The Distribution and Abundance of the Bottlenose Dolphin, Tursiops truncatus in Virginia

Robert A. Blaylock

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THE DISTRIBUTION AND ABUNDANCE
OF THE BOTTLENOSE DOLPHIN,
TURSIOPS TRUNCATUS,
IN VIRGINIA

A Thesis
Presented to
The Faculty of the School of Marine Science
The College of William and Mary in Virginia

In Partial Fulfillment
of the Requirements for the Degree of
Master of Arts

by
Robert A. Blaylock
1984
APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirements for the degree of

Master of Arts

Robert A. Blaylock

Approved December, 1984

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The author wishes to thank Dr. Herbert M. Austin for his encouragement and guidance from the inception of this project and for his assistance in obtaining the funding necessary to complete it. A debt of gratitude is due Dr. James G. Mead, Division of Mammals, Smithsonian Institution, for sharing with me his knowledge of cetaceans in general, and the coastal bottlenose dolphin in particular.

I especially wish to acknowledge the consistent and invaluable participation of Mr. Sam White, pilot, and Mr. Richard A. Byles and Ms. Roslyn Bowman, observers, throughout all of the aerial surveys. Without their help, this work could not have been done.

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ABSTRACT

Aerial surveys were conducted in July-October 1980, and May-June 1981, in the Chesapeake Bay mouth and the nearshore coastal waters of Virginia south of Cape Charles to assess the distribution and abundance of bottlenose dolphins (Tursiops truncatus). Ancillary data were collected to examine relationships between dolphin density and distribution and selected environmental factors. Individual dolphins that were recognizable by distinctively shaped or scarred dorsal fins were photographically recorded during small boat surveys and from shore.

716.6 linear km of aerial surveys in the Chesapeake Bay mouth resulted in 5 herd sightings which gave a strip census density estimate of 0.0035 ± 0.00182 S.E. herds km\(^{-2}\). Aerial surveys totalling 435.1 linear km along the coast between Cape Charles and False Cape (within 2 km of shore) produced 48 herd sightings and a strip census density estimate of 0.0435 ± 0.00232 S.E.). Data from Chesapeake Bay mouth transects were not sufficient for line transect analysis, but the coastal surveys resulted in an estimated herd density of 0.0811 ± 0.00125 herds km\(^{-2}\) based on a Fourier series analysis of herd distribution perpendicular to the transect. Dolphins were sighted primarily within 1.6 km of the shore.

There was a direct relationship between monthly mean herd density and water temperature, but no relationship between mean herd density and air temperature. This suggests that dolphin distribution is
related to the distribution of its prey. There was no significant difference in the number of dolphins moving with or against tidal flow.

During 1980 and 1981, 24 individuals were identified and photographed. Of 7 identified in 1980, 5 were resighted in 1981, suggesting seasonal residency. Twelve *Tursiops* were stranded and retrieved during the study period, but there was no apparent relationship between strandings and estimated monthly abundance.
THE DISTRIBUTION AND ABUNDANCE
OF THE BOTTLENOSE DOLPHIN,
TURSIOPS TRUNCATUS,
IN VIRGINIA
INTRODUCTION

Bottlenose dolphins (*Tursiops sp.*) are widely distributed throughout temperate and tropical oceans of the world (Rice 1977). The Atlantic bottlenose dolphin, *Tursiops truncatus*, is found along the U.S. Atlantic coast (CETAP 1981, Schmidly 1981), the Gulf of Mexico (Fritts and Reynolds 1981, Schmidley 1981), the Lesser Antilles (Caldwell and Caldwell 1975), and at least as far south as Argentina (Wursig 1978). It is common in the northern Chesapeake Bight (Rowlette 1980) and Virginia's coastal waters (CETAP 1981).

Atlantic bottlenose dolphins were the focus of a sporadic fishery along Hatteras Island, North Carolina (True 1891, Townsend 1914, Mead 1975) from circa 1797 to 1929. Mitchell (1975), from cumulative catch records of this historical fishery, estimated a minimum population size of 13,748 dolphins. Mead (personal communication) and data presented in this work suggest that they are seasonally abundant in Virginia and are part of the same population that occurs seasonally along the North Carolina coast north of Cape Hatteras. Two seasonal peaks in catches of the former fishery—during the fall, the beginning of the season, and spring, the end of the season—are indicative of migration. True's (1891) reports of fishermen's observations that these dolphins were usually seen travelling southerly in the fall and northerly in the spring, with only a few remaining near Hatteras during the summer, are further evidence for a northward spring migration and a southward autumn migration.
Analysis of recent aerial surveys along the northern and mid-Atlantic U.S. coast conducted by the University of Rhode Island suggests a bimodal longitudinal distribution of bottlenose dolphins (CETAP 1981). This they interpreted as separate nearshore and offshore areas of abundance. The nearshore was judged the primary area based on the mode of sightings-by-depth-interval. Multiple peaks of sightings at different latitudes indicated a discontinuous north-south distribution. This suggests the presence of multiple populations or sub-populations contradicting Orr's (Ms) report of a single U.S. Atlantic coast population.

The southern Virginia coastal region and the Chesapeake Bay are being increasingly populated by man. This has led to increased impact on local marine habitats in the form of coastal development (such as bulkheading, dredging, etc.), increased water-born traffic and increased pollution. To what extent these changes affect indigenous marine mammals is difficult to determine if those populations are undefined. Marine mammal strandings could indicate peaks in mortalities, abundance, or both, or could be the result of man's activities. Since implementation of the Marine Mammal Protection Act of 1972, the Federal government has assumed the responsibility for protection of marine mammals, including taking measures to identify and rectify human-marine mammal conflicts. In order to achieve this it was also mandated that marine mammal populations potentially affected adversely by man be identified and quantified so that such impacts might be recognized and avoided.

The major objective of this study was to quantify the occurrence of *Tursiops truncatus* spatially and temporally in the inshore coastal
waters between Cape Charles and False Cape, Virginia, including the Chesapeake Bay mouth, and estimate the population size during the season of maximum abundance. In Virginia, the bottlenose dolphin is most abundant during the summer, which is also the peak period of human habitation in the resort areas along the Virginia coast resulting in a time of increased water-related activities of man.

It was also considered appropriate to determine natality periods and relative abundance of calves, since, as is the case in most large mammals, the young are most subject to high mortalities.

