NOAA TECHNICAL MEMORANDUM NMFS-SEFSC 476

VHF-Radio Tracking of a North Atlantic Right Whale (*Eubalaena glacialis*) Female and Calf in the Calving Ground: Preliminary Results -January 1999

Christopher K. Slay[1]
Steven L. Swartz[2]
Amy Knowlton[1]
Stephanie Martin[1]
Joseph Roman[1]
Anthony Martinez[2]
James Tobias[2]

[1] Edgerton Research laboratory, New England Aquarium, Central Wharf,
Boston, Massachusetts 02110

[2]Southeast Fisheries Science Center, NOAA Fisheries
75 Virginia Beach Drive, Miami, Florida 33149

U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Conrad Lautenbacher, Jr., Under Secretary for Oceans and Atmosphere

NATIONAL MARINE FISHERIES SERVICE
William Hogarth, Assistant Administrator for Fisheries

January 2002

This Technical Memorandum series is used for documentation and timely communication of preliminary results, interim reports, or special-purpose information. Although the memoranda are not subject to complete formal review, editorial control, or detailed editing, they are expected to reflect sound professional work.

NOTICE

This report should be cited as follows:

Slay, C.K., S.L. Swartz, A.R. Knowlton, S.Martin, J. Roman, A. Martinez, and J. Tobias. 2002. VHF-Radio Tracking of a North Atlantic Right Whale (*Eubalaena glacialis*) Female and calf in the Calving Ground: Preliminary Results 1999. NOAA Technical memorandum NMFS-SEFSC-476, 21pp.

This report has an internal document No. PRD-01/02-04

IWC Scientific Committee Document Ref: SC/51/CAWS-5

Copies of this report can be obtained from:

Director, Protected Resources Branch or
Southeast Fisheries Science Center
NOAA Fisheries
75 Virginia Beach Drive
Miami, FL 33149

National Technical Information Center
5825 Port Royal Road
Springfield, VA 22161
(703) 605-6000, (800) 553-6847
Http://www.ntis.gov/numbers.htm

ABSTRACT

A VHF transmitter was attached to a North Atlantic right whale cow on January 20, 1999, approximately 30 NM (nautical miles) east of Fernandina Beach, Florida. The whale and her calf were tracked continuously for 44 hours, when tracking was abandoned due to bad weather. The pair was relocated on January 25, 1999 and tracked continuously for an additional 96 hours. This report presents data from those two tracking episodes, giving fine-scale movement, swim speed and comparing day and night surface/dive intervals. Information on the duration of the whales= time at the surface and behavior is relevant to right whales= vulnerability to collisions with ships and sightability by aerial surveys designed to reduce the potential for ship/whale collisions.

INTRODUCTION

The North Atlantic right whale *(Eubalaena glacialis*) population, less than 350 individuals, is showing no signs of recovery (Caswell, et al, 1999) while southern hemisphere populations appear to be growing about 6%-7% per year. Failure to show signs of recovery, despite international protection since 1937, has been attributed to a variety of factors, including the effects of human activity on mortality rates (Reeves et al., 1978; Kraus et al., 1988a, Kenney and Kraus, 1992). Ship collisions kill more right whales than do any other documented cause of mortality. Of the 17-anthropogenic right whale moralities documented since 1970, 15 were due to collisions with vessels.

North Atlantic right whales give birth and over winter in the near shore coastal waters between Savannah, Georgia, and West Palm Beach, Florida, with an area of high-density occurring along sixty miles of coastline between Brunswick, Georgia, and St. Augustine, Florida. Three major ship channels, serving three commercial shipping ports and two military bases, transect this high-density area. Since 1988, a total of 7 ship/whale collisions, including 4 moralities, are known to have occurred in this region.

Since 1994, aerial surveys, dubbed Early Warning System (EWS) surveys, have been conducted during the calving season to locate right whales and provide whale detection services to all mariners in the calving ground, including the Navy, the Army Corps of Engineers, port authorities, harbor pilots, and the Coast Guard. These groups use the sighting information to decrease the potential for collisions with right whales. For example, sea-going dredges under contract to the Army Corps of Engineers, some capable of speeds up to 14 knots (26 km/hr), must slow to five knots during nighttime or limited visibility operation during the 24 hour period following a right whale sighting within 15 NM of the dredging transit zone. (Slay, et al, 1998)

To better understand the vulnerability of calving right whales and the effectiveness of current mitigation strategies, the New England Aquarium and the National Marine Fisheries Service implanted a VHF-radio transmitter into the blubber layer of a right whale cow during the 1999 calving season. By tracking this animal and continuously monitoring signals from the transmitter the whale's surface/dive behavior, fine-scale movement and swimming speed were documented. This provided information on the duration of time the whale remained on the surface and vulnerable to collisions with ships, its availability to be sighted by aerial surveys, and how far it might move in a 24-hour period. Of additional interest were certain temporal or spatial variables, which are associated with increased vulnerability. For example, do calves tend to nurse more at certain times than others? Do female whales with calves sleep at the surface at specific times? Are there specific behaviors associated with water depth or other oceanographic features which increase the vulnerability of these animals to ship strikes?

A right whale cow, #1612, was tagged with a VHF transmitter on January 20, 1999 approximately 30 NM east of Fernandina Beach, Florida. She and her calf were then tracked continuously for 44 hours, when tracking was abandoned due to bad weather. The right whale pair was relocated on January 25, 1999 and tracked continuously for an additional 96 hours. This report presents data from those two tracking episodes, giving fine-scale movement, swim speed and comparing day and night surface/dive intervals.

METHODOLOGY

The study area was located between Brunswick and St. Augustine because calving right whales concentrate within 20 NM of that coastline during the peak of the calving season. (Slay, et al, 1998). This also allowed the use of the EWS aerial surveys, conducted over this area daily from December 1 - March 31 each year, to locate right whales for tagging.

