Aerial Surveys for Protected Marine Species in the Norfolk Canyon Region: 2018–2019 Final Report

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Cover Photo Credit:

A True's beaked whale (*Mesoplodon mirus*) about to surface off the coast of Virginia. Photographed by Todd Pusser. Photograph taken under National Marine Fisheries Service permit No. 16239 issued to Dan Engelhaupt/HDR.

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Acronyms and Abbreviations

AFTT	Atlantic Fleet Training and Testing
BSS	Beaufort Sea State
NARW	North Atlantic right whale
km	kilometer(s)
m	meter(s)
NFC	Norfolk Canyon
NM	nautical mile(s)
OPAREA	Operating Area
SD	standard deviation
U.S.	United States
VACAPES	Virginia Capes

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1. Introduction and Background

This project is intended to provide baseline information on the species composition, density, distribution, and basic behavior of marine mammals and sea turtles present within the United States (U.S.) Navy's Virginia Capes (VACAPES) Operating Area (OPAREA). This study is part of a larger, multi-institutional, marine mammal and sea turtle monitoring program of U.S. Navy range complexes along the U.S. Atlantic Coast and Gulf of Mexico supporting Atlantic Fleet Training and Testing (AFTT).

In 2007, baseline aerial and vessel surveys, as well as a passive acoustic monitoring component, began in Onslow Bay, North Carolina. Over the past decade, these surveys have expanded to include study areas off the coasts of Jacksonville, Florida; Cape Hatteras, North Carolina; and Virginia Beach, Virginia. In Onslow Bay, four years of monitoring yielded a comprehensive representation of the density, distribution, and abundance of marine mammals and sea turtles and provided new insights into residency patterns among pelagic delphinid cetaceans in this region (Read et al. 2014). Nearly ten years of monitoring in Jacksonville (see Cummings et al. 2018), and over six in Cape Hatteras (see McAlarney et al. 2018a), have provided similar information on the density and distribution patterns of marine mammals and sea turtles in those areas.

In 2015, to serve the operational needs of the AFTT program, survey effort was extended farther north into the VACAPES OPAREA, creating the Norfolk Canyon (NFC) study area (McAlarney et al. 2016, 2017, 2018b). Beginning in early 2018, HDR assumed the lead on the remainder of surveys planned for the NFC survey area. This report builds on the past body of work completed by researchers at the University of North Carolina at Wilmington, and describes aerial survey monitoring activities conducted in the NFC study area from 2018–2019.

2. Summary of Norfolk Canyon Aerial Surveys

This document summarizes the results on aerial surveys conducted in the NFC study area from April 2018 through August 2019. The objective was to conduct two days of effort each month, flying a subset of the 16 tracklines that span the study area (**Figure 1**).

Surveys commenced in April 2018 and continued through August 2019, covering 15 of the 17 months in that period (**Table 2**). September was the only month between both years in which a survey was not flown. A total of 185 tracklines (13,364.5 kilometers [km]) was completed over 23 days.

A total of 490 sightings of 19,498 individual cetaceans was encountered while on effort during the 23 days of aerial surveys (**Table 3**). Sixteen species of cetaceans were documented while on effort, including common dolphins (*Delphinus delphis*; 59 sightings of 11,103 individuals), common bottlenose dolphins (*Tursiops truncatus*; 147 sightings of 2,519 individuals), Atlantic spotted dolphins (*Stenella frontalis*; 22 sightings of 1,874 individuals), Risso's dolphins (*Grampus griseus*; 44 sightings of 1,062 individuals), striped dolphins (*Stenella coeruleoalba*, 17 sightings of 1,235 individuals), short-finned pilot whales (*Globicephala macrorhynchus*; 94 sightings of 1,297 individuals), sperm whales (*Physeter macrocephalus*; 22 sightings of 61

individuals), True's beaked whales (*Mesoplodon mirus*; 1 sighting of 5 individuals), Sowerby's beaked whales (*Mesoplodon bidens*; 1 sighting of 4 individuals), kogiid whales (*Kogia* sp.; 10 sightings of 17 individuals), North Atlantic right whales (NARW) (*Eubalaena glacialis*; 2 sightings of 8 individuals), blue whales (*Balaenoptera musculus*; 1 sighting of 1 individual), sei whales (*Balaenoptera borealis*; 3 sightings of 4 individuals), minke whales (*Balaenoptera acutorostrata*; 4 sightings of 4 individuals), fin whales (*Balaenoptera physalus*, 25 sightings of 57 individuals), humpback whales (*Megaptera novaeangliae*; 9 sightings of 22 individuals), unidentified small whales (1 sighting of 2 individuals), unidentified large whales (6 sightings of 6 individuals), unidentified beaked whales (5 sightings of 9 individuals), unidentified dolphins (12 sightings of 198 individuals), and unidentified cetaceans (5 sightings of 10 individuals).

An additional 90 off-effort cetacean sightings were recorded: common dolphins (7 sightings of 307 individuals), common bottlenose dolphins (44 sightings of 855 individuals), Atlantic spotted dolphins (2 sightings of 210 individuals), Risso's dolphins (4 sightings of 43 individuals), striped dolphins (1 sighting of 400 individuals) pilot whales (4 sightings of 45 individuals), sperm whales (3 sightings of 4 individuals), kogiid whales (1 sighting of 1 individual), minke whales (2 sightings of 2 individuals), fin whales (2 sightings of 2 individuals), humpback whales (8 sightings of 9 individuals), unidentified dolphins (11 sightings of 233 individuals), and unidentified cetaceans (1 sighting of 3 individuals).

A total of 407 sightings of 1,496 sea turtles was recorded during the project duration (**Table 3**). Of these, 1,387 were identified as loggerhead (*Caretta caretta*), 49 as Kemp's ridley (*Lepidochelys kempii*), 36 as leatherback (*Dermochelys coriacea*), and 24 as unidentified hardshell turtles. Sea turtles were detected during 10 of 11 survey months, with highest abundances observed in May and June. In addition to cetaceans and sea turtles, observations of other pelagic marine vertebrates were recorded during these surveys. These included a whale shark (*Rhincodon typus*), a great white shark (*Carcharodon carcharias*), a blue shark (*Prionace glauca*), basking sharks (*Cetorhinus maximus*), unidentified hammerhead sharks (*Sphyrna* sp.), giant mantas (*Mobula birostris*), Chilean devil rays (*Mobula tarapacana*), giant devil rays *(Mobula mobular*), cownose rays (*Rhinoptera bonasus*), ocean sunfish (*Mola* sp.), unidentified large black-and-white mobulid rays, and unidentified sharks.

All data from this project will be made publically available through the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations hosted by Duke University.

3. Methods

3.1 Survey Design and Logistics

The primary study area includes the waters between approximately 80 and 160 km (43 nautical miles [NM] to 86 NM) offshore of Virginia Beach, Virginia, encompassing an area of approximately 9,200 square km (~2,700 square NM). (**Table 1**, **Figure 1**). The entire NFC study area falls within the airspace of the U.S. Navy's Fleet Area Control and Surveillance Facility VACAPES OPAREA, and each transect line was 74 km (40 NM). As this is controlled special-use airspace, pilots contacted Fleet Forces Atlantic Exercise Coordination Center the morning

of planned survey flights to coordinate potential area closures and/or airspace restrictions. Survey plans were modified to avoid interacting with any activities, or "hot" airspace.

Table 1. Coordinates for trackline end points for the Norfolk Canyon study area.

Transect Line Number	Western Waypoint		Eastern Waypoint	
	Latitude (N)	Longitude (W)	Latitude (N)	Longitude (W)
61	37.3213	75.1611	37.3213	74.3337
60	37.2463	75.1611	37.2464	74.3337
59	37.1715	75.1611	37.1715	74.3337
58	37.0965	75.1611	37.0965	74.3337
57	37.0216	75.1611	37.0216	74.3337
56	36.9466	75.1611	36.9466	74.3337
55	36.8717	75.1611	36.8717	74.3337
54	36.7968	75.1611	36.7968	74.3337
53	36.7219	75.1611	36.7219	74.3337
52	36.6469	75.1611	36.6469	74.3337
51	36.5720	75.1611	36.5720	74.3337
50	36.4970	75.1611	36.4970	74.3337
49	36.4221	75.1611	36.4221	74.3337
48	36.3472	75.1611	36.3472	74.3337
47	36.2722	75.1611	36.2722	74.3337
46	36.1973	75.1611	36.1973	74.3337

Survey flights originated from Signature Flight Support at Norfolk International Airport in Norfolk, Virginia. All flights were conducted in an Orion Aviation (Siler City, North Carolina) Cessna 337 Skymaster with two pilots and two observers (positioned at the left and right windows in the rear seats of the aircraft). Surveys were flown at 305-meter (m) altitude and 100-knot (185 km/hour) speed. Observers continuously scanned the trackline and used an inclinometer to obtain a vertical angle to a sighting when a detection was made within the observer's field of view. Survey data were collected on an Apple® iPad using *COMPASS* (see Richlen et al. 2019), a U.S. Navy-funded, marine mammal survey software platform. Photographs were taken with a Canon 1DX Mark II equipped with a Canon 100- to 400-millimeter telephoto lens for all sightings when feasible, and were used to substantiate species identification and behavior, if necessary.

Whenever possible, coordination with the HDR vessel survey team (see Engelhaupt et al. 2019) was attempted to maximize the potential of sightings between platforms. Because the vessel team was not conducting line-transect surveys, the aerial team was able to position the vessel on aerial-based sightings that included priority species for the vessel-based research project to conduct photo-identification, tagging, and biopsy sampling.

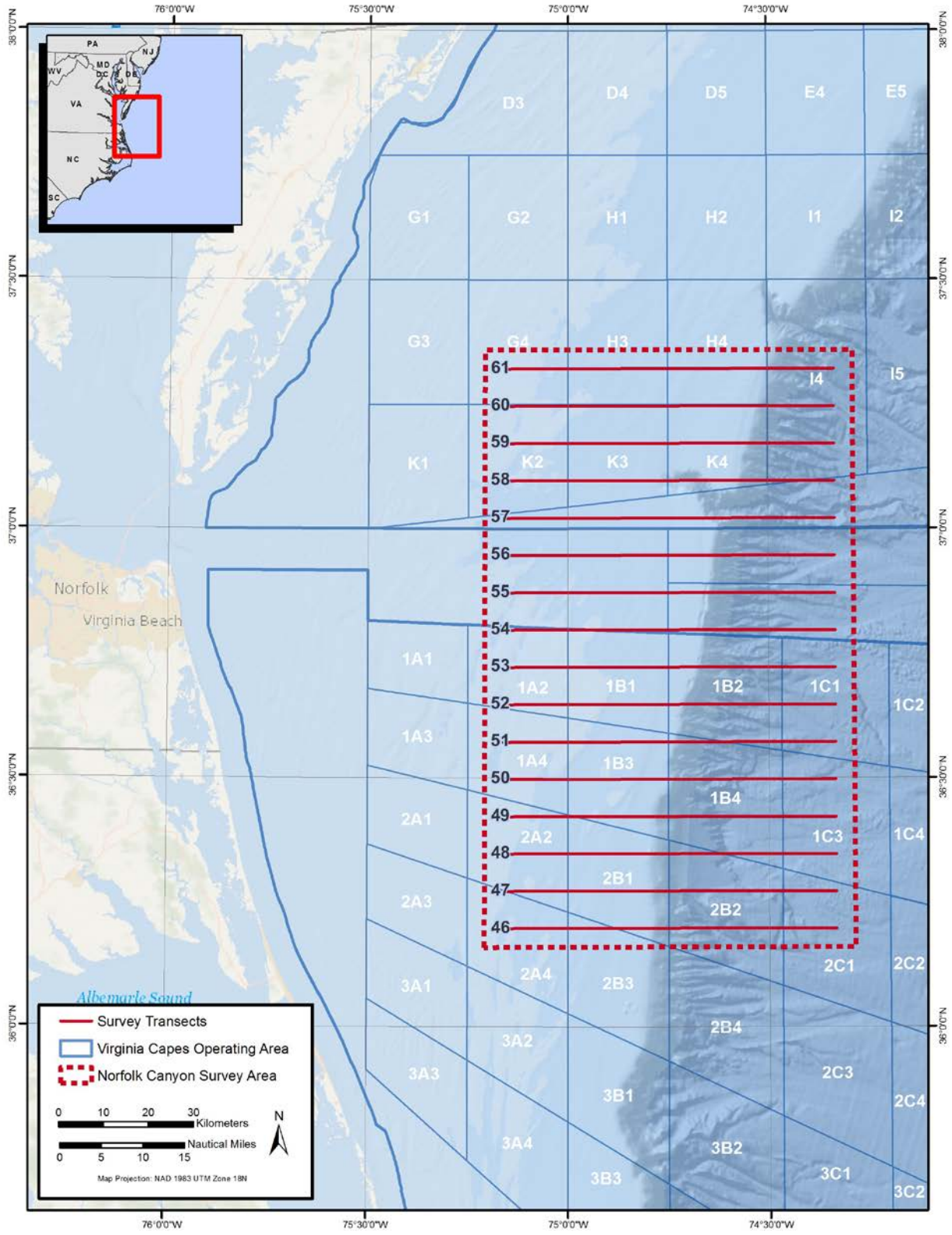

Figure 1. Norfolk Canyon study area off the coast of Virginia and North Carolina, showing the underlying U.S. Navy VACAPES operating area and areas associated surface grid.

4. Results

Survey efforts resulted in 185 completed tracklines totaling 13,364.5 km (**Table 2, Figure 3**). Conditions during the 23 survey days ranged from Beaufort Sea State (BSS) 0 to 5. The tracklines flown on any given survey were a consequence of many variables, including the overall goal of evenly distributed effort, the working area of the vessel survey team, sea conditions (BSS) affecting the viewing area, weather conditions affecting the aircraft, military operations in the OPAREA, and other airspace restrictions. These variables resulted in a slight skew towards higher effort distribution in the central portion of the study area, with the highest effort on tracklines 51 to 59 (**Figure 2**). This inadvertently resulted in the greatest effort centered in proximity of the Norfolk Canyon.

Table 2. Survey effort and Hobbs hours (engine-on time) during aerial surveys of the Norfolk Canyon study area in 2018–2019.

Date	Tracklines Flown	Total km Flown	Hobbs Hours
9-Apr-2018	61 to 56	427.2	4.4
11-Apr-2018	61 to 54	496.9	7.2
25-May-2018	61 to 54	554.9	6.4
16-Jun-2018	53 to 46	557.5	7.3
17-Jun-2018	61 to 54	573.4	5.2
14-Jul-2018	61 to 54	588.8	6.4
5-Aug-2018	61 to 54	549.6	7.0
6-Aug-2018	53 to 46	593.9	7.2
19-Oct-2018	61 to 51	813.0	7.5
12-Nov-2018	53 to 46	590.4	4.6
1-Dec-2018	53 to 46	585.6	4.4
19-Dec-2018	59 to 52	597.9	5.0
4-Jan-2019	61 to 54	587.2	4.3
17-Jan-2019	58 to 51	594.8	4.6
26-Jan-2019	53 to 46	584.8	6.4
10-Feb-2019	60 to 53	570.4	4.8
8-Mar-2019	57 to 50	592.1	4.7
28-Mar-2019	53 to 46	586.7	5.3
23-Apr-2019	55 to 48	590.4	5.3
27-Jun-2019	61 to 54	586.2	4.8
28-Jun-2019	53 to 46	583.5	4.9
29-Jul-2019	53 to 46	584.8	5.2
12-Aug-2019	59 to 52	574.8	5.0
23 Days	**185 Tracklines**	**13364.5 km**	**127.9 hrs**

Key: km = kilometer(s), hrs = hours; Hobbs = genericized trademark for the meter used in aviation to measure the time an aircraft is in use.

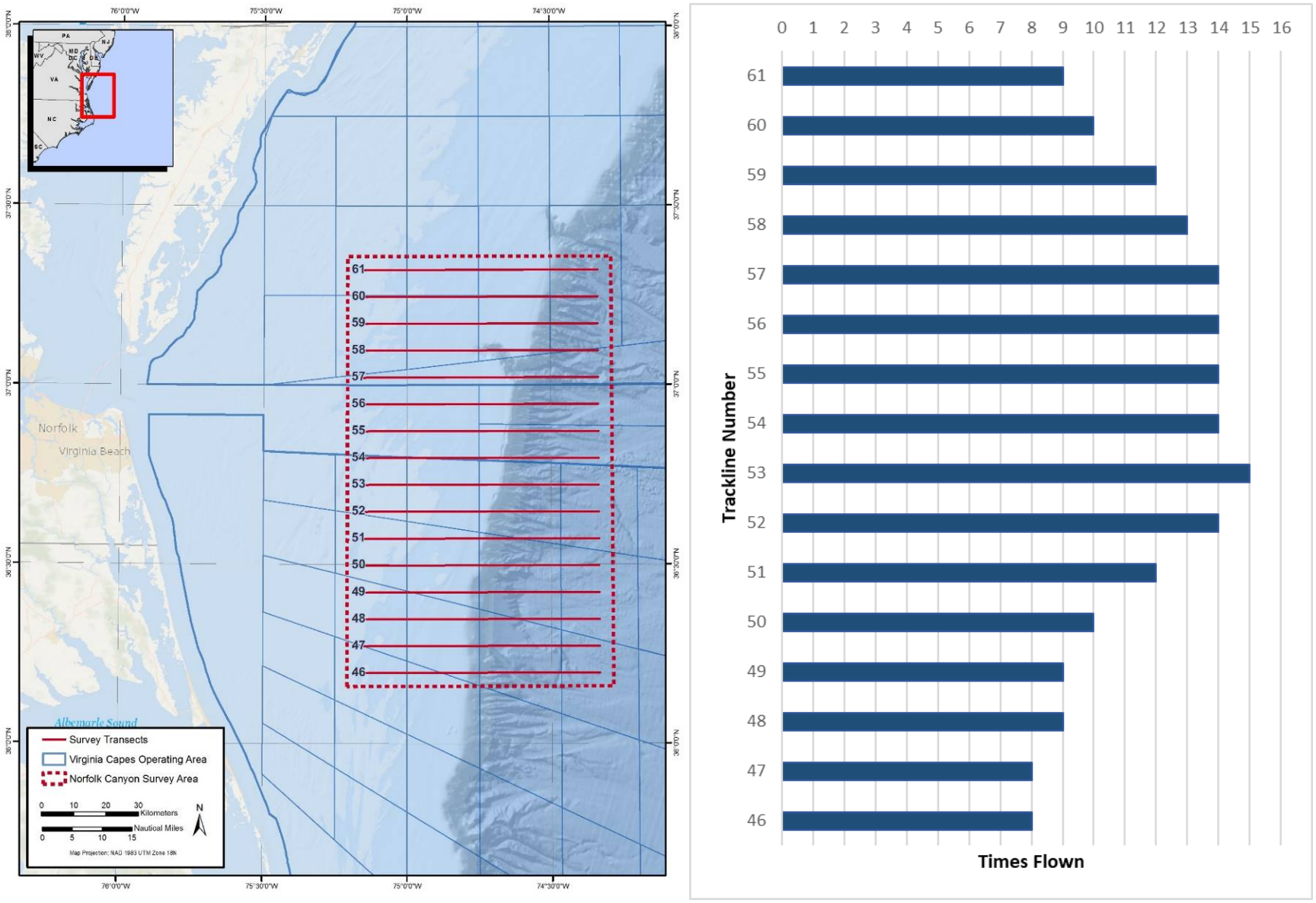

Figure 2. Planned tracklines and realized survey effort in the Norfolk Canyon study area for 2018–2019.

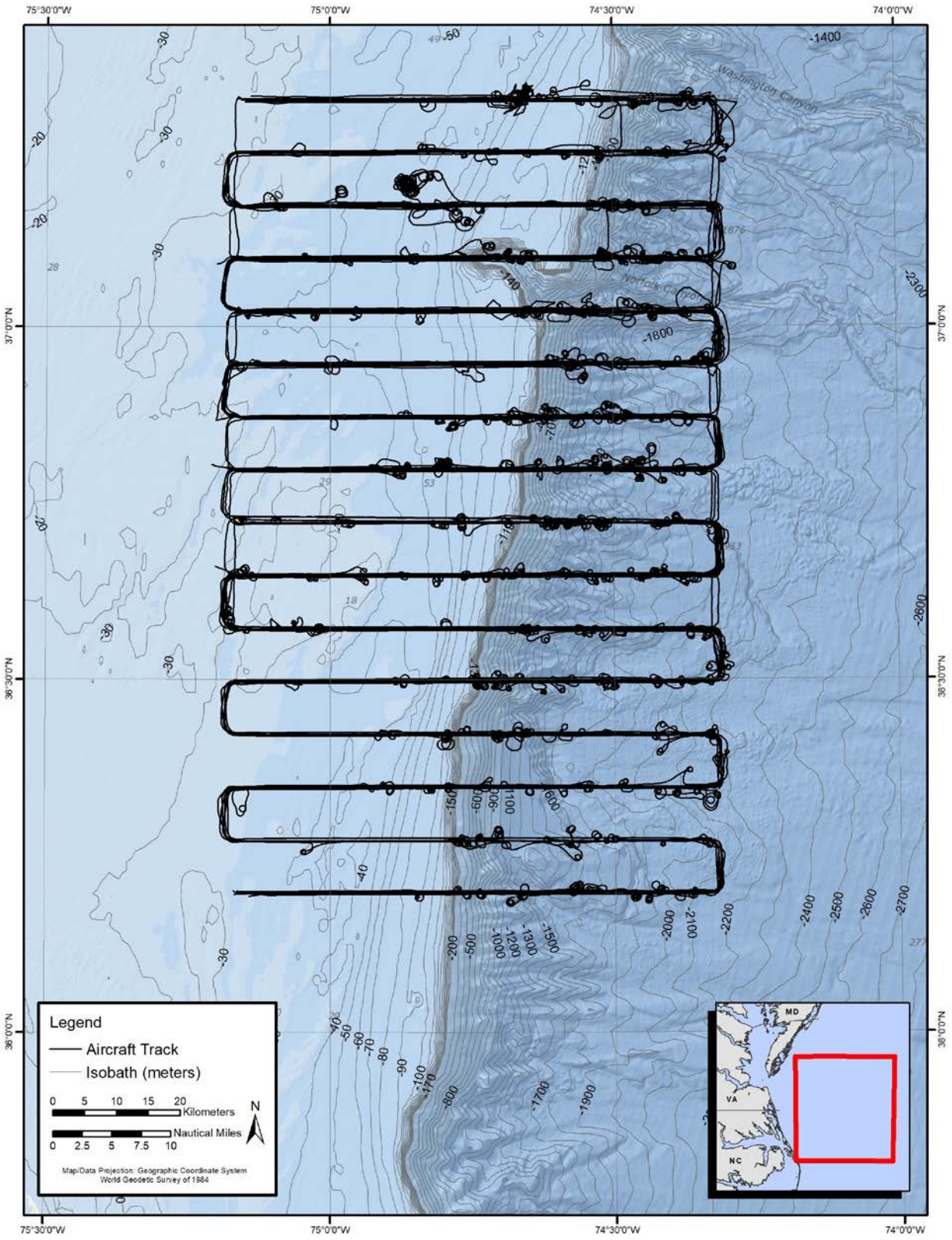

Figure 3. Survey tracks for all effort conducted in the Norfolk Canyon study area in 2018–2019.