Aerial surveys have been used increasingly in recent years to investigate cetacean abundance. Much of the recent survey work has quantified *Tursiops truncatus* in areas where live-capture operations occur (Leatherwood et al. 1979, Barham et al. 1980, Leatherwood 1979, Odell and Reynolds 1980). Leatherwood et al. (1978) evaluated techniques for aerial censuses of bottlenose dolphins and concluded that strip census (Gates 1979) was the most reliable method of density estimation when the distribution of sighting distances from the transect did not fit well to parametric models. Since then, Burnham et al. (1980) developed a nonparametric approach to line transect data analysis that does not restrict the analyst to parametric models of perpendicular sighting distances. In this study standardized sampling methods (Leatherwood et al. 1978) were used in conjunction with nonparametric line transect analysis methods (Burnham et al. 1980) to establish a minimum population estimate for *Tursiops truncatus* in southern Virginia coastal waters.

Because they are migratory in Virginia, the abundance and distribution of the bottlenose dolphin might be influenced by
environmental factors. Water temperature influences the migrations of many fish species, and thus may indirectly affect the occurrence and distribution of the dolphin population. As air breathing mammals, they may also be affected by air temperatures, perhaps getting their migration cue from either the air temperature or its rate of change. Budget limitations precluded the observation of dolphin distribution on the temporal scale necessary to compare dolphin density relative to sea or air temperature change, but relationships between monthly dolphin density and average monthly sea and air temperatures were investigated.

Understanding what a population estimate represents requires that the residency status of the animals enumerated be known. Observation of bottlenose dolphins at close range allows the recognition of individuals identifiable by marks, cuts and scars on their dorsal fins (Wursig 1978, Shane 1980). Photographs of identifiable dolphins from two successive years were obtained and scrutinized to determine if the same individuals returned the next year. Taken on a random basis, photo-identification of the same individual in successive years provides evidence for a seasonally resident population. These dorsal fin photographs may also be compared with the dorsal fins of dolphins stranded at a later date. If previously identified, this can provide useful information about that particular animal as well as the population in general. A catalog of recognizable dolphin dorsal fins is appended for this purpose.

It seems probable that an increase in stranded dolphins would accompany an increase in dolphin density. The mandates of the Marine Mammal Protection Act of 1972 provide the opportunity for authorized
researchers to investigate marine mammal strandings to determine the cause of death and to collect natural history and morphological data. The author is authorized to examine and necropsy stranded marine mammals in Virginia and North Carolina, the records of which are on file at the Division of Mammals, Smithsonian Institution, Washington, D.C. These records were used in conjunction with monthly population estimates to examine relationships between dolphin density and strandings of individuals.
METHODS

Aerial Surveys

Aerial surveys were conducted during July-October 1980, and May-June 1981, from a high-winged, single-engine aircraft (U6A DeHavilland Beaver in 1980, and Cessna 172 Skyhawk in 1981). An altitude of 152 meters and an airspeed of 148-167 kilometers per hour were maintained during surveys. Two observers positioned on opposite sides of the aircraft visually searched out to about one mile of either side of the aircraft. A recorder/navigator sitting forward of the observers and next to the pilot helped to maintain predetermined transect lines and searched ahead of the aircraft for dolphins. All personnel were in contact with one another via intercom and the same observers participated in all of the surveys.

When dolphins were sighted, the perpendicular distance from the flight path to the herd center was determined from taped markings on the wing struts in 1980 or a hand-held inclinometer (Suunto PM-5) in 1981 while the aircraft was in level flight. The wing strut markings used in 1980 were calibrated with runway markings prior to the first survey flight and left in place throughout 1980. The location, direction of travel and behavior of herds was noted, and the number of dolphins, including the number of calves, was recorded. Because of the difficulty of obtaining accurate counts of herds of more than approximately 150 dolphins, these were estimated to the nearest 50
animals. Transect lengths and the survey area were measured with a
digital planimeter from the appropriate NOS/NOAA navigation charts
using the mean of three readings.

Two types of survey schemes were used depending upon the area
surveyed (Figure 1). Systematic, latitudinally-oriented transects
were flown in the Chesapeake Bay mouth (CBM, Figure 2). The starting
point for each survey was randomized and each transect was 4 nautical
miles from the previous to avoid the possibility of counting the same
dolphins twice. Two exceptions to this regime occurred, but in
neither case was any transect less than 2 nautical miles from the
previous. Three or four transects were flown during each survey and
each survey covered approximately 30 percent of the 762 km$^2$ total
survey area. CBM surveys were flown only in 1980 (Figure 2).

Longshore surveys were flown in 1980 and 1981 parallel to the coast 1
m off the beach from Cape Charles to False Cape except for the transit
between Cape Charles and Cape Henry.

Because of low numbers of sightings in the Chesapeake Bay mouth,
dolphin herd density in this area was estimated using strip census
methodology (modified from Gates 1979). For comparison, longshore
survey data were treated similarly. The data from the 1980 longshore
surveys were sufficient to also estimate density in that area using
line transect analysis (Burnham et al. 1980). Line transect analysis
provides a function to compensate for objects (in this case dolphins)
which were present but not seen.
Figure 1. The Chesapeake Bay mouth survey area (enclosed in dark lines) and the nearshore coastal survey area (shaded area).
Figure 2. Chesapeake Bay mouth transects. The numbers represent the transects flown on separate survey dates.
Data from all CBM surveys were pooled and herd density ($\hat{D}$) was computed as:

$$\hat{D} = n/(2Lw)$$

where $n =$ the number of herds sighted, $L =$ the transect length in kilometers and $w =$ the effective strip width. The effective strip width was truncated at 1 km and represents the distance from the transect line where herd sightings rapidly fell off. Since we were able to see and identify marine turtles (Caretta caretta) at distances approaching 1 km (Blaylock and Byles 1981) this strip width seems reasonable.

The variance of the herd density estimate was calculated by treating each survey as a replicate (replication over time) with:

$$s^2 = \sum (D_i - \hat{D})^2/(y - 1)$$

where $D_i =$ the herd density for each replicate, and $y =$ the number of replicates.

Since it is unlikely that all animals within a strip were seen, the estimate of abundance using strip census methods must be regarded as an absolute minimum.

Line transect methods, as opposed to strip census methods, take into account the reduction in sightability with herd distance from the transect by computing a probability density function [$f(x)$] using a model describing this decrease. Burnham et al. (1980) discuss the theory behind line transect methodology and the reader is referred to their monograph for a detailed discussion.

