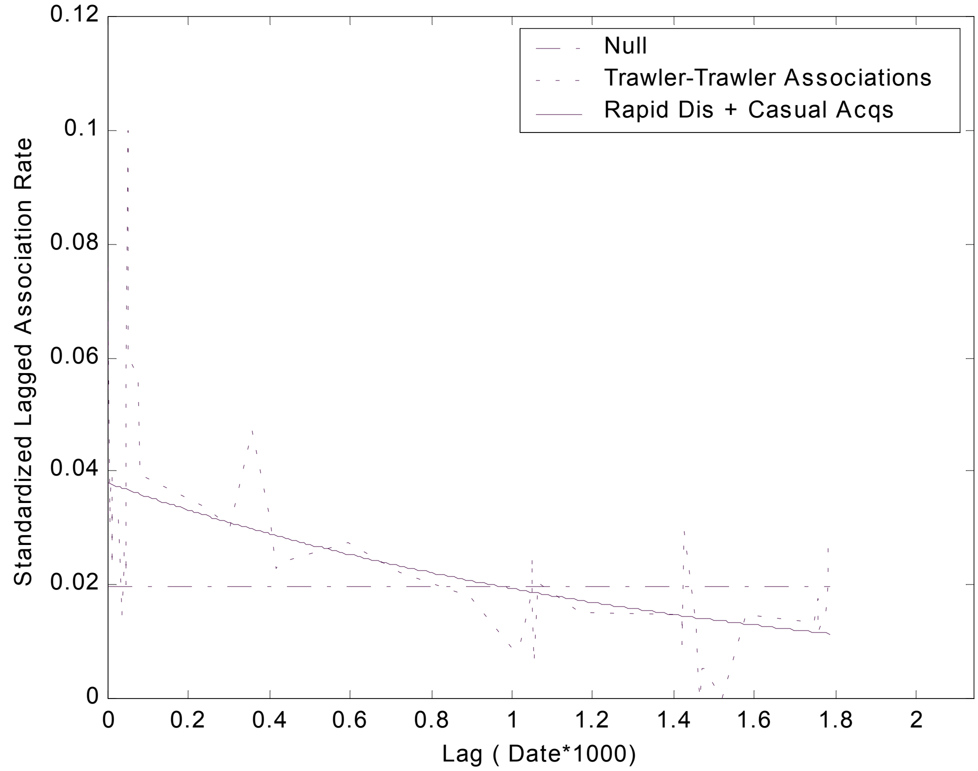

Figure 4. Standardized lagged association rates (SLAR) for trawler dolphins. The null represents association rates resulting from completely random associations. The descriptive model that most closely matched the data was “Rapid disassociations and casual acquaintances” (Whitehead 1999).

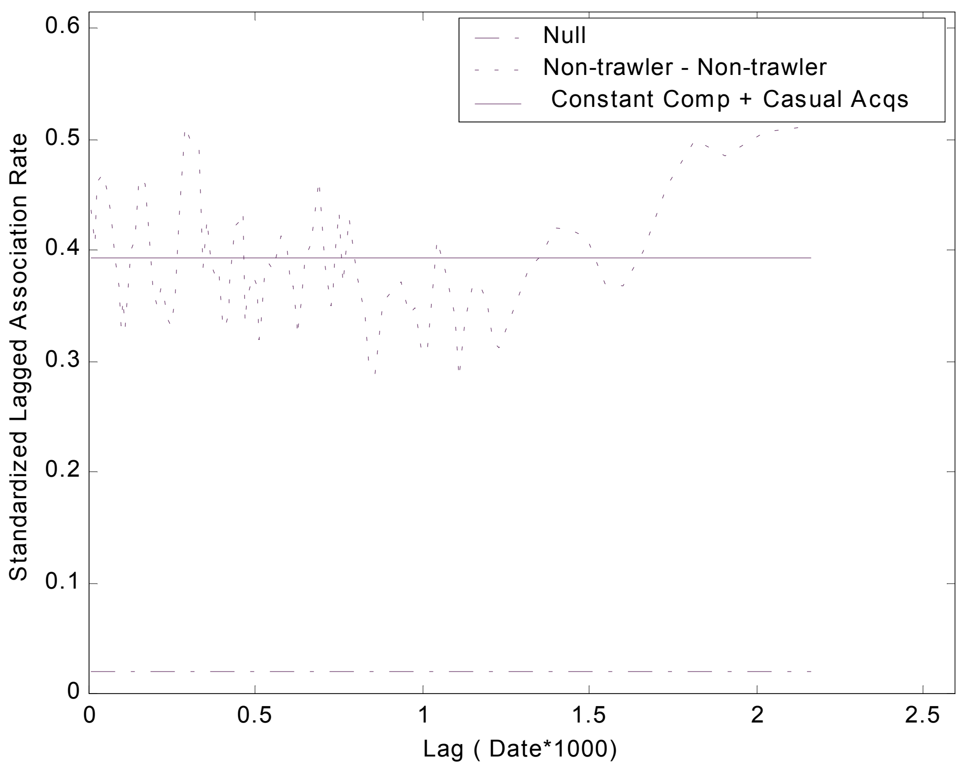

Figure 5. Standardized lagged association rates (SLAR) for non-trawler dolphins. The null represents association rates resulting from completely random associations. Several models fit these data equally well; "Constant companions and casual acquaintances" is shown here (Whitehead 1999).

models fit these data equally well; of these, “Constant companions and casual acquaintances” is illustrated in Figure 5.