The tag used for this project consisted of a Telonics[1] uMK7 transmitter housed in a surgical-quality, stainless steel cylinder, the anterior end of which was conical and held stainless steel cutting edges to allow for penetration through the skin and into the blubber. Immediately aft of the blades were stainless steel wire barbs to prevent the tag from dislodging. The overall length of the tag was 8.5 cm and the outside diameter was 1.9 cm. A 14-cm coil spring/urethane coated antenna protruded from the anterior end of the tag and proved to be durable, returning to its upright orientation after being bent by contact between mother and calf. The 148.600 MHz transmitter was powered by lithium batteries and emitted a 20mW signal in 20 msec pulses every 600 msecs.

The tag was attached to an aluminum arrow shaft with a friction fit plastic coupling. Upon impact with the whale the coupling released the tag, leaving it imbedded in the whale's skin and blubber. Tagging was conducted from the bow of a 5.5-m rigid-hull inflatable boat powered by a four-stroke 90 horsepower outboard. Approaches to the whale were made at idle speed and were aborted if the whales reacted, in order to wait for another attempt when they had resumed resting at the surface. The four-stroke engine is much quieter than traditional two-stroke outboards making close approaches to whales easier. Prior to tagging, photographs and videotape were obtained to verify the whale=s identification as #1612.

Subsequent tracking of the tagged whale and its calf was conducted from the *R.V. Jane Yarn*, a 20 meter, steel hull, converted Navy transport vessel, owned and operated by NOAA=s Gray=s Reef National Marine Sanctuary. The vessel was fitted an A-frame, aluminum flying bridge on the bow which provided a 1 meter x 1.5 meter platform, 4 meters above the waterline, to accommodate two observers. Behavior information recorded during daytime included: magnetic bearing and distance from the vessel, surface behavior (e.g., resting, nursing, rolling, swimming, etc.). The bow observers utilized a Yagi antenna mounted on a 2-m mast that could be rotated 360 degrees. The antenna was attached to

---

[1] The use of trade names in this report does not constitute the endorsement of the U.S. National Marine Fisheries Service.

an Advanced Telemetry Systems Receiver (ATS)[2] receiver which allowed them to quickly locate the whale visually and to correlate signals received with observed behavior.

The primary radio receiving system included an array of four 2 m Yagi antennas oriented 90 degrees apart (i.e., one directed at the bow, stern, port beam, starboard beam). This array was mounted on a 8-m mast fixed to the center of the vessels upper deck. This antenna array was approximately 10 meters above the waterline. The antenna array was connected to an ATS radio receiver located in the vessel's wheelhouse. The four antenna leads were coupled to an ATS Automatic Direction Finding unit (ADF). The ADF processed the radio tag signals and indicated which of the four antennas in the array was receiving the strongest signal. This allowed the vessel crew to maintain the same general course as that of the whale during night and during periods of limited daytime visibility (e.g., fog). The ADF also provided a measure of relative received signal strength, which was equated with distance from the vessel during daytime observations, and allowed the vessel crew to estimate distance to the whale during nighttime. At all times the vessel remained at least 0.5 km or greater distance from the whale to minimize influencing the whale's behavior.

Each surfacing and dive as inferred from the received radio signals were logged on a notebook computer running a data-logging program. The data-logging program automatically recorded time of surfacing, duration of surfacing, time of dive, and duration of dive. The program allowed the computer operator to also enter vessel position, environmental conditions, and notes. A second written data long was also maintained as a backup to the computer data logging system and for recording additional notes and commentary.

RESULTS

There were fewer right whales sighted in the winter calving ground off the southeastern United States in 1999 than in any season since 1991, despite the fact that aerial survey effort was greater this winter than in any previous season. Since the beginning of the systematic EWS aerial survey in 1994, an average of 68 right whale sightings was obtained each season. The 1999 EWS aerial survey effort produced only five sightings, which included only three mother-calf pairs. Thus, opportunities for tagging whales were limited.

On January 20, 1999 whale #1612 was located approximately 30 NM offshore of Fernandina Beach, Florida at 1426 hours. The pair was observed logging (resting) at the surface. Photographs and video were obtained of the whales before making approaches to attach the tag. The VHF radio tag was applied to the whale at 1503 hours, and at the location N 30E 35.5 x W 080E 55.2. The

[2] The use of trade names in this report does not constitute endorsement of the U.S. National Marine Fisheries Service.

placement of the tag on the whale was approximately 2.5 m behind the blowholes and 0.5 m left of the dorsal midline. Antenna orientation was 10 degrees off vertical and all but 1 cm of the tag penetrated below the surface of the whale's skin. The pair swam away immediately after tagging but there was no other apparent response to the event. At 1510 hours #1612 was observed resting at the surface and the calf was nursing. Strong signals were received and monitored from the inflatable. At approximately 1530 hours the primary tracking vessel, the R.V. Jane Yarn, arrived at the location of the tagged whale and assumed the primary tracking of its movements.

A total of 140 hours of continuous tracking yielded 132 hours of surface and dive behavior information as monitored from the radio tag signals during two tracking episodes. The first episode began at approximately 1600 on January 20, 1999, the day the whale #1612 was tagged, and continued until approximately 1400 on January 22, 1999 when the tracking vessel was forced ashore by deteriorating weather. The second tracking episode began at approximately 1500 on January 25, 1999 and continued until approximately 1400 on January 29, 1999.

The 132 hours of radio tag monitoring information included 827 surface and dive intervals by whale #1612 (Figures 1 and 2). The mean length of the surface intervals was 3.19 minutes (CV 1.60) with a 95% confidence interval from 2.84 minutes to 3.54 minutes and a maximum surface interval of 66.30 minutes (Table 1). The mean length of dives was 5.52 minutes (CV 0.91) with a 95% confidence interval from 5.18 minutes to 5.86 minutes and a maximum dive of 28.30 minutes. Visual observations during daylight hours confirmed that patterns of surfacings and dives less than approximately 1- minute were the result of whale #1612 bobbing at the water's surface and submerging the radio tag's antenna. An analysis of surface and dive intervals > 1 minute gave a mean surface interval of 4.69 minutes (CV 1.25, N= 530) with a 95% confidence interval from 4.19 minutes to 5.19 minutes with a maximum surface interval of 66.30 minutes. The mean for dives > 1 minute was 7.04 minutes (CV 0.68, N= 636) with a 95% confidence interval from 6.66 minutes to 7.41 minutes with a maximum dive of 28.30 minutes

If you assume these short surfacings and short dives of < 1 minute in duration represent continuous periods at the surface, mean total time at the surface (TTS) can be estimated by combining the means for surface and dives < 1 minute long with the mean for surface intervals > 1 minute. The mean for surface intervals < 1 minute is 0.50 minutes, the mean for dives < 1 minute is) 0.47 minutes, and the mean for surface intervals > 1 minute is 4.67 minutes, for a TTS of 5.64 minutes compared to the mean for dive intervals > 1 minute of 7.03 minutes This suggests that Right Whale #1612 spent approximately 45% of the time at the surface and approximately 55% below the surface on dives longer than 1 minute.

