South Fork Wind Farm
Atlantic Cod Spawning Survey

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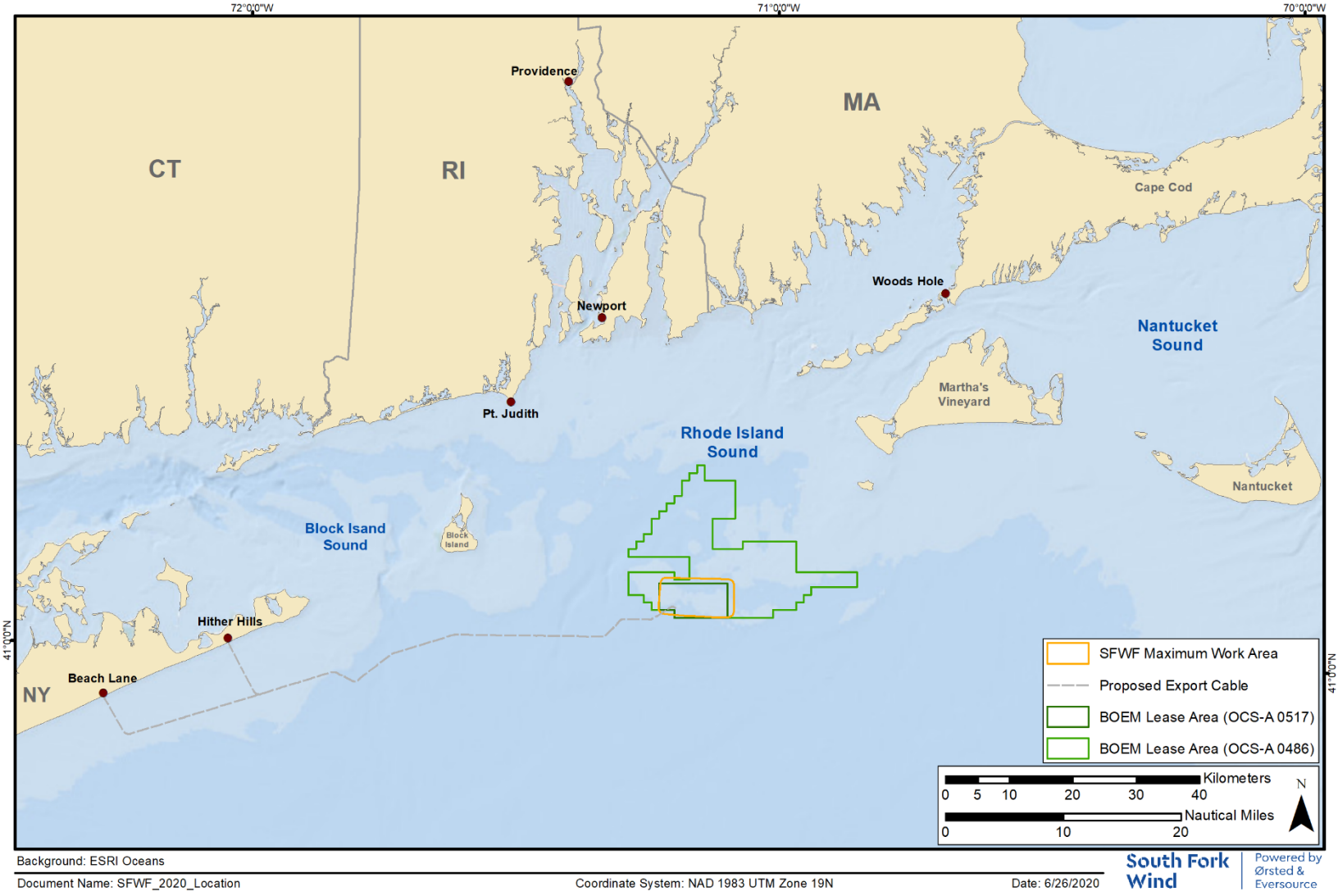

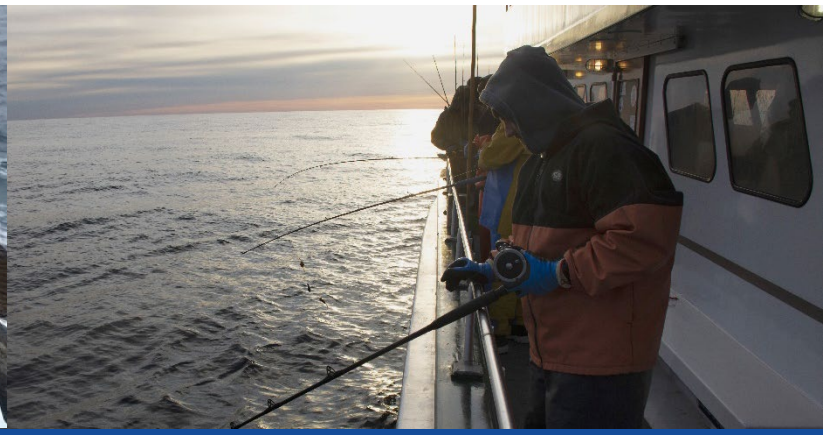

Final Report
December 2018 through April 2019

Prepared by
INSPIRE ENVIRONMENTAL

South Fork Wind Farm
Observational Atlantic Cod Spawning Survey
December 2018 - April 2019
Final Report