The spatial distributions of sightings of dolphins with and without trawlers in the Southport area overlapped (Figure 6). However, all overlap involved sightings of T dolphins with and without trawlers. No overlap in the spatial distributions of T and NT dolphins occurred in the Southport area (Figure 7). All NT dolphin sightings were concentrated in the inlet and close to shore, whereas T dolphin sightings were spread throughout the Southport study area and further offshore. A seemingly unusual trawler sighting occurred on 3/27/99, when three dolphins, 10030, 60020, and FB703, were sighted with a trawler close to shore (Figure 7). These are the same three dolphins that were grouped with the NT dolphins in a cluster analysis (Figure 3). They were sighted with a trawler only once and they associated only with NT dolphins.

The majority of sightings (89.3%) of NT dolphins occurred in more northern portions of the Wilmington study area, primarily in the Intracoastal Waterway (Figure 8, Table 1). In contrast, most sightings (81%) of T dolphins were in Southport. Sightings of T dolphins outside the Southport area were all in the ocean, with the exception of the sightings of the three dolphins (10030, 60020, and FB703) previously discussed (Figures 8 and 9, Table 1).

Activity data were collected from 21 groups of dolphins in Southport, totaling 34.6 hours of observational data. However, all of the sightings in Southport except one (10/25/98, 12 minutes) for which activity budget data were available contained T animals. Therefore, in order to compare activity budgets of T and NT dolphins, NT dolphin activity budgets from five sightings in other locations, including the Intracoastal

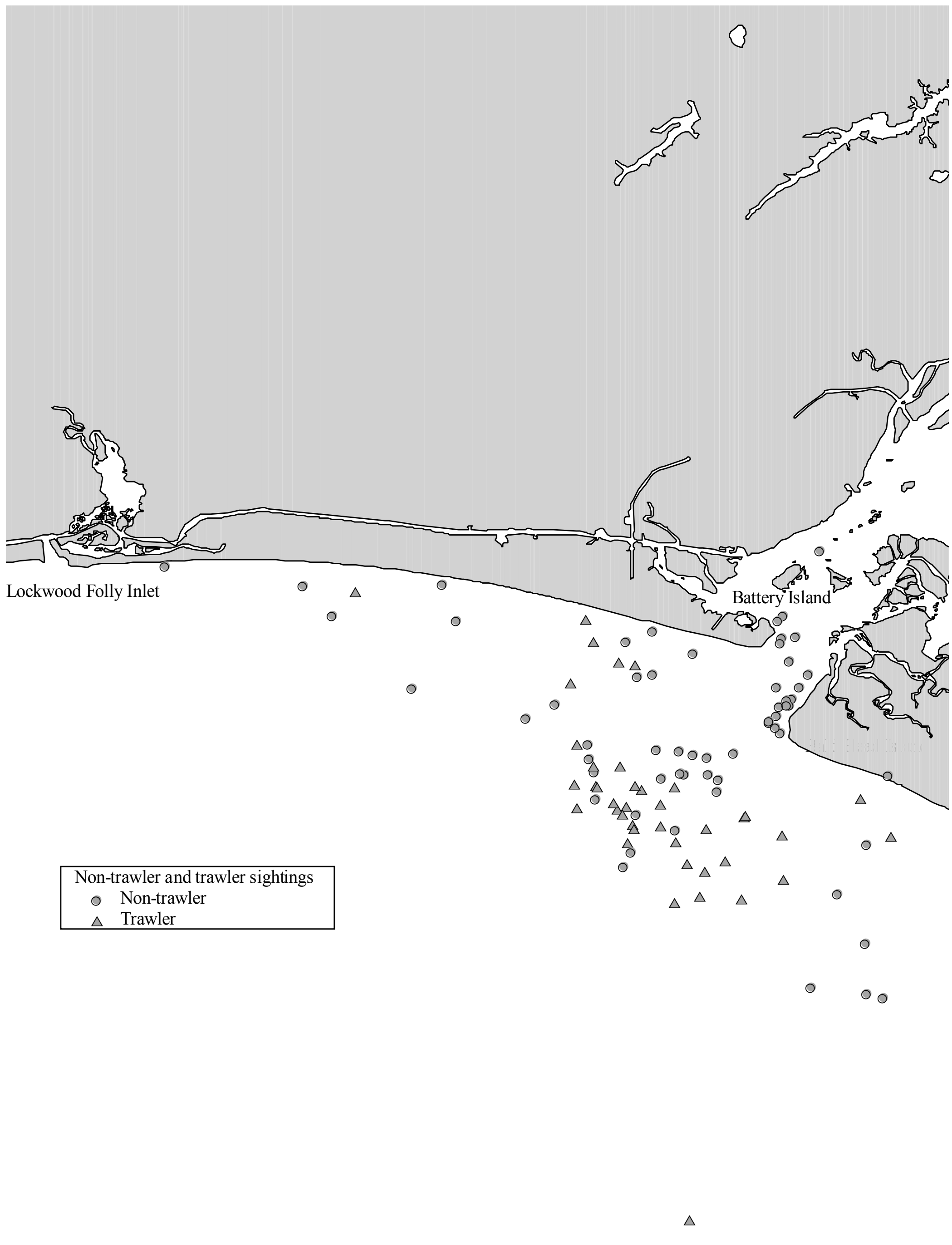

Figure 6. Distribution of sightings of dolphins with and without trawlers in the Southport, NC area.