One objective of this program was to determine whether surfacing and dive behavior differed during daylight and nighttime hours. For this comparison the surface-dive data were sub-sampled into daylight (0700-1800) hours and nighttime (1900-0600) hours. The mean daytime surfacing interval was 2.82 minutes (CV 1.42) with a 95% confidence interval from 2.43 minutes to 3.22 minutes (Table 1).

The mean nighttime surface interval was 3.54 minutes (CV 1.68) with a 95% confidence interval from 2.97 minutes to 4.11 minutes The mean daytime dive interval was 5.43 minutes (CV 0.97) with a 95% confidence interval from 4.29 minutes to 5.94 minutes. The mean nighttime dive interval was 5.602 minutes (CV 0.86) with a 95% confidence interval from 5.14 minutes to 6.06 minutes

Hourly surface and dive intervals, their 95% confidence intervals and maximum and minimum range are shown in Figures 3 and 4, respectively. The mean hourly surface intervals ranged from a high of 4.64 minutes (CV 1.02) between 2200-2300 hours to a low of 2.30 minutes (CV 1.96) between 1200 and 1300 hours (Table 2). The hourly surface intervals did not show any obvious trend throughout the day or night. The mean hourly dive intervals ranged from a high of 0.94 (CV 0.75) minutes between 0400 and 0500 hours to a low of 4.05 minutes (CV 1.23) between 1400 and 1500 hours (Table 3). Mean dive intervals appeared to increase from approximately 5 minutes to approximately 7 minutes following sunrise between 0500 and 1000 hrs. Dives then trended to decrease to approximately 4 minutes in the afternoon around 1600 hrs, but remained at around 5 minutes throughout the night. The reason for this increase and then decrease in dive intervals is not clear.

The movements and distances covered by whale # 1612 were approximated from the position of the tracking vessel and received signal strength from the VHF radio transmitter. During the daytime the whales were kept in visual range (except for periods of fog) and at a distance of at least 0.5 km but usually about 1-1.5 km from the tracking vessel. Received signal strength was correlated with these distances so that at nighttime the tracking vessel could maintain an approximate distance from the whales as estimated by the received signal strength. Plots of whale # 1612's tracks as inferred from the vessel positions are shown in Figures 5 and 6.

Whale # 1612 moved at approximately 1 knot (NM/hr) throughout the periods of tracking. Her greatest rate of movement was 2.1 knots, averaged over a 12-hour period. The total distance traveled during the first tracking episode was 46 NM, and during the second tracking episode was 99 NM. The distance traveled during daylight hours (approximately 12 hours) ranged from 7 NM to 16 NM, and the distance traveled during nighttime hours ranged from 8 NM to 16 NM.

Future analyses of these data will include comparison of the movements of whale #1612 with environmental parameters such as sea surface temperature, bathymetry, and ship activities in proximity of the whales= location during the tracking periods.

DISCUSSION

At present, the primary strategies for reducing right whale mortality associated with shipping in the calving ground rely on visually locating whales and alerting the operators of large vessels of their presence. The visual detection of these whales is accomplished by aerial survey efforts designed for that specific purpose, by crew members onboard ships designated to watch for right whales and by volunteers on recreational vessels and in beachfront dwellings. The ability to detect these animals is directly related to the amount of time that they are visible at the surface. Studies have been conducted to ascertain the sightability of right whales in the calving ground.

The only published study concerning sightability of right whales in the calving ground, (Hain, et al 1999), concluded that 33% of the mother/calf right whales in the EWS study area would be sighted during an aerial survey when conditions were favorable (good visibility, Beaufort <4). These results were determined by combining Aview-time values@ from aircraft passing over a parcel of water with the surface/dive behavior of right whales observed in the calving ground. Mean Asurface time@ for mothers was 54% based on 11 hours visual observation during eight Afollows@ from an airship of five different cow/calf pairs. The results of 132 hours of around-the-clock radio tracking have given us a mean surface time for right whale #1612 of 45%. This suggests that the sightability of mother/calf pairs in the area of the calving ground most heavily used by both whales and ships may be lower than previously thought.

The protocols for the operation of large commercial vessels using the three major channels in the high-density area of the calving ground are still being formulated. However, the Corps of Engineers, the Navy and the Coast Guard have specific guidelines for vessels transiting near whale sightings. The most proactive of these protocols, in use by the Corps, requires that sea-going dredges reduce speed during nighttime or limited visibility operation during the 24-hour period following a right whale sighting within 15 NM of the dredging operations. The Navy has indicated a willingness to modify operations of vessels transiting the entrance channel for the Kings Bay Naval Base if whales are present in the channel and will take precautionary measures if whales have been sighted within 10 NM of their area of operations during the previous 24-hour period.

Effectiveness of such mitigation measures is linked to the distance a right whale can travel in a 24-hour period. The tracking of #1612 reveals that a right whale with a young calf can cover as much as 30 NM in a 24-hour period, and that female right whales with calves can spend prolonged periods of time (up to an hour) at the surface either moving slowly or not at all.

Further analyses of behavioral data, as well as bathymetric and sea surface temperature data will refine the interpretation of the results of this project. However, the initial examination of the results from this tracking study underscore the vulnerability of these animals to shipping activity and the limitations of current management measures to mitigate interactions between whales and ships. The sightability and the rate of movement of right whales must be taken into account when developing future management protocols for reducing right whale mortality associated with shipping in the calving ground.