4.1 Marine Mammal Sightings

A total of 490 sightings of 19,498 individual cetaceans, comprising 16 species, was recorded while on effort during the reporting period (**Table 3, Figure 4**). An additional 90 off-effort cetacean sightings of 2,114 individuals were recorded during the same surveys. A sighting was considered off-effort if it occurred while transiting to, or from, the study area and/or during a cross-leg between planned track lines, or seen while investigating a separate sighting cue. If two species were seen associated with the same sighting cue, both were considered on-effort. All sightings (on- and off-effort) for each individual species are summarized in the following sections. The total number of individuals listed represents the best estimate of group size. Five endangered species, NARW, blue whale, fin whale, sei whale, and sperm whale were encountered in the study area during these surveys.

All off-effort sightings for each species have been included in the individual species tables, but were only presented on the species maps if the sighting occurred in the general proximity of the study area (i.e., not on the transit to and from the airport and study area).

Table 3. Numbers of on-effort sightings and individuals for each species by month for the Norfolk Canyon study area for all 2018–2019 surveys.

Species	Numbers of	Month												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Common dolphin	Sightings	8	7	8	10	9	8	3	2	-			4	59
	Individuals	3734	514	1123	648	803	2689	137	145	-			1310	11103
Common bottlenose dolphin	Sightings	18	4	5	14	5	43	11	27	-	9		11	147
	Individuals	184	32	183	237	48	661	317	658	-	111		96	2519
Atlantic spotted dolphin	Sightings				2		6	9	4	-	1			22
	Individuals				155		417	900	385	-	17			1874
Risso's dolphin	Sightings			1		3	13	8	16	-			3	44
	Individuals			15		29	249	409	313	-			47	1062
Striped dolphin	Sightings	5	4		3	1			1	-			3	17
	Individuals	495	200		170	40			125	-			205	1235
Short-finned pilot whale	Sightings	6		1	3	2	27	7	34	-	9		5	94
	Individuals	112		22	78	22	297	113	471	-	125		57	1297
Sperm whale	Sightings	1		7	3		5	2	4	-				22
	Individuals	1		7	5		25	5	18	-				61
True's beaked whale	Sightings						1			-				1
	Individuals						5			-				5
Sowerby's beaked whale	Sightings									-			1	1
	Individuals									-			4	4
Kogiid whale	Sightings			1			6		2	-			1	10
	Individuals			1			9		5	-			2	17
North Atlantic right whale	Sightings				2					-				2
	Individuals				8					-				8
Sei whale	Sightings				3					-				3
	Individuals				4					-				4
Minke whale	Sightings			1	2				1	-				4
	Individuals			1	2				1	-				4
Fin whale	Sightings	2	5	2	9		2	1	3	-		1		25
	Individuals	4	24	2	16		2	1	4	-		4		57

Species	Numbers of	Month												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Humpback whale	Sightings			4	5					-				9
	Individuals			13	9					-				22
Blue whale	Sightings		1							-				1
	Individuals		1							-				1
Unidentified beaked whale	Sightings	3					1		1	-				5
	Individuals	4					3		2	-				9
Unidentified small whale	Sightings									-			1	1
	Individuals									-			2	2
Unidentified large whale	Sightings			1	4		1			-				6
	Individuals			1	4		1			-				6
Unidentified dolphin	Sightings			1	1		3	1	2	-	3		1	12
	Individuals			75	1		27	1	64	-	15		15	198
Unidentified cetacean	Sightings	2		1		1				-	1			5
	Individuals	5		1		3				-	1			10
Cetacean Summary	**Total sightings**	**45**	**21**	**33**	**61**	**21**	**116**	**42**	**98**		**23**	**1**	**30**	**490**
	Total individuals	**4539**	**771**	**1444**	**1340**	**945**	**4385**	**1883**	**2180**		**269**	**4**	**1738**	**19498**
Loggerhead sea turtle	Sightings	1		2	22	39	116	34	83	-	29	1		327
	Individuals	1		2	77	349	615	62	243	-	37	1		1387
Kemp's ridley sea turtle	Sightings					6	12	1	6	-				25
	Individuals					16	24	1	8	-				49
Leatherback sea turtle	Sightings	2	1				6		24	-	1			34
	Individuals	2	1				6		26	-	1			36
Unidentified hardshell	Sightings				2	3	8	2	4	-	2			21
	Individuals				3	3	8	2	6	-	2			24
Sea Turtle Summary	**Total sightings**	**3**	**1**	**2**	**24**	**48**	**142**	**37**	**117**		**32**	**1**		**407**
	Total individuals	**3**	**1**	**2**	**80**	**368**	**653**	**65**	**283**		**40**	**1**		**1496**

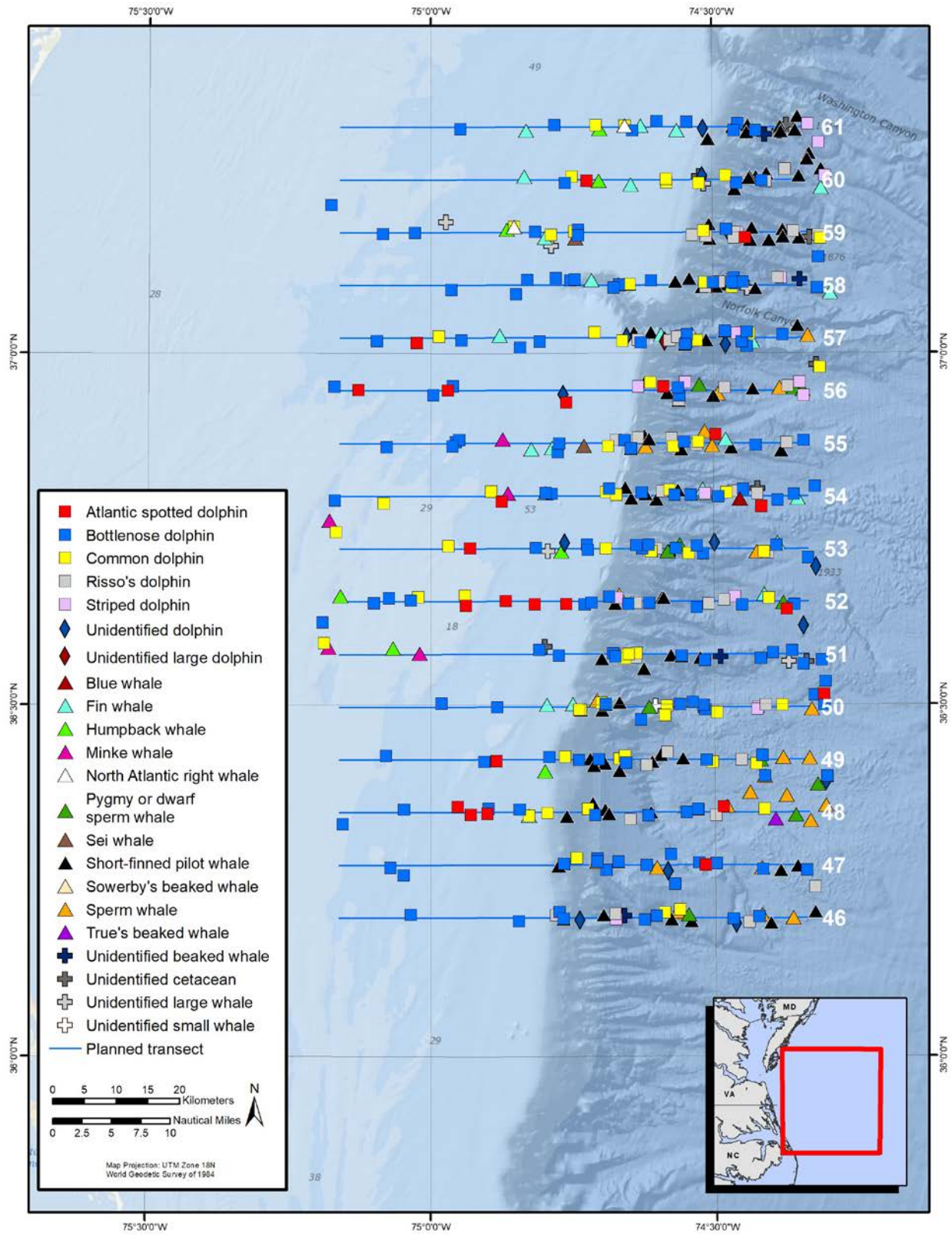

Figure 4. Cetacean sightings recorded during aerial surveys in the Norfolk Canyon study area in 2018–2019.

4.2 Dolphins

4.2.1 Common dolphin (*Delphinus delphis*)

Common dolphins were the most abundant cetacean species encountered in the NFC study area. Fifty-nine on-effort sightings of 11,103 individuals (mean group size=188.2, standard deviation [*SD*]=365.1) were observed, largely centered on the continental shelf-break (**Table 4, Figure 5**). Seven additional off-effort sighting of 307 individuals were recorded. Common dolphin group sizes were highly variable, with the largest groups between 1,000 and 1,800 individuals, and smaller groups fewer than 25 animals. All sightings with groups of 500 or more individuals were recorded at or beyond the shelf-break in deeper waters. This species was seen in nine of the eleven survey months, with no observations recorded during the months of October and November.

Table 4. Common dolphin (*Delphinus delphis*) sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
9-Apr-2018	9:46:25	37.3239	74.6551	61	3	12
11-Apr-2018	10:09:46	37.1800	74.8524	59	3	4
11-Apr-2018	11:05:41	37.1732	74.7454	59	4	33
11-Apr-2018	11:38:37	37.0984	74.6474	58	3	50
*11-Apr-2018	15:55:14	36.8682	74.6869	55	4	30
*25-May-2018	9:04:17	37.1006	74.5148	58	1	50
25-May-2018	9:10:39	37.0945	74.4663	58	1	30
*25-May-2018	9:19:33	37.1629	74.3088	-	1	21
25-May-2018	9:28:20	37.1741	74.5160	59	1	18
25-May-2018	10:12:10	37.2426	74.5813	60	1	15
25-May-2018	10:16:34	37.2420	74.5238	60	1	600
25-May-2018	10:50:38	37.3245	74.7069	61	1	7
25-May-2018	13:37:14	37.0278	74.4359	57	2	60
*25-May-2018	13:43:26	36.9796	74.3109	-	2	26
25-May-2018	14:34:54	36.8741	74.5267	55	3	60
25-May-2018	14:53:03	36.8023	74.4775	54	3	6
25-May-2018	15:01:29	36.8030	74.6899	54	2	7
16-Jun-2018	10:43:35	36.3468	74.7951	48	1	500
16-Jun-2018	11:35:11	36.4270	74.7638	49	2	28
16-Jun-2018	14:29:40	36.4937	74.7360	50	2	1000
16-Jun-2018	16:07:41	36.7229	74.6913	53	1	950
17-Jun-2018	11:19:33	37.0184	74.6607	57	3	45
5-Aug-2018	13:38:26	37.0358	74.7134	57	2	75
5-Aug-2018	15:16:32	36.7991	74.6721	54	2	70
1-Dec-2018	10:11:57	36.4937	74.7387	50	4	550
19-Dec-2018	11:01:38	36.9587	74.6117	56	0	110
19-Dec-2018	12:02:44	36.8035	74.8936	54	1	150

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
19-Dec-2018	12:30:22	36.7156	74.5453	53	1	500
4-Jan-2019	9:17:05	37.1684	74.7865	59	3	50
4-Jan-2019	11:02:18	36.8678	74.5707	55	3	80
26-Jan-2019	9:46:02	36.6556	74.9401	52	1	11
26-Jan-2019	9:49:03	36.6538	75.0222	52	1	8
*26-Jan-2019	9:54:46	36.5884	75.1883	-	1	100
26-Jan-2019	10:12:52	36.5700	74.6576	51	1	1700
*26-Jan-2019	13:15:32	36.4910	75.3122	-	2	65
26-Jan-2019	13:32:07	36.4242	74.6680	49	2	1800
26-Jan-2019	14:09:03	36.3526	74.7235	48	3	50
26-Jan-2019	15:03:11	36.2051	74.5892	46	3	35
10-Feb-2019	8:54:49	36.7189	74.6106	53	3	22
10-Feb-2019	9:01:51	36.7179	74.4118	53	2	90
10-Feb-2019	9:31:38	36.8055	74.5780	54	3	35
10-Feb-2019	11:02:19	37.0179	74.5284	57	2	300
10-Feb-2019	11:33:03	37.1072	74.7780	58	2	30
10-Feb-2019	12:18:30	37.2526	74.4764	60	1	2
10-Feb-2019	12:25:27	37.2511	74.7499	60	3	35
8-Mar-2019	10:45:47	36.6523	74.4037	52	4	18
8-Mar-2019	11:43:58	36.4998	74.3806	50	4	40
8-Mar-2019	11:55:25	36.5035	74.6994	50	5	70
28-Mar-2019	10:37:25	36.7265	74.9689	53	2	50
28-Mar-2019	12:09:59	36.5740	74.6371	51	3	85
28-Mar-2019	12:33:36	36.4992	74.5841	50	4	10
28-Mar-2019	14:04:08	36.2824	74.7439	47	3	550
28-Mar-2019	14:32:42	36.2095	74.5628	46	2	300
23-Apr-2019	11:18:21	36.7871	75.0833	54	2	5
*23-Apr-2019	11:22:15	36.7461	75.1680	-	2	15
23-Apr-2019	12:38:59	36.5722	74.6512	51	2	70
23-Apr-2019	12:58:13	36.4893	74.4964	50	2	35
23-Apr-2019	13:11:44	36.5013	74.6918	50	1	375
23-Apr-2019	13:51:52	36.4275	74.6588	49	2	40
23-Apr-2019	14:20:48	36.3431	74.8271	48	1	24
27-Jun-2019	9:23:47	37.2473	74.5818	60	2	16
27-Jun-2019	10:47:54	37.0241	74.9859	57	3	10
28-Jun-2019	10:15:40	36.4858	74.5875	50	1	140
29-Jul-2019	10:40:06	36.4192	74.5038	49	1	60
29-Jul-2019	10:42:18	36.4169	74.4271	49	1	40
29-Jul-2019	10:52:41	36.3517	74.4133	48	1	37

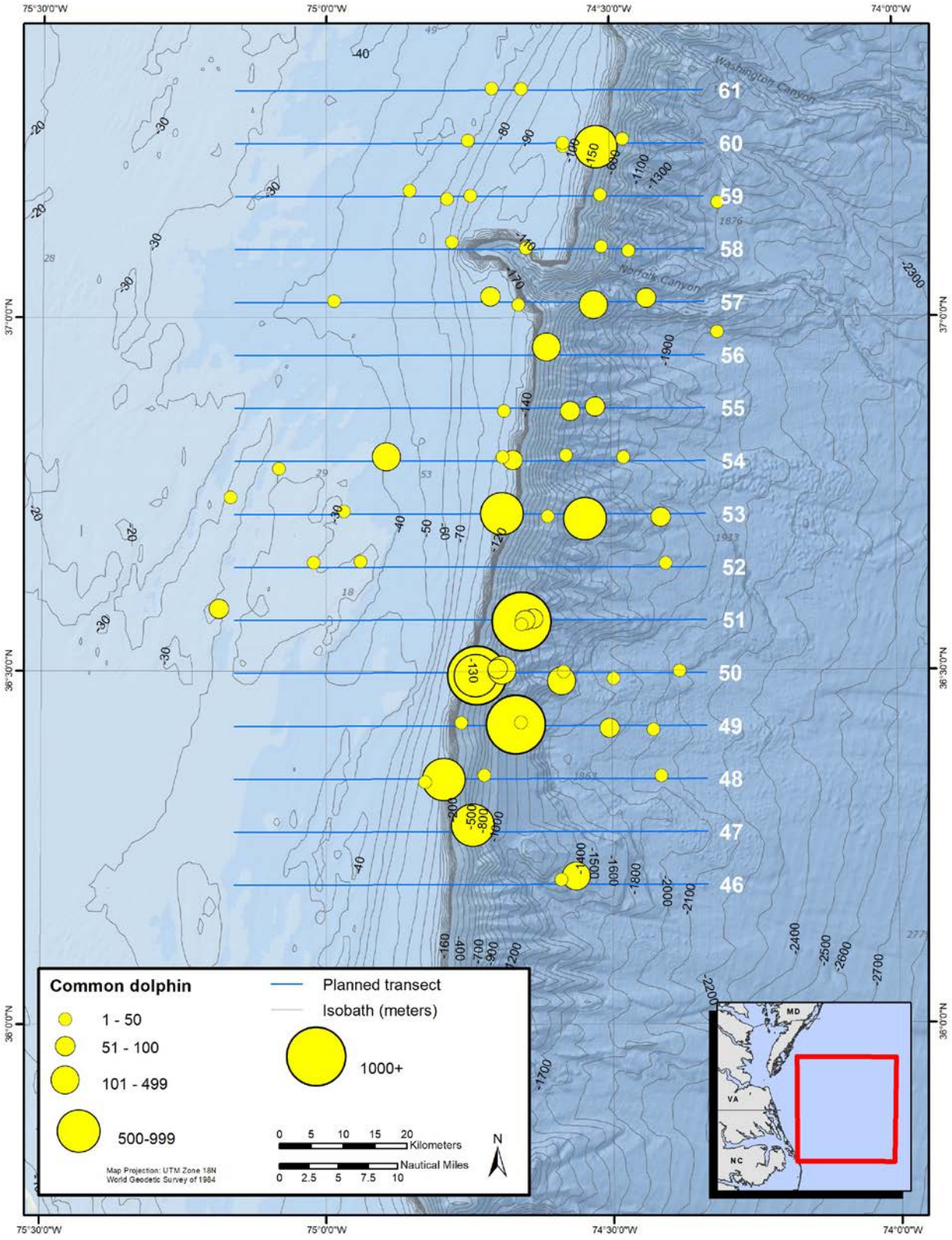

Figure 5. Common dolphin (*Delphinus delphis*) sightings, indicating group size, for all 2018–2019 surveys.

4.2.2 Common bottlenose dolphin (*Tursiops truncatus*)

Common bottlenose dolphins were the most frequently encountered cetacean in the NFC study area. One hundred forty-seven on-effort sightings totaling 2,519 individuals of common bottlenose dolphins were recorded in 10 of the 11 months surveyed (**Table 5**, **Figure 6**). Groups ranged in size between 1 and 100 individuals (mean=17.1, *SD*=17.4).

Fewer sightings and smaller groups occurred in shallower waters, while larger groups were found in deeper waters. Most sightings occurred in waters beyond the 50 m isobath. Based on the distance from shore (i.e., more than 34 km), most of these bottlenose dolphins were likely the offshore ecotype (Torres et al. 2003).