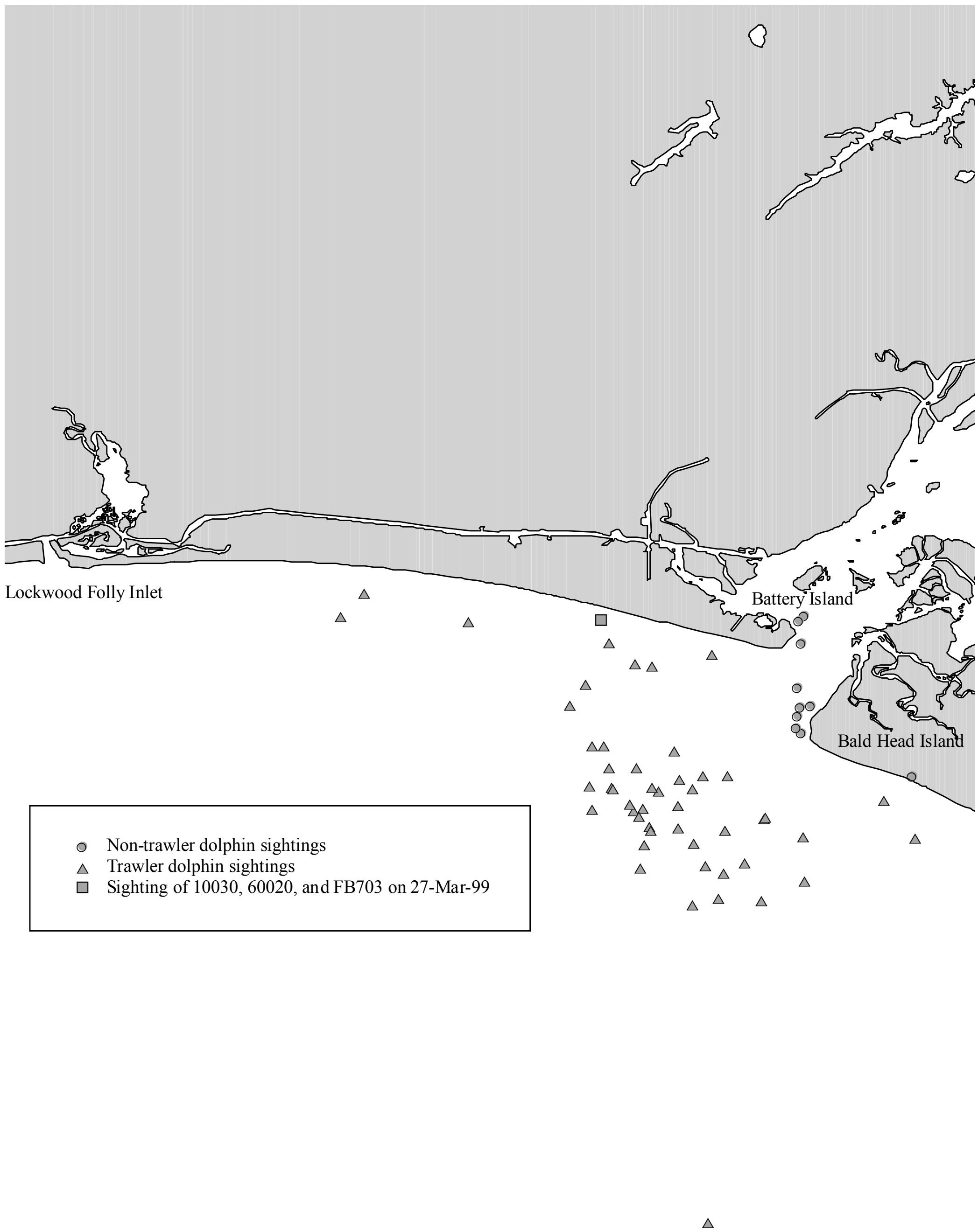

Figure 7. Distribution of trawler and non-trawler dolphins in the Southport, NC area. Note that sightings of non-trawler dolphins are concentrated in the inlet, whereas sightings of trawler dolphins are more widely distributed. The location of the unusual trawler sighting on 3/27/99 is also indicated (see text for description).