Two perpendicular sighting distance models were used with the 1980 longshore survey data. The negative exponential model (Gates et al. 1968), modified for grouped, truncated data (Burnham et al. 1980)
was used for comparison to previous surveys undertaken elsewhere. However, because the negative exponential estimator is not robust to pooling of data nor does it satisfy the criteria that the derivative of \( f(0) \) equal 0 (Burnham et al. 1980), the Fourier series estimated \( f(0) \) was used in the final estimate of herd density. Robustness implies that the model is relatively insensitive to slight departures from the inherent assumptions.

Herd sightings were grouped into 200 meter intervals from the transect and truncated at 1 kilometer. The herd density was estimated as:

\[
\hat{D} = \frac{n f(0)}{2L}
\]

For the negative exponential estimator:

\[
f(0) = \frac{g(x)}{u_w}
\]

where \( u_w \) = the integral from 0 thru \( w \) of \( g(x) \), with \( g(0) = 1 \), \( x \) = the perpendicular distance from the transect to the herd, \( w \) = the strip width and \( g(x) = e^{-a}(x) \), where \( a \) = the number of parameters used in the estimation.

With the Fourier series estimator:

\[
f(0) = \frac{1}{[w + \cos(3.14159(x/w))]}.
\]

The results of statistical analyses are reported herein as the probability (P) of observing a deviation as large or larger solely due to chance.
Boat Surveys

Meandering surveys were conducted from a small outboard motor-powered boat on several occasions. Typically, the boat was launched at Lynnhaven Inlet in the morning, run to Cape Henry, to Rudee Inlet (parallel to, and about 1/2 mile from shore), then to Cape Charles and back to Lynnhaven Inlet. When dolphins were encountered, the motor was shut off and the boat allowed to drift near the herd. An attempt was made to count the animals and the time, behavior and direction of travel of the herd were noted. In addition, dorsal fins were photographed for individual indentification where possible. Photographs were taken with a 35 mm camera (Olympus OM-1) equipped with a telephoto zoom lens (Albinar 80-210mm) and automatic film advance (Olympus Winder-1).

Nearby dolphins soon left the vicinity of the boat when it was not underway. Consequently, in 1981, the vessel was run at a slow speed parallel to and near the herd. Even at some distance from the boat, dolphins would usually approach when it was operated in this manner.

In 1981, because of the physical constraints of operating the boat and photographing dorsal fins simultaneously, only cursory data were obtained and efforts were concentrated on photographing dorsal fins.
Shore Observations

Observations of passing dolphins were made from shore at one of two locations manned on an opportunistic basis during the summer of 1980: an abandoned pier on the west side of Fisherman's Island at Cape Charles or a U. S. Navy owned lookout tower at 68th Street in Virginia Beach. Dolphins passing these stations were counted, and the time, behavior and direction of travel noted. Some dorsal fin photographs were taken at Fisherman's Island, but because of the distance of the dolphins from shore, most of these were of little use. For this reason, photography was not undertaken at the Virginia Beach site.

Ancillary Data Collection

There is a gap in recorded sea surface water temperatures available from NOAA in the study area because of the closing of the Chesapeake Bay lighthouse in early 1980. Surface water temperatures were available from the VIMS pier (approximately 7 miles from the York River mouth) and complete sets of monthly average sea water temperatures from the Chesapeake Bay lightship (Lat. 36°54'15.8"N / Long. 75°42'47.1"W) were available for the years 1973 through 1977. Linear regression of the latter (Y) against VIMS pier monthly average sea water temperatures (X) resulted in the relationship

\[ Y = 0.837X + 1.811°C \ (r^2 = 0.94) \]

This relationship was used to estimate the average monthly sea water temperature near the Chesapeake Bay
mouth and nearshore Virginia Beach. Monthly mean air temperatures at Norfolk, Virginia were obtained from the Environmental Data Information Services, NOAA, Asheville, N.C.

It was originally assumed that coastal fronts such as the Chesapeake Bay plume would be visible on enough occasions to examine dolphin distribution in relation to them. However, fronts were only rarely discernable, and on those occasions when dolphins were present they were present in both water masses.

Tidal data obtained from NOAA Tide Tables were used to examine the movement of dolphin herds in relation to tidal stage and direction.

The frequency of dolphin strandings (investigated by the author and on file with the Smithsonian Institution, Anon 1976-1981) linearly regressed against survey-estimated monthly abundance of Tursiops was used to examine the relationship between live dolphin abundance and dolphin strandings. The temporal stranding frequency of Tursiops between North Carolina (north of Ocracoke Island) and Virginia was compared to see if any patterns emerged.
RESULTS

Aerial Surveys

Chesapeake Bay Mouth

Six aerial surveys of the Chesapeake Bay mouth area (Figure 2) during June through August of 1980 covered 716.6 linear km, an average of 119.4 linear km per survey. Each survey represented approximately 31% of the 762 km$^2$ survey area assuming a strip width of 2 km (1 km to each side of the aircraft). A total of five herd sightings resulted in a strip census estimated herd density ($\hat{D}$) of 0.004 herds per km$^2$ ($\pm$ 0.0018 S.E.) (Table 1). Mean herd size ($\overline{H}$) was 32.8 dolphins per herd ($\pm$ 30.70 S.E.). These data result in an estimated dolphin density ($\hat{P}$) of 0.12 dolphins per km$^2$ ($\pm$ 0.092 S.E.).

Southern Virginia Coast

Nine surveys during July through October 1980, and May and June 1981, totaling 559.7 linear km, resulted in 48 herd sightings. The strip census herd density estimate was 0.044 herds per km$^2$ ($\pm$ 0.0023 S.E.) (2 km strip width) with a mean herd size of 33.7 dolphins per herd ($\pm$ 23.97 S.E.). Strip census estimated dolphin density then, was
Table 1. Strip census results from aerial surveys of *Tursiops truncatus* in the Chesapeake Bay mouth and southern coastal waters of Virginia. \( \hat{D} \) represents herd density (herds/km\(^2\)), \( \bar{H} \) is the mean herd size (dolphins/herd) and \( \hat{P} \) is the estimated dolphin density (dolphins/km\(^2\)).