Table 5. Common bottlenose dolphin (*Tursiops truncatus*) sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
9-Apr-2018	10:25:06	37.3288	74.5452	61	3	12
9-Apr-2018	10:27:22	37.3262	74.4544	61	2	37
9-Apr-2018	10:40:08	37.2418	74.4572	60	2	30
9-Apr-2018	10:51:52	37.2423	74.7615	60	2	45
*9-Apr-2018	11:03:56	37.2110	75.1810	60	2	2
9-Apr-2018	11:16:51	37.1727	74.8147	59	3	4
9-Apr-2018	11:18:49	37.1756	74.7386	59	3	12
*11-Apr-2018	9:07:01	37.3073	75.1810	-	2	115
11-Apr-2018	9:18:45	37.3186	74.9478	61	3	4
*11-Apr-2018	14:15:35	36.9712	75.9562	-	3	2
*11-Apr-2018	14:23:08	36.9943	75.5743	-	2	3
11-Apr-2018	16:18:57	36.8022	74.6273	54	4	20
*25-May-2018	8:30:21	36.9798	75.9603	-	2	11
*25-May-2018	8:35:26	37.0148	75.6904	-	1	25
25-May-2018	8:57:59	37.0976	74.6663	58	1	12
25-May-2018	10:45:15	37.3297	74.5983	61	1	17
25-May-2018	10:54:50	37.3244	74.7805	61	1	4
*25-May-2018	11:17:15	37.1477	75.6290	-	1	4
*25-May-2018	11:24:56	37.0066	75.9926	-	1	4
*25-May-2018	13:08:10	36.9745	75.4952	-	1	1
25-May-2018	13:19:40	37.0187	74.9455	57	3	8
25-May-2018	13:31:43	37.0131	74.5491	57	2	7
16-Jun-2018	9:14:49	36.1928	74.8455	46	2	7
16-Jun-2018	9:19:16	36.1966	74.7669	46	2	7
16-Jun-2018	9:38:38	36.1960	74.4687	-	2	13
16-Jun-2018	9:58:43	36.2750	74.4985	47	3	24
16-Jun-2018	10:01:16	36.2455	74.5712	47	3	8

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
16-Jun-2018	10:08:17	36.2821	74.7077	47	2	50
16-Jun-2018	10:25:35	36.2687	75.0713	47	2	1
16-Jun-2018	10:53:38	36.3477	74.5499	48	2	45
16-Jun-2018	11:21:54	36.4218	74.5147	49	1	9
16-Jun-2018	11:38:39	36.4217	74.7914	49	2	4
*16-Jun-2018	12:01:48	36.6448	75.7005	-	1	2
16-Jun-2018	14:41:00	36.4933	74.5166	50	2	22
*16-Jun-2018	14:48:50	36.5331	74.3105	-	1	17
*16-Jun-2018	14:51:25	36.5624	74.3119	-	1	12
16-Jun-2018	15:05:02	36.5706	74.7744	51	1	2
16-Jun-2018	15:05:54	36.5790	74.8088	51	1	10
16-Jun-2018	15:33:51	36.6433	74.7284	52	1	13
16-Jun-2018	15:44:21	36.6420	74.4509	52	1	3
16-Jun-2018	16:06:02	36.7228	74.6265	53	1	4
*17-Jun-2018	8:52:23	37.0549	75.7636	-	1	3
17-Jun-2018	10:07:01	37.1696	75.0852	59	2	11
17-Jun-2018	11:29:29	37.0311	74.4783	57	3	2
17-Jun-2018	12:55:26	36.8069	74.4483	54	3	10
17-Jun-2018	13:07:27	36.8004	74.7864	54	2	1
*14-Jul-2018	9:01:22	37.1494	75.7478	-	3	10
14-Jul-2018	10:47:30	37.0987	74.4600	58	3	2
*14-Jul-2018	11:27:16	36.9797	75.7904	-	3	1
*14-Jul-2018	11:28:17	36.9715	75.8400	-	3	1
*14-Jul-2018	11:29:32	36.9622	75.9014	-	3	5
*14-Jul-2018	11:30:24	36.9500	75.9425	-	3	8
14-Jul-2018	14:56:04	36.8763	74.6573	55	2	6
14-Jul-2018	15:27:36	36.7988	74.5403	54	2	25
*14-Jul-2018	16:00:15	36.8474	75.7162	-	2	18
*5-Aug-2018	10:21:23	37.1365	74.3121	-	1	24
5-Aug-2018	10:31:03	37.1072	74.4626	58	1	14
5-Aug-2018	13:47:18	37.0110	74.4418	57	1	6
5-Aug-2018	14:09:46	36.9427	74.5568	56	1	9
*5-Aug-2018	14:44:32	36.8597	74.7758	55	1	16
5-Aug-2018	15:03:43	36.7912	74.3875	54	1	44
5-Aug-2018	15:11:01	36.7986	74.5695	54	1	29
*5-Aug-2018	15:15:19	36.8079	74.6849	54	1	12
5-Aug-2018	15:22:04	36.8013	74.7970	54	1	25
6-Aug-2018	9:26:10	36.1950	74.6246	46	1	8
6-Aug-2018	9:31:17	36.1991	74.4233	46	1	35

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
6-Aug-2018	9:46:33	36.2762	74.5283	47	1	16
*6-Aug-2018	9:49:48	36.2882	74.5778	47	1	75
6-Aug-2018	9:56:02	36.2775	74.6706	47	1	8
6-Aug-2018	9:56:55	36.2775	74.7073	47	1	4
6-Aug-2018	10:19:06	36.3309	75.1552	48	1	30
6-Aug-2018	10:29:30	36.3526	74.8988	48	1	16
6-Aug-2018	10:37:50	36.3437	74.7112	48	1	8
6-Aug-2018	10:42:19	36.3431	74.6172	48	1	76
6-Aug-2018	11:17:22	36.4230	74.7045	49	1	70
*6-Aug-2018	11:25:10	36.4193	74.9057	49	1	30
*6-Aug-2018	14:00:37	36.5377	75.2452	-	4	1
6-Aug-2018	14:09:33	36.4972	74.8836	50	2	17
6-Aug-2018	14:26:02	36.4999	74.5198	50	2	13
6-Aug-2018	14:40:44	36.5771	74.3632	51	1	28
6-Aug-2018	15:45:07	36.7151	74.5195	53	1	36
19-Oct-2018	8:55:31	36.8719	74.7729	55	2	9
19-Oct-2018	9:08:45	36.8756	74.3404	55	2	4
19-Oct-2018	9:29:49	36.9407	74.9956	56	2	7
19-Oct-2018	9:49:00	37.0082	74.8421	57	2	5
19-Oct-2018	10:02:11	37.0143	74.5471	57	2	2
19-Oct-2018	10:20:32	37.1034	74.6093	58	2	2
19-Oct-2018	10:24:16	37.1041	74.7525	58	2	2
19-Oct-2018	10:27:29	37.0841	74.8494	58	2	20
19-Oct-2018	10:50:58	37.1679	74.7385	59	2	52
*19-Oct-2018	11:55:22	37.2859	74.4828	-	2	60
*19-Oct-2018	12:22:35	37.0090	75.6971	-	3	5
*19-Oct-2018	12:30:41	36.9677	76.0777	-	3	7
19-Dec-2018	9:29:26	37.1712	75.0287	59	1	3
19-Dec-2018	10:07:20	37.1045	74.8293	58	2	5
19-Dec-2018	10:20:17	37.0175	75.0960	57	1	8
19-Dec-2018	10:44:13	37.0165	74.4487	57	1	5
19-Dec-2018	11:12:04	36.9533	74.9613	56	0	9
19-Dec-2018	11:17:36	36.9528	75.1709	56	0	4
19-Dec-2018	11:23:05	36.8668	75.0783	55	0	8
19-Dec-2018	11:26:24	36.8740	74.9560	55	0	15
19-Dec-2018	12:09:31	36.7908	75.1700	54	1	25
19-Dec-2018	12:23:20	36.7283	74.7241	53	1	3
19-Dec-2018	12:26:19	36.7279	74.6154	53	1	11
4-Jan-2019	8:28:55	37.3168	74.6416	61	3	16

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
4-Jan-2019	8:34:43	37.3166	74.4230	61	3	5
4-Jan-2019	8:44:24	37.2455	74.4120	60	2	8
4-Jan-2019	9:36:38	37.1011	74.4468	58	3	7
17-Jan-2019	9:29:01	37.0259	74.3769	57	2	4
17-Jan-2019	10:40:14	36.8772	74.9501	55	3	15
26-Jan-2019	9:07:26	36.7274	74.6372	53	2	2
26-Jan-2019	9:26:35	36.6427	74.3587	52	2	12
26-Jan-2019	9:38:47	36.6545	74.6856	52	2	7
26-Jan-2019	9:50:20	36.6519	75.0742	52	1	4
26-Jan-2019	10:19:49	36.5702	74.5581	51	1	25
26-Jan-2019	11:03:22	36.5024	74.9815	50	1	1
*26-Jan-2019	11:11:21	36.5580	75.3144	-	1	4
*26-Jan-2019	11:13:55	36.6290	75.4149	-	1	15
*26-Jan-2019	13:06:49	36.6639	75.6762	-	1	90
*26-Jan-2019	13:14:23	36.5098	75.3645	-	2	40
26-Jan-2019	13:41:17	36.4284	74.4166	49	3	30
26-Jan-2019	14:28:41	36.2583	75.0481	47	1	7
26-Jan-2019	14:37:38	36.2744	74.7662	47	2	16
26-Jan-2019	14:42:15	36.2657	74.6917	47	2	12
26-Jan-2019	14:45:12	36.2728	74.6208	47	2	8
26-Jan-2019	15:17:00	36.2020	75.0351	46	2	5
*10-Feb-2019	8:28:18	36.8701	75.7015	-	3	17
*10-Feb-2019	8:32:24	36.8196	75.5164	-	3	6
10-Feb-2019	9:54:19	36.8677	74.9619	55	3	4
10-Feb-2019	10:56:39	37.0156	74.6277	57	2	2
10-Feb-2019	11:28:24	37.0933	74.6753	58	2	18
10-Feb-2019	11:33:03	37.1072	74.7780	58	2	8
8-Mar-2019	10:23:28	36.7206	74.7230	53	2	7
*8-Mar-2019	11:09:12	36.6175	75.1915	52	2	10
*28-Mar-2019	12:24:40	36.5140	74.3239	51	4	60
28-Mar-2019	13:10:18	36.4219	74.7395	49	2	8
28-Mar-2019	13:19:14	36.3987	74.4123	49	3	60
28-Mar-2019	13:46:49	36.3517	75.0473	48	2	8
28-Mar-2019	14:16:02	36.2662	74.4167	47	2	100
*23-Apr-2019	10:06:42	36.9318	75.9263	-	2	50
23-Apr-2019	10:42:02	36.8691	74.4250	55	1	16
23-Apr-2019	10:51:17	36.7994	74.3586	54	3	26
23-Apr-2019	12:18:31	36.6487	75.0353	52	2	6
23-Apr-2019	13:05:45	36.4795	74.6299	50	1	10

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
23-Apr-2019	13:11:44	36.5013	74.6918	50	1	6
23-Apr-2019	13:38:40	36.4277	75.0794	49	2	9
*27-Jun-2019	8:20:43	36.9388	75.9942	-	2	10
27-Jun-2019	9:05:55	37.3166	74.4613	61	3	60
27-Jun-2019	10:07:49	37.1761	74.4758	59	2	30
27-Jun-2019	10:16:31	37.0923	74.3146	59	2	10
27-Jun-2019	10:22:42	37.1000	74.4660	58	2	8
27-Jun-2019	10:29:34	37.1049	74.7447	58	2	7
27-Jun-2019	10:52:39	37.0167	74.8073	57	3	50
27-Jun-2019	10:59:41	37.0268	74.5460	57	2	22
27-Jun-2019	11:50:47	36.8741	74.5519	55	2	15
*28-Jun-2019	8:21:14	36.8652	75.9332	-	2	8
28-Jun-2019	9:01:00	36.7227	74.5678	53	1	20
28-Jun-2019	9:19:22	36.6448	74.6143	52	1	1
28-Jun-2019	9:20:57	36.6438	74.6518	52	1	30
28-Jun-2019	9:22:43	36.6460	74.7165	52	1	1
28-Jun-2019	9:36:11	36.6451	75.1006	52	2	2
28-Jun-2019	9:52:47	36.5735	74.6783	51	1	27
28-Jun-2019	9:53:02	36.5693	74.6748	51	1	13
28-Jun-2019	10:01:25	36.5663	74.4179	51	1	12
28-Jun-2019	10:01:57	36.5740	74.3967	51	1	3
*28-Jun-2019	10:08:03	36.5000	74.3071	51	1	33
28-Jun-2019	10:14:02	36.5041	74.5387	50	1	50
28-Jun-2019	10:48:46	36.4178	74.6568	49	1	14
28-Jun-2019	10:58:16	36.3984	74.3023	49	1	5
28-Jun-2019	11:09:21	36.3517	74.5302	48	2	1
28-Jun-2019	11:17:34	36.3515	74.8438	48	1	26
28-Jun-2019	12:09:28	36.2004	74.6037	46	2	8
29-Jul-2019	8:29:03	36.7263	74.5302	53	3	40
29-Jul-2019	8:35:02	36.7269	74.3900	53	3	75
29-Jul-2019	8:50:41	36.6389	74.5309	52	2	27
29-Jul-2019	9:38:34	36.5634	74.5168	51	3	34
29-Jul-2019	9:44:31	36.5577	74.3432	51	2	60
29-Jul-2019	9:59:03	36.5011	74.5611	50	2	25
29-Jul-2019	11:44:15	36.2650	74.3393	47	1	7
29-Jul-2019	12:02:42	36.2063	74.7742	46	0	16
*12-Aug-2019	7:38:23	37.0084	75.9643	-	1	6
*12-Aug-2019	7:44:51	37.0959	75.6649	-	1	4
12-Aug-2019	8:29:04	37.1001	74.4995	58	1	12

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
12-Aug-2019	8:44:01	37.0903	74.9636	58	0	15
12-Aug-2019	9:19:24	37.0301	74.4400	57	0	40
12-Aug-2019	9:35:02	36.9509	74.5626	56	1	40
12-Aug-2019	10:08:53	36.8645	74.6457	55	0	18
*12-Aug-2019	10:25:42	36.8104	74.3216	55	0	14
12-Aug-2019	10:30:06	36.7960	74.4922	54	0	14
12-Aug-2019	11:04:28	36.7232	74.8148	53	1	27
*12-Aug-2019	11:28:45	36.7090	74.3339	53	1	14

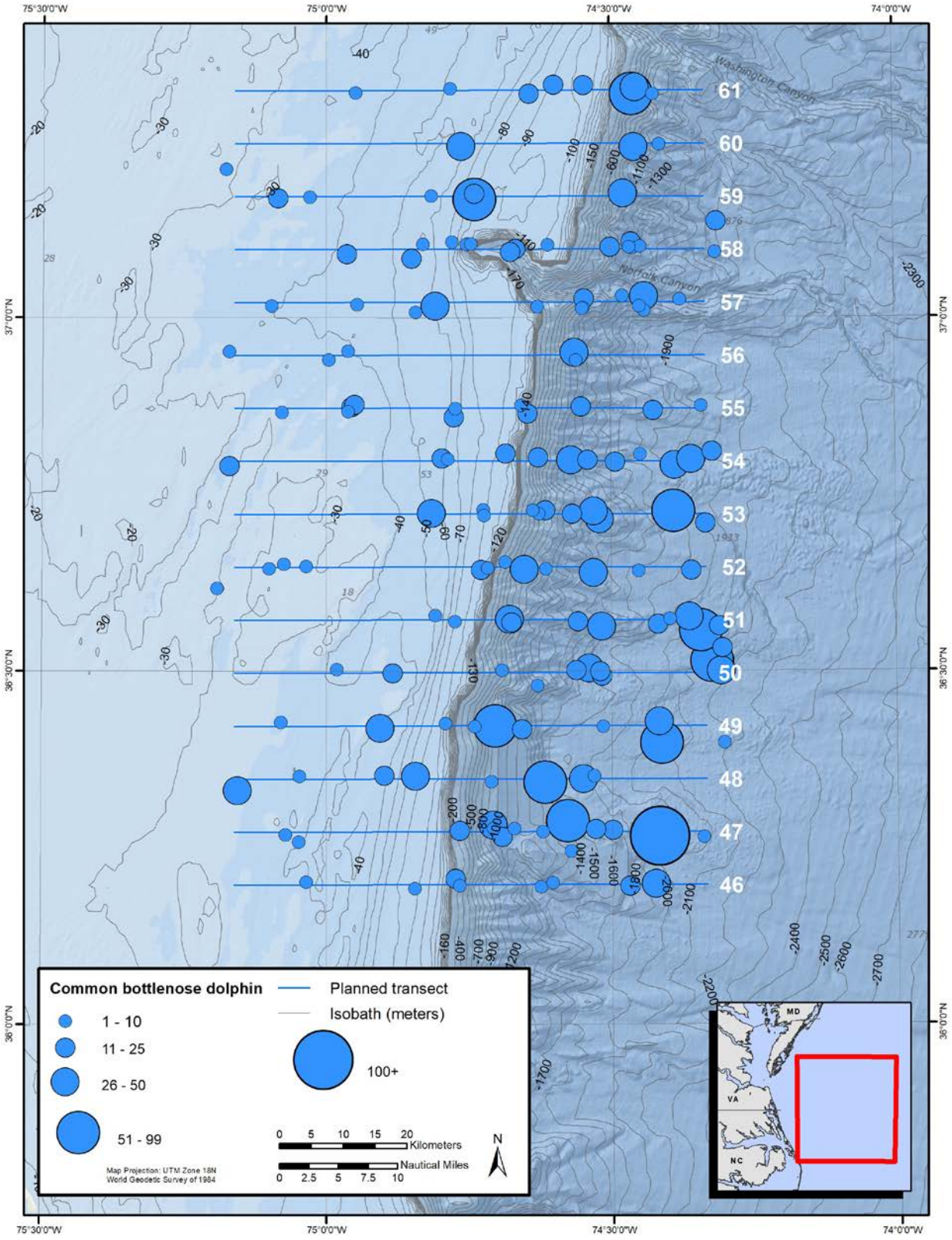

Figure 6. Common bottlenose dolphin (*Tursiops truncatus*) sightings, indicating group size, for all 2018–2019 surveys.

4.2.3 Atlantic spotted dolphin (*Stenella frontalis*)

Twenty-two sightings of Atlantic spotted dolphins comprised of 1,874 individuals were observed while on effort. Group size ranged between 12 and 175 (mean=85.2, *SD*=41.5) (**Table 6, Figure 7**). There were also two off-effort sightings of 210 individuals.

There are two distinct forms, or ecotypes, of the Atlantic spotted dolphin in the western North Atlantic: a heavily spotted, larger form that typically occurs on the continental shelf and is most often encountered around the 200-m isobath or shallower, and a less spotted and smaller form that occurs farther offshore and around islands (Perrin et al. 1987, 1994). Examination of photographs collected during each sighting recorded on these surveys suggests that both ecotypes are present within the study area and all sightings aligned with this pattern. Regardless of ecotype, all sightings of Atlantic spotted dolphins occurred between the months of April and October.

Table 6. Atlantic spotted dolphin (*Stenella frontalis*) sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time (local)	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
16-June-2018	10:37:58	36.3460	74.9005	48	1	115
16-June-2018	15:28:37	36.6484	74.8680	52	1	75
14-July-2018	9:56:52	37.2454	74.7228	60	3	175
14-July-2018	10:34:42	37.1644	74.4420	59	3	45
14-July-2018	14:34:34	36.9482	75.1283	56	3	135
14-July-2018	13:04:53	36.8847	74.4962	55	2	105
14-July-2018	15:18:45	36.7820	74.4155	54	3	95
14-July-2018	15:38:54	36.7893	74.8751	54	2	50
5-Aug-2018	14:14:22	36.9315	74.7642	56	2	75
*6-Aug-2018	14:33:37	36.5151	74.3070	50	1	185
6-Aug-2018	15:18:19	36.6434	74.8165	52	1	150
19-Oct-2018	9:18:03	36.9528	74.5885	56	2	17
23-Apr-2019	12:06:28	36.6439	74.7608	52	2	90
23-Apr-2019	13:43:28	36.4204	74.8846	49	2	65
27-Jun-2019	11:24:45	36.9473	74.9697	56	3	80
28-Jun-2019	11:05:31	36.3552	74.4853	48	2	90
28-Jun-2019	11:19:48	36.3442	74.9298	48	1	45
28-Jun-2019	11:21:53	36.3552	74.9529	48	1	12
29-Jul-2019	8:42:45	36.6358	74.3717	52	2	125
29-Jul-2019	9:04:51	36.6415	74.3717	52	3	85
29-Jul-2019	11:36:49	36.2726	74.5173	47	1	85
*12-Aug-2019	7:51:51	37.1365	75.3209	-	1	25
12-Aug-2019	9:01:25	37.0147	75.0248	57	1	130
12-Aug-2019	11:01:20	36.7231	74.9308	53	1	30

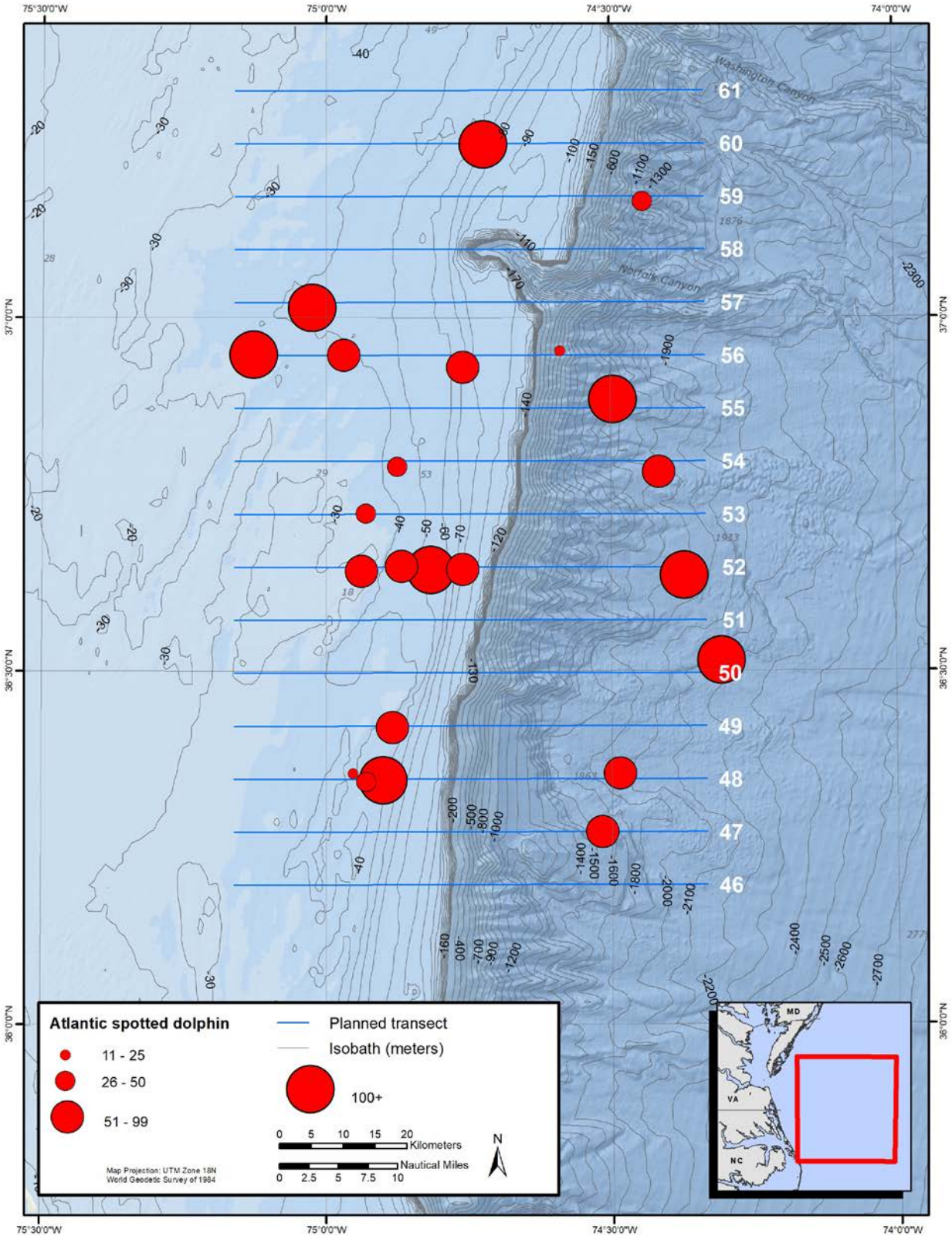

Figure 7. Atlantic spotted dolphin (*Stenella frontalis*) sightings, indicating group size, for all 2018–2019 surveys.