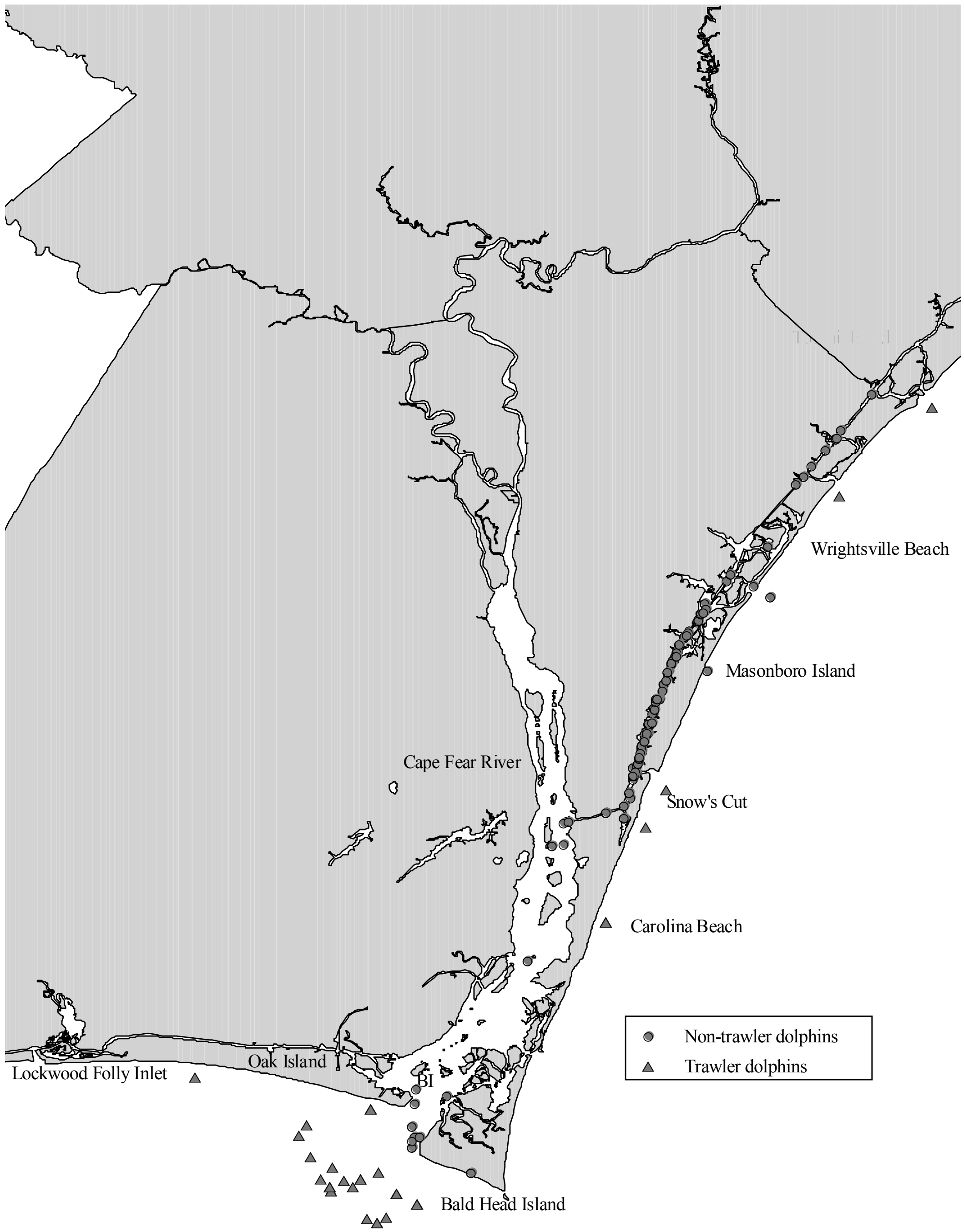

Figure 8. Distribution of NT and T dolphins throughout the Wilmington, NC study site. Note that most sightings of NT dolphins occurred north of Southport, primarily in the Intracoastal Waterway, whereas sightings of T dolphins occurred mainly in Southport. Sightings of T dolphins outside of Southport were in the ocean, with the exception of 10030, 60020, and FB703 (shown in Figure 9).