Prepared for:

South Fork Wind | Powered by Ørsted & Eversource

Deepwater Wind South Fork, LLC

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LIST OF ACRONYMS

BOEM	Bureau of Ocean Energy Management
COP	Construction and Operations Plan
CPUE	Catch per Unit Effort
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
QA/QC	Quality Assurance/Quality Control
RIDEM	Rhode Island Department of Environmental Management
SFWF	South Fork Wind Farm
TL	Total Length

1.0 INTRODUCTION

INSPIRE Environmental designed and conducted an observational Atlantic cod (*Gadus morhua*) spawning survey (survey) at the request of Deepwater Wind South Fork LLC. to support the South Fork Wind Farm (SFWF) project (Figure 1-1). The survey was comprised of a hook and line investigation onboard for-hire fishing vessels to assess the presence of Atlantic cod spawning activity around the proposed SFWF work area and has a design modified from the reconnaissance Atlantic cod survey conducted during the winter and spring of 2018 (INSPIRE 2019). The SFWF work area is a 1000 m buffered region around the proposed wind turbine generator locations, and comprises the area where work, including anchoring, may occur in the region. The hook and line survey assessed spawning activity of Atlantic cod in and around the work area by determining the maturation stage of collected adult Atlantic cod. Additionally, the survey documented the catch of other fish species present. This final survey report provides the rationale, design, methods, and results of the observational Atlantic cod spawning survey conducted from December 2018 through April 2019.

The survey was designed and conducted in consideration of several federal regulations and guidelines, as well as concerns raised by stakeholders regarding Atlantic cod spawning in the area of the SFWF:

1. Construction and Operations Plan (COP) requirements pursuant to 30 CFR Part 585 (Bureau of Ocean Energy Management [BOEM], 2016), specifically:
    - § 585.626 – Provide results of biological surveys with supporting data on fish populations.
    - § 585.627 – Assist BOEM in complying with the National Environmental Policy Act (NEPA) and other relevant laws by providing detailed information on fish biological resources.
2. BOEM Guidelines for Providing Information on Fisheries for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585 (BOEM, 2019), specifically;
    - “Identify and confirm the dominant benthic, demersal, and pelagic fish species within the project footprint and surrounding areas.”
    - “Collect additional information aimed at reducing uncertainty associated with existing fish data and/or to help inform the interpretation of survey results.”
    - Produce survey results that identify “seasonal presence/absence of commercially and recreationally important fish and shellfish.”
3. Concerns raised by federal and state regulators as well as the recreational and commercial fishing industry about the potential presence and habitat utilization of spawning Atlantic cod in the SFWF work area.

Data presented in this final survey report are used to characterize Atlantic cod and other marine fish sampled from December 2018 through April 2019, prior to permitting or construction of the SFWF. Atlantic cod spawning stage was assessed for legal-sized individuals volunteered for sampling at each location.

1.1 Survey Goals and Objectives

The observational Atlantic cod spawning survey aimed to:

- Identify areas the for-hire fleet out of Point Judith, RI fishes for Atlantic cod.
    - Vessels conducted normal fishing operations and researchers did not direct the captains where to fish.
- Identify the location of any cod spawning aggregations encountered during the survey.
- Assess maturity and spawning stage of Atlantic cod caught.
- Provide descriptive results from this survey.
    - This survey is not intended to determine significant differences in cod presence or spawning in the SFWF Project Area relative to surrounding waters.

1.2 Survey Rationale

Atlantic cod is historically an important cultural and commercial species in New England and the population in southern New England has been declining in recent decades. Atlantic cod is believed to be dependent on geographically specific (on the scale meters to tens of meters) spawning areas. Cod spawning on or near Cox Ledge, are thought to belong to a southern, winter-spawned complex to the south of Cape Cod (Zemeckis et al., 2014a). Cod spawning has been associated with bottom water temperatures that range from 0 °C to 10 °C (Brander, 1993) and areas of rough bottom habitat (Siceloff and Howell, 2013), such as rocky slopes (Meager et al., 2010) and cobble or boulder outcrops (Dean et al., 2012). Inter-annual spawning site fidelity has been well described through tagging/telemetry studies (Robichaud and Rose, 2001; Skjæraasen et al., 2011; Dean et al., 2014; Zemeckis et al., 2014b). These characteristics emphasize the importance of gathering site-specific information on Atlantic cod spawning near proposed offshore development.

Atlantic cod abundance data are sparse in federal or state databases for the Rhode Island-Massachusetts Wind Energy Area and the Massachusetts Wind Energy Area. This includes areas within and around the SFWF work area. The data that do exist are too sparse in both time and space to conduct meaningful assessments. Much of the data that are available do not include spawning maturation staging, making the identification of spawning grounds impossible. The area in and around the SFWF work area is too rocky to be sampled by bottom trawls, effectively limiting the survey effort in the region by the National Oceanic and Atmospheric Administration Northeast Fisheries Science Center (NOAA NEFSC) spring and fall trawl surveys. Additionally, the timing of these surveys does not coincide with the timing of cod spawning in the region. Therefore, the observational Atlantic cod spawning survey was

designed to collect additional data, using a proven fishing methodology for the habitat and species, to expand our knowledge of the area. Prior studies have used the maturity stage of haddock (*Melanogrammus aeglefinus*) as a proxy for the likelihood of spawning occurring at a location (Burchard et al., 2013, 2014).