4.2.4 Risso's dolphin (*Grampus griseus*)

Risso's dolphins were encountered on effort 44 times totaling 1,062 individuals, all in groups of fewer than 120 individuals (mean=24.1, *SD*=23.6) (**Table 7, Figure 8**). Four off-effort sightings of 43 total individuals occurred during offshore cross-legs. All sightings were near the continental shelf-break or in deeper waters. From a spatial perspective, the distribution of Risso's dolphin sightings closely mirrors that of pilot whales, albeit with different temporal patterns. Ninety-one percent of all of the Risso's dolphin sightings over the course of the project were recorded in the months of May through August.

Table 7. Risso's dolphin (*Grampus griseus*) sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
*9-Apr-2018	11:32:17	37.1671	74.3120	-	3	4
25-May-2018	9:24:16	37.1716	74.4610	59	1	7
25-May-2018	10:23:47	37.2439	74.4052	60	1	15
25-May-2018	14:28:47	36.8768	74.6724	55	3	7
*25-May-2018	14:32:15	36.8810	74.6335	-	3	10
16-Jun-2018	9:42:05	36.1913	74.4407	46	2	35
17-Jun-2018	10:25:38	37.1676	74.5362	59	3	31
17-Jun-2018	11:23:20	37.0912	74.6334	57	3	12
14-Jul-2018	10:48:47	37.0939	74.5129	58	3	60
14-Jul-2018	14:13:51	36.9333	74.5613	56	2	30
5-Aug-2018	9:23:52	37.2614	74.3705	60	2	7
5-Aug-2018	10:27:16	37.1071	74.3847	58	2	15
5-Aug-2018	14:54:32	36.8702	74.5286	55	1	7
5-Aug-2018	15:11:44	36.8034	74.5911	54	1	24
*6-Aug-2018	9:40:44	36.2411	74.3250	-	1	20
6-Aug-2018	10:39:18	36.3376	74.6487	48	1	20
6-Aug-2018	10:47:29	36.3431	74.4986	48	1	6
6-Aug-2018	11:06:51	36.4223	74.4529	49	1	12
6-Aug-2018	11:10:01	36.4335	74.5838	49	1	35
6-Aug-2018	15:29:31	36.6440	74.5098	52	1	4
6-Aug-2018	15:42:12	36.7162	74.4052	53	1	12
6-Aug-2018	15:50:17	36.7224	74.6014	53	2	29
19-Dec-2018	9:58:09	37.1039	74.4648	58	2	15
19-Dec-2018	10:03:15	37.0972	74.6659	58	2	18
19-Dec-2018	11:49:17	36.8042	74.4645	54	1	14
8-Mar-2019	8:54:44	36.9533	74.3678	56	4	15
27-Jun-2019	10:12:56	37.1735	74.3567	59	2	8
27-Jun-2019	10:16:31	37.0926	74.3146	59	2	28
27-Jun-2019	10:23:16	37.1011	74.4881	58	2	25

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
27-Jun-2019	10:58:51	37.0183	74.5771	57	2	6
27-Jun-2019	11:12:29	36.9513	74.4800	56	2	9
27-Jun-2019	11:56:48	36.8727	74.3703	55	2	10
27-Jun-2019	12:02:42	36.8004	74.4233	55	2	4
28-Jun-2019	9:15:32	36.6494	74.4823	52	1	60
28-Jun-2019	9:55:52	36.5677	74.6387	51	1	14
*28-Jun-2019	10:58:16	36.3984	74.3023	49	1	9
28-Jun-2019	12:14:16	36.2014	74.7804	46	3	7
29-Jul-2019	9:31:56	36.5728	74.6551	51	3	80
29-Jul-2019	9:54:52	36.5000	74.4098	50	2	9
29-Jul-2019	9:59:03	36.5011	74.5611	50	2	120
29-Jul-2019	10:37:01	36.4148	74.6199	49	1	21
29-Jul-2019	10:55:49	36.3516	74.5296	48	1	14
29-Jul-2019	12:00:16	36.2031	74.5296	46	0	75
12-Aug-2019	8:12:01	37.1663	74.5118	59	1	18
12-Aug-2019	8:13:19	37.1639	74.4621	59	1	10
12-Aug-2019	9:16:06	37.0232	74.5635	57	0	27
12-Aug-2019	10:15:06	36.8792	74.5738	55	0	63
12-Aug-2019	11:39:19	36.6451	74.6376	52	1	24

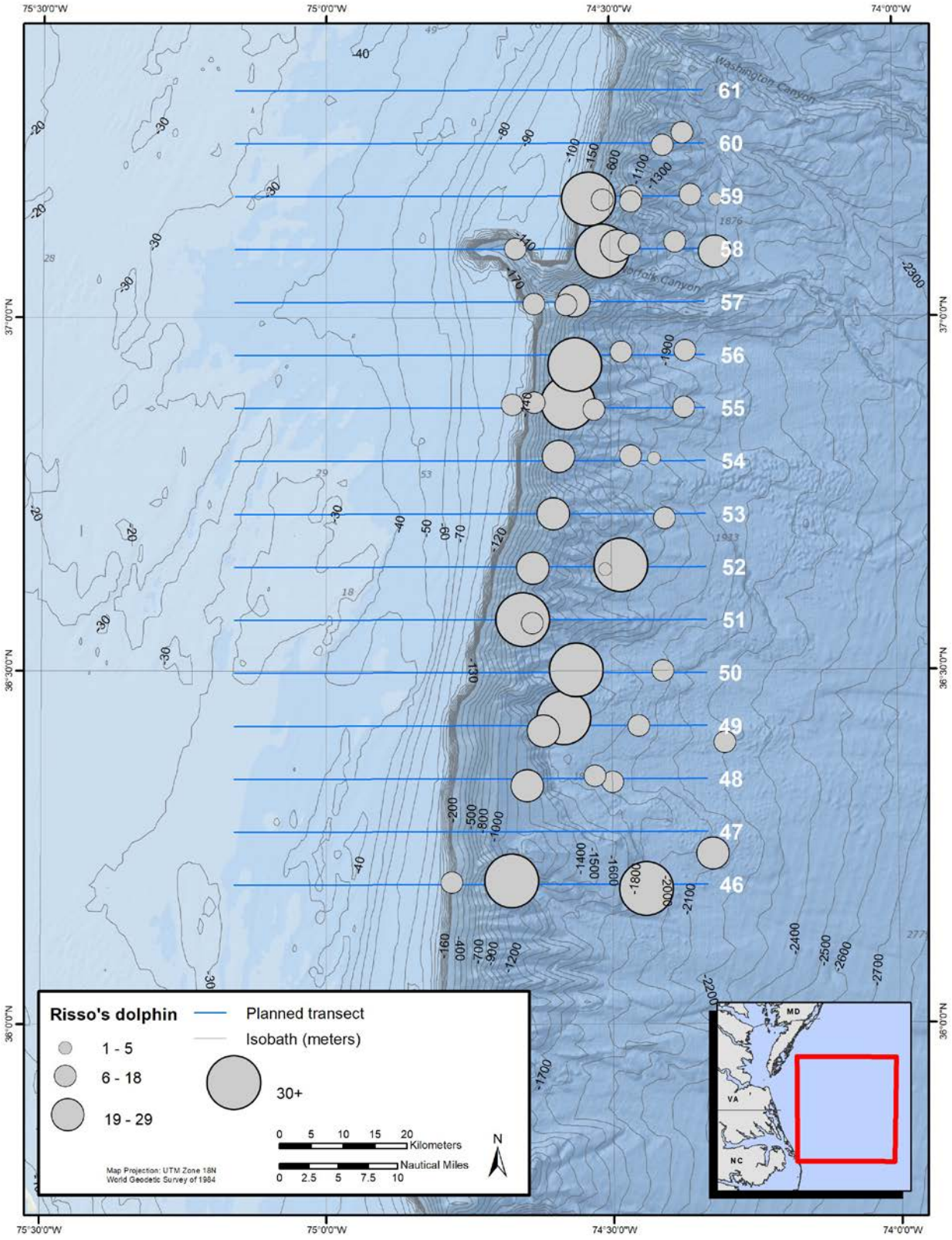

Figure 8. Risso's dolphin (*Grampus griseus*) sightings, indicating group size, for all 2018–2019 surveys.

4.2.5 Striped dolphin (*Stenella coeruleoalba*)

Striped dolphins were recorded during seventeen on-effort sightings, totaling 1,235 individuals. All but one group were observed beyond the 500-m isobath, with a mean group size of 72.6 (*SD*=43.8) (**Table 8, Figure 9**). One off-effort sighting of 400 individuals was also observed in transit between the offshore ends of tracklines. Nearly half of the groups consisted of 60 or fewer individuals. All of the larger groups consisting of 100 or more individuals were distributed further offshore and occurred at the far eastern ends of the survey tracklines. Over seventy percent of all striped dolphin sightings were made during the winter months of December through February.

Table 8. Striped dolphin (*Stenella coeruleoalba*) sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes off-effort sightings.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
9-Apr-2018	10:30:31	37.3254	74.3301	61	2	35
9-Apr-2018	10:34:55	37.2519	74.2999	61	2	35
9-Apr-2018	12:19:58	37.0247	74.5560	61	4	100
*25-May-2018	10:30:14	37.2991	74.3105	-	1	400
25-May-2018	13:48:00	36.9584	74.3471	56	2	40
5-Aug-2018	13:57:03	36.9416	74.3482	56	1	125
1-Dec-2018	8:35:13	36.1958	74.6749	57	3	25
1-Dec-2018	10:26:33	36.4967	74.4229	56	3	120
19-Dec-2018	12:50:47	36.6527	74.6714	54	1	60
17-Jan-2019	9:35:31	37.0284	74.4574	57	2	60
26-Jan-2019	9:12:41	36.7210	74.6155	53	2	90
26-Jan-2019	9:31:18	36.6538	74.4631	52	2	110
26-Jan-2019	10:42:19	36.4940	74.4245	50	2	175
26-Jan-2019	10:46:53	36.4985	74.5176	50	2	60
10-Feb-2019	10:20:48	36.9590	74.5496	56	2	100
10-Feb-2019	10:26:57	36.9523	74.6327	56	2	20
10-Feb-2019	11:16:27	37.1065	74.3785	58	2	5
10-Feb-2019	12:03:07	37.1707	74.4557	59	1	75

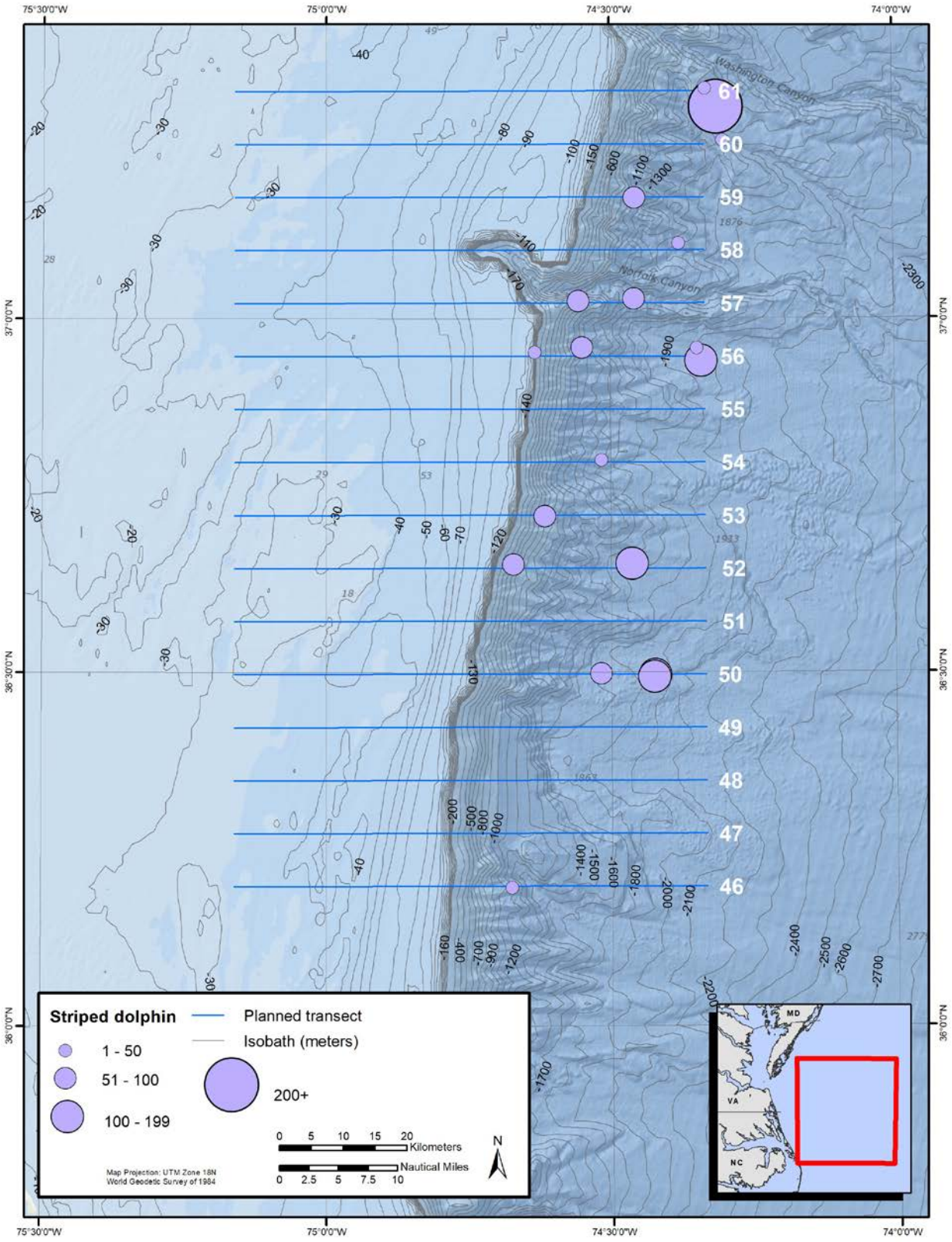

Figure 9. Striped dolphin (*Stenella coeruleoalba*) sightings, indicating group size, for all 2018–2019 surveys.

4.2.6 Short-finned pilot whale (*Globicephala macrorhynchus*)

Short-finned pilot whales were observed on effort 94 times for a total of 1,297 individuals, and were seen in 9 of the 11 months in which surveys were conducted. Another 4 observations of 45 individuals were recorded as off-effort sightings. Group sizes ranged from 1 to 60 individuals (mean=13.8, *SD*=9.2) (**Table 9**). All pilot whales were observed beyond the 100-m isobaths, from the continental shelf-break into waters deeper than 2,100 m (**Figure 10**). The possibility of spatial overlap between short-finned and long-finned (*Globicephala melas*) pilot whales within the NFC study area exists to some degree, although all pilot whale sightings recorded during these surveys were most likely of the short-finned species.

Table 9. Short-finned pilot whale (*Globicephala macrorhynchus)* sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
11-Apr-2018	11:38:37	37.0984	74.6473	58	3	2
25-May-2018	13:31:43	37.0131	74.5491	57	2	12
25-May-2018	14:40:54	36.8623	74.3801	55	3	10
16-Jun-2018	9:19:16	36.1966	74.7669	46	2	8
*16-Jun-2018	9:50:06	36.2062	74.3242	-	2	3
16-Jun-2018	9:52:55	36.2714	74.3551	47	2	9
16-Jun-2018	10:08:17	36.2821	74.7076	47	2	3
16-Jun-2018	10:15:39	36.2749	74.7663	47	2	22
16-Jun-2018	10:50:00	36.3520	74.6935	48	1	10
16-Jun-2018	11:25:02	36.4217	74.5560	49	1	4
16-Jun-2018	11:26:53	36.4222	74.5943	49	1	1
16-Jun-2018	11:28:44	36.4066	74.6677	49	2	11
16-Jun-2018	14:29:40	36.4937	74.7360	50	2	21
16-Jun-2018	14:59:57	36.5721	74.5764	51	1	14
17-Jun-2018	9:29:23	37.3224	74.3786	61	3	9
*17-Jun-2018	9:35:49	37.2624	74.3064	-	3	10
17-Jun-2018	10:32:52	37.1760	74.3754	59	3	4
17-Jun-2018	11:29:29	37.0311	74.4783	57	3	6
17-Jun-2018	11:59:07	36.9439	74.5810	56	2	26
17-Jun-2018	13:02:40	36.7932	74.6011	54	3	4
14-Jul-2018	9:39:16	37.3176	74.3523	61	3	16
14-Jul-2018	10:48:47	37.0939	74.5129	58	3	16
14-Jul-2018	14:13:51	36.9333	74.5613	56	2	13
5-Aug-2018	9:07:05	37.3049	74.5073	61	2	9
5-Aug-2018	9:11:13	37.3219	74.4630	61	2	11
5-Aug-2018	9:15:02	37.3141	74.4382	61	2	14
5-Aug-2018	9:18:31	37.3151	74.3774	61	2	26
5-Aug-2018	9:19:05	37.3371	74.3478	61	2	6

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
*5-Aug-2018	9:21:27	37.2843	74.3276	-	2	18
5-Aug-2018	9:23:15	37.2522	74.3461	60	2	15
5-Aug-2018	9:27:38	37.2520	74.4335	60	2	17
5-Aug-2018	9:28:04	37.2334	74.4607	60	2	12
5-Aug-2018	10:13:24	37.1838	74.5060	59	1	8
5-Aug-2018	10:18:12	37.1614	74.3996	59	1	13
5-Aug-2018	10:19:34	37.1641	74.3459	59	1	19
5-Aug-2018	10:29:48	37.0924	74.4242	58	1	10
5-Aug-2018	10:34:17	37.0952	74.4943	58	1	22
5-Aug-2018	13:42:14	37.0346	74.6442	57	1	11
5-Aug-2018	13:44:30	37.0373	74.6103	57	1	15
5-Aug-2018	13:51:40	37.0426	74.3515	57	1	28
5-Aug-2018	14:05:42	36.9534	74.4381	56	1	11
5-Aug-2018	14:08:32	36.9413	74.5764	56	1	13
5-Aug-2018	14:10:16	36.9611	74.6261	56	1	6
5-Aug-2018	14:49:56	36.8835	74.6228	55	1	9
5-Aug-2018	15:15:53	36.7940	74.6454	54	1	7
6-Aug-2018	9:56:02	36.2775	74.6706	47	1	3
6-Aug-2018	10:02:37	36.2721	74.7754	47	1	22
6-Aug-2018	10:36:35	36.3423	74.7607	48	1	26
6-Aug-2018	11:13:27	36.4199	74.6101	49	1	20
6-Aug-2018	14:19:09	36.4928	74.6980	50	2	12
6-Aug-2018	14:50:31	36.5705	74.6644	51	2	21
19-Oct-2018	9:00:50	36.8640	74.5569	55	2	16
19-Oct-2018	9:05:25	36.8660	74.4684	55	2	24
19-Oct-2018	10:14:11	37.0979	74.4843	58	2	27
19-Oct-2018	10:18:46	37.1066	74.5412	58	2	7
19-Oct-2018	10:58:59	37.1628	74.5051	59	2	14
19-Oct-2018	11:00:48	37.1612	74.4331	59	2	5
19-Oct-2018	11:02:13	37.1662	74.3745	59	2	16
19-Oct-2018	11:08:18	37.2511	74.4222	60	2	5
19-Oct-2018	11:46:00	37.3247	74.4366	61	2	11
1-Dec-2018	8:41:47	36.1930	74.5420	46	3	14
19-Dec-2018	9:58:57	37.1022	74.4960	58	2	6
19-Dec-2018	11:54:41	36.8062	74.5631	54	1	18
19-Dec-2018	11:56:58	36.8097	74.6563	54	1	9
19-Dec-2018	12:46:58	36.6530	74.5923	52	1	10
*4-Jan-2019	8:41:26	37.2761	74.3311	61	3	14
26-Jan-2019	10:16:10	36.5521	74.6245	51	1	24

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
26-Jan-2019	10:19:49	36.5702	74.5581	51	1	25
26-Jan-2019	10:46:53	36.4985	74.5176	50	2	12
26-Jan-2019	10:53:31	36.5039	74.6675	50	2	28
26-Jan-2019	14:05:12	36.3478	74.6130	48	3	4
26-Jan-2019	15:08:04	36.2024	74.6965	46	3	19
8-Mar-2019	10:27:23	36.7210	74.5784	53	3	22
23-Apr-2019	11:59:42	36.6529	74.5891	52	2	16
23-Apr-2019	13:11:44	36.5013	74.6918	50	1	60
27-Jun-2019	9:17:01	37.2557	74.4036	60	2	10
27-Jun-2019	9:19:10	37.2492	74.4351	60	2	2
27-Jun-2019	11:00:46	37.0190	74.5122	57	2	3
28-Jun-2019	8:51:30	36.7192	74.6098	53	1	3
28-Jun-2019	9:21:33	36.6446	74.6747	52	1	13
28-Jun-2019	9:52:17	36.5662	74.6982	51	1	8
28-Jun-2019	9:58:44	36.5678	74.5249	51	1	11
28-Jun-2019	10:47:13	36.4239	74.7194	49	1	15
28-Jun-2019	10:47:50	36.4178	74.6936	49	1	40
28-Jun-2019	10:58:16	36.3984	74.3023	49	1	5
28-Jun-2019	11:09:21	36.3517	74.5302	48	2	10
28-Jun-2019	11:59:21	36.1902	74.4023	46	2	25
29-Jul-2019	10:32:47	36.4146	74.7130	49	1	36
29-Jul-2019	11:00:00	36.3461	74.6869	48	1	4
29-Jul-2019	11:00:58	36.3608	74.7148	48	1	23
29-Jul-2019	11:42:48	36.2649	74.3850	47	1	5
12-Aug-2019	11:57:39	36.1961	74.5769	46	0	11
12-Aug-2019	8:14:08	37.1788	74.4300	59	1	10
12-Aug-2019	8:31:36	37.0945	74.5187	58	1	12
12-Aug-2019	8:32:48	37.1023	74.5187	58	1	16
12-Aug-2019	10:08:53	36.8645	74.6457	55	0	14
12-Aug-2019	10:10:13	36.8785	74.6139	55	0	5
12-Aug-2019	10:33:25	36.8006	74.6205	54	0	17