<table>
<thead>
<tr>
<th>Month/year</th>
<th>Survey area</th>
<th>#Surveys</th>
<th>( \hat{D} )</th>
<th>( \bar{H} )</th>
<th>( \hat{P} )</th>
<th>%calves</th>
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<tr>
<td>Jul 80</td>
<td>Bay mouth</td>
<td>2</td>
<td>0.0040</td>
<td>43.5</td>
<td>0.174</td>
<td>11.5</td>
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<tr>
<td>Aug 80</td>
<td>Bay mouth</td>
<td>4</td>
<td>0.0032</td>
<td>25.7</td>
<td>0.008</td>
<td>3.6</td>
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<tr>
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<td>Va. coast</td>
<td>2</td>
<td>0.0441</td>
<td>36.1</td>
<td>1.592</td>
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<tr>
<td>Aug 80</td>
<td>Va. coast</td>
<td>3</td>
<td>0.0445</td>
<td>20.0</td>
<td>0.911</td>
<td>5.1</td>
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<td>Sep 80</td>
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<td>2</td>
<td>0.0441</td>
<td>61.4</td>
<td>2.710</td>
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<td>Oct 80</td>
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<td>0.0401</td>
<td>14.8</td>
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<td>-0-</td>
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<tr>
<td>May 81</td>
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<td>45.0</td>
<td>0.360</td>
<td>-0-</td>
</tr>
<tr>
<td>Jun 81</td>
<td>Va. coast</td>
<td>1</td>
<td>0.0241</td>
<td>37.0</td>
<td>0.892</td>
<td>9.5</td>
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Figure 3. The Fourier series probability density function curve fit to a histogram of the distribution of dolphin herd sightings from the transect \([f(0)=1.838]\).
1.47 dolphins per km$^2$ (+1.041 S.E.) for comparison with Chesapeake Bay mouth density estimates.

Line transect analysis of 1980 coastal aerial surveys resulted in a herd density of 0.081 herds per km$^2$ (+0.0126 S.E.) using the Fourier series estimated $f(0)=1.838$ (Figure 3) to correct for herds present but not seen. Using the negative exponential model (Figure 4) $f(0)=2.733$ and the herd density estimate becomes 0.121 herds per km$^2$ (+0.0282 S.E.). The negative exponential model appeared to better fit the actual distribution of perpendicularly sighting distances than did the Fourier series model ($X^2$, P<.10 vs P<.30), but there was no significant difference between the actual sighting distribution and the model computed distribution with either model (Birnbaum-Hall test, P<.05, Conover 1971). However, for theoretical reasons given in Burnham et al. (1980) and discussed later in this thesis, the Fourier series estimated herd density was used in the model corrected population estimate.

Dolphin density ($\hat{P}$) is the product of the Fourier series-corrected herd density estimate ($\hat{D}$) and the mean herd size ($\bar{H}$). The variance of this product following Goodman (1960, from Leatherwood et al. 1978) is:

$$S^2\hat{P} = \bar{H}^2S^2(\hat{D}) + S^2(\bar{H})\hat{D}^2 - S^2(\hat{D})S^2(\bar{H})$$
Figure 4. The negative exponential probability density function curve fit to a histogram of the distribution of dolphin herd sightings from the transect \[ f(0) = 2.733 \].
The line transect estimated number of *Tursiops* in the southern Virginia coastal region from Cape Charles to Cape Henry, within 2 km of shore, during July through October 1980, was $340 \pm 245$ (S.E.). The 95% confidence interval, assuming asymptotic normality and $Z = 1.96$, is $\pm 72$ dolphins.

**Herd Composition**

Because of the survey altitude observations of herd composition are limited to the relative number of calves per herd. Dolphins obviously much smaller than the others and accompanied by a larger dolphin were considered to be calves. Odell and Reynolds (1980) noted changes in geometric herd structure presumably caused by the aircraft noise at altitude of 305 m, particularly during circling to obtain accurate counts of herd size. We also observed rapid changes in geometric herd structure and behavior from our survey altitude of 152 m. More often than not, dolphins would rapidly dive upon our second approach.

The percentage of calves in dolphin herds showed some change on a monthly basis in the coastal survey area (Table 1). The percentage of calves peaked in June and steadily declined thereafter (Figure 5). The overall mean percentage of calves in herds in the Chesapeake Bay mouth in 1980 was 6.2% ($\pm 7.15$% S.E.) and in the coastal area, 4.9% ($\pm 3.32$% S.E.).
Figure 5. Percent calf composition of herds by month.
Herd Distribution

Dolphins were never sighted more than 1.6 km from shore during Chesapeake Bay mouth surveys nor during subsequent forays up to 8 km offshore of the coastal survey area. Plots of dolphin herds sighted during aerial surveys in 1980 and 1981 (Figure 6A-D) imply a uniform distribution along the southern coastal area although some clumping of herd sightings at Cape Henry and at Cape Charles (Fisherman's Island) is apparent. Dolphins were never sighted in water >10 m deep. However, all of the coastal survey was over water <10 m in depth and only a small portion of the Chesapeake Bay mouth is >10 m deep. Therefore, these data are inconclusive of depth preference of bottlenose dolphins.

Herd density was directly related to sea surface temperature (r=0.87) during May-June 1981 and July-October 1980. Relative to this, there was also a direct relationship between dolphin density and sea surface temperatures (R =0.85). There was no apparent relationship between between air temperature and herd or dolphin density (r=-0.14).

Herd Movement

There was no significant difference between the number of dolphins moving north or south in the coastal area throughout the time frame of this study (t-test, P<.05), but there was a steady decline in northward travel from June through October (Figure 7) (the t' distribution approximates the t distribution when there is
Figure 6, A–D. NOS hydrographic charts of the southern Virginia coastal region showing the distribution of dolphin herd sightings during aerial surveys.
NOTE E
Chesapeake Bay Bridge & Tunnel
(Privately maintained lights)
Trestles A and B—In each trestle section the fixed
navigation openings for small craft consists of a group
of 3 spans. A fixed green light marks centerline of
each span and fixed red lights mark outermost
bridge support piling on each side of the openings.
North Channel & Fisherman Inlet Bridges - A fixed
green light marks each mid-channel, with fixed red
lights marking channel limits. Fixed red obstruction
lights mark each pier in Trestles C and D.
LYNNHAVEN INLET
Lynnhaven Inlet is subject to continual change.
HEIGHTS
Heights In feet above Mean Low Water.