ACKNOWLEDGMENTS

Offshore whale research requires the help of many minds and hands. We were fortunate to have the support of many exceptional people and organizations. First and foremost, we thank the staff of the NOAA National Ocean Service Gray=s Reef Sanctuary and Sanctuary Director Reed Bohne. The captains of the *Jane Yarn*, Bruce Cowden and Ralph Rogers, were essential to the success of this project. They and their NOAA colleagues John Erickson, Michelle Finn, and Peter Fischel worked tirelessly, often under extreme conditions. We also thank the Early Warning System aerial survey teams for locating what few right whales there were in the study area and for assisting with aerial observations. Mr. Joe Contillo and Mr. Jack Javich of the NMFS Southeast Fisheries Science Center assisted with 24-hr tracking duties. Mr. Coleman Langshaw and the Fernandina Harbor Marina provided docking and hospitality, making shoreside time enjoyable. To all, we offer our heartfelt thanks.

LITERATURE CITED

Caswell, H., M. Fujiwara, S. Breault. 1999. Declining Survival Probability Threatens North Atlantic Right Whale. Proceedings of the National Academy of Sciences.

Hain, J. H.W., S. L. Ellis, R. D. Kenney, C. K. Slay. 1999. Sightability of right whales in coastal waters of the southeastern United States with implications for the aerial monitoring program. Pp. 191-207, In, G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manley, L.L. McDonald, and D.G. Robertson (eds.), Marine Mammal Survey and Assessment Methods. A.A. Balkema:Rotterdam, Netherlands.

Kenney, R.D., and S.D. Kraus. 1993. Right whale mortality - a correction and an update. Mar. Mamm. Sci. 9: 445-446.

Kraus, S.D. 1990. Rates and potential causes of mortality in North Atlantic right whales (Eubalaena glacialis). Mar. Mamm. Sci. 6: 278-291.

Kraus, S.D. 1985. "A review of the status of right whales (*Eubalaena glacialis*) in the western North Atlantic with a summary of research and management needs." National Technical Information Services Publication PB86-154143. 61p.

Kraus, S.D., M.J. Crone, and A.R. Knowlton. 1988a. "The North Atlantic Right Whale," pp. 684-698, in Chandler, W.J., ed., Audubon Wildlife Report 1988/1989. Academic Press, N.Y. 816 p.

Reeves, R.R., J.G. Mead, and S.K. Katona. 1978. The right whale, *Eubalaena glacialis*, in the western North Atlantic. Report to the International Whaling Commission 28:303-312.

Slay, C. K., S. D. Kraus, P. K. Hamilton, and A. R. Knowlton, L. A. Conger, 1998. Aerial Surveys To Reduce Ship Collisions With Right Whales In The Coastal Waters Of Georgia And Northeast Florida, Final Reports to the National Marine Fisheries Service, Miami, FL, 1994-1998

Slay, C. K., and S. D. Kraus, Right Whale Satellite Tagging and Habitat Use Patterns in the Coastal Waters of the Southeastern United States, Final Report to the National Marine Fisheries Service, 1997

List of Tables:

List of Figures:

Table 1. Surface and dive statistics for right whale # 1612.

Table 1. Surface and Dive Statistics for Right Whale #1612.

SAMPLE	N	MEAN	CV	SD	95% CL LCL	95% CL UCL	RANGE MIN	RANGE MAX
ALL SURFACINGS	827	3.19	1.60	5.11	2.84	3.54	0.01	66.30
ALL DIVES	827	5.52	0.91	5.03	5.18	5.86	0.00	28.30
SURFACINGS > 1 MIN	530	4.69	1.25	5.86	4.19	5.19	1.00	66.30
DIVES > 1 MIN	636	7.04	0.68	4.79	6.66	7.41	1.03	28.30
DAYTIME SURFACINGS	404	2.82	1.43	4.03	2.43	3.22	0.01	46.60
NIGTHTIME SURFACINGS	423	3.54	1.68	5.94	2.97	4.11	0.01	66.30
DAYTIME DIVES	404	5.43	0.97	5.25	4.92	5.94	0.00	23.68
NIGHTTIME DIVES	423	5.60	0.86	4.83	5.14	6.06	0.02	28.30

ALL TIMES ARE IN MINUTES

Table 2. Hourly surface interval statistics for right whale # 1612.

Table 2. Hourly Surface Interval Statistics for Right Whale No. 612

HOUR	N	MEAN	CV	STD. DEV	95% CL LCL	95% CL UCL	RANGE MIN	RANGE MAX
1	48	3.01	1.67	5.01	1.56	4.46	0.26	27.60
2	41	4.26	2.47	10.50	0.95	7.58	0.12	66.30
3	35	2.89	1.03	2.98	1.86	3.91	0.01	12.80
4	45	3.18	1.76	5.59	1.50	4.86	0.20	34.00
5	30	4.35	2.02	8.80	1.07	7.63	0.08	49.80
6	32	3.50	0.92	3.23	2.35	4.67	0.01	13.04
7	37	2.54	0.92	2.33	1.77	3.32	0.05	9.10
8	31	2.78	0.59	1.65	2.18	3.38	0.03	6.74
9	37	3.02	0.96	2.90	2.05	3.98	0.03	15.30
10	34	2.85	1.08	3.04	1.77	3.92	0.10	15.78
11	40	3.00	0.92	2.74	2.12	3.88	0.03	12.32
12	34	3.26	0.86	2.80	2.29	4.24	0.02	11.05
13	45	2.30	1.96	4.52	0.95	3.66	0.14	26.20
14	30	3.15	2.68	8.45	0.00	6.30	0.05	46.60
15	20	2.44	1.09	2.66	1.20	3.68	0.33	11.10
16	32	2.55	1.09	2.77	1.55	3.55	0.21	10.00
17	34	2.49	1.32	3.28	1.35	3.63	0.30	15.30
18	30	3.51	1.92	6.74	1.00	6.02	0.20	33.20
19	37	2.62	0.94	2.46	1.80	3.44	0.01	8.90
20	38	2.72	0.91	2.46	1.91	3.53	0.30	10.80
21	34	4.10	1.99	8.17	1.25	6.94	0.08	47.40
22	30	4.42	1.14	5.05	2.54	6.31	0.13	24.70
23	26	4.64	1.02	4.73	2.73	6.55	0.20	18.70
24	27	3.70	1.62	5.99	1.34	6.07	0.68	31.90

Table 3. Hourly dive interval statistics for right whale # 1612.