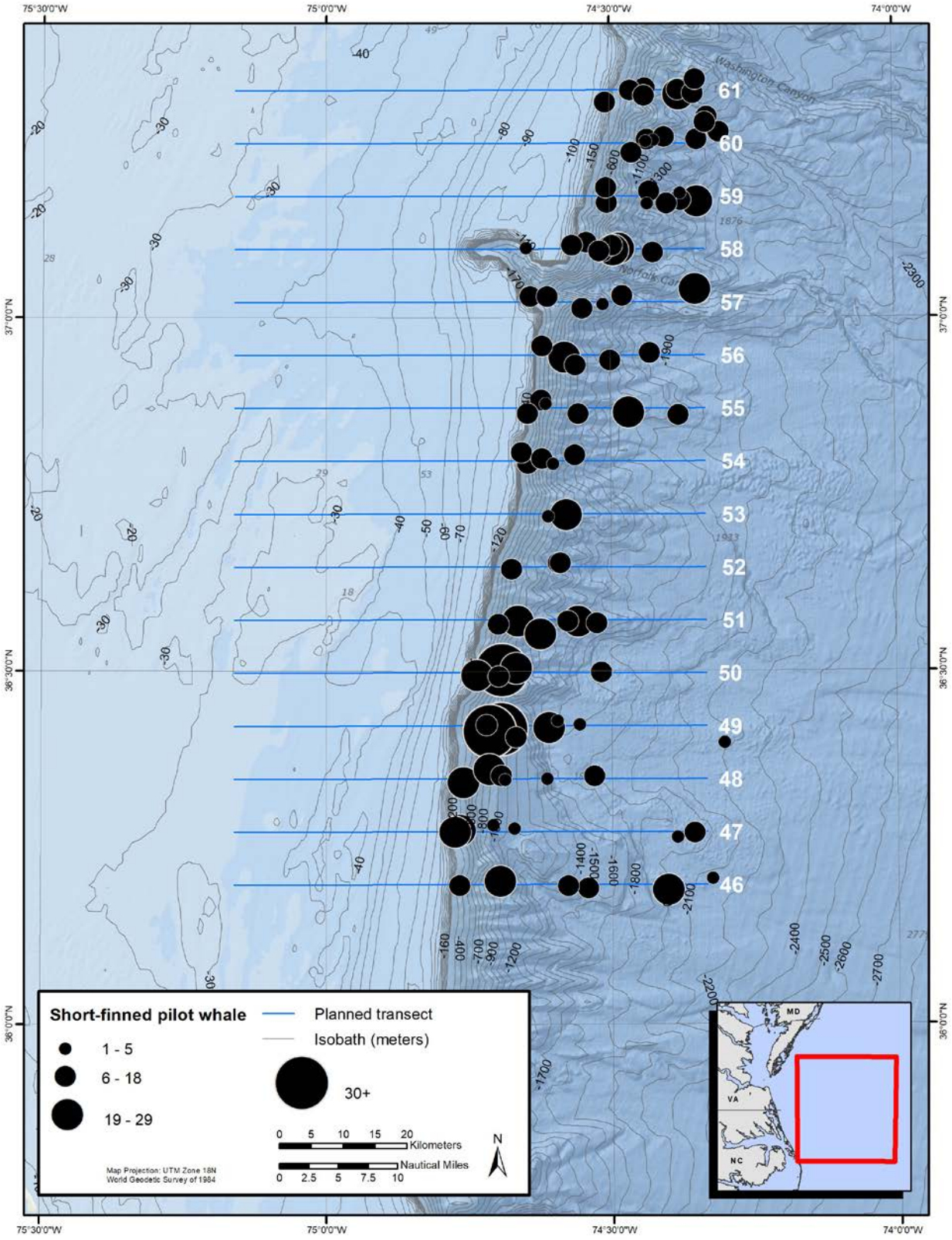

Figure 10. Pilot whale (*Globicephala macrorhynchus*) sightings, indicating group size, for all surveys in 2018–2019.

4.3 Whales

4.3.1 Sperm whale (*Physeter macrocephalus*)

Sperm whales were observed while on effort 22 times for a total of 61 individuals (**Table 10, Figure 11**). Three off-effort sightings, totaling four individuals, were also recorded between tracklines. All but four sightings occurred at or beyond the 1,000-m isobath, with three sightings of three individuals seen just beyond the continental shelf break near the 400-m isobath south of Norfolk Canyon. Sperm whales were recorded in six out of the eleven survey months, but notably were not seen from October through March, save for one sighting of one individual in January.

Based on our observations, all 2018–2019 sperm whale sightings were generally concentrated into two sections of the study area, an area east-southeast of Norfolk Canyon and another far to the southeast. On two occasions, sightings were of large socio-sexual groups interacting at the surface. Both of these sightings included a mix of age-classes with individuals logging, hanging vertically in the water, nursing, jaw-clapping, and engaging in head-to-head, body-body, and genital-region contact while swimming.

Table 10. Sperm whale (*Physeter macrocephalus*) sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
11-Apr-2018	14:55:05	37.0255	74.3318	57	4	2
11-Apr-2018	15:02:02	36.9505	74.3827	56	4	2
11-Apr-2018	15:59:13	36.8680	74.6203	55	4	1
16-Jun-2018	9:29:53	36.2050	74.5659	46	2	21
16-Jun-2018	9:56:39	36.2687	74.4174	47	2	1
*16-Jun-2018	11:15:01	36.3572	74.3047	-	1	1
17-Jun-2018	11:52:22	36.9429	74.4920	56	2	1
17-Jun-2018	12:40:25	36.8896	74.5153	55	3	1
6-Aug-2018	9:56:55	36.2775	74.7073	47	1	2
6-Aug-2018	10:55:48	36.4247	74.3331	48	0	9
6-Aug-2018	11:05:02	36.4255	74.3793	49	1	1
*26-Jan-2019	13:49:04	36.3355	74.3319	-	3	1
26-Jan-2019	14:59:25	36.2018	74.4183	46	3	1
8-Mar-2019	9:35:12	36.8691	74.5025	55	4	1
28-Mar-2019	11:20:35	36.6566	74.6672	52	4	1
28-Mar-2019	12:36:43	36.5070	74.7070	50	4	1
28-Mar-2019	13:19:14	36.3987	74.4123	49	3	1
28-Mar-2019	13:28:09	36.3714	74.3740	48	3	1
28-Mar-2019	13:32:14	36.3762	74.4382	48	3	1
28-Mar-2019	13:32:51	36.3566	74.4786	48	3	1
28-Jun-2019	12:06:45	36.2068	74.5670	46	2	1

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
29-Jul-2019	9:49:43	36.4939	74.3284	-	2	2
29-Jul-2019	11:34:41	36.2693	74.6025	47	1	3
29-Jul-2019	11:49:11	36.1974	74.3638	46	0	2
12-Aug-2019	11:20:56	36.7179	74.4243	53	1	6

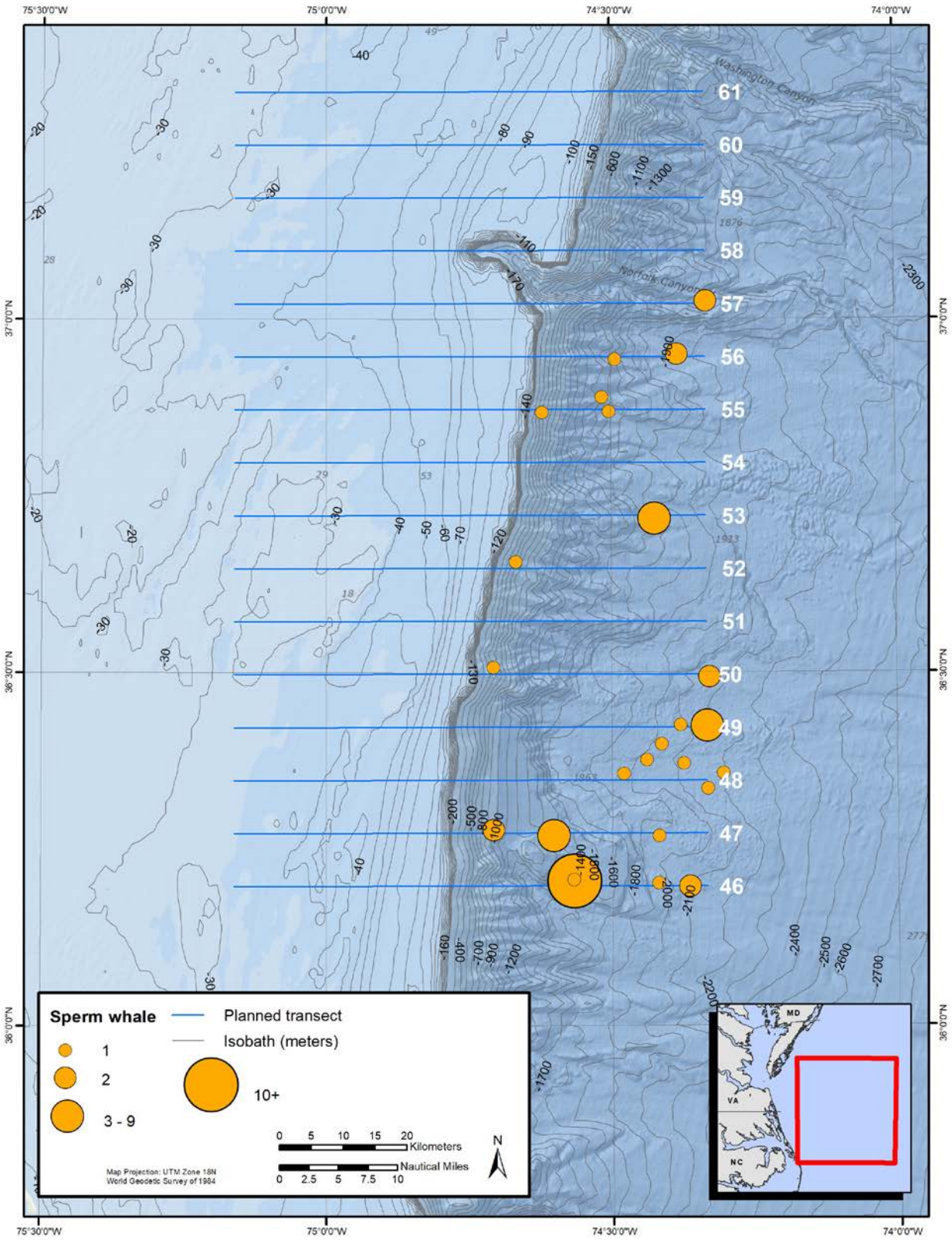

Figure 11. Sperm whale (*Physeter macrocephalus*) sightings, indicating group size, for all 2018–2019 surveys.

4.3.2 True's beaked whale (*Mesoplodon mirus*)

One sighting of 5 True's beaked whales was recorded on 16 June 2018 (**Table 11, Figure 12**). The observation occurred in the southeastern portion of the study area, in deep waters around the 2100-m isobath. The whales were differentiated from the sympatric, and closely related, Gervais' beaked whale by distinctive pale-white melons and forward position of erupted teeth in the lower jaw of males (McLellan et al. 2018, Mead 1989, Moore 1966).

Table 11. True's beaked whale (*Mesoplodon mirus*) sighting in the Norfolk Canyon study area in 2018.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
16-Jun-2018	11:01:39	36.3380	74.5372	48	1	5

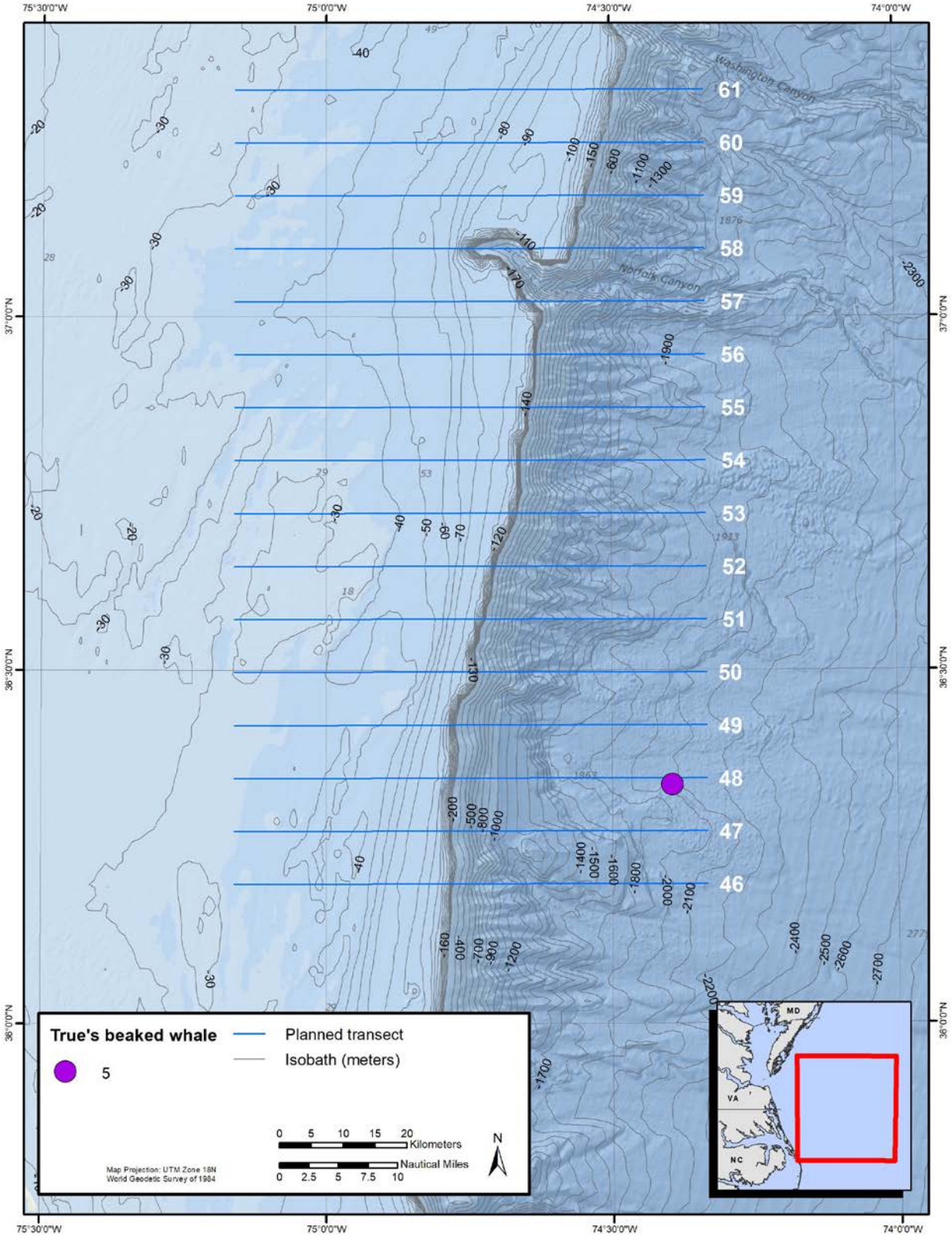

Figure 12. True's beaked whale (*Mesoplodon mirus*) observation recorded during June 2018 survey.

4.3.3 Sowerby's beaked whale (*Mesoplodon bidens*)

One sighting of 4 Sowerby's beaked whales was recorded on 19 December 2018 (**Table 12, Figure 13**). The group was sighted on the southern rim of the canyon that extends east into the bathyal zone, approximately 8 km east of the continental shelf break in deep waters and in proximity to the 1,000-m isobath. This observation was very close (approximately 3 km to the northwest) to another group of Sowerby's beaked whales that was located simultaneously by the HDR vessel conducting a concurrent marine mammal survey (Engelhaupt et al. 2019). The group sighted by the aircraft was heading in the same direction as the group sighted by the vessel and these records have been logged independently.

Table 12. Sowerby's beaked whale (*Mesoplodon bidens*) sighting in the Norfolk Canyon study area in 2018.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
19-Dec-2018	10:34:32	37.0274	74.5372	57	1	4

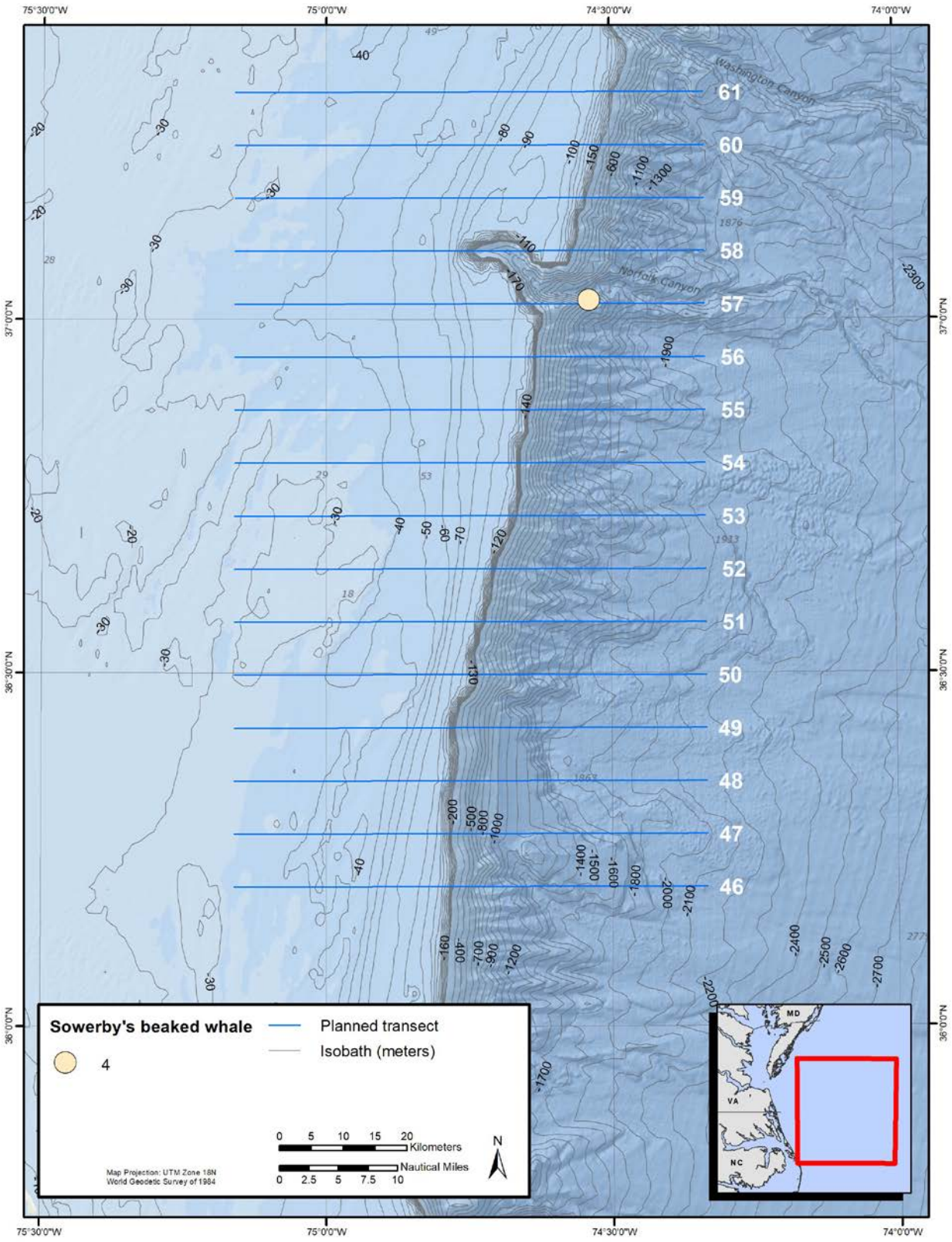

Figure 13. Sowerby's beaked whale (*Mesoplodon bidens*) observation recorded during December 2018 survey.

4.3.4 Pygmy or dwarf sperm whale (*Kogia* sp.)

Ten sightings of 17 individual kogiid whales were recorded in the study area during 2018–2019 (**Table 13**). All of these sightings occurred in deep waters beyond the 1,100-m isobath (**Figure 14**). Four of the sightings were comprised of a cow/calf pair. All animals were seen resting at the surface and identification to species was not conclusive, even with accompanying photographic images.