A reconnaissance Atlantic cod spawning survey, using hook and line methods, was conducted by INSPIRE in the winter of 2018 (INSPIRE 2019). Atlantic cod are known to actively feed while in spawning condition (Michalsen et al., 2008; Krumsick and Rose, 2012); therefore, the use of hook and line methods, including jigging and baited hooks, is considered a prudent sampling methodology. The winter 2018 survey demonstrated that for-hire fishing vessels equipped with modern fish finder technology and captained by knowledgeable anglers were able to locate Atlantic cod spawning locations. When cod spawning aggregations are large, echosounders provide a clear image of where, and how large, the aggregation is. For-hire fishing vessels, like those used in both the 2018 and 2018-2019 surveys, provide an adequate amount of room for many anglers to fish at the same time, thus increasing the chance for catch in active spawning aggregations.

The Atlantic cod spawning survey in winter 2018 confirmed the presence of spawning cod around the SFWF Project Area. One large spawning aggregation was located southwest of the SFWF Project Area. No large spawning aggregations were identified within the SFWF Project Area during the 2018-2019 survey. The hook and line survey proved to a be a successful methodology for identifying Atlantic cod spawning aggregations and collecting spawning cod. However, the lack of spawning aggregations within the SFWF Project Area limited the number of cod sampled and the ability to locate active aggregations. The 2018-2019 observational survey extended the information gained from the winter 2018 survey by following the fleet for an additional fishing season using a modified survey design. The 2018-2019 survey was performed as an observational survey, where catch was sampled on regularly scheduled trips during normal fishing operations to maximize the overall catch and increase sampling opportunities of active aggregations.

2.0 METHODS

The sampling methodology used is detailed in the INSPIRE South Fork Wind Farm: For-Hire Fleet Atlantic Cod Observation Survey Protocol (INSPIRE, 2018). Atlantic cod and demersal fisheries resources in and around the SFWF study area were surveyed using a for-hire fishing vessel with an INSPIRE scientist onboard to serve as an observer and conduct biological sampling of the catch. The sampling took place using standardized methods on normally scheduled fishing trips from December 2018 to April 2019. Twenty total trips were targeted for the survey.

2.1 Sampling Design

A scientific observer deployed on regularly scheduled for-hire fishing vessel hook and line trips from December 2018 to April 2019, totaling 13 cruises. Timing of observed trips was predominantly determined by prevailing weather conditions. All fishing locations were determined by the captain to optimize catch for patrons.

Each location fished was referred to as a sampling station. Total time spent fishing at each location was at the discretion of the captain. At each station the observer recorded the starting location (latitude/longitude), starting water depth, start and end fishing times, if legal sized fish were caught, total count of sub-legal Atlantic cod caught, presence/absence of bycatch species caught, sea surface temperature, general weather conditions, notes on other vessels present, and whether an Atlantic cod spawning aggregation was indicated by the vessel's echosounder.

2.2 Angling Methods

During the transit at the start of each trip, the onboard observer approached each angler/group of anglers to explain the purpose of the project, the sampling involved, and to ask if they were willing to participate in the survey. Participating anglers fished for cod with rod and reel using jigs and teasers or baited hooks at the discretion of each angler. Fishing effort (e.g., number of anglers, length of time hooks in water) was not standardized across fishing stations or fishing trips; however, the number of anglers fishing on each trip was noted.

2.3 Fish Sampling

Only legal sized fish (at least 56 cm total length) were sampled for this survey. Angler participation in the survey was voluntary therefore not all legal sized fish that were caught were sampled. When participant Atlantic cod were landed, the total length (TL cm) and weight (g) were recorded. Those fish were then dissected to determine sex, spawning maturation stage, and to record the gonad weight (Hutchings et al., 1999; Siceloff and Howell, 2013; Dean et al., 2014). The maturity stage of each individual dissected was assigned based on guidelines determined by Burnett et al. (1989) and updated by O'Brien et al. (1993): immature, developing, ripe, ripe and running, spent, resting, unknown (Table 2-1). Photographs of gonads were recorded for all individuals dissected for QA/QC analysis. Any photographs where maturation stage was in question were sent to members of the NOAA NEFSC Population Biology Branch

for consultation. Sub-legal fish (<56cm TL) at each location were tallied. Data recorded for all sampled cod, including assigned maturation stage can be found in Appendix A.

2.4 Physical and Oceanographic Conditions

Sea surface conditions including air temperature (°C), wind speed (knots) and direction, and swell height (feet) and direction were recorded at the first fishing station each day. Depth and sea surface temperature were recorded at each fishing location.

2.5 Data Analysis

The following sections describe the methods used to present and evaluate each of the various types of data collected during the observational Atlantic cod spawning survey. Summary tables and graphical presentations are used to illustrate the results across the entire survey time period.