Table 3. Hourly Dive Interval Statistics for Right Whale No. 612

HOUR	N	MEAN	CV	STD. DEV	95% CL LCL	95% CL UCL	RANGE MIN	RANGE MAX
1	48	4.55	0.79	3.59	3.50	5.59	0.20	12.11
2	41	5.45	0.86	4.67	3.98	6.93	0.23	17.98
3	35	4.85	0.80	4.69	4.24	7.46	0.15	17.72
4	45	4.90	0.97	4.73	3.48	6.32	0.20	17.48
5	30	7.94	0.75	5.98	5.71	10.17	0.14	20.55
6	32	6.83	0.76	5.22	4.95	8.71	0.52	16.54
7	37	6.22	0.84	5.23	4.48	7.96	0.03	16.43
8	31	7.80	0.77	5.99	5.61	10.00	0.24	19.95
9	37	7.80	0.80	6.22	5.73	9.87	0.08	22.30
10	34	6.90	0.78	5.37	5.03	8.77	0.10	23.68
11	40	6.59	0.79	5.24	4.92	8.27	0.00	17.12
12	34	5.54	1.00	5.55	3.61	7.48	0.18	19.76
13	45	4.40	1.14	5.00	2.90	5.90	0.04	19.55
14	30	4.34	1.18	5.10	2.44	6.24	0.14	15.68
15	20	4.05	1.23	5.00	1.72	6.38	0.11	17.68
16	32	3.79	1.23	4.65	2.12	5.47	0.16	17.14
17	34	4.55	0.84	3.82	3.22	5.88	0.42	13.72
18	30	4.56	1.06	4.82	2.77	6.36	0.06	17.83
19	37	4.19	0.98	4.11	2.82	5.56	0.26	17.30
20	38	5.07	0.79	3.99	3.76	6.38	0.10	17.63
21	34	6.12	1.01	6.19	3.96	8.27	0.02	28.30
22	30	5.07	0.91	4.62	3.34	6.79	0.20	15.11
23	26	5.07	0.98	4.95	3.08	7.07	0.10	19.02
24	27	4.88	0.71	3.46	3.51	6.25	0.05	10.77

Table 4. Daytime and nighttime track segments whale #1612.

Table 4. Daytime and Nighttime Tracks and Rates of Movement for Whale # 1612

TRACK SEGMENT	START TIME	END TIME	TOTAL TIME (HRS)	DISTANCE KM	RATE NM/HR
1	17:00:40	17:59:00	1	9	9.0
2	18:00:29	06:59:40	13	16	1.2
3	07:50:56	17:59:29	10.2	7	0.7
4	18:01:22	05:54:58	11.9	13	1.1
5	13:17:44	17:59:24	4.7	10	2.1
6	15:05:00	17:55:00	2.8	4	1.4
7	18:05:00	06:55:00	12.8	8	0.6
8	07:05:00	17:56:00	10.9	11	1.0
9	18:06:00	06:50:00	12.7	13	1.0
10	17:50:00	07:00:00	10.8	16	1.5
11	18:00:00	06:50:00	12.8	15	1.2
12	07:00:00	17:50:00	10.8	12	1.1
13	18:00:00	06:50:00	12.8	14	1.1
14	07:00:00	14:20:00	7.3	6	0.8

Figure 1. Surface intervals (N= 827).

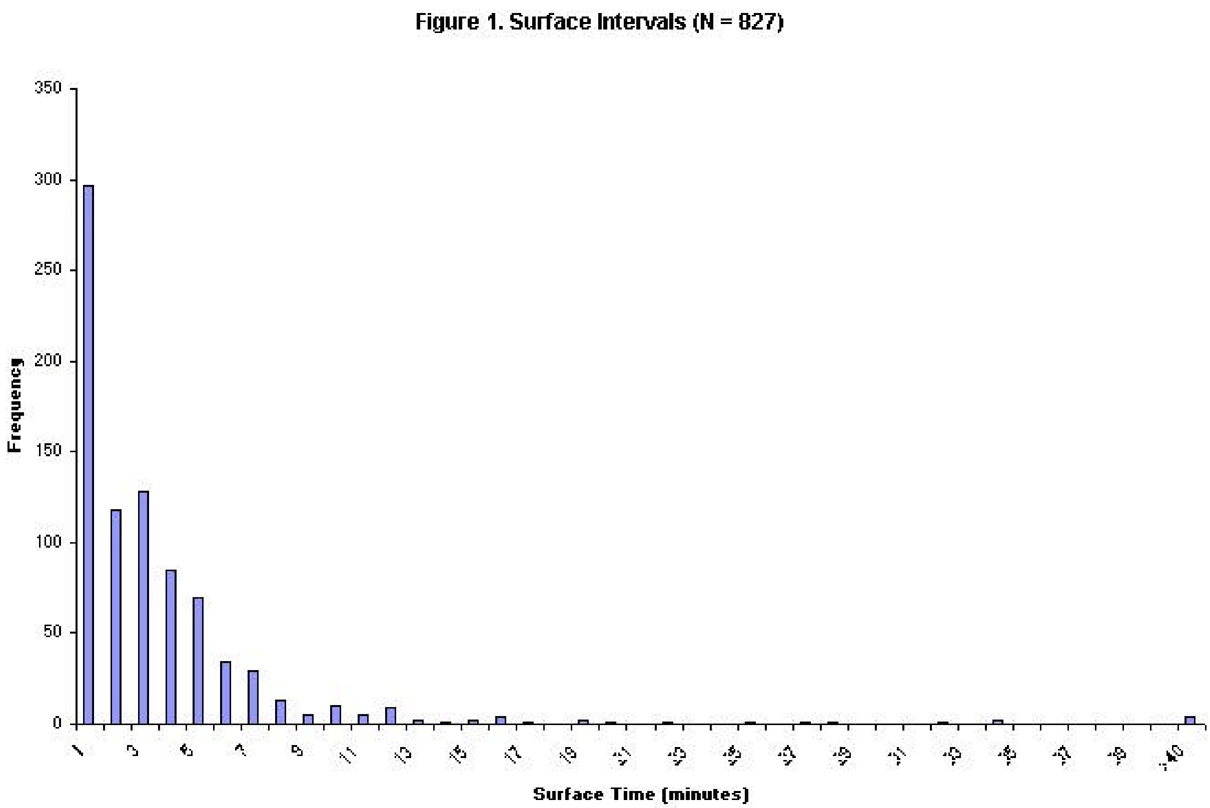

Figure 2. Dive intervals (N=827).