NOTE F
CAUTION
The Chesapeake Bay Bridge Tunnel
complex has on several occasions suffered
damage from vessels due to adverse
weather conditions. Currents in excess of
three knots can be expected in the area.
Mariners transiting this area are urged to be
particularly alert in regards to the weather
situation. The National Weather
Service provides 24 hour weather broad-
casting on 162.55 MHz. The Local Marine
operator also transmits weather informa-
tion at 0700, 1300, and 1900 local
time on 2538 and 2650 kHz. Transmitting
schedules are subject to change, see Notice
to Mariners. Maneuvering in close prox-
imity of the bridge-tunnel complex is
discouraged.
Traffic Separation Scheme

The recommended route for entering or departing from Chesapeake Bay is marked by a tinted purple line centered on a fairway buoy which separates the sides of inbound and outbound vessels. Boats should leave all buoys on their port side. The pilotage area is marked by a tinted yellow line. Traffic within the precautionary area may consist of vessels operating between the Sound Shoals and Chesapeake Channel, and one of the established traffic lanes. Vessels are advised to exercise extreme caution in navigating within this area.

Only marine radio beacons have been calibrated for surface use. Limitations on the use of certain other radio signals as aids to marine navigation can be found in the U.S. Coast Guard Light Lists and Defense Mapping Agency Hydrographic/Topographic Center Publication 117 (A & B). Radio direction-finder bearings to commercial broadcasting stations are subject to error and should be used with caution.

Station positions are shown thus:
- (Accurate location)
- (Approximate location)

Regulations for ocean dumping sites are contained in 40 CFR Parts 220-229. Additional information concerning the regulations and requirements for use of the sites may be obtained from the Environmental Protection Agency (EPA).
DANGER AREA 56
52204.52 (see note A)

False Cape
Sand dunes
False Cape Landing

BACK BAY
NATIONAL WILDLIFE REFUGE
(proposed area)

Monhegan Cove

2 ft
depth

1969

Long Island
Marsh

Redwood Bay

BACK BAY
NATIONAL WILDLIFE REFUGE
(proposed area)
Figure 7. Directed herd movement by month. The points indicate the percent of the total of herds sighted during that month which were travelling either north or south. Where they do not total 100% some herds were not exhibiting directed movement.
heterogeneity of variance between means). This was accompanied by an increase in southward travel in June through October with the exception of the month of September (Figure 7). There was no significant difference in dolphin movement with or against tidal flow in the coastal survey area (t-test, P<.05). The data are insufficient to analyze these factors relative to Chesapeake Bay mouth sightings.

Dolphin Behavior

Complex behavior was observed in 18.2% of the dolphin herds sighted in the coastal survey area. The term "complex" is used here to describe behavior which could be play, mating or feeding behavior. Obvious feeding behavior, where dolphins were observed to be charging into schools of fish, comprised 4% of the complex behavior noted.

In addition to the difficulty of interpreting dolphin behavior from an airplane, their behavior often changed abruptly when the aircraft circled the herd so that individuals could be counted more accurately. Most often, the dolphins would dive and stay submerged until the aircraft passed. This was often preceded by tail-slapping behavior by many individuals.

The most often observed behavior was simply swimming in a highly directional manner which I term travelling. This comprised 81.2% of all behavioral observations and was almost always parallel to shore. Although herd behavior often changed when the aircraft neared, when first sighted the travelling herds were usually composed of many smaller groups of closely spaced individuals. These groups most often
consisted of 3-6 individuals, but could be a single animal or a group of 10-12 as well. Groups such as these were separated by distances as close as a few meters or as distant as several tens of meters. Herds were occasionally more than a kilometer in length, but never more than a few tens of meters in width.

No significant associations between dolphins and birds, herptiles or other marine mammals were observed, nor were any other species of marine mammal seen during aerial surveys.

**Small Boat Surveys**

In 1980, 27.25 hours of meandering surveys resulted in 4 dolphin herd sightings. In 1981, 12 herds were sighted during 40.5 hours of meandering boat surveys (Table 2). The mean herd sizes estimated from these surveys—39.3 dolphins per herd in 1980 and 42.6 dolphins per herd in 1981—should be viewed with caution. Lear and Bryden (1980) discussed the considerable difficulty of obtaining accurate counts of dolphins from small boats. The problem is even more severe when the observer is attempting to simultaneously count and photograph individual dolphins. Furthermore, bottlenose dolphins often approach small boats (personal observations) thus biasing any abundance estimate based on such surveys. Because of this, and to better concentrate on photographing dorsal fins for identification of individuals, only cursory attempts were made to count dolphins encountered during the small boat operations.

Nicks and cuts in the trailing edge of dolphins' dorsal fins and misshapen and abberant dorsal fins have been used to identify
Table 2. Boat survey results (FI=Fisherman's Island, LC=Little Creek, CH=Cape Henry, ER=Elizabeth River, CBBT=Chesapeake Bay Bridge-Tunnel, RUDEE=Rudee Inlet, LYNN=Lynnhaven Inlet, VB=Virginia Beach, VIMS=Virginia Institute of Marine Science).

<table>
<thead>
<tr>
<th>Date</th>
<th>Locations</th>
<th>Obs. Hrs</th>
<th># Dolphins</th>
<th># Herds</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 Aug 80</td>
<td>ER</td>
<td>3.0</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>6 Sep 80</td>
<td>LYNN-RUDEE-LYNN</td>
<td>4.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7 Sep 80</td>
<td>LYNN-CH-LYNN</td>
<td>7.5</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>13 Sep 80</td>
<td>LYNN-FI-CH-LYNN</td>
<td>6.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14 Sep 80</td>
<td>LYNN-CH-FI-LYNN</td>
<td>5.3</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Totals 1980</td>
<td></td>
<td>27.4</td>
<td>157</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Average herd size 1980=39.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 Jul 81</td>
<td>LC-FI-CBBT-LC</td>
<td>8.0</td>
<td>33</td>
<td>2</td>
</tr>
<tr>
<td>15 Jul 81</td>
<td>LC-CH-LC-VB-LC</td>
<td>10.0</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>27 Jul 81</td>
<td>LYNN-CH-FI-LYNN</td>
<td>7.5</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>28 Jul 81</td>
<td>LYNN-CH-RUDEE-CH-LYNN</td>
<td>4.8</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>5 Aug 81</td>
<td>RUDEE-CH-RUDEE</td>
<td>5.0</td>
<td>120</td>
<td>1</td>
</tr>
<tr>
<td>7 Aug 81</td>
<td>RUDEE-CH-CBBT-VIMS</td>
<td>5.3</td>
<td>230</td>
<td>3</td>
</tr>
<tr>
<td>Totals 1981</td>
<td></td>
<td>40.6</td>
<td>506</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Average herd size 1981=42.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
individual dolphins (Wursig 1978, Shane 1980). During 1980, 422 photographs (35 mm) were taken of dolphins in the study area from small boats. Of these, 60% were not useable (out of focus, wrong exposure, etc., or the dolphin dove), leaving 167 useable photographs including those of 7 recognizable individuals. Photographs were useable if at least the outline of the dorsal fin was discernable when contact printed and viewed under 40X magnification. In 1981, a total of 764 photographs resulted in 579 (~76%) useable photographs, 17 of which were of recognizable individuals. Out of the total of 24 recognizable individuals photographed in those two years, 5 (~21%) were observed both years (Figure 8a-e). Appendix A catalogs all of the individuals identifiable from dorsal fin photographs taken during this study.