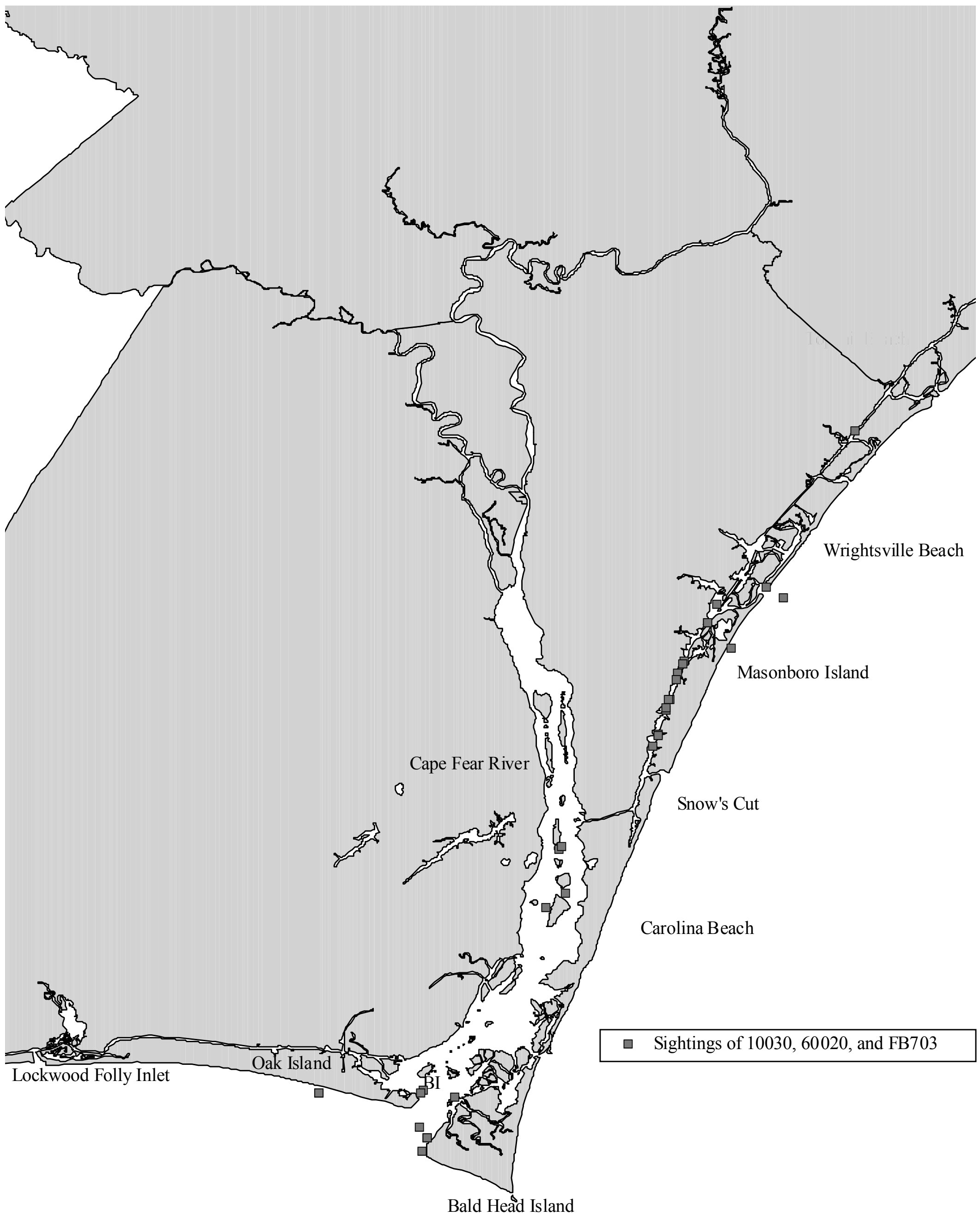

Figure 9. Sighting locations of 10030, 60020, and FB703 throughout the Wilmington, NC study site. Note that most sightings occurred north of Southport, primarily in the Intracoastal Waterway, similar to those of NT dolphins (Figure 8).

Table 1. Number of sightings in the Southport, North Carolina area and total number of sightings for each individual dolphin sighted three or more times in Southport.

	ID	# of Southport Sightings	Total # of Sightings
T Dolphins	10030	3	19
	10240	4	5
	10250	3	3
	10260	3	4
	10330	3	3
	10340	3	3
	10530	3	4
	10540	3	4
	10650	3	3
	20120	4	4
	20130	3	3
	20160	7	8
	20170	3	3
	20180	6	6
	20220	3	3
	50040	5	6
	50200	3	3
	60020	3	5
	60260	5	5
	60270	3	3
	60290	4	4
	60310	5	6
	60320	3	3
	60340	6	6
	60350	4	4
	60370	3	3
	60390	3	3
	70770	4	4
	70790	4	4
	70860	4	5
	70870	4	5
	70880	3	4
	70890	5	5
	70920	3	3
	70930	4	5
	71020	4	4
	71050	5	5
	73150	4	4
	80480	4	4
	80510	3	3
	80570	6	6
	80840	4	4
	80850	3	3
	90170	3	4
	FB703	4	12
NT Dolphins	70170	5	28
	70320	3	38
	70610	3	39
	70990	3	39
	80120	3	39
	FB706	3	3

Waterway and the ocean off of Masonboro Island, were used (Figure 8). These sightings contained at least one of the six dolphins identified as NT dolphins in this study. This resulted in 9.9 hours of data from six sightings of NT dolphins.

T dolphins had significantly different activity budgets than NT dolphins ($p<0.0001$, Figure 10). NT animals spent significantly less time feeding (1.4%) than T animals with a trawler (51.5%) or without trawlers (19.1%). T animals without a trawler spent significantly more time socializing (13.3%) than T animals with a trawler (2.4%) or NT animals (5.1%). NT animals spent significantly more time traveling (67.0%) than did T dolphins either with (45.0%) or without (38.1%) a trawler. In addition, T dolphins without a trawler spent significantly less time traveling than T dolphins with a trawler. NT animals and T animals without a trawler spent significantly more time milling (24.2% and 18.0% respectively) than did T animals with a trawler (1.2%). Finally, T animals without a trawler spent significantly more time milling/traveling (13.3%) than did T animals with a trawler (0%) or NT animals (2.3%).

Occurrence of both T and NT animals in Southport varied with season (Table 2). NT dolphin sightings occurred in Southport only in fall and winter. Fewer sightings than were expected (based on survey effort) occurred in fall, spring, and summer, and more sightings than were expected occurred in winter in Southport ($p<0.0001$). However, these dolphins were seen in all seasons in other parts of the Wilmington study area (Figure 8). More sightings of T dolphins than were expected (based on survey effort) occurred in fall and summer, and fewer than expected occurred in winter and spring ($p=0.033$). However, there was one sighting with a trawler in the winter (2/13/99) and two sightings with trawlers in the spring (3/27/99 and 5/28/03).