Table 13. Pygmy or dwarf sperm whale (*Kogia* sp.) sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
16-Jun-2018	11:12:04	36.3442	74.3580	48	1	1
16-Jun-2018	11:19:22	36.4221	74.4194	49	1	1
17-Jun-2018	11:39:03	36.9476	74.3413	56	3	3
17-Jun-2018	11:46:45	36.9503	74.3570	56	3	1
19-Dec-2018	10:57:07	36.9559	74.5241	56	0	2
28-Mar-2019	14:28:48	36.2020	74.5468	46	2	1
28-Jun-2019	9:11:00	36.6455	74.3774	52	1	2
28-Jun-2019	10:18:36	36.4977	74.6152	50	1	1
*29-Jul-2019	10:47:29	36.3871	74.3187	49	1	1
12-Aug-2019	11:12:17	37.7185	74.5814	53	1	1
12-Aug-2019	11:15:18	36.7284	74.5602	53	1	4

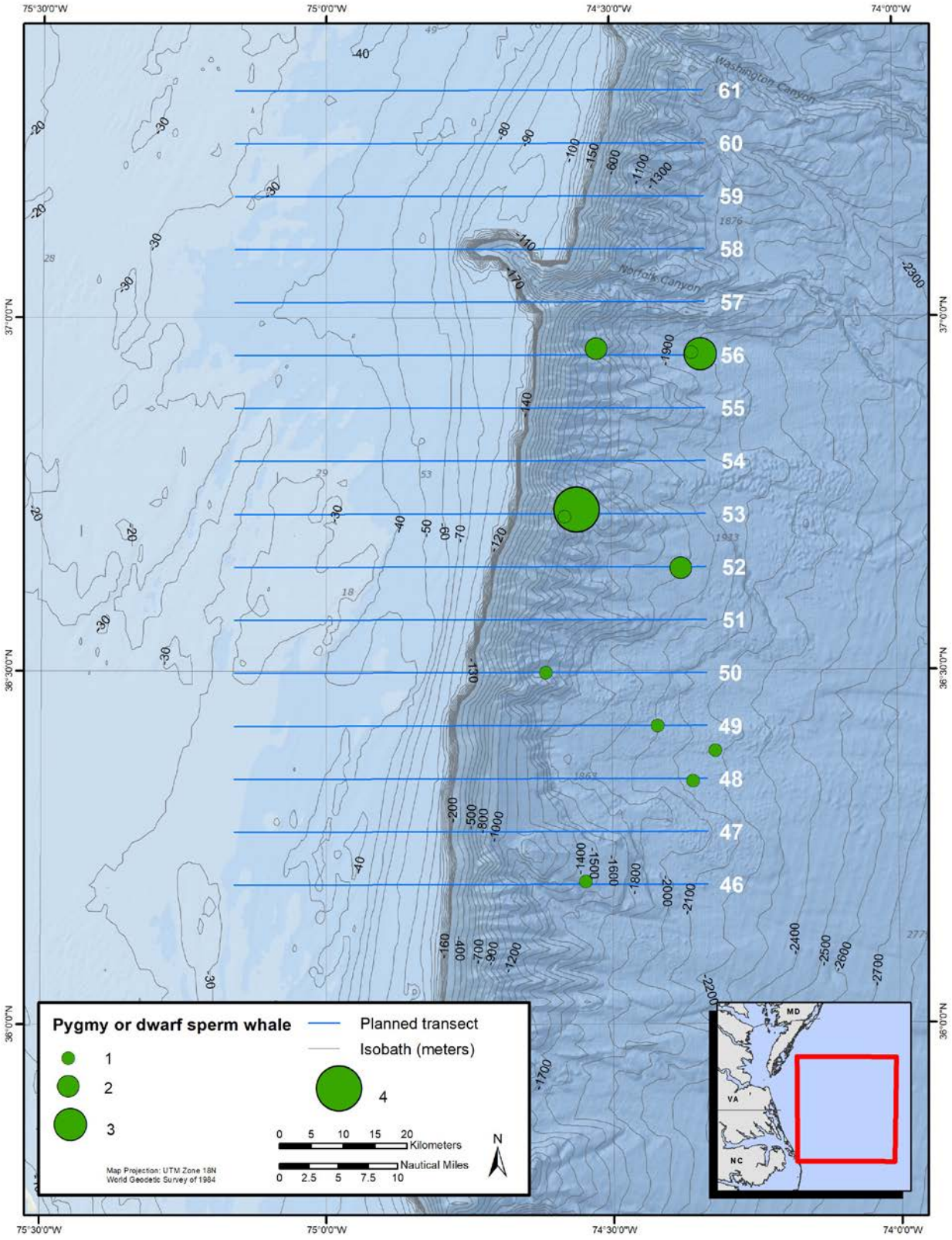

Figure 14. Pygmy or dwarf sperm whale (*Kogia* sp.) sightings, indicating group size, for all 2018–2019 surveys.

4.3.5 North Atlantic right whale (*Eubalaena glacialis)*

Two sightings of 8 individual NARW were made in 2018, both in April (**Table 14**, **Figure 15**). These observations were both within multi-species sightings, where multiple cetacean species were seen in close association. Both sightings were in proximity to closely associated common dolphins, humpback whales, and fin whales. A minke whale was also noted during the 9 April sighting. The baleen whales comprising both sightings were seen foraging (humpbacks were seen cooperatively feeding using bubble netting techniques), while the common dolphins were scattered and seen swimming close to the rostrums of both NARW and fin whales. The NARW were seen open-mouth surface feeding and multiple surface defecation events were observed.

All photographs from the encounters were forwarded to NARW experts at the New England Aquarium and National Oceanic and Atmospheric Administration for matching. Quality identification photographs of the animals allowed researchers to match 7 of the 8 whales to the North Atlantic Right Whale Catalog.

Table 14. North Atlantic right whale (*Eubalaena glacialis*) sightings in the Norfolk Canyon study area for all 2018–2019 surveys.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
9-Apr-2018	9:46:25	37.3239	74.6551	61	3	5
11-Apr-2018	10:09:46	37.1800	74.8524	59	3	3

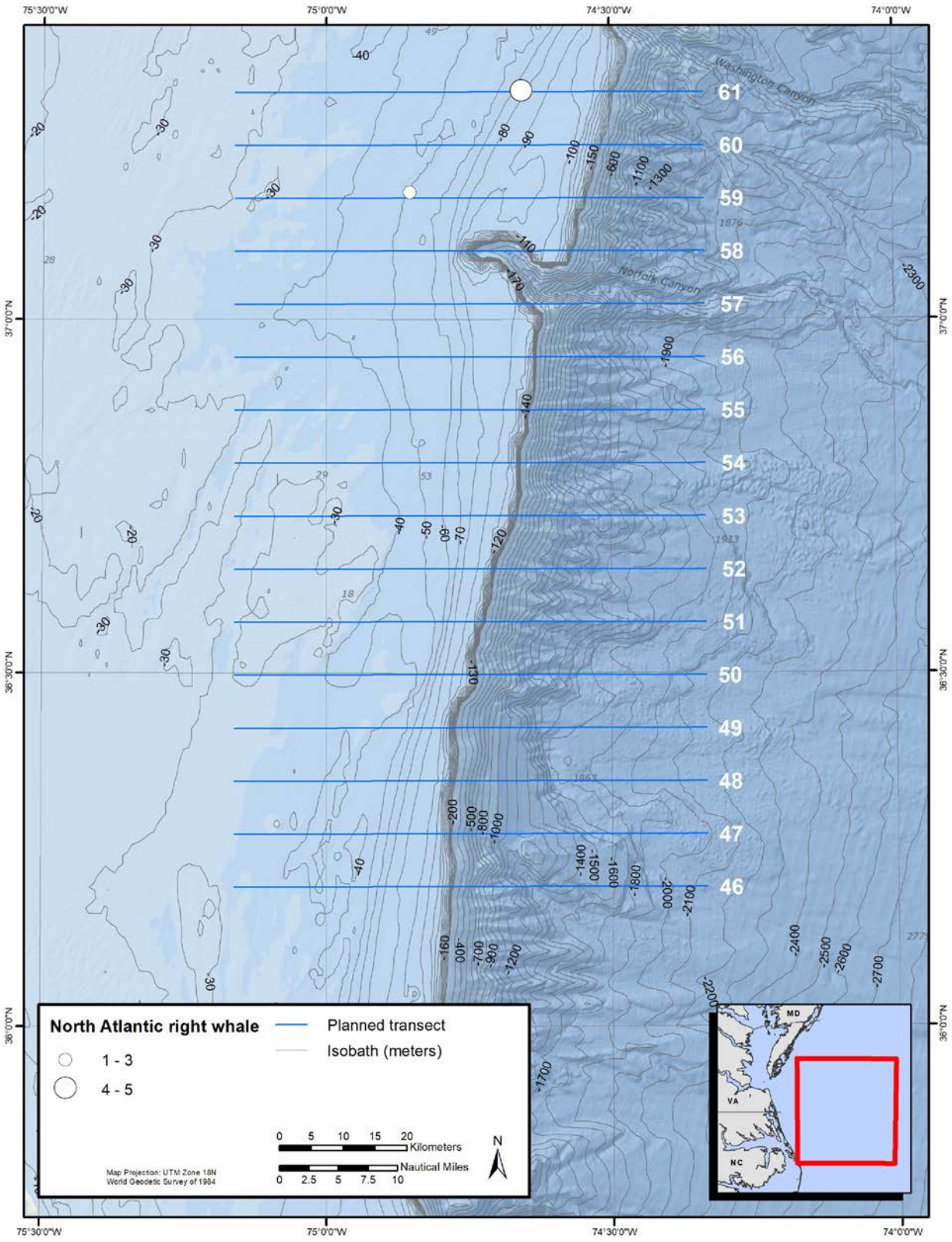

Figure 15. North Atlantic right whale (*Eubalaena glacialis*) sightings, indicating group size, for all 2018–2019 surveys.

4.3.6 Sei whale (*Balaenoptera borealis*)

Three sightings of 4 individual sei whales were recorded in 2018, all in April (**Table 15**). Two of the sightings were made over the continental shelf on the 80-m isobath, while the other sighting was recorded in the deeper waters of the Norfolk Canyon (**Figure 16**). All of these sei whales coincided spatio-temporally with the April sightings of NARWs, and high numbers of observed basking sharks, strongly indicating the presence of high levels of copepod prey in the study area.

Table 15. Sei whale (*Balaenoptera borealis*) sightings in the Norfolk Canyon study area for all 2018–2019 surveys.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
11-Apr-2018	11:05:54	37.1636	74.7435	59	4	1
11-Apr-2018	11:41:44	37.0981	74.6674	58	3	1
11-Apr-2018	15:49:22	36.8687	74.7289	55	4	2

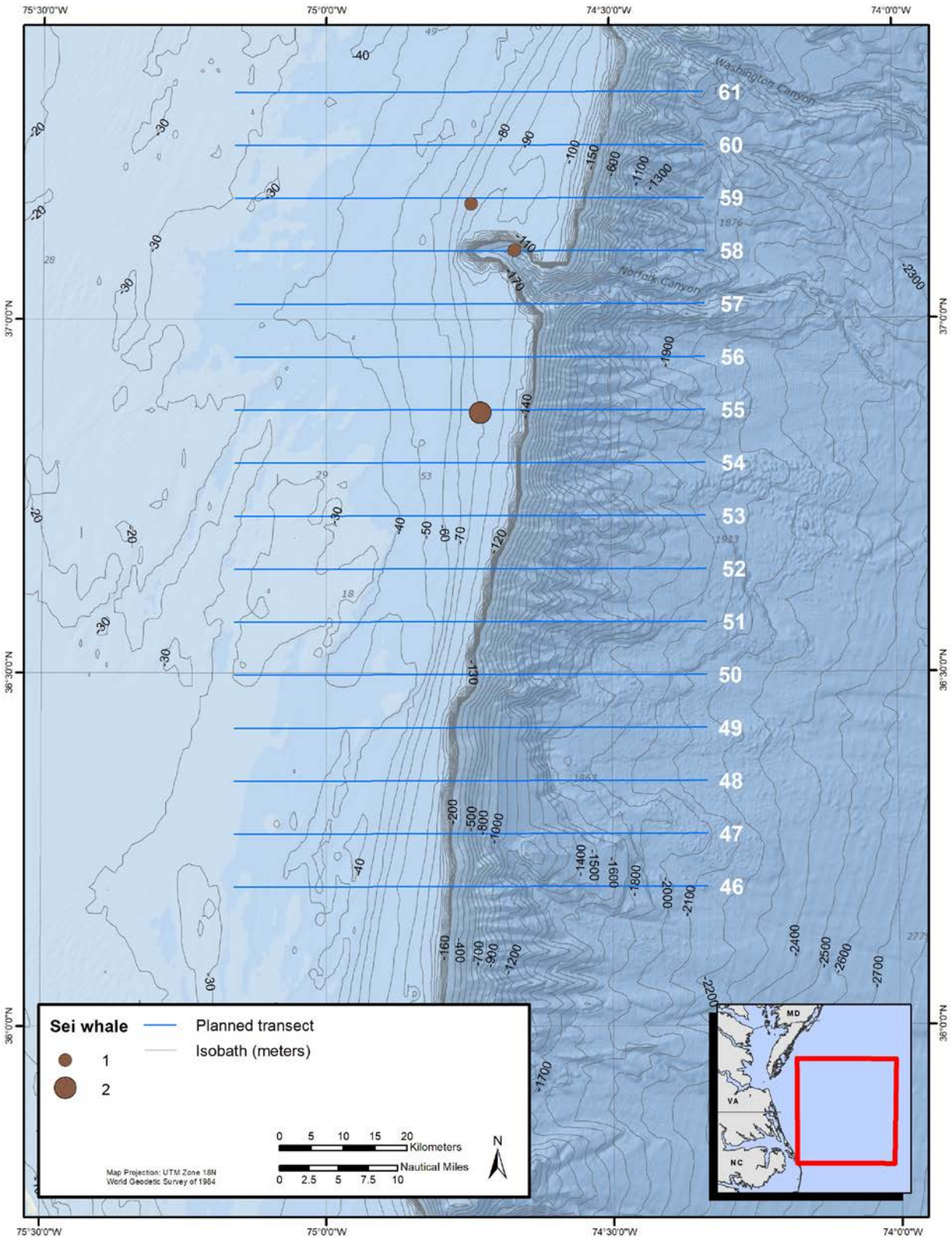

Figure 16. Sei whale (*Balaenoptera borealis*) sightings, indicating group size, for all surveys in 2018–2019.

4.3.7 Minke whale (*Balaenoptera acutorostrata*)

Four sightings of four individual minke whales were recorded over the continental shelf between the 30- and 40-m isobaths (**Table 16**, **Figure 17**). There were also two off-effort sightings of one individual each. The lone sighting in 2018 was part of a multi-species observation that included three other species of baleen whales (NARW, fin, and humpback) in a closely associated feeding aggregation.

Table 16. Minke whale (*Balaenoptera acutorostrata*) sightings in the Norfolk Canyon study area for all 2018–2019 surveys. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
9-Apr-2018	9:46:25	37.3239	74.6551	61	3	1
*28-Mar-2019	11:43:15	36.5817	75.1804	-	2	1
28-Mar-2019	11:56:41	36.5737	75.0196	51	2	1
23-Apr-2019	10:28:55	36.8778	74.8724	55	2	1
*23-Apr-2019	11:21:46	36.7622	75.1790	-	2	1
12-Aug-2019	10:39:46	36.8011	74.8636	54	0	1

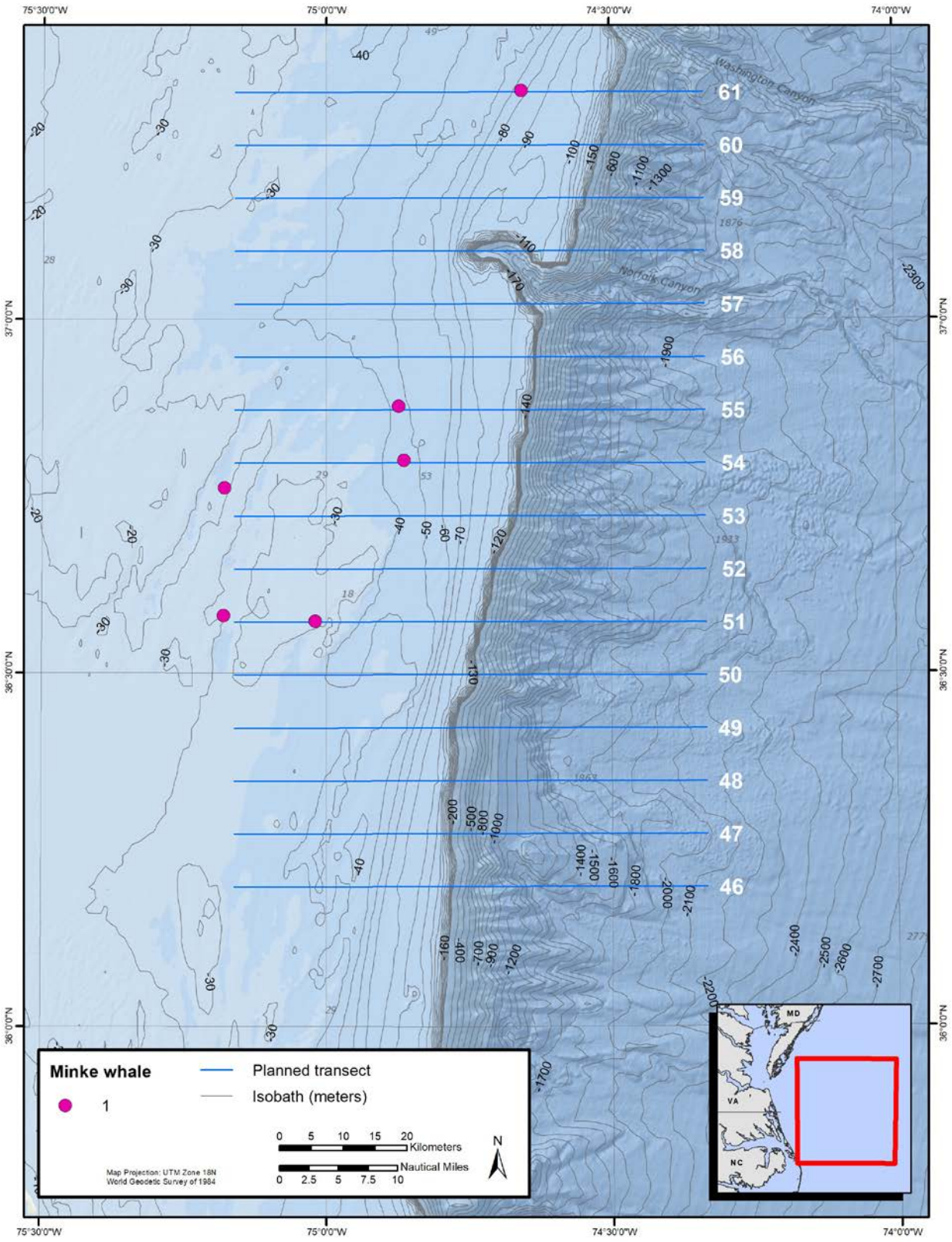

Figure 17. Minke whale (*Balaenoptera acutorostrata*) observations recorded during all 2018–2019 surveys indicating group size.

4.3.8 Fin whale (*Balaenoptera physalus*)

Fin whales were observed on-effort within the study area 25 times, totaling 57 individual whales (**Table 17, Figure 18**). Two off-effort sightings of two individuals were also recorded. Sightings of fin whales in 2018 were all made over the continental shelf between the 50- and 100-m isobaths, while all but five 2019 sightings were recorded in deep waters beyond the shelf break. Two sightings in 2018 (on 9 and 11 April) were part of multi-species sightings within feeding aggregations with NARW, humpback, and minke whales. One sighting, on 10 February 2019, was comprised of 15 individuals and were seen surface feeding with at least one blue whale. Fin whales were recorded in eight out of the eleven survey months.

Table 17. Fin whale (*Balaenoptera physalus*) sightings in the Norfolk Canyon study area for all 2018–2019 surveys. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
9-Apr-2018	9:46:25	37.3239	74.6551	61	3	2
9-Apr-2018	10:44:54	37.2396	74.6446	60	2	2
9-Apr-2018	12:10:16	37.0255	74.8780	61	4	1
11-Apr-2018	9:44:58	37.2512	74.8341	60	3	1
11-Apr-2018	10:09:46	37.1780	74.8524	59	3	2
11-Apr-2018	11:52:25	37.1042	74.7148	58	3	2
11-Apr-2018	15:40:04	36.8656	74.7857	55	4	3
14-Jul-2018	9:23:18	37.3166	74.8302	61	3	1
5-Aug-2018	10:01:52	37.1645	74.7972	59	1	1
5-Aug-2018	14:39:58	36.8641	74.8222	55	1	1
5-Aug-2018	15:22:04	36.8013	74.7970	54	1	2
12-Nov-2018	10:00:37	36.5007	74.7952	50	4	4
17-Jan-2019	11:06:06	36.8004	74.5157	54	3	3
17-Jan-2019	11:27:39	36.7304	74.3877	53	4	1
10-Feb-2019	9:07:40	36.7932	74.3512	54	3	1
10-Feb-2019	9:15:29	36.7928	74.4535	54	3	5
10-Feb-2019	9:25:18	36.8071	74.5190	54	3	15
10-Feb-2019	10:06:13	36.8781	74.4784	55	2	2
10-Feb-2019	10:59:13	37.0265	74.5920	57	2	1
*10-Feb-2019	11:12:07	37.0860	74.2916	57	2	1
*10-Feb-2019	12:11:25	37.2350	74.3070	59	1	1
8-Mar-2019	8:43:06	37.0168	74.4301	57	5	1
28-Mar-2019	11:07:30	36.6577	74.4116	52	4	1
23-Apr-2019	13:19:13	36.5016	74.7497	50	1	2
23-Apr-2019	14:20:48	36.3431	74.8270	48	1	1
27-Jun-2019	8:55:58	37.3236	74.6272	61	3	1
27-Jun-2019	9:00:39	37.3168	74.5629	61	3	1

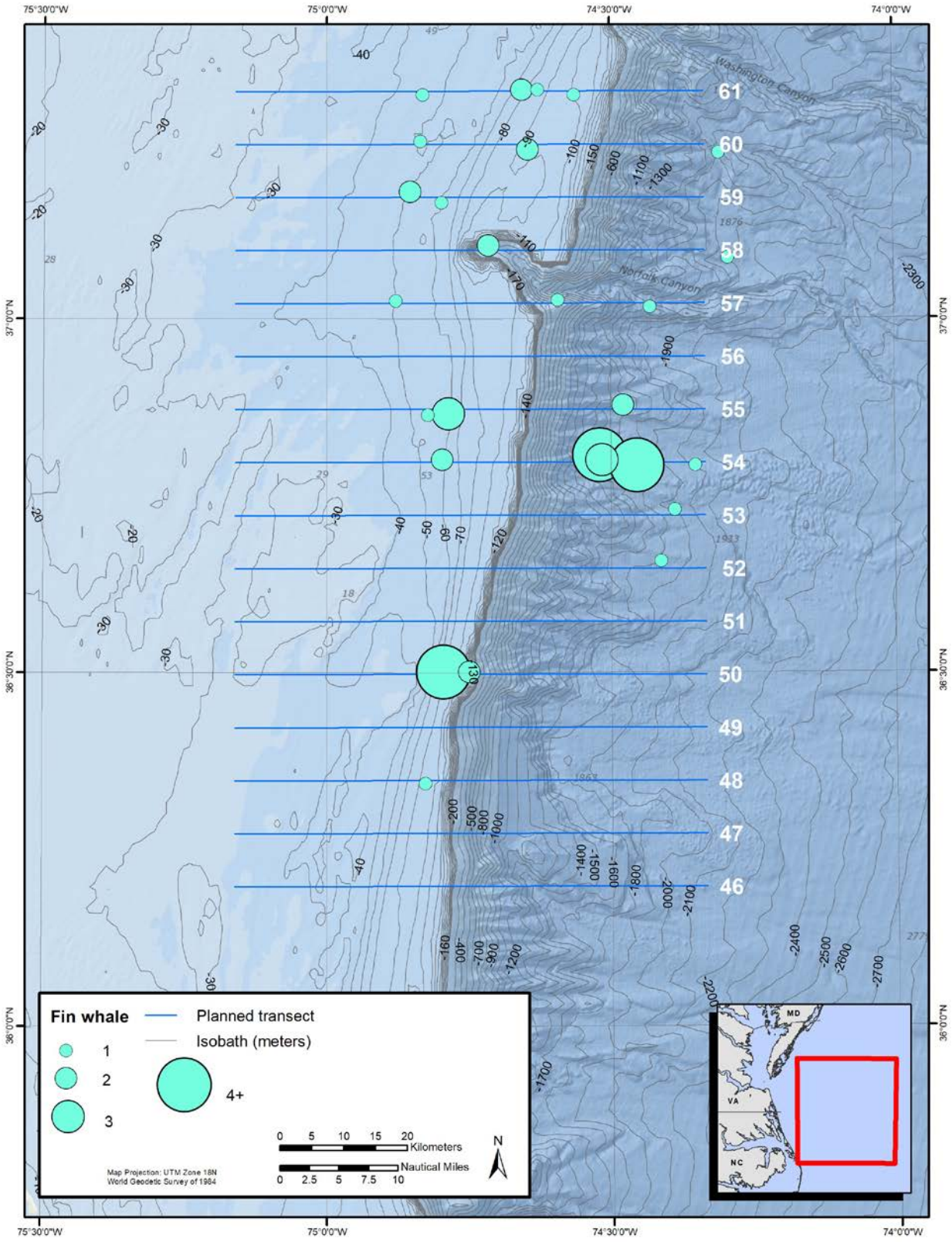

Figure 18. Fin whale (*Balaenoptera physalus*) sightings, indicating group size, for all surveys in 2018–2019.