2.5.1 Physical and Oceanographic Conditions

Recorded sea state conditions are reported in Appendix B and described in Section 4.0.

2.5.2 Fishing Location Summary

Location, start and end fishing time, water depth, and fishing mode (drift or anchor) were recorded at every fishing location during each trip. Fishing locations are presented visually in Section 4.0 and tables are in Appendix C.

2.5.3 Cod Catch and Spawning Stage

Descriptive summaries of landed cod and spawning stage are presented visually and in tables in Section 4.0.

2.5.4 Bycatch Species

Bycatch species (any species other than Atlantic cod) were recorded as presence/absence at any particular fishing location where they were caught. Data were not collected on individuals from bycatch species. A summary of bycatch species is presented in tables in Section 4.0.

2.6 Cruise Summary Reports

Summary reports were generated each month during the survey period. Each monthly report summarized all the trips that occurred during that month. These reports were distributed to Ørsted, NOAA, and the Rhode Island Department of Environmental Management (RIDEM). Each monthly summary report included information on where fishing occurred, how many cod were caught, and how many individuals were sampled on each survey trip.

Table 2-1. Maturity Staging Criteria Used During the Northeast Fisheries Science Center Trawl Surveys Used in Determining Atlantic Cod Maturity (from O'Brien et al., 1993)

Stage	Description and Criteria
Female	
Immature	Ovary paired, tube-like, small relative to body cavity; colorless to pink jell-like tissue, no visible eggs; thin transparent outer membrane.
Developing	Ovaries large, occupying up to 2/3 of the body cavity; blood vessels prominent when present; ovary appears granular as yellow to orange yolked eggs develop. A mix of yolked and hydrated eggs.
Ripe	Ovaries large, may fill entire body cavity; hydrated eggs present. Transparent ovary wall.
Ripe and Running	Eggs flow from vent with little or no pressure to abdomen.
Spent	Ovaries flaccid, sac-like similar in size to ripe ovaries; color red to purple; ovary wall thickened, cloudy and translucent; some hydrated eggs may adhere to ovary wall.
Resting	Ovaries smaller than ripe ovaries, but larger than immature. Interior jell-like, no visible eggs.
Male	
Immature	Testes small relative to body cavity, colorless to gray and translucent. Testes narrow, lobed and elongated, resembles crimped ribbon.
Developing	Testes large, grey to off-white, firm consistency with very little or no milt present.
Ripe	Testes larger than 'Developing', chalk white, consistency mostly liquid. Milt flows easily when testes dissected.
Ripe and Running	Chalk white milt flows easily from the vent with little or no pressure on abdomen. Once dissected, milt flows easily.
Spent	Testes flaccid, may contain residual milt, less robust than 'Ripe'. Edges or other parts of testes starting to turn reddish to brown or grey as milt recedes.
Resting	Testes shrunken in size relative to 'Ripe'. Color is yellow, brown or grey with little or no milt.

3.0 QUALITY ASSURANCE AND QUALITY CONTROL

3.1 Sampling

Photographs were taken of all cod gonads to allow for secondary review and confirmation of initial spawning stage delineations. Secondary review of spawning stage resulted in the correction of three spawning stage delineations across the entire duration of the survey.

3.2 Data Management

INSPIRE Environmental conducted a comprehensive review of all data collected on all cod survey trips. Hard copy data sheets were reviewed for data entry errors prior to importing into a relational database. Fish sampling locations were plotted to ensure positions were recorded correctly.

4.0 RESULTS

4.1 Summary of Survey Sampling Effort

For-hire vessels were chartered out of Pt. Judith, RI (Frances Fleet and Seven B's). Thirteen total sampling trips were conducted, and all originated from Pt. Judith (~25 nautical miles to survey location). Trips were largely run during the latter half of the week or weekend due to availability of clients. In some instances, the time between trips was lengthy due to adverse weather conditions. Cruise details are provided in Table 4-1.

4.2 Physical and Oceanographic Conditions

The survey was conducted from the second week of December (12/14/2018) until the first week of April (4/7/2019). The sea state on survey days was frequently calm, characterized by small swells and light winds. Relatively calm sea conditions were required for vessel and scientific researcher safety during the survey. Mean wind speed during surveys was 5 knots (8 ft/s) with a maximum sustained wind speed of 15 knots (25 ft/s). Mean swell height during surveys was 0.3 m (2 feet) with a maximum swell of approximately 1.5 m (5 feet). The mean air temperature during surveys was 5.5 °C (42 °F) with a minimum air temperature of -3.8 °C (25 °F) and a maximum of 7.8 °C (46 °F). Recorded physical and oceanographic conditions are reported tabularly in Appendix B.

4.3 Fishing Location Summary

All locations fished as part of the survey are shown in Figure 4-1. Fishing locations were determined based on the captain's knowledge and experience and were concentrated on known wrecks and reefs in the region as well as at areas of relatively rapid changes in bottom elevation (slopes). All but one fishing effort occurred outside the SFWF work area and fishing locations were primarily to the south and west of the SFWF work area. The one effort inside the work area occurred on the first trip of the season, had a high catch of sub-legal and some legal-sized fish, and was not revisited on any subsequent trips. Fishing effort was widespread, and locations were rarely visited more than once throughout the duration of the survey.