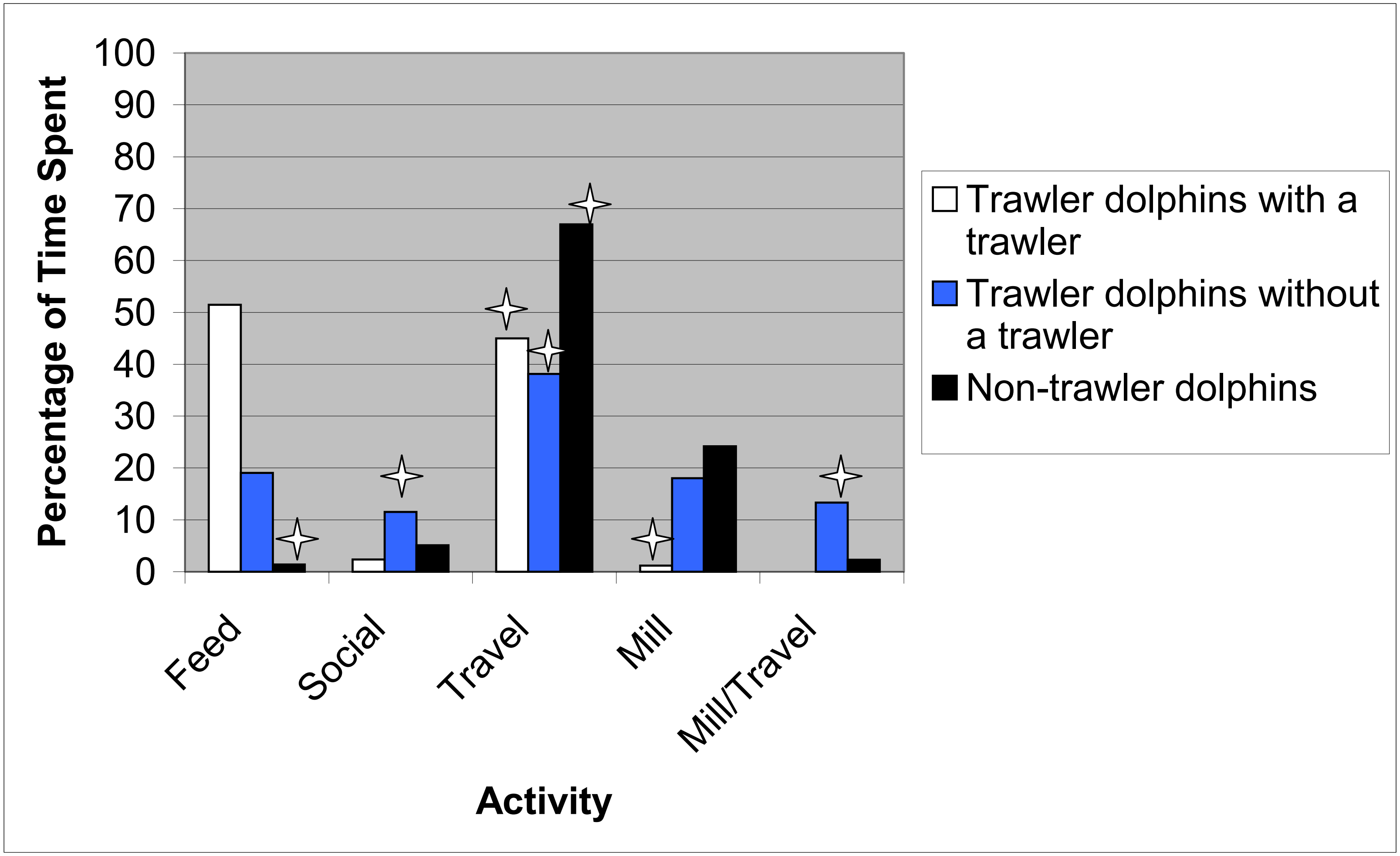

Figure 10. Percentage of time spent by NT dolphins and T dolphins with and without a trawler in various activities. Stars are placed over the categories that are significantly different (either higher or lower) from the other two within each activity, with the exception of travel where all categories are significantly different from each other.

Table 2. Seasonality of trawler sightings ($p=0.033$, $\chi^2=8.77$) and non-trawler sightings ($p<0.0001$, $\chi^2=25.88$) in Southport, NC. Expected values were calculated by determining the proportion of surveys that occurred in each season, and multiplying this proportion by the total number of trawler or non-trawler sightings.

		Trawler Sightings		**Non-Trawler Sightings**	
Season	**Total # of Surveys**	**Observed**	**Expected**	**Observed**	**Expected**
Fall	19	24	18.6	2	3.7
Winter	6	1	5.9	8	1.2
Spring	6	2	5.9	0	1.2
Summer	21	24	20.6	0	4.0
Total	52	51	51	10	10

Group sizes of dolphins with trawlers were significantly larger than group sizes of sightings without trawlers (p=0.0020, F=10.07). Mean group size was 12.7 (SD=2.7) for 59 non-trawler sightings and 26.1 (SD=3.3) for 40 trawler sightings. However, when non-trawler sightings were divided according to whether or not T dolphins were present (which resulted in a smaller sample size because sightings where no identifications were made could not be included), there was no significant difference in overall group size (p=0.5942, F=0.5253). Mean group size was 18.0 (SD=7.5) for 10 sightings of NT animals, 27.6 (SD=7.5) for 11 sightings of T animals without a trawler, and 25.9 (SD=3.7) for 40 sightings of T animals with a trawler.

DISCUSSION

Results support the prediction that distinct, non-associating groups of T and NT dolphins occur in Southport, NC. Associations between T and NT dolphins were very rare (mean CoA=0.01, 93% of associations=0), and were significantly different than T-T associations and NT-NT associations. This is similar to the findings of Chilvers and Corkeron (2001), who found non-associating groups of T and NT dolphins in Moreton Bay, Australia. However, in Southport, three T animals were seen with NT animals. These three dolphins were seen with a trawler only once, on 3/27/99. They were the only animals identified with this trawler, which was out in the spring (not the shrimp season) and was much closer to shore than usual. In addition, these three dolphins were never seen with other T animals and were seen frequently enough with NT dolphins to be grouped with them in a cluster analysis (Figure 3). Sightings of these three dolphins in the Intracoastal Waterway in more northern portions of the study area support the idea that they should be classified as NT dolphins (Figure 9). None of the T dolphins were ever sighted in the Intracoastal Waterway; sightings north of Southport occurred only in the ocean. In addition, several T dolphins have been sighted south of Southport, near Myrtle Beach, SC[3].