4.3.9 Humpback whale (*Megaptera novaeangliae*)

Humpback whales were observed over the continental shelf in the Norfolk Canyon study area **(Table 18, Figure 19**). There were nine sightings, totaling twenty-two individuals seen on effort, and an additional eight off-effort sightings totaling nine individuals. All of the off-effort sightings were recorded within a few miles of the shoreline as the survey aircraft either departed or returned to the airport.

Two of the on-effort sightings in 2018 (on 9 and 11 April) were part of multi-species observations which also included NARWs, fin, and minke whales. Because NFC surveys in 2018 were initiated after the expected peak winter occurrence of humpback whales in the region, the numbers of both on- and off-effort sightings of humpback whales in 2018 were reduced, and were not expected to increase again until the following winter (see Aschettino et al. 2019).

Table 18. Humpback whale (*Megaptera novaeangliae*) sightings in the Norfolk Canyon study area for all 2018–2019 surveys. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
9-Apr-2018	9:46:25	37.3239	74.6551	61	3	5
9-Apr-2018	10:47:47	37.2451	74.7019	60	2	1
9-Apr-2018	11:12:49	37.1759	74.8648	59	3	1
11-Apr-2018	9:25:27	37.3188	74.7000	61	3	1
11-Apr-2018	10:09:46	37.1780	74.8524	59	3	1
*12-Nov-2018	11:47:44	36.8328	74.3035	-	3	1
*4-Jan-2019	11:42:05	36.8648	74.7658	-	3	1
*26-Jan-2019	11:25:44	36.9061	75.9029	-	1	1
*26-Jan-2019	13:05:34	36.6742	75.7392	-	1	1
*26-Jan-2019	15:37:13	36.5869	75.8032	-	1	1
*26-Jan-2019	15:39:51	36.6875	75.8733	-	1	1
*10-Feb-2019	12:53:46	36.9633	76.0033	-	3	1
*8-Mar-2019	8:13:06	39.9811	75.6334	-	3	2
28-Mar-2019	10:46:11	36.7186	74.7696	53	2	2
28-Mar-2019	11:35:22	36.6549	75.1594	52	2	1
28-Mar-2019	11:50:40	36.5808	75.0666	51	2	3
28-Mar-2019	13:03:14	36.4060	74.7989	49	2	7

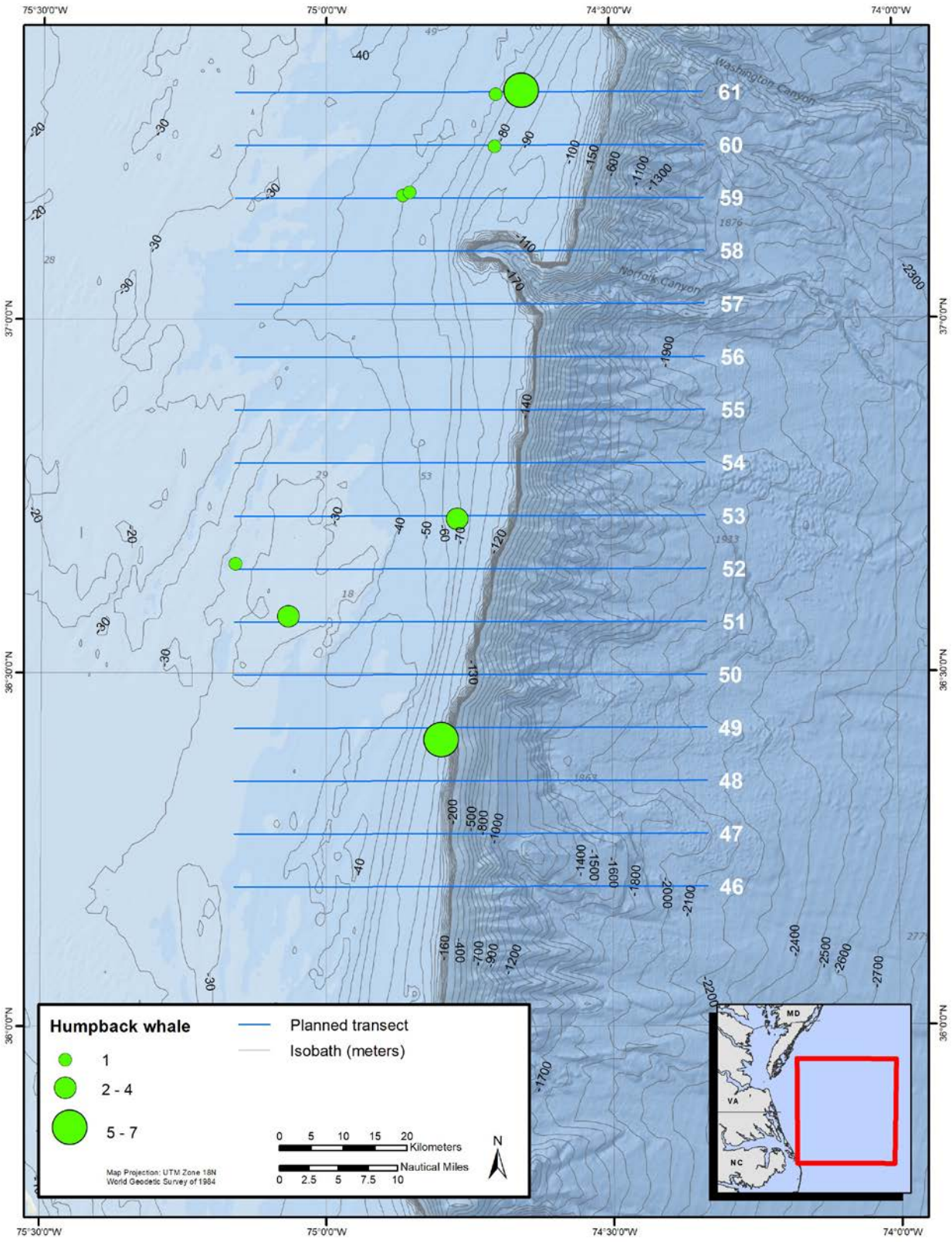

Figure 19. Humpback whale (*Megaptera novaeangliae*) sightings, indicating group size, for all surveys in 2018–2019.

4.3.10 Blue whale (*Balaenoptera musculus*)

One sighting of an adult blue whale was recorded in the Norfolk Canyon study area on 10 February, 2019 (**Table 19**, **Figure 20**). The whale was observed in deep water beyond the continental shelf break, feeding amongst fifteen fin whales in an area roughly 4 km^2.

Blue whales are an endangered species, and sightings in the Mid-Atlantic are extremely rare. Along with an HDR vessel sighting of a juvenile blue whale in April 2018 (see Engelhaupt et al. 2019), these sightings mark the first time this species has been documented with photographs off the coast of Virginia. It also represents the southernmost confirmed sighting in the waters of the United States Atlantic Exclusive Economic Zone.

Table 19. Blue whale (*Balaenoptera musculus*) sighting in the Norfolk Canyon study area in 2019.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Best Count
10-Feb-2019	9:15:29	36.7928	74.4535	54	3	1

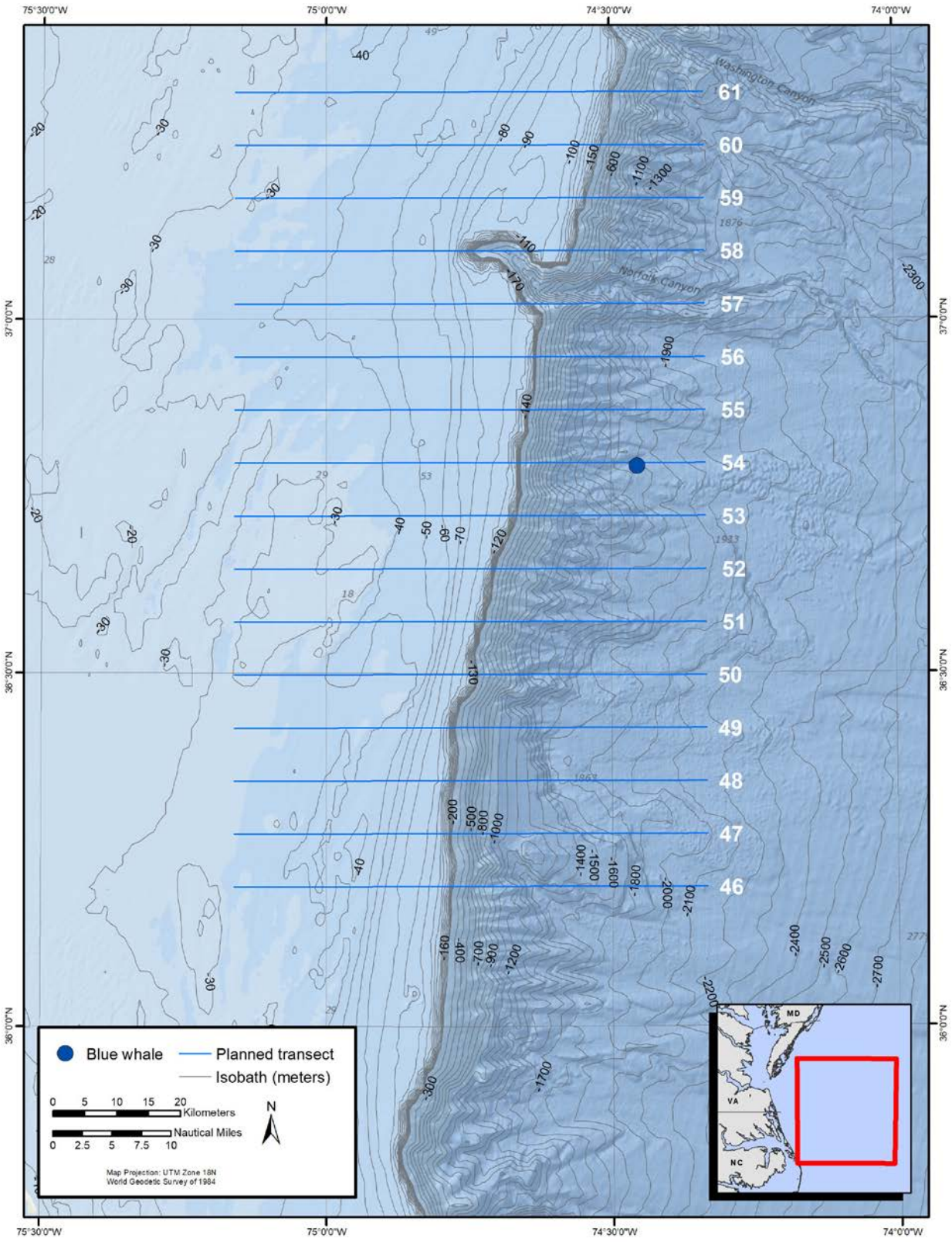

Figure 20. Blue whale (*Balaenoptera musculus*) observation recorded during 2019 survey.

4.4 Sea Turtles

There were 407 on-effort sightings, totaling 1,496 individuals, of three sea turtle species during the reporting period (see **Figure 21**; and **Table 20**, **Table 21**, and **Table 22** in **Sections 4.4.1**, **4.4.2**, **and 4.4.3**, respectively). These included 21 sightings, totaling 24 turtles, not identified to species. These records were denoted as unidentified hardshell turtles.

Loggerhead sea turtles (*Caretta caretta*) represented the majority (92.7 percent) of total sea turtles sighted. The other two sea turtle species identified in the study area were Kemp's ridley (*Lepidochelys kempii,* 3.3 percent of total sea turtles sighted) and leatherback turtles (*Dermochelys coriacea*; 2.4 percent of total sea turtles observed). Unidentified hardshell turtles represented 1.6 percent of total sea turtles recorded.

4.4.1 Loggerhead sea turtle (*Caretta caretta*)

Sightings of loggerhead sea turtles occurred in 9 of 11 months surveyed, with 327 sightings of 1,387 animals (**Table 20, Figure 21**). There were also 38 sightings of 115 individuals recorded off-effort. The majority of sightings occurred inside the 70-m isobath, with only a few observations in deeper waters.

Table 20. Loggerhead sea turtle (*Caretta caretta)* sightings in the Norfolk Canyon study area in 2018–2019.

Date	Total Count On Effort	Total Count Off Effort
25-May-2018	349	53
16-Jun-2018	214	9
17-Jun-2018	290	0
14-Jul-2018	14	24
5-Aug-2018	90	0
6-Aug-2018	47	11
19-Oct-2018	37	7
12-Nov-2018	1	0
26-Jan-2019	1	0
8-Mar-2019	1	0
28-Mar-2019	1	0
23-Apr-2019	77	10
27-Jun-2019	25	0
28-Jun-2019	86	1
29-Jul-2019	48	0
12-Aug-2019	106	0

4.4.2 Kemp's ridley sea turtle (*Lepidochelys kempii*)

Twenty-five sightings of 49 Kemp's ridley sea turtles were recorded in the study area, almost all inshore of the 50-m isobath (**Table 21, Figure 21**). Four sightings of 13 turtles were also recorded while off effort. Sightings of Kemp's ridley turtles occurred between May and August.

Table 21. Kemp's ridley sea turtle (*Lepidochelys kempii*) sightings in the Norfolk Canyon study area in 2018–2019.

Date	Total Count On Effort	Total Count Off Effort
25-May-2018	16	0
16-Jun-2018	10	10
17-Jun-2018	12	0
14-Jul-2018	1	1
5-Aug-2018	1	0
6-Aug-2018	2	0
27-Jun-2019	1	0
28-Jun-2019	1	2
12-Aug-2019	5	0

4.4.3 Leatherback sea turtle (*Dermochelys coriacea*)

Thirty-four on-effort sightings of 36 individual leatherback sea turtles were recorded in the study area, largely within inshore waters (**Table 22, Figure 21**). There were also 6 sightings of 6 individuals recorded while off effort. Aside from three that occurred beyond the continental shelf break near the 500-m and 2,000-m isobaths, all other leatherback sea turtles were observed inshore of the 40-m isobath.

Table 22. Leatherback sea turtle (*Dermochelys coriacea)* sightings in the Norfolk Canyon study area in 2018–2019.

Date	Total Count On Effort	Total Count Off Effort
16-Jun-2018	2	1
14-Jul-2018	0	1
5-Aug-2018	7	0
6-Aug-2018	11	2
19-Oct-2018	1	0
26-Jan-2019	2	0
10-Feb-2019	1	0
27-Jun-2019	3	0
28-Jun-2019	1	0
12-Aug-2019	8	2

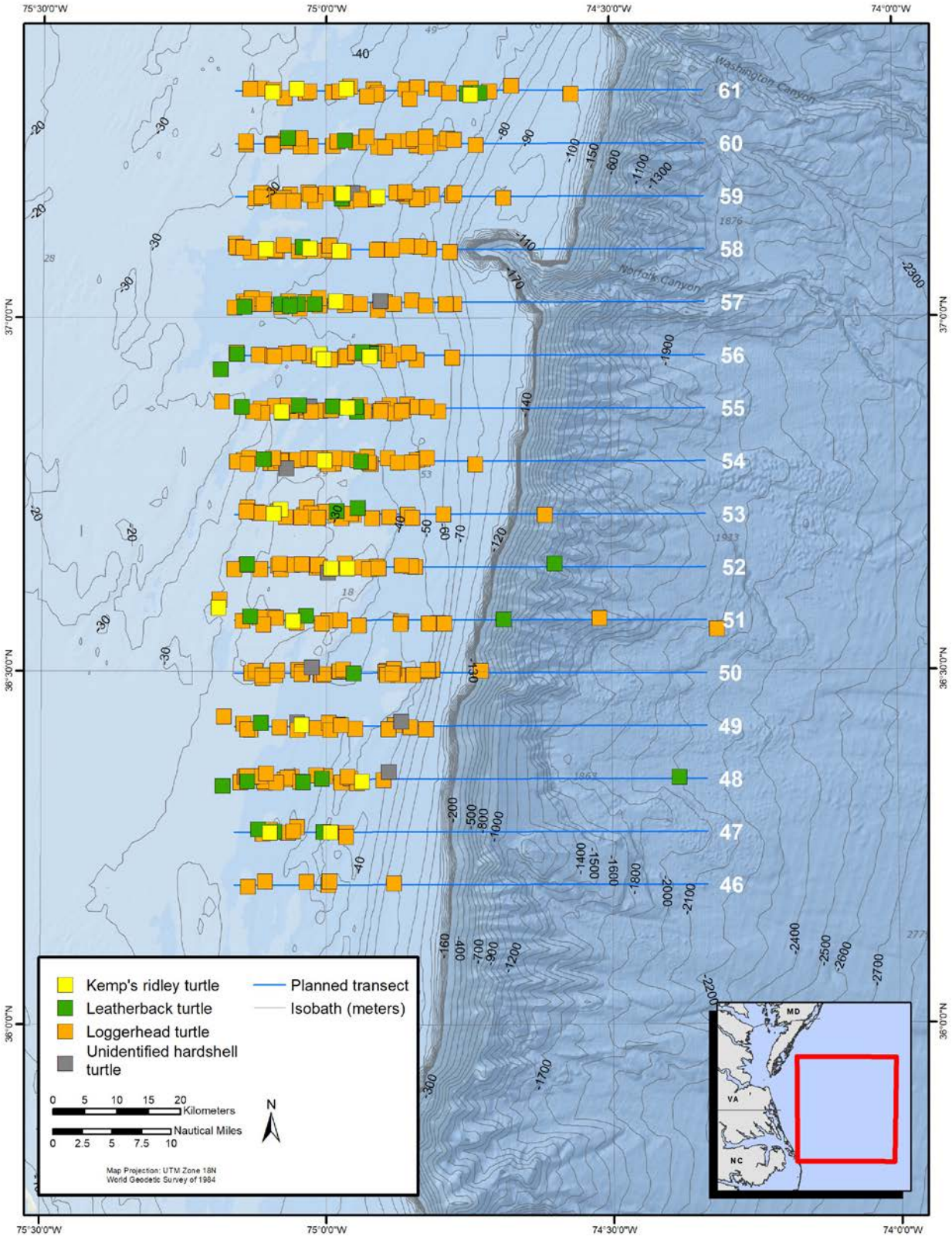

Figure 21. All sea turtle sightings recorded in the Norfolk Canyon study area in 2018–2019.

4.5 Other Marine Vertebrate Sightings

4.5.1 Chondrichthyan fishes

Sightings of large pelagic marine vertebrates other than cetaceans and sea turtles were also recorded during surveys in 2018–2019. One whale shark was seen offshore to the southeast of Norfolk Canyon. A great white shark, blue shark, unidentified hammerhead (*Sphyrna* sp.), and other unidentified sharks were also recorded. Additionally, four species of rays were identified: 4 manta rays (all *Mobula birostris*), 2 giant devil rays, 188 Chilean devil rays, 15,661 cownose rays, and 6 large black-and-white mobulids. The label "large black-and-white mobulid" was chosen to designate large rays that were seen clearly to be black and white but were unable to be identified to either *Mobula mobular* or *Mobula birostris*. Seventeen basking sharks were recorded between January and April. All sightings are represented in **Table 23** and **Figure 22**.

Table 23. Chondrichthyan fish sightings in the Norfolk Canyon study area in 2018–2019. Asterisk in date denotes an off-effort sighting.