Shore Based Observations

Observations from the pier at Fisherman's Island yielded approximately 50% more sightings per hour than those from the lookout tower at Virginia Beach (Table 3). The average number of dolphin herd sightings (or of lone dolphins) was 0.30/hr at Virginia Beach and 0.48/hr at Fisherman's Island. A total of 49.5 hours of observation over 7 days at both locations yielded 20 dolphin herd sightings for an average of 0.40 observations/hr. Some photographs were taken with a telephoto lens at the Fisherman's Island station but were not useful for individual identifications because of the distance of the dolphins from the observer. Photographs were not attempted at Virginia Beach because the lookout tower at Virginia Beach is approximately 24 m in
Figure 8 a-e. Dolphins sighted in successive years, recognizable by distinctive dorsal fins. Photographs with the same letter prefix are of the same individual. Different numbers indicate photographs taken in different years. The lines indicate features used in identification.
Table 3. Shore-based dolphin observations. Va. Bch. refers to the lookout tower at 69th street in Virginia Beach and Fish. I. refers to Fisherman's Island at Cape Charles.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Obs. time</th>
<th>No. observations</th>
<th>No. dolphins</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 Jul 80</td>
<td>Va. Bch.</td>
<td>5.7 hr</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>26 Jul 80</td>
<td>&quot;</td>
<td>5.3</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3 Aug 80</td>
<td>&quot;</td>
<td>6.0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>20 Jun 80</td>
<td>Fish. I.</td>
<td>6.0</td>
<td>3</td>
<td>69</td>
</tr>
<tr>
<td>21 Jun 80</td>
<td>&quot;</td>
<td>9.5</td>
<td>3</td>
<td>37</td>
</tr>
<tr>
<td>22 Jun 80</td>
<td>&quot;</td>
<td>9.5</td>
<td>4</td>
<td>84+</td>
</tr>
<tr>
<td>5 Jul 80</td>
<td>&quot;</td>
<td>7.5</td>
<td>5</td>
<td>236+</td>
</tr>
</tbody>
</table>
height, about 150 m from the shoreline and the dolphins were usually at least 600 m offshore. Thus, the distance from the observer to the dolphins was usually greater than 650 m.

Strandings

During 1980 and 1981, 13 Tursiops truncatus were reported stranded on beaches in Virginia. Of these, 12 were retrieved, examined and reported to the National Marine Fisheries Service and the Smithsonian Institution Scientific Event Alert Network (SEAN). One of the stranded animals had apparent shark inflicted wounds, but it was not possible to determine whether these had been inflicted pre- or post-mortem. Two others had what appeared to be net marks but the cause of death was not determined.

A compilation of the relative number of Tursiops truncatus strandings by month in North Carolina (north of Ocracoke Island) and Virginia for the years 1976 through 1981 (Figure 9) from files of the Division of Mammals, Smithsonian Institution (Mead, personal communication) shows a lag of approximately one month between spring/summer peaks in strandings between the two areas. However, there was no apparent relationship between dolphin or dolphin herd density and dolphin strandings in Virginia in 1980 and 1981.
Figure 9. *Tursiops truncatus* strandings by month, relative to the overall total number of strandings, in North Carolina (north of Ocracoke Island) and Virginia, 1976-1981 composite.
RELATIVE NUMBER OF STRANDINGS

N.C. (n=59)
Va. (n=36)

MONTHS (1978-1981)

RELATIVE NUMBER OF STRANDINGS

N.C. (n=59)
Va. (n=36)

MONTHS (1978-1981)
DISCUSSION

Herd Density and Distribution

Dolphin herd density in the Chesapeake Bay mouth (based on the strip census estimate) was significantly lower than in the southern Virginia coastal survey area (t-test, P<.01). Inshore *Tursiops truncatus* are found close to the beach in this area (CETAP 1981) and are generally found within 1.6 km of shore along the Virginia coast (personal observations). Preliminary flights along the perimeter of the Chesapeake Bay mouth survey area prior to the coastal surveys provided no evidence to refute the Chesapeake Bay mouth survey results. That is to say, herd density was still low even when flying only nearshore in that area.

There was no significant difference in mean herd size (t-test, P<.05) nor in the calf composition of herds (t-test, P<.05) between the Chesapeake Bay mouth and the southern Virginia coastal survey areas. This suggests that the *Tursiops truncatus* found in the Chesapeake Bay during the late summer may be a component of the coastal population. This may seem obvious since bottlenose dolphins do not appear in the Chesapeake Bay until late summer when coastal *Tursiops* are abundant.

Table 4 is a compilation of bottlenose dolphin sightings solicited from residents, commercial fishermen and Virginia Institute
TABLE 4. Incidental sightings of *Tursiops truncatus* reported by commercial fishermen and V.I.M.S. researchers in the Chesapeake Bay.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location where sighted</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Jul 81</td>
<td>York River near Glouc. Pt.</td>
<td>B. Meehan, VIMS</td>
</tr>
<tr>
<td>29 Aug 81</td>
<td>York River bridge</td>
<td>D. Estes, VIMS</td>
</tr>
<tr>
<td>3 Sep 81</td>
<td>York River mouth</td>
<td>R. Byles, VIMS</td>
</tr>
<tr>
<td>4 Sep 81</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>30 Jul 82</td>
<td>Rappahannock River</td>
<td>H. Krause, fisherman</td>
</tr>
<tr>
<td>23 Aug 82</td>
<td>York River mouth</td>
<td>R. Byles, VIMS</td>
</tr>
<tr>
<td>18 Sep 82</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>26 Aug 83</td>
<td>York Spit Light</td>
<td>&quot;</td>
</tr>
<tr>
<td>23 Sep 83</td>
<td>New Point Light</td>
<td>&quot;</td>
</tr>
<tr>
<td>2 Oct 83</td>
<td>Bouy 9 near York R.</td>
<td>&quot;</td>
</tr>
<tr>
<td>2 Oct 83</td>
<td>near York R. mouth</td>
<td>&quot;</td>
</tr>
<tr>
<td>18 Oct 83</td>
<td>Middle Ground</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
of Marine Science researchers in the Bay. Note that all of these sightings occur in the late summer. A plot of these observations and boat and aerial survey sightings (Figure 10) reveals a widely scattered distribution in the lower Chesapeake Bay. Small herds were reported from the western portion of the Bay (3-30 individuals), whereas much larger herds of several hundred animals have been observed in the eastern portion (nearer the ocean). This suggests that the dolphins enter the Bay en masse, then disperse.