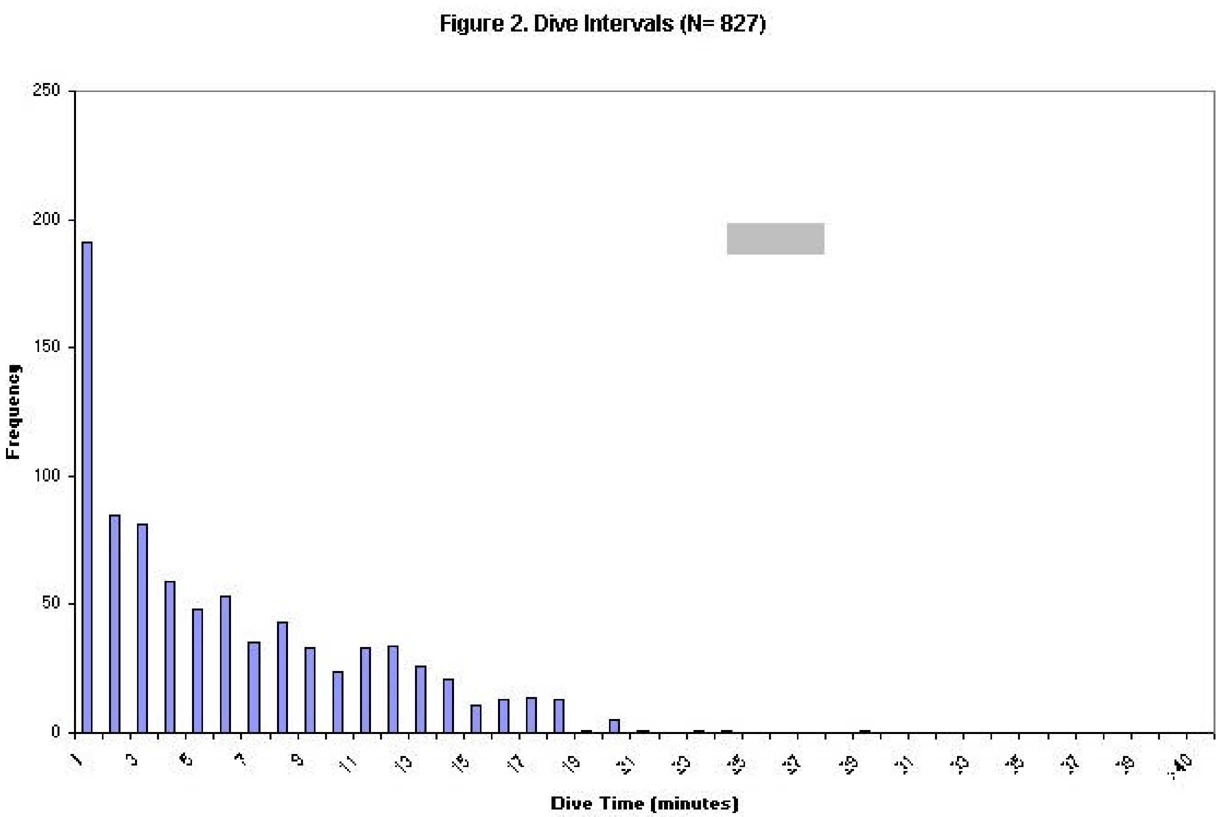

Figure 3. Hourly surface intervals: line = range (max.,min.), bar = 95% confidence interval.