4.4 Cod Catch and Spawning Stage

A total of 218 Atlantic cod were caught during the survey, with collections occurring on trips from December through March. No Atlantic cod were caught on the one trip made in April. Of the 218 fish caught, 137 fish were sub-legal and not sampled. Of the 81 legal-sized fish caught, 16 were non-participant fish and not sampled. Therefore, 65 Atlantic cod were sampled during this year's survey (Table 4-2). Sex ratio was nearly even, with 33 females (51%) and 32 males (49%) sampled. Of the 65 cod sampled, seven were determined to be immature (5 females, 2 males). Maturation stage by month for both sexes is presented in Figure 4-2. Two fishing locations from the first trip in mid-December each produced thirteen spawning condition Atlantic cod (Figure 4-3). One of those locations was within the SFWF work area (Figure 4-4). Although this site produced the highest amount of spawning condition cod for a single fishing effort on any trip, the site was not fished again during the sampling season. In 2018, the large spawning aggregation

identified during the survey was located to the Southwest of the work area and was revisited repeatedly throughout January and the early part of February of that year.

The relationship between length and weight (Le Cren, 1951; Jakob et al., 1996), was related to spawning status for both males and females (Figure 4-5), with longer, heavier fish in either a ripe, ripe and running, or spent state. Cod catch by cruise and spawning stage (Table 4-2) are presented tabularly. Example images of cod ovaries in immature, developing, ripe, ripe and running, and spent stages are shown in Figure 4-6.

4.5 Bycatch Species

Eighteen (18) bycatch species were landed during Year 2 of the survey. Cunner (*Tautogolabrus adspersus*) was the most caught species and was caught on 35% of fishing efforts. Black sea bass (*Centropristis striata*) were the second most caught species and were caught on 19% of fishing efforts. Bycatch summarized by species and percent occurrence is summarized in Table 4-3.

4.6 Health and Safety

No safety incidents, near misses, or injuries were reported on any cruise during the survey.

Table 4-1. Cruise Details for Atlantic Cod Spawning Survey

Cruise ID	Date	Port	Vessel	Captain	Anglers Aboard
19-01	12/14/2018	Pt. Judith, RI	Lady Frances	Mike O'Grady	30 anglers
19-02	12/19/2018	Pt. Judith, RI	Seven B's	Rusty Benn	9 anglers
19-03	1/12/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	18 anglers
19-04	1/13/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	13 anglers
19-05	2/3/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	16 anglers
19-06	2/4/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	20 anglers
19-07	2/5/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	18 anglers
19-08	2/17/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	23 anglers
19-09	2/23/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	28 anglers
19-10	3/9/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	25 anglers
19-11	3/14/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	27 anglers
19-12	3/30/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	9 anglers
19-13	4/7/2019	Pt. Judith, RI	Lady Frances	Mike O'Grady	20 anglers

Table 4-2. Summary Detail of Atlantic Cod Sampled During Survey by Cruise and Station ID

Cruise ID	Maturity Stage						Total Cod
	Developing	Immature	Resting	Ripe	Ripe and Running	Spent	
19-01	4	2	0	6	10	2	24
19-02	2	2	0	4	0	0	8
19-03	0	0	0	0	0	1	1
19-04	1	1	0	1	0	1	4
19-05	0	0	1	0	1	0	2
19-06	0	0	1	0	1	0	2
19-07	0	0	0	0	0	0	0
19-08	0	0	1	1	3	2	7
19-09	1	0	1	0	2	0	4
19-10	1	1	0	2	0	3	7
19-11	2	0	0	1	0	0	3
19-12	0	0	1	1	0	1	3
Total Cod	11	6	5	16	17	10	65

Table 4-3. Summary Detail of Bycatch Species by Cruise ID

Common Name	Scientific Name	Cruise ID												
		19-01	19-02	19-03	19-04	19-05	19-06	19-07	19-08	19-09	19-10	19-11	19-12	19-13
Atlantic Mackerel	*Scomber scombrus*	X	X	X	X				X					
Conger Eel	*Conger oceanicus*		X											
Black Sea Bass	*Centropristis striata*	X	X	X	X			X	X	X				
Cunner	*Tautogolabrus adspersus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Haddock	*Melanogrammus aeglefinus*	X												
Longhorn Sculpin	*Myoxocephalus octodecimspinosus*		X			X	X	X	X	X	X	X		
Northern Sea Robin	*Prionotus carolinus*					X								
Ocean Pout	*Zoarces americanus*	X							X	X	X	X		
Pollock	*Pollachius virens*		X	X		X			X	X				
Red Hake	*Urophycis chuss*	X			X				X	X				
Scup	*Stenotomus chrysops*	X	X	X	X									
Sea Raven	*Hemitripterus americanus*								X	X		X		
Silver Hake	*Merluccius bilinearis*	X			X									
Smooth Dogfish	*Mustelus canis*			X				X	X					
Spiny Dogfish	*Squalus acanthias*			X				X	X					
Squeteague	*Cynoscion regalis*	X												
Tautog	*Tautoga onitis*	X												X
Winter Skate	*Leucoraja ocellata*	X	X						X	X				

5.0 DISCUSSION

The reconnaissance and observational Atlantic cod spawning surveys were designed and conducted to provide qualitative descriptions of Atlantic cod spawning locations, if they existed, in and around the SFWF work area during the winter and spring of 2018 and 2018-2019. In 2018, the cod fishing season was not productive with only seventeen fish sampled throughout the fishing season. Also in 2018, one large cod spawning aggregation was identified to the southwest of the of the work area. In the 2018-2019 survey, the number of cod sampled increased to 65 individuals, but no large spawning aggregations were identified on any fishing trips.