Mean coefficients of association among dolphins in Southport were relatively low, similar to those in other studies (Brager *et al.* 1994, Quintana-Rizzo and Wells 2001, Koster 2002), and in accordance with their fission-fusion society. However, results from random permutations of the dataset indicate that both means and standard deviations of associations between and among T and NT dolphins were significantly different from random. Standard deviations that are significantly higher than random reflect the occurrence of preferred associations. SLAR's supported these findings, indicating that NT dolphins associated well above chance levels throughout the duration of the study. T dolphin SLAR's were also above chance levels, but were less stable over long time periods. However, it is important to note that SLAR's can be biased when using small data sets (Whitehead 1995). T dolphins were sighted only an average of 4.7 times each, which may explain why the SLAR's dropped below the chance level. In contrast, NT dolphins were sighted an average of 31 times each, providing a stronger basis for examining association rates over time; however, the number of NT dolphins was small (six). Whitehead (1995) stated that seasonality of sightings could also bias lagged association rates; T dolphins were seen primarily in summer and fall, whereas NT dolphins were seen year round (in the overall data set).

Unlike Chilvers and Corkeron (2001), the distribution of T and NT dolphins showed no overlap. Overall, NT animals seemed to be more estuarine than T animals. NT

[3] Rob Young, Coastal Carolina University, unpublished data

animals had only 10.7% of their sightings in Southport, where the habitat is open and exposed. When NT dolphins were found in Southport, they occurred in the inlet, shallows, and very close to shore. More often NT dolphins were sighted in the enclosed protected waters of the Intracoastal Waterway (Figure 8). In contrast, T dolphins were sighted exclusively in the ocean, with the exception of the three dolphins involved in the March trawler sighting (10030, 60020, and FB703). This suggests that these animals could perhaps be categorized as oceanic and estuarine dolphins rather than T and NT dolphins (respectively).

Results support the hypothesis that activity budgets of NT and T dolphins are different from each other ($p<0.0001$). When not with trawlers, T dolphins socialized more than NT dolphins. This supports the prediction that associating with trawlers enables these dolphins to spend less time searching for food, and more time socializing. However, in contrast to the prediction that T dolphins would spend less time feeding than NT dolphins, feeding was not observed in NT dolphins very often (1.4% of the time). This could be due to the fairly conservative definition of feeding used, which included an observation of a fish in the dolphin's mouth, or obvious feeding behaviors such as lunging and rushing at the surface. It is likely that time spent milling and/or traveling by NT dolphins was in search of food (Shane 1990), which is supported by the fact that NT dolphins spent significantly more time traveling than T dolphins with or without a trawler. Additionally, the data set was likely biased in the other direction for T dolphins, as their activity was always classified as feeding while with a trawler. However, if in fact T dolphins do spend more time feeding than do NT dolphins, this could reflect that the fish are of poor quality, or that T dolphins are in poor condition, both of which could require them to spend more time feeding.

As predicted, seasonality of dolphin sightings in Southport was related to the presence of shrimp trawlers. In general, sightings of T dolphins occurred in the summer and fall, when most trawlers were present. However, there were three trawler sightings in winter and spring. The winter sighting was of one unidentified animal with a trawler; it is not known if it was a T or NT dolphin. The sighting on 5/28/03 occurred with a trawler and contained T animals. This sighting was not unusual in that it occurred close to the beginning of the trawler season in June. The sighting on 3/27/99 occurred with a trawler very close to shore, and the three animals identified (10030, 60020, and FB703) were classified as T animals even though this was the only time they were seen with a trawler, as described earlier (all other trawler dolphins except two, 20220 and 10340, were seen at least twice with a trawler). Thus, this may have been an unusual occurrence of opportunistic trawler feeding that occurred because the T dolphins were not in the area, and/or because the trawler was close to shore in an area where NT dolphins were regularly seen.

NT dolphins also were seasonal in their occurrence in Southport, with sightings only in fall and winter. Sightings in more northern portions of the study area occurred in all four seasons. Reasons for the seasonal bias of the sightings of NT dolphins in Southport could include prey distribution and abundance or a decrease in predators in the area. Schwartz (1984) found that most sharks were seasonal off the North Carolina coast, being absent in the winter months. The majority of sightings of NT dolphins in Southport were in winter, supporting the idea that predator avoidance may be involved in the seasonality of their occurrence in Southport.

Again as predicted, group sizes were larger when dolphins were with trawlers, supporting the idea that trawlers provide a concentrated source of food. Past studies have found that groups are usually larger when not feeding (Waples 1997, Bearzi *et al.* 1999, Connor 2000), which probably reflects competition for food resources. When non-trawler sightings were divided according to whether they contained T or NT dolphins, the mean group sizes of T dolphins with trawlers (25.9) and not with trawlers (27.6) were almost identical. This indicates that these large groups are maintained even when not in the presence of trawlers. The mean group size of NT dolphins was smaller (18.0), although this difference was not significant. The large group sizes of T dolphins, regardless of whether they are with a trawler, suggest that these large groups may reduce predation risk. This idea is in accordance with the theory that predation risk is greater for animals in more open habitats as compared to those in more enclosed habitats (Norris and Schilt 1988).

If trawlers do provide an abundant a concentrated source of food, then why do all dolphins not engage in trawler foraging? This could be explained, at least in part, by the fact that non-trawler dolphins do not have access to trawlers. Non-trawler dolphins are not found offshore where trawlers usually operate and are only found in Southport in the winter when trawlers are not present. Another (possibly related) contributing factor could be an increased predation risk associated with trawler foraging, since trawlers usually are about two to three miles offshore. Trawler dolphins in Southport appear to have more shark bite scars when compared to non-trawler dolphins. In a preliminary analysis of photographs of 157 dolphins with trawlers and 158 dolphins that were not with trawlers (and that were sighted in areas where trawler dolphins do not occur), there were no shark bite scars on the dolphins without trawlers but there were nine instances of scars on trawler dolphins. Four of these were obvious shark bite scars; in the other five cases the scars were likely from sharks but photo clarity was not sufficient to positively determine whether or not they were from sharks. This suggests that an increased threat of shark attacks may be a factor contributing to why some dolphins do not associate with trawlers. In Shark Bay, Australia, dolphins feed in sub-optimal areas due to the increased presence of tiger sharks in more optimal areas (Heithaus and Dill 2002). However, some juveniles are known to take on this increased risk of predation by feeding in the more food rich areas, indicating that the trade-off of costs and benefits may differ for different dolphins (Heithaus and Dill 2002, Heithaus 2004).