Bottlenose dolphins frequently enter bays and estuaries (Caldwell and Caldwell 1972, Hogan MS) and in the Chesapeake Bay may often travel as far north as the Rappahannock River, the Mobjack Bay and the York River (see Table 4). During the time of this study, I observed a group of approximately 60 *Tursiops* in the Elizabeth River at Norfolk, Virginia. On another occasion (also during the time-frame of this study), I observed a single, live, apparently healthy *Tursiops* in Cypress Creek, near Smithfield, Virginia, approximately 15 miles inland. The single animal was undoubtedly a stray, but I can only speculate on the possible reasons for groups of bottlenose dolphins entering the Chesapeake Bay and its tributaries.

The most obvious reason for groups of bottlenose dolphins to enter the Chesapeake Bay is in search of prey or as the result of following schools of fish entering the Bay. Atlantic croaker (*Micropogon undulatus*), spot (*Leiostomus xanthurus*) and sea trout (*Cynoscion sp.*), reported to be the main prey of *Tursiops* in this area (Leatherwood et al. 1977), are abundant in the Chesapeake Bay during the summer months. The higher *Tursiops* density in the southern
Figure 10. Chart of the distribution of *Tursiops truncatus* sightings in the Chesapeake Bay and southern Virginia coastal region.
Virginia coastal survey area suggests that prey are plentiful there as well, but competition is much higher.

Another, perhaps anthropomorphic, possibility might be that entering brackish water may rid dolphins of the commensal barnacle *Xenobalanus cf. X. globicipitis*. However, it is not anthropomorphic to suggest that the presence of these barnacles may be bothersome to the dolphins in light of the reported sensitivity of their skin (Slijper 1962). It has also been suggested that dolphins change the surface configuration of their skin to achieve laminar flow (Purves 1963) implying that they are (at least subconsciously) aware of their swimming efficiency. Removal of these commensals could possibly improve swimming efficiency. Furthermore, dolphins held in fresh water soon begin to slough skin. It is possible that this could cause the removal of these barnacles, but this has not been proven by experiment nor by observation. However, I have not observed a stranded dolphin in the Chesapeake Bay with these barnacles attached, although the calcareous attachment points still present indicated that the dolphin once carried the barnacles. I have, however, often seen stranded bottlenose dolphins along Virginia Beach with these barnacles (often numerous) still attached several days post-mortem.

Two peaks in the monthly mean herd size—in May and September (Figure 11)—suggest that these are the peak periods of *Tursiops truncatus* migration along Virginia's coast. Herd density is relatively constant from July through October, but dolphin abundance peaks in July and September. These data suggest that the dolphins form larger herds during migration which split up into smaller, more
Figure 11. Histograms of herd density ($\hat{D}$), mean herd size ($\bar{H}$) and dolphin density ($\hat{P}$)—strip census estimates from coastal aerial surveys—by month.
widely dispersed herds in areas of seasonal residency. The decline in
dolphin density in August could indicate dispersal of small herds into
the Chesapeake Bay and its tributaries. The stability in herd density
from July through August, coupled with the decline in dolphin density
in August, supports the idea of smaller, widely dispersed herds. The
step-wise increase in dolphin density and the decrease in average herd
size from May through July, when compared with the dramatic increase
in both in August, suggests a protracted northerly spring migration
and an abrupt southerly fall migration.

**Population Estimate**

That 5 of the 7 individuals identified by their dorsal fins in
1980 were resighted in 1981 is evidence that some of the bottlenose
dolphins in Virginia's nearshore coastal waters are seasonal
residents. The probability of such resightings would be exceedingly
low if all of the dolphins were transient. It may be assumed then,
for purposes of population estimation, that at least a portion of the
bottlenose dolphins in the southern Virginia nearshore coastal region
form a seasonally resident population. However, such an estimation is
valid only for that area surveyed, a 62.3 km strip 2 km in width,
alongshore from Cape Charles to False Cape, Virginia, during July
through September, 1980.

The theory behind line transect methods of estimation of animal
abundance is discussed in detail by Burnham et al. (1980). Because
the negative exponential model is not robust to pooling of data, is
not model robust, and does not satisfy the shape criteria that the
derivative of the correction factor \( f(0) = 0 \), it is not appropriate for use in line transect abundance estimates even if the model otherwise fits the data. However, it has been used in estimates of bottlenose dolphin abundance elsewhere, therefore was computed here for comparison (Table 5).

The final estimate of *Tursiops truncatus* abundance is based on the Fourier series model because it meets the aforementioned criteria, but should be considered a minimum for several reasons. These include the assumptions which are inherent to line transect theory and the fact that some of them are difficult, if not impossible, to meet in aerial surveys of marine mammals.

The first basic assumption in line transect theory is that all objects on the transect line are never missed (i.e. \( g(0) = 1 \)). In this study, an observer (also serving as recorder) sat in front and scanned ahead of the aircraft for dolphins. This may have helped reduce the number of missed sightings, but there is no way to verify this. Other surveys have utilized aircraft with forward visibility afforded by a clear nose cone in which an observer sat (CETAP 1981, Fritts and Reynolds 1981). Others have displaced \( g(0) \) to the sides of the aircraft where visibility was assured (Thompson 1981). Because in this study when one observer sighted a herd near the transect line the other observer also saw a herd near the transect on the opposite side, we recorded this as one herd sighting, and I am reasonably certain that most herds were counted. However, there is no way to be sure that single dolphins were sighted when they were directly on the transect line.
Table 5. Some density estimates of bottlenose dolphins in the U.S. Atlantic and Gulf coasts.