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Total Count	Comments
9-Apr-2018	11:25:51	37.1747	74.4697	59	3	4	Basking shark
9-Apr-2018	11:37:27	37.0926	74.4389	58	3	2	Basking shark
9-Apr-2018	12:38:34	36.9457	74.5397	56	4	1	Basking shark
11-Apr-2018	11:56:37	37.1146	74.5144	58	3	5	Basking shark
11-Apr-2018	15:40:04	36.8656	74.7857	55	4	1	Basking shark
16-Jun-2018	9:29:53	36.2050	74.5659	46	2	1	Giant devil ray
16-Jun-2018	10:06:51	36.2756	74.6509	47	2	1	Chilean devil ray
16-Jun-2018	10:14:52	36.2712	74.7347	47	2	1	Hammerhead
16-Jun-2018	10:19:02	36.2682	74.8309	47	2	1	Hammerhead
16-Jun-2018	10:27:39	36.2717	75.1542	47	1	2	Hammerhead
*16-Jun-2018	10:30:07	36.3285	75.1867	-	2	4	Hammerhead
16-Jun-2018	11:43:27	36.4219	74.9200	49	1	1	Large mobulid
16-Jun-2018	11:44:46	36.4218	74.9735	49	1	1	Hammerhead
16-Jun-2018	11:47:05	36.4216	75.0656	49	1	1	Hammerhead
16-Jun-2018	11:48:01	36.4214	75.1036	49	1	2	Chilean devil ray
*16-Jun-2018	14:14:52	36.5454	75.3004	-	2	50	Cownose ray
*16-Jun-2018	14:17:34	36.5027	75.178	-	2	1	Cownose ray
16-Jun-2018	14:19:19	36.4971	75.1021	50	2	13	Hammerhead
16-Jun-2018	14:44:20	36.5	74.4501	50	2	1	Large mobulid
16-Jun-2018	14:45:01	36.4971	74.4232	50	2	1	Large mobulid
16-Jun-2018	15:03:49	36.5722	74.7263	51	1	1	Chilean devil ray
16-Jun-2018	15:07:29	36.5761	74.8722	51	1	4	Unidentified shark
16-Jun-2018	15:10:00	36.5705	74.9693	51	1	1	Chilean devil ray
16-Jun-2018	15:12:51	36.5712	75.0776	51	1	1	Chilean devil ray
16-Jun-2018	15:19:29	36.6397	75.1328	52	1	2	Chilean devil ray

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Total Count	Comments
16-Jun-2018	15:39:27	36.6497	74.6309	52	1	9	Hammerhead
16-Jun-2018	15:54:03	36.7244	74.3581	53	1	2	Chilean devil ray
16-Jun-2018	15:57:28	36.7186	74.5144	53	1	1	Whale shark
16-Jun-2018	16:07:13	36.7172	74.6722	53	1	18	Hammerhead
16-Jun-2018	16:15:49	36.7236	74.8772	53	1	3	Hammerhead
16-Jun-2018	16:22:35	36.718	75.0667	53	1	600	Cownose ray
17-Jun-2018	9:44:30	37.2467	74.5104	60	3	5	Hammerhead
17-Jun-2018	9:53:42	37.2449	74.5104	60	2	1	Hammerhead
17-Jun-2018	9:57:50	37.2487	74.9976	60	2	1	Hammerhead
17-Jun-2018	10:24:01	37.1760	74.6025	59	3	1	Hammerhead
17-Jun-2018	10:51:22	37.0968	74.6765	58	3	2	Hammerhead
17-Jun-2018	11:09:13	37.0248	75.0624	57	2	1	Hammerhead
17-Jun-2018	11:15:49	37.0184	74.8071	57	2	1	Hammerhead
17-Jun-2018	12:06:58	36.9491	74.6297	56	2	1	Hammerhead
17-Jun-2018	12:19:12	36.9457	75.1248	56	2	25	Cownose ray
17-Jun-2018	13:04:57	36.8040	74.6903	54	3	1	Hammerhead
17-Jun-2018	13:17:27	36.8006	75.1307	54	2	30	Cownose ray
17-Jun-2018	13:18:12	36.7945	75.1622	54	2	50	Cownose ray
14-Jul-2018	14:33:30	36.9512	75.0878	56	3	1	Chilean devil ray
14-Jul-2018	14:48:20	36.8773	74.9441	55	3	1	Chilean devil ray
14-Jul-2018	15:43:13	36.7939	74.9275	54	2	1	Chilean devil ray
5-Aug-2018	10:43:39	37.0968	75.0073	58	2	1	Chilean devil ray
5-Aug-2018	14:39:58	36.8641	74.8222	55	2	2	Chilean devil ray
6-Aug-2018	9:13:14	36.1984	75.0062	46	0	2	Hammerhead
*6-Aug-2018	10:53:44	36.3600	74.3137	-	0	1	Large mobulid
6-Aug-2018	14:49:33	36.5796	74.6255	51	2	1	Unidentified shark
6-Aug-2018	15:03:16	36.5709	75.0080	51	2	1	Chilean devil ray
6-Aug-2018	15:05:54	36.5772	75.1138	51	2	1	Hammerhead
6-Aug-2018	15:15:09	36.6475	74.9419	52	2	2	Chilean devil ray
6-Aug-2018	16:07:34	36.7343	75.1401	53	2	2	Large mobulid
19-Oct-2018	9:54:02	37.0131	74.7105	57	2	2	Unidentified shark
19-Oct-2018	14:34:33	36.7933	74.8710	54	2	3	Chilean devil ray
19-Oct-2018	14:34:33	36.7933	74.8710	54	2	400	Cownose ray
19-Oct-2018	15:23:29	36.6482	74.8365	57	3	1	Unidentified shark
26-Jan-2019	9:29:40	36.6497	74.4007	52	2	1	Unidentified shark
26-Jan-2019	10:01:49	36.5663	75.0324	51	1	1	Unidentified shark
26-Jan-2019	10:19:49	36.5702	74.5581	51	1	1	Giant devil ray
26-Jan-2019	10:46:28	36.5048	74.5013	50	2	1	Unidentified shark
26-Jan-2019	13:31:34	36.4229	74.6903	49	2	1	Unidentified shark

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Total Count	Comments
26-Jan-2019	14:02:33	36.3503	74.5624	48	3	1	Basking shark
*10-Feb-2019	10:23:47	36.9615	74.5849	56	2	1	Basking shark
10-Feb-2019	11:20:27	36.1053	74.4434	58	2	1	Basking shark
8-Mar-2019	10:27:23	36.7210	74.5784	53	3	1	Unidentified shark
8-Mar-2019	10:54:58	36.6477	74.6178	52	4	1	Unidentified shark
8-Mar-2019	11:31:04	36.5712	74.5334	51	3	1	Basking shark
23-Mar-2019	11:07:27	36.8003	74.9277	54	2	1	Great white shark
23-Mar-2019	11:43:14	36.7248	74.4172	53	1	1	Chilean devil ray
23-Mar-2019	13:59:03	36.4297	74.5749	49	2	1	Chilean devil ray
27-Jun-2019	9:16:20	37.2502	74.3870	60	2	2	Chilean devil ray
27-Jun-2019	10:00:00	37.1729	74.5098	59	2	1	Manta ray
27-Jun-2019	10:09:37	37.1740	74.4045	59	2	9	Chilean devil ray
27-Jun-2019	10:37:59	37.0961	75.0862	58	2	100	Cownose ray
27-Jun-2019	11:02:32	37.0183	74.4699	57	2	1	Chilean devil ray
27-Jun-2019	11:03:07	37.0176	74.4464	57	2	1	Chilean devil ray
27-Jun-2019	11:03:47	37.0247	74.4197	57	2	5	Chilean devil ray
27-Jun-2019	11:12:07	36.9512	74.4656	56	2	1	Chilean devil ray
27-Jun-2019	11:13:51	36.9509	74.5342	56	2	1	Chilean devil ray
27-Jun-2019	12:06:36	36.8029	74.4802	55	2	4	Chilean devil ray
27-Jun-2019	12:07:17	36.8034	74.5058	55	2	1	Chilean devil ray
28-Jun-2019	8:48:55	36.7183	74.7119	53	1	3	Hammerhead
28-Jun-2019	8:51:30	36.7192	74.6098	53	1	1	Manta ray
28-Jun-2019	9:01:50	36.7176	74.5334	53	1	3	Chilean devil ray
28-Jun-2019	9:02:27	36.7240	74.5082	53	1	10	Chilean devil ray
28-Jun-2019	9:14:05	36.6517	74.4309	52	1	1	Chilean devil ray
28-Jun-2019	9:15:59	36.6445	74.4989	52	1	15	Chilean devil ray
28-Jun-2019	9:22:43	36.6460	74.7165	52	1	3	Blue shark
28-Jun-2019	9:23:36	36.6502	74.7521	52	1	3	Hammerhead
28-Jun-2019	9:31:07	36.6417	75.0258	52	2	500	Cownose ray
28-Jun-2019	9:41:53	36.5638	75.1268	51	2	500	Cownose ray
28-Jun-2019	9:42:26	36.5670	75.1041	51	2	300	Cownose ray
28-Jun-2019	9:42:41	36.5633	75.0930	51	2	5000	Cownose ray
28-Jun-2019	9:43:04	36.5647	75.0776	51	2	2000	Cownose ray
28-Jun-2019	9:43:31	36.5742	75.0583	51	2	2000	Cownose ray
28-Jun-2019	9:44:23	36.5687	75.0229	51	2	800	Cownose ray
28-Jun-2019	9:44:45	36.5729	75.0077	51	2	700	Cownose ray
28-Jun-2019	9:46:02	36.5606	74.9542	51	2	900	Cownose ray
28-Jun-2019	9:49:42	36.5686	74.8024	51	1	3	Hammerhead
28-Jun-2019	9:50:44	36.5690	74.7601	51	1	3	Hammerhead

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Total Count	Comments
28-Jun-2019	9:52:17	36.5662	74.6982	51	1	1	Chilean devil ray
28-Jun-2019	9:57:41	36.5687	74.5659	51	1	1	Chilean devil ray
28-Jun-2019	10:01:02	36.5731	74.4336	51	1	1	Chilean devil ray
*28-Jun-2019	10:05:32	36.5224	74.3064	-	1	1	Chilean devil ray
28-Jun-2019	10:10:12	36.5030	74.3979	50	1	1	Chilean devil ray
28-Jun-2019	10:11:05	36.4912	74.4316	50	1	3	Chilean devil ray
28-Jun-2019	10:12:28	36.5025	74.4819	50	1	24	Chilean devil ray
28-Jun-2019	10:13:14	36.4922	74.5096	50	1	2	Chilean devil ray
28-Jun-2019	10:15:05	36.4952	74.5736	50	1	7	Chilean devil ray
28-Jun-2019	10:22:01	36.5014	74.7461	50	1	2	Hammerhead
28-Jun-2019	10:23:25	36.5023	74.7982	50	1	2	Hammerhead
28-Jun-2019	10:32:52	36.4907	75.1463	50	1	150	Cownose ray
28-Jun-2019	10:38:15	36.4242	75.0843	49	1	3	Cownose ray
28-Jun-2019	10:39:20	36.4246	75.0392	49	1	2	Cownose ray
28-Jun-2019	10:45:09	36.4183	74.8035	49	1	4	Hammerhead
28-Jun-2019	10:45:39	36.4253	74.7833	49	1	1	Hammerhead
28-Jun-2019	10:46:11	36.4180	74.7607	49	1	1	Hammerhead
28-Jun-2019	10:49:37	36.4260	74.6233	49	1	2	Chilean devil ray
28-Jun-2019	10:50:53	36.4232	74.5730	49	1	1	Chilean devil ray
28-Jun-2019	10:51:39	36.4229	74.5436	49	1	6	Chilean devil ray
28-Jun-2019	10:52:10	36.4177	74.5228	49	1	3	Chilean devil ray
28-Jun-2019	11:02:16	36.3498	74.3636	48	2	1	Hammerhead
28-Jun-2019	11:11:45	36.3520	74.6165	48	2	8	Chilean devil ray
28-Jun-2019	11:12:14	36.3450	74.6358	48	2	1	Chilean devil ray
28-Jun-2019	11:14:13	36.3535	74.7140	48	1	1	Chilean devil ray
28-Jun-2019	11:15:13	36.3452	74.7532	48	1	1	Chilean devil ray
28-Jun-2019	11:15:46	36.3438	74.7739	48	1	4	Hammerhead
28-Jun-2019	11:16:53	36.3515	74.8173	48	1	4	Hammerhead
28-Jun-2019	11:38:52	36.2737	74.8123	47	2	600	Cownose ray
28-Jun-2019	11:40:11	36.2768	74.7577	47	3	1	Chilean devil ray
28-Jun-2019	11:40:49	36.2660	74.7322	47	3	3	Chilean devil ray
28-Jun-2019	11:41:58	36.2776	74.6842	47	3	2	Chilean devil ray
28-Jun-2019	11:49:47	36.2758	74.4777	47	2	1	Chilean devil ray
28-Jun-2019	12:13:00	36.2019	74.7341	46	3	4	Chilean devil ray
29-Jul-2019	8:25:57	36.7192	74.6530	0	3	1	Chilean devil ray
29-Jul-2019	9:04:51	36.6415	74.9382	52	3	300	Cownose ray
29-Jul-2019	9:12:49	36.6513	75.0891	0	3	400	Cownose ray
29-Jul-2019	9:19:25	36.5762	75.1297	51	3	75	Cownose ray
29-Jul-2019	9:21:53	36.5668	75.0377	51	3	175	Cownose ray

Date	Time	Latitude (N)	Longitude (W)	Track Number	BSS	Total Count	Comments
29-Jul-2019	9:37:04	36.5749	74.5752	51	3	4	Chilean devil ray
29-Jul-2019	9:55:42	36.5010	74.4396	50	2	1	Unidentified shark
29-Jul-2019	10:04:31	36.5005	74.6512	50	2	1	Chilean devil ray
29-Jul-2019	10:35:35	36.4158	74.6732	49	1	4	Chilean devil ray
29-Jul-2019	10:39:49	36.4239	74.5145	49	1	1	Chilean devil ray
29-Jul-2019	10:41:23	36.4177	74.4561	49	1	1	Chilean devil ray
29-Jul-2019	10:54:32	36.3511	74.4822	48	1	2	Chilean devil ray
29-Jul-2019	10:57:30	36.3536	74.5934	48	1	5	Chilean devil ray
29-Jul-2019	11:27:32	36.2691	74.7557	47	1	1	Manta ray
29-Jul-2019	11:33:37	36.2668	74.6461	47	1	1	Chilean devil ray
29-Jul-2019	11:43:27	36.2675	74.3585	47	1	1	Chilean devil ray
29-Jul-2019	12:11:46	36.2021	75.0659	46	0	1	Hammerhead
12-Aug-2019	10:10:13	36.8785	74.6139	55	0	1	Manta ray
12-Aug-2019	10:17:09	36.8688	74.4951	55	0	1	Chilean devil ray
12-Aug-2019	11:08:18	36.7262	74.7317	53	1	1	Hammerhead
12-Aug-2019	11:12:17	36.7185	74.5814	53	1	1	Chilean devil ray
12-Aug-2019	11:18:22	36.7233	74.5176	53	1	1	Chilean devil ray
12-Aug-2019	11:19:08	36.7170	74.4875	53	1	1	Chilean devil ray
*12-Aug-2019	11:28:45	36.7090	74.3339	53	1	2	Chilean devil ray
12-Aug-2019	11:32:40	36.6499	74.3988	52	1	3	Chilean devil ray
12-Aug-2019	11:33:18	36.6518	74.4236	52	1	4	Chilean devil ray
12-Aug-2019	11:34:10	36.6511	74.4595	52	1	1	Chilean devil ray

Key: “Large mobulid” = Large black and white mobulid

4.5.2 Other fishes

Sightings of ocean sunfish (*Mola* sp.) were recorded on every survey, with a total of 371 individuals observed across all survey days. Accounting for distribution of survey effort, ocean sunfish sightings were distributed fairly evenly throughout the study area in both deep and shallow waters, with mean numbers relatively stable throughout the duration of this project (**Table 24, Figure 22**).

Table 24. Ocean sunfish (*Mola* sp.) sightings in the Norfolk Canyon study area for all 2018–2019 surveys.

Date	Total Count (On- and Off-Effort)	Count Off-Effort
9-Apr-2018	7	0
11-Apr-2018	2	0
25-May-2018	19	1
16-Jun-2018	15	0
17-Jun-2018	23	1

Date	Total Count (On- and Off-Effort)	Count Off-Effort
14-Jul-2018	11	0
5-Aug-2018	19	0
6-Aug-2018	12	2
19-Oct-2018	25	3
12-Nov-2018	1	1
1-Dec-2018	26	1
19-Dec-2018	8	1
4-Jan-2019	2	1
17-Jan-2019	2	0
26-Jan-2019	23	0
10-Feb-2019	2	0
8-Mar-2019	7	1
28-Mar-2019	19	0
23-Apr-2019	76	2
27-Jun-2019	5	1
28-Jun-2019	13	0
29-Jul-2019	16	0
12-Aug-2019	23	0

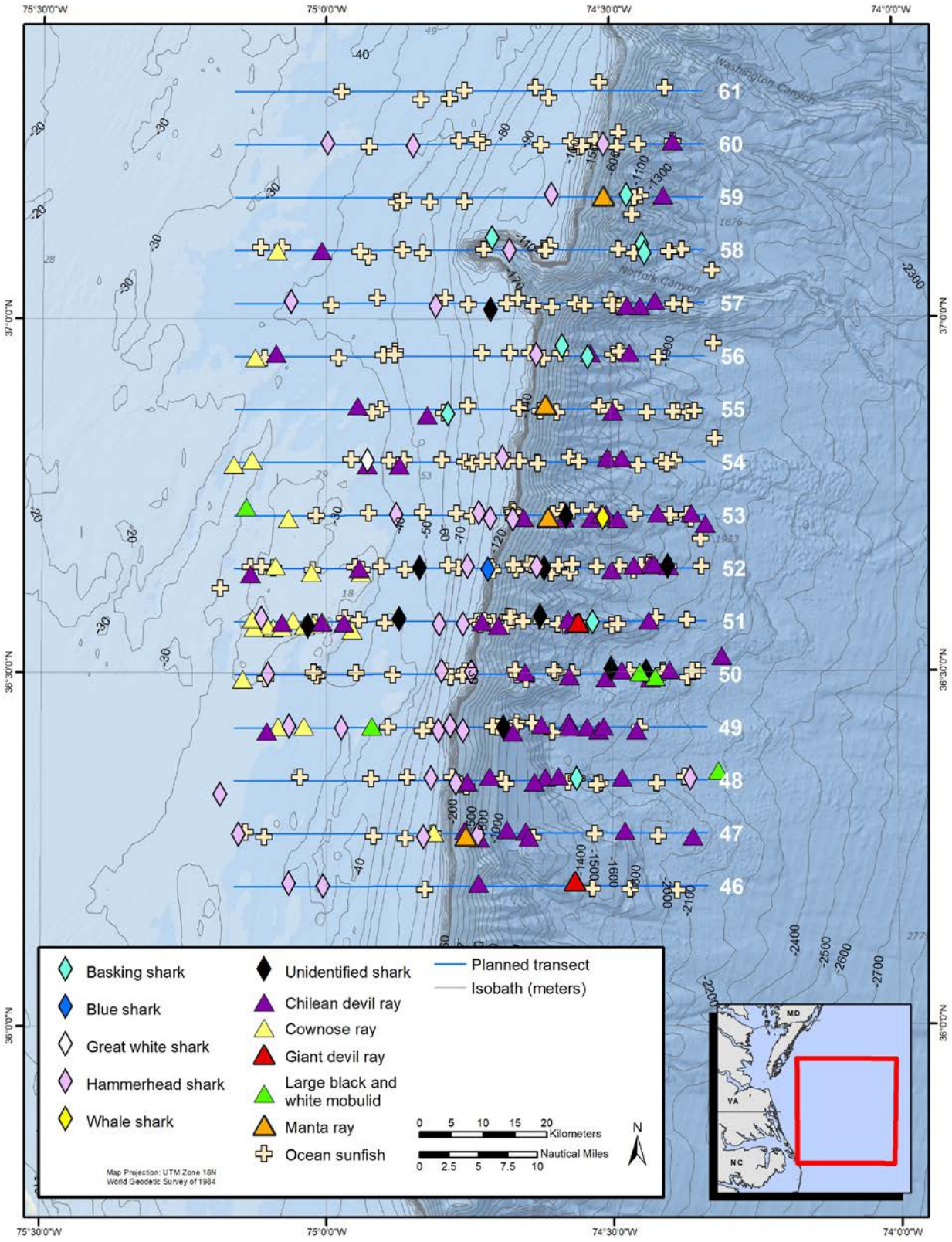

Figure 22. All pelagic marine vertebrate (other than cetaceans and sea turtles) sightings recorded in the Norfolk Canyon study area for all 2018–2019 surveys.

5. Future Efforts

These twenty-three surveys took place from early 2018 through summer 2019, completing over four years of effort initiated by UNCW in March 2015. This robust dataset provides an opportunity to examine spatial/temporal occurrence patterns, abundance and density estimates for the Norfolk Canyon region.

The results reported here, and previously by UNCW, have demonstrated rich species diversity in the VACAPES OPAREA. HDR efforts captured sightings of protected cetacean species such as NARW, blue, fin, sei, and sperm whales. Additionally, the observations of multiple beaked whale species, which are particularly sensitive to anthropogenic sound sources, are of significant interest due to their presence in the U.S. Navy training and testing ranges where possible exposure to sonar and other anthropogenic sounds are of particular concern. These sightings, along with valuable observations of non-cetacean endangered species, such as the whale shark, giant manta ray, and giant devil ray, accentuate the broader value and importance of these efforts. These surveys provide baseline data establishing a point of reference for potential future comparison and evaluation of trends in occurrence and abundance.

Given that this region is a high-use area for commercial shipping in addition to military activities, this study has proven to be a valuable component of the continued monitoring efforts funded by the U.S. Navy. The ability to document the occurrence of protected animals is especially significant when continuing data collection over a longer temporal span in this rapidly changing environment.

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