Since a mass-mortality event that took place in 1987-1988, the coastal migratory stock of bottlenose dolphins along the Atlantic coast has been listed as depleted (Scott *et al.* 1988). Thus, understanding the stock structure, social structure, and movement patterns of mid-Atlantic bottlenose dolphins has become very important (Scott *et al.* 1998). McLellan *et al*. (2002) used stranding records gathered over 25 years and found that there was a complex stock structure of coastal migratory dolphins. This idea is also supported by photo-identification and genetic work, which have identified a southern NC management unit between Beaufort, NC and Murrell's Inlet, South Carolina (Wang *et al.* 2002, Figure 11). Southport is centrally located within this management unit, and thus it is important to understand factors affecting the occurrence of dolphins in this area. Shrimp trawlers may be one such factor; this idea is supported by the fact that many

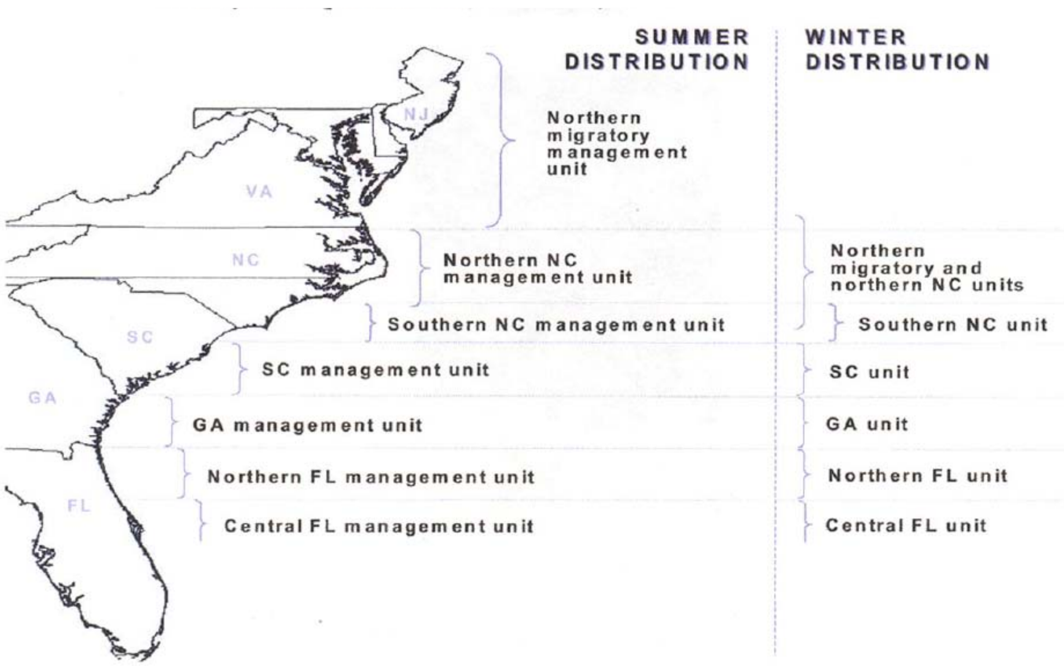

Figure 11. Management units of the coastal bottlenose dolphin along the Atlantic seaboard (Wang *et al.* 1994). Note the Southern, NC management unit between Beaufort, NC and Murrell's Inlet, SC.

trawler dolphins have been seen with trawlers since the inception of Southport area surveys (about five years ago). In addition, three trawler dolphins were seen with shrimp trawlers in the ocean off of Carolina Beach during opportunistic sightings in the early 1990's[4]. These observations suggest that trawler dolphins may be dependent on trawlers for food. Thus, as importation of shrimp from overseas reduces the number of shrimp trawlers in the southeastern US, the importance of shrimp trawlers as a food source for these dolphins may need to be factored into management considerations.

Finally, this study supports the idea that a complex mix of resident, migratory, oceanic, and estuarine dolphins occur along the mid-Atlantic coast. Trawler dolphins were found only in the ocean whereas non-trawler dolphins occurred primarily in enclosed, protected waters or extremely close to shore in the ocean. So, the observed separation between T and NT dolphins could have less to do with whether or not they feed with trawlers and more to do with the fact that they are different stocks, one which has trawlers within its range. Clearly more work needs to be done to define the stock structure of mid-Atlantic bottlenose dolphins, including the potential occurrence of oceanic and estuarine populations.

[4] Conducted by George Rountree (unpublished data)

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APPENDIX A

Definitions of activities recorded for *Tursiops truncatus* (Urian and Wells 1996, Jones and Sayigh 2002)

Mill: surfacing of dolphins in random directions

Travel: surfacing of dolphins in one consistent direction

Mill/Travel: a combination of the previous two activities; may occur when dolphins are checking an area for fish

Feed: fish seen in mouth; also included behaviors associated with feeding such as rushing at surface, lunging, swirling water, and following behind a shrimp trawler

Social: interactions between and among dolphins, usually involves contact and/or leaping

With boat: dolphins approach or travel alongside a boat