Directed fishing effort in and around the SFWF area did not prove to be a productive method of sampling for spawning Atlantic cod. The change in sampling design for 2018-2019 was more productive for catching Atlantic cod in spawning condition but led to much less effort within the SFWF (Figure 4-7). Only one location within the work area was fished during the sampling season. While it did produce thirteen individuals in spawning condition, the location was never fished again on any trips for the rest of the season. All other fishing effort occurred to the south and west of the work area.

For-hire fishing vessels, like those used in this survey, provide an adequate amount of room for eight or more anglers leading to increased fishing effort at each location. A drawback of using large for-hire fishing vessels is vessel speed. Due to the limitations in vessel speed, it is difficult to both cover a large area attempting to locate aggregations of cod with an echosounder, and/or fish numerous locations during a standard 12-hour survey day. When attempting to cover a large area and identify relatively small, spatially explicit cod spawning aggregations, vessel speed can be a major limitation. A smaller, faster fishing vessel would provide a greater opportunity to cover a larger area but would limit the number of potential anglers contributing to the survey (and therefore potentially reducing the number of fish caught).

Anecdotal accounts suggest the majority of the for-hire fishing fleet experienced low cod catches for the entirety of the 2018-2019 winter season. Vessel captains regularly communicated via VHF during fishing trips and all reported low catches. While this survey season produced more Atlantic cod than the previous year, catches were lower than expected based on previous years' experiences of the vessel captains.

The reconnaissance and observational Atlantic cod spawning surveys confirmed the presence of spawning cod in and around the SFWF work area, though no spawning aggregations were identified within the work area as part of these surveys. One large spawning aggregation was located southwest of the work area in 2018 and but no large spawning aggregations were identified at any fishing locations during the 2018-2019 season.

Future work in the area of Cox Ledge should examine, in more detail, the spawning behaviors, site fidelity, and habitat use of Atlantic cod. Work conducted in Massachusetts Bay (Hernandez et al., 2013; Dean et al, 2014; Zemeckis et al., 2019) has examined behavior and site fidelity on

known Atlantic cod spawning grounds. These studies used novel technologies (acoustic telemetry; passive acoustic monitoring) to gain insight into the seasonal and spatial extent of spawning in Massachusetts Bay. Similar work conducted in the area of Cox Ledge would provide additional, and valuable, information on Atlantic cod spawning in the region. These technologies would also provide long-term monitoring solutions that would be applicable to multiple species that utilize the SFWF and surrounding wind energy areas (Ingram et al., 2019)

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South Fork Wind Farm
Observational Atlantic Cod Spawning Survey
December 2018 - April 2019
Final Report

FIGURES

Prepared for:

South Fork Wind | Powered by Ørsted & Eversource

Deepwater Wind South Fork, LLC

Prepared by:

Brian Gervelis
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INSPIRE Environmental
513 Broadway
Newport, Rhode Island 02840