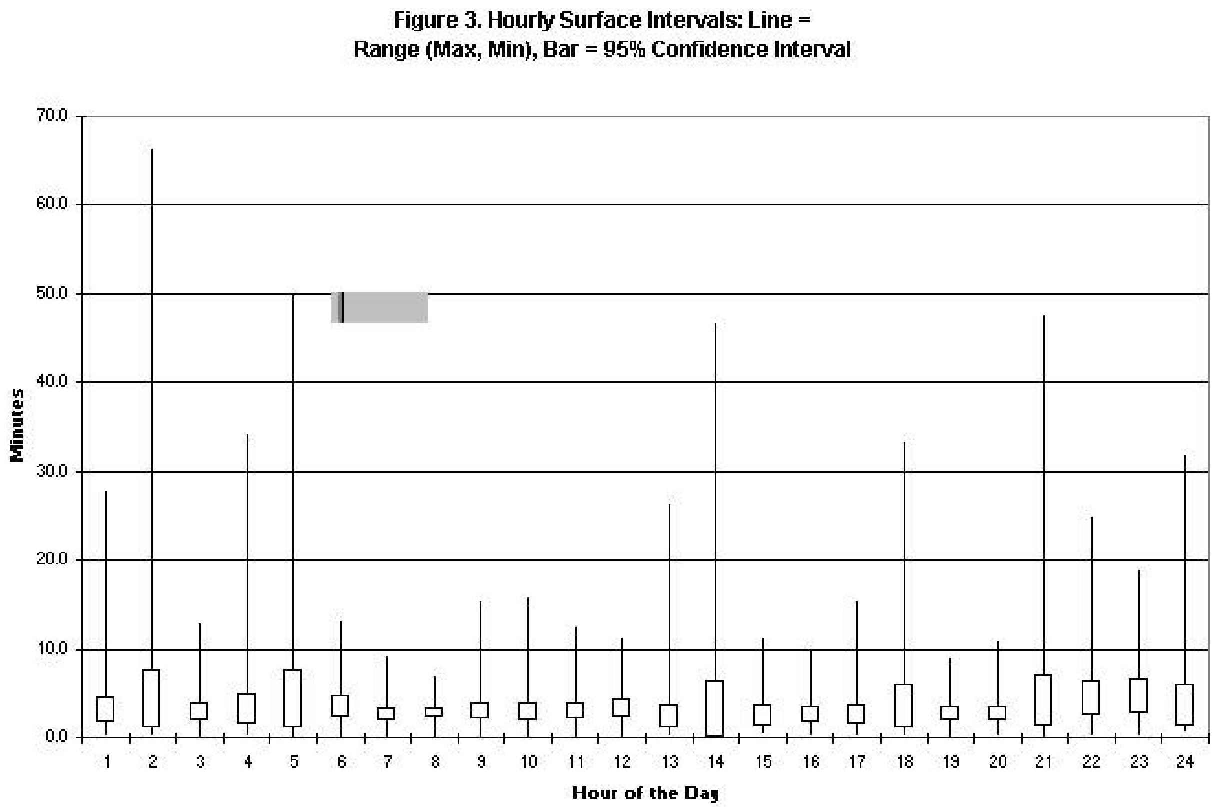

Figure 4. Hourly dive intervals: line = range (max.,min.), bar = 95% confidence interval.

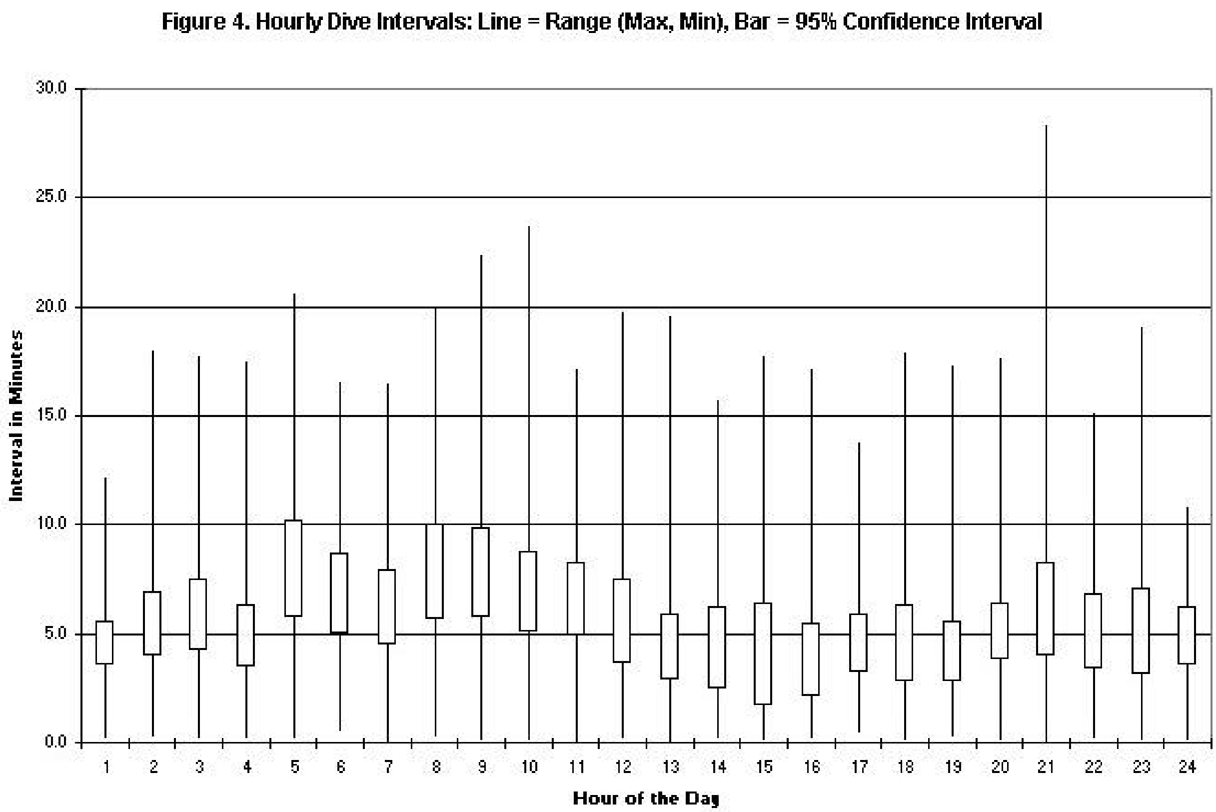

Figure 5. Daytime and nighttime track segments for whale # 1612.