<table>
<thead>
<tr>
<th>Location</th>
<th>Dates</th>
<th>Type Survey</th>
<th>Dolphins/km²</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippi</td>
<td>1975</td>
<td>Strip</td>
<td>0.23</td>
<td>Leatherwood</td>
</tr>
<tr>
<td>Gulf Coast</td>
<td></td>
<td></td>
<td></td>
<td>et al. 1978</td>
</tr>
<tr>
<td>Louisiana</td>
<td>1975</td>
<td>Strip</td>
<td>0.44</td>
<td>&quot;</td>
</tr>
<tr>
<td>Gulf Coast</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fla. Gulf Coast: June</td>
<td>1975-</td>
<td>Strip</td>
<td></td>
<td>Odell and</td>
</tr>
<tr>
<td>Panhandle</td>
<td>May 1976</td>
<td></td>
<td>0.12</td>
<td>Reynolds</td>
</tr>
<tr>
<td>Peninsula</td>
<td></td>
<td></td>
<td>0.06</td>
<td>1980</td>
</tr>
<tr>
<td>Indian-Banana R. Aug</td>
<td>1977</td>
<td>Strip</td>
<td>0.68</td>
<td>Leatherwood</td>
</tr>
<tr>
<td>Complex, Fla.</td>
<td></td>
<td></td>
<td></td>
<td>1979</td>
</tr>
<tr>
<td>Port Aransas-</td>
<td>Mar-Apr</td>
<td>Strip</td>
<td>0.75</td>
<td>Barham, et</td>
</tr>
<tr>
<td>Matagorda, Tex.</td>
<td>1978</td>
<td></td>
<td></td>
<td>al. 1980</td>
</tr>
<tr>
<td>Indian-Banana R. May</td>
<td>1980</td>
<td>Line Transect</td>
<td>0.88</td>
<td>Thompson 1981</td>
</tr>
<tr>
<td>Complex, Fla.</td>
<td>Aug 1980</td>
<td>&quot;</td>
<td>1.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nov 1980</td>
<td>&quot;</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>Southern</td>
<td>Jul-Oct</td>
<td>Line Transect</td>
<td>0.12</td>
<td>This thesis</td>
</tr>
<tr>
<td>Virginia Coast</td>
<td>1980</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Another assumption which was easily met because of the speed of the aircraft is that all objects are fixed at the time of initial sighting and are not counted twice. Since the aircraft was travelling at 148-167 km/hr and transects were separated by at least 2 nautical miles, and in most cases 4 nautical miles, there is little likelihood that any dolphins were counted twice.

A third assumption of line transect theory is that no measurement errors occur. We used taped wing strut markings during the 1980 surveys requiring rounding to the nearest 5 degree, so there is no doubt that the sighting distances are somewhat inaccurate for those data. Furthermore, it was also neccessary to estimate the numbers of animals in very large herds. In 1981, perpendicular sighting distances were measured with an inclinometer, possibly reducing the sighting measurement error.

Sightings must be independent of one another for accuracy in line transect estimation of animal abundance. This is most applicable to species which flee in response to the presence of the investigator thereby becoming momentarily more visible. With bottlenose dolphins, the opposite is more likely the case. As previously noted, dolphins would often dive upon the approach of the aircraft. However, they must return to the surface to breathe and can then be counted.

The probability of sighting is assumed to be independent of herd size. Intuitively, it would seem apparent that the larger the herd, the greater the possibility of sighting it. However, in this study there was no relationship between herd size and perpendicular sighting distance (r=0.09).
Distribution Relative to Sea and Air Temperatures

The relationship between dolphin density and seawater temperature underscores the significance of the relationship between herd density and seawater temperature. This supports the premise of dispersal into smaller, scattered herds. The relationship between herd density and seawater temperature is probably not directly causal, but is more likely related to the distribution and abundance of the bottlenose dolphins' prey. Fish are known to migrate in response to changes in seawater temperature. If dolphin distribution is directly related to prey distribution and abundance the lack of a significant relationship between dolphin distribution and abundance and air temperature is moot.

Natality

The peak in the percentage of calves in dolphin herds in June suggests a high level of births in the spring. There was no significant correlation however, between the percentage of calves present and mean herd size, herd density or dolphin density.

Mead (1975), citing True (1891), states that "Information received from the fishermen at the Hatteras fishery indicated that fetuses were generally small in September, increasing in size as the season progressed". This, as well as Townsend's (1914) data (also cited in Mead 1975), suggests an autumn peak in bottlenose dolphin births in this population. However, according to Essapian (1963) mating of bottlenose dolphins occurs in the spring and birth occurs
about one year later (McBride and Kritzler 1951, Tavolga and Essapian 1957). The data presented here tend to confirm a spring natality peak, but neither confirm nor refute the possibility of a second, autumn peak in natality.
SUMMARY AND CONCLUSIONS

1) *Tursiops truncatus* density in the Chesapeake Bay mouth during the summer of 1980 was estimated at 0.12 dolphins per km$^2$ ($\pm$ 0.092 S.E.), an order of magnitude less than the estimated density of coastal *Tursiops*—1.47 dolphins per km$^2$ ($\pm$ 1.041 S.E.). These are strip census density estimates since herd density in the Chesapeake Bay mouth was too low for use of line transect methods.

2) The coastal Virginia *Tursiops truncatus* population was estimated at 340 individuals ($\pm$ 72, 95% confidence limits) using line transect analysis and the Fourier series estimated $f(0)=1.838$ to correct for dolphins present but not seen during aerial surveys.

3) Calves comprised 6.2% ($\pm$ 7.15% S.E.) of the herds in the Chesapeake Bay mouth and 4.9% ($\pm$ 3.32% S.E.) in the southern Virginia coastal survey area. The highest percentages of calves were seen in the early summer indicating a spring natality peak.

4) There was no relationship between reported *Tursiops* strandings and *Tursiops* density estimated from aerial surveys.

5) There was a relationship between *Tursiops* density and seawater temperature, probably in response to prey distribution.

6) The *Tursiops* found Virginia’s coastal waters, including the Chesapeake Bay, appear to be seasonally resident in the summer, immigrating in the spring and emigrating in the fall from and to more southerly areas.
7) More data are needed to further characterize this population. In particular, the following is needed:

   a) Additional aerial surveys to better enumerate the dolphin density.

   b) Radio-tracking studies to determine the extent of their migration.

   c) Additional photo-identification studies to provide information on the length of individuals' residency, social interactions and herd composition.
APPENDIX

Catalog of Identifiable Individual Dolphins
### Key to Dorsal Fin Photographs

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Key to Dorsal Fin Photographs continued...

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Univ. New York, Stoney Brook.
Robert Alvie Blaylock III