June 2020

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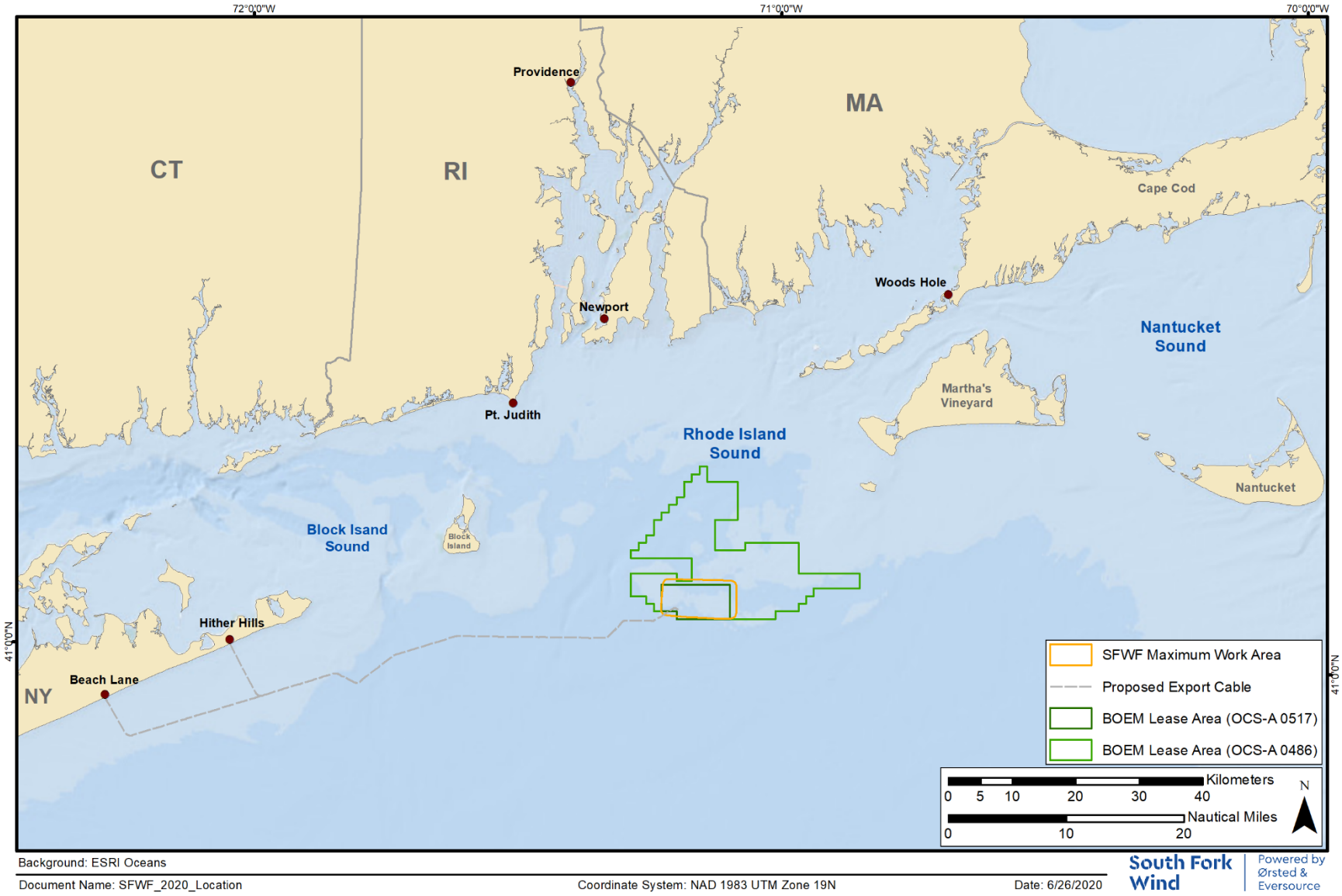


Figure 1-1. Location of the SFWF work area

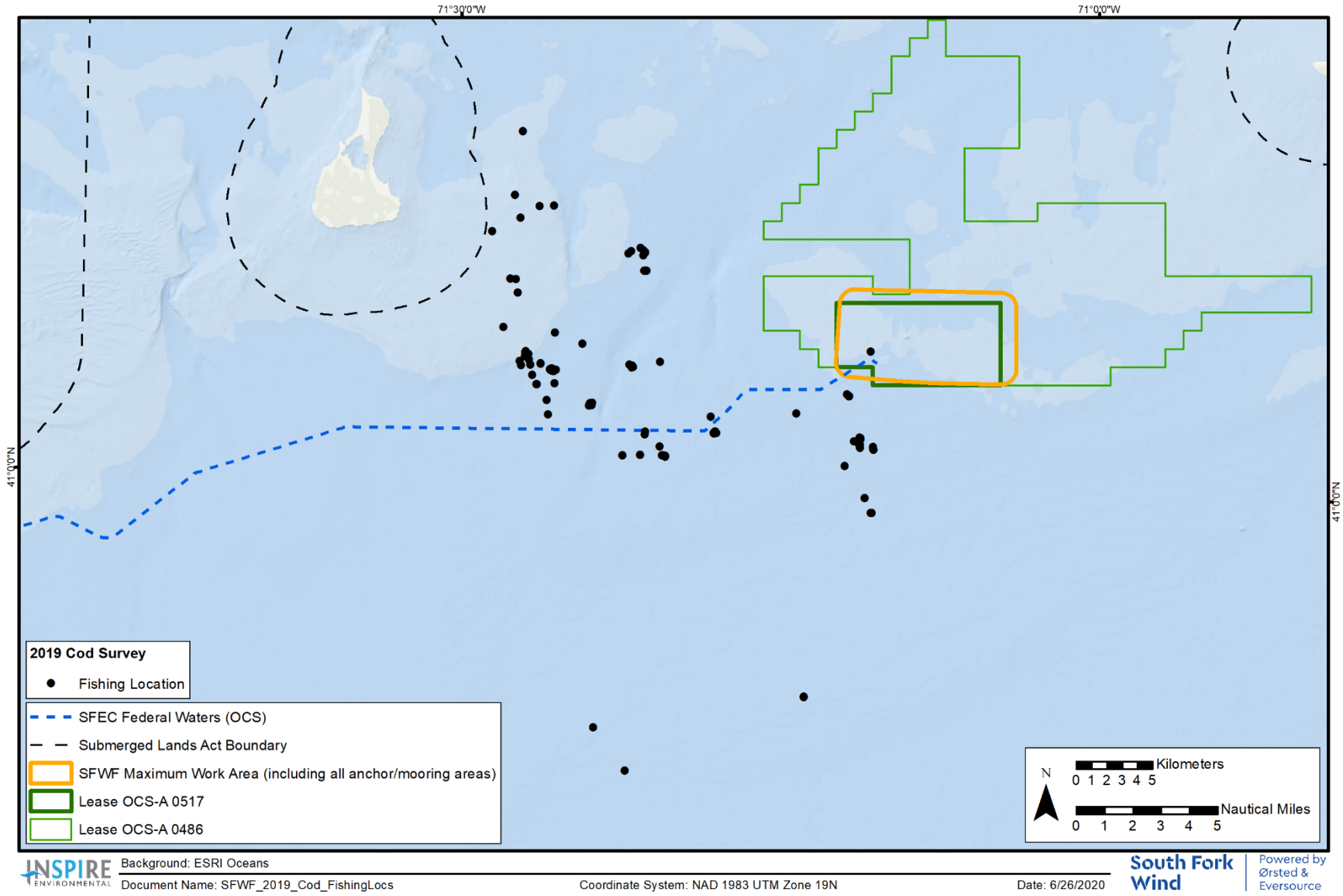


Figure 4-1. Locations of all fishing survey efforts that occurred throughout the observational Atlantic cod spawning survey

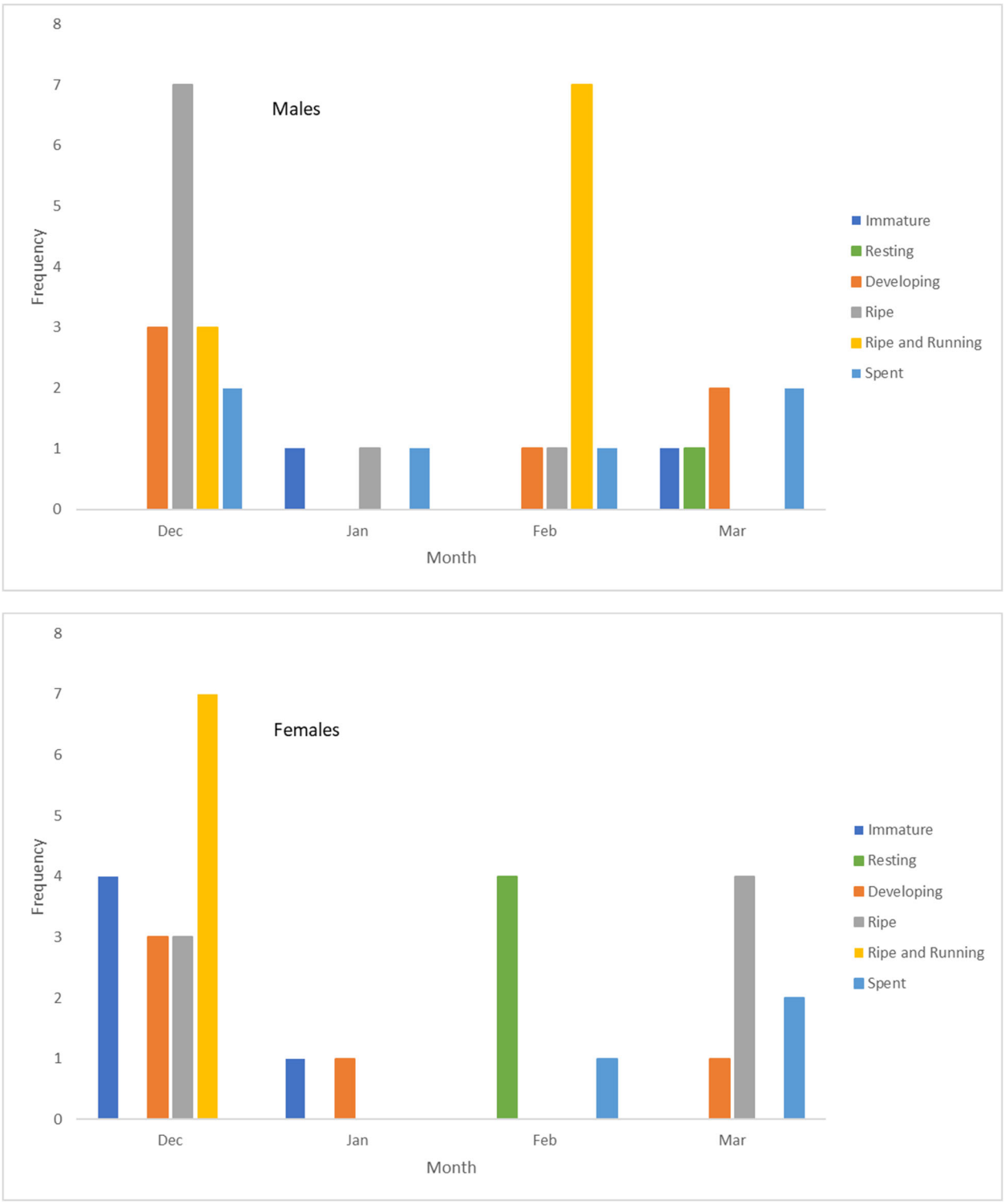


Figure 4-2. Number of individuals sampled per maturation stage by month for male and female Atlantic cod