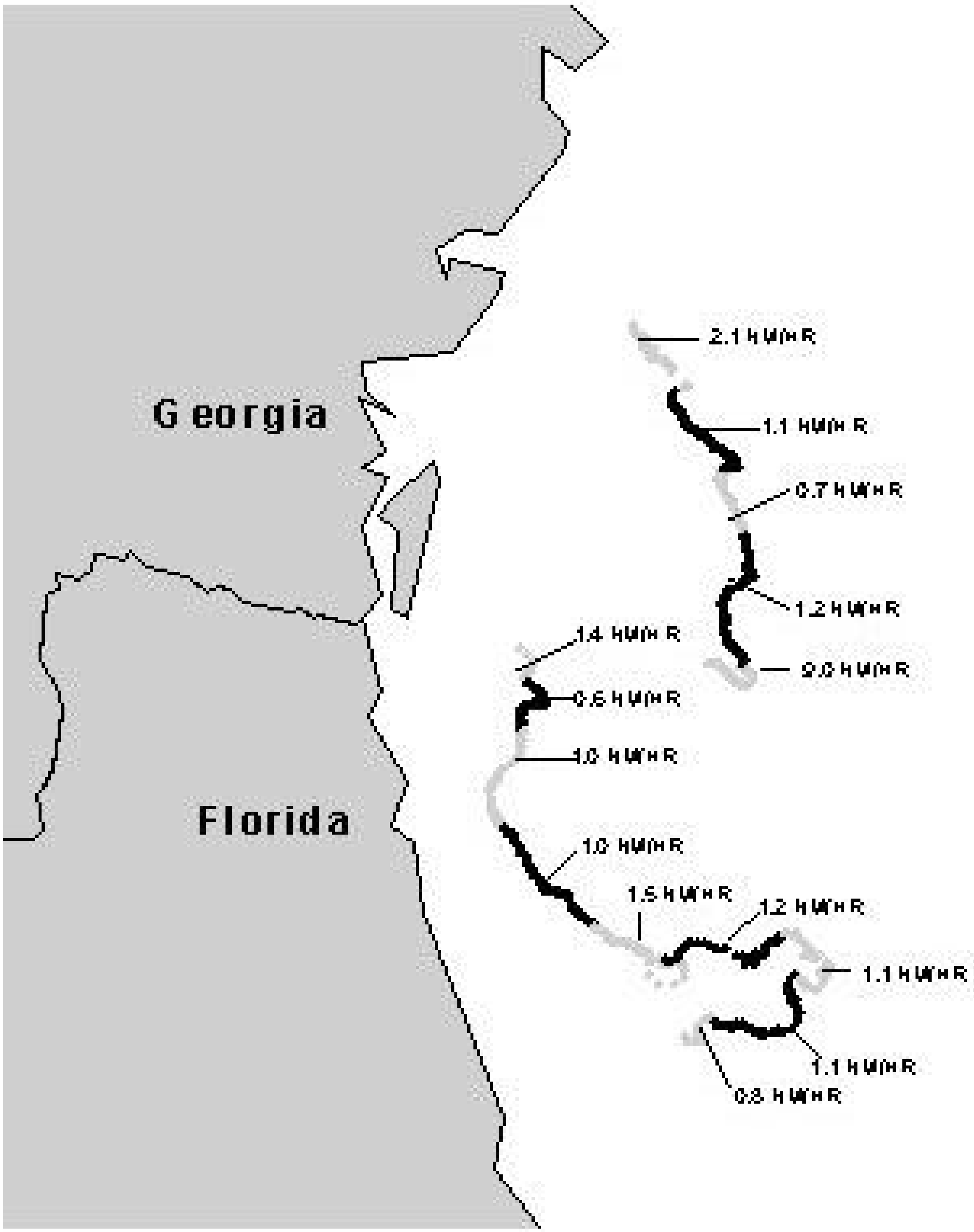

Figure 6. Daytime and nighttime distances traveled by whale # 1612.

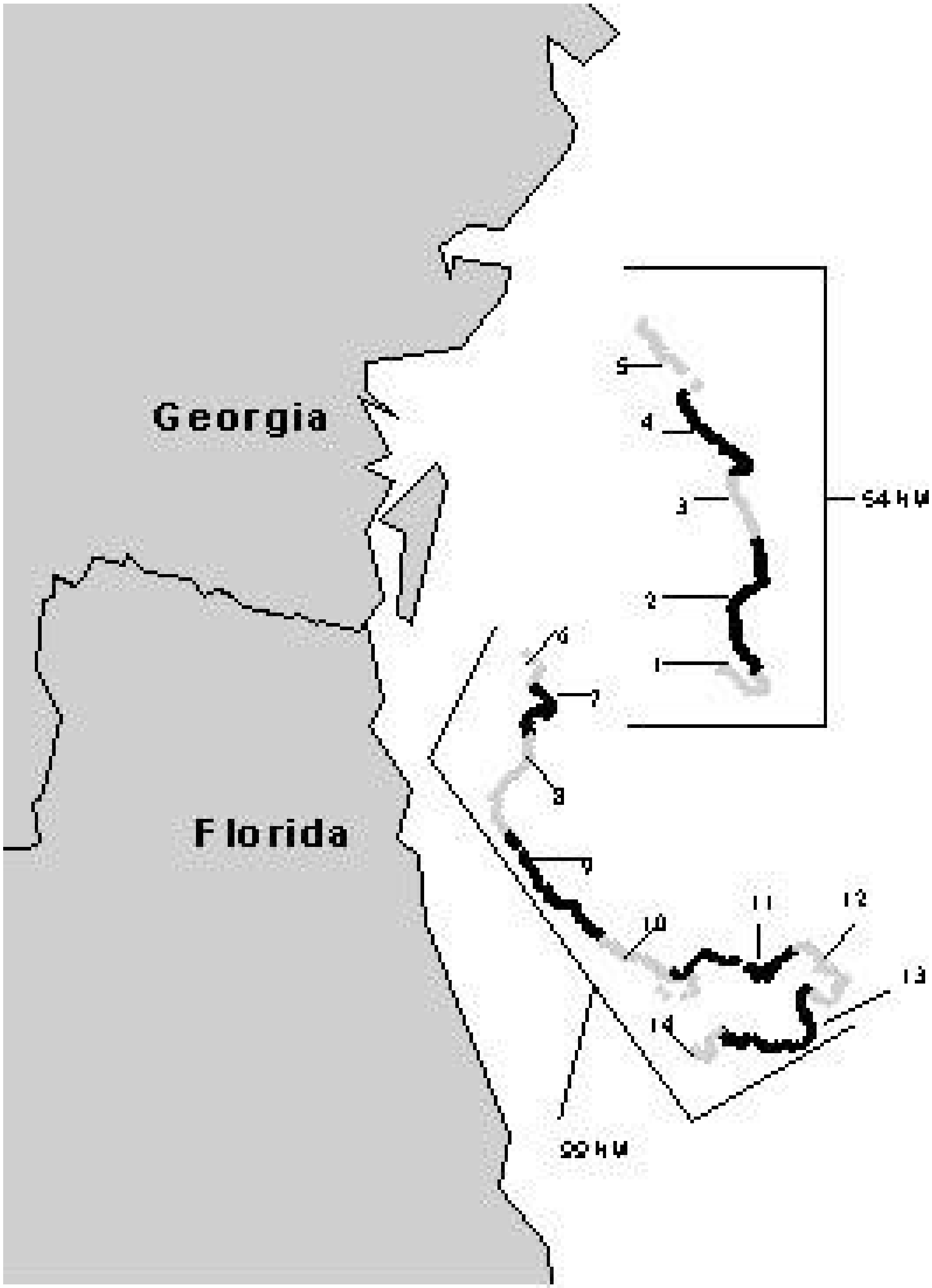

Figure 7. Movement tracks and sea surface temperatures for whale #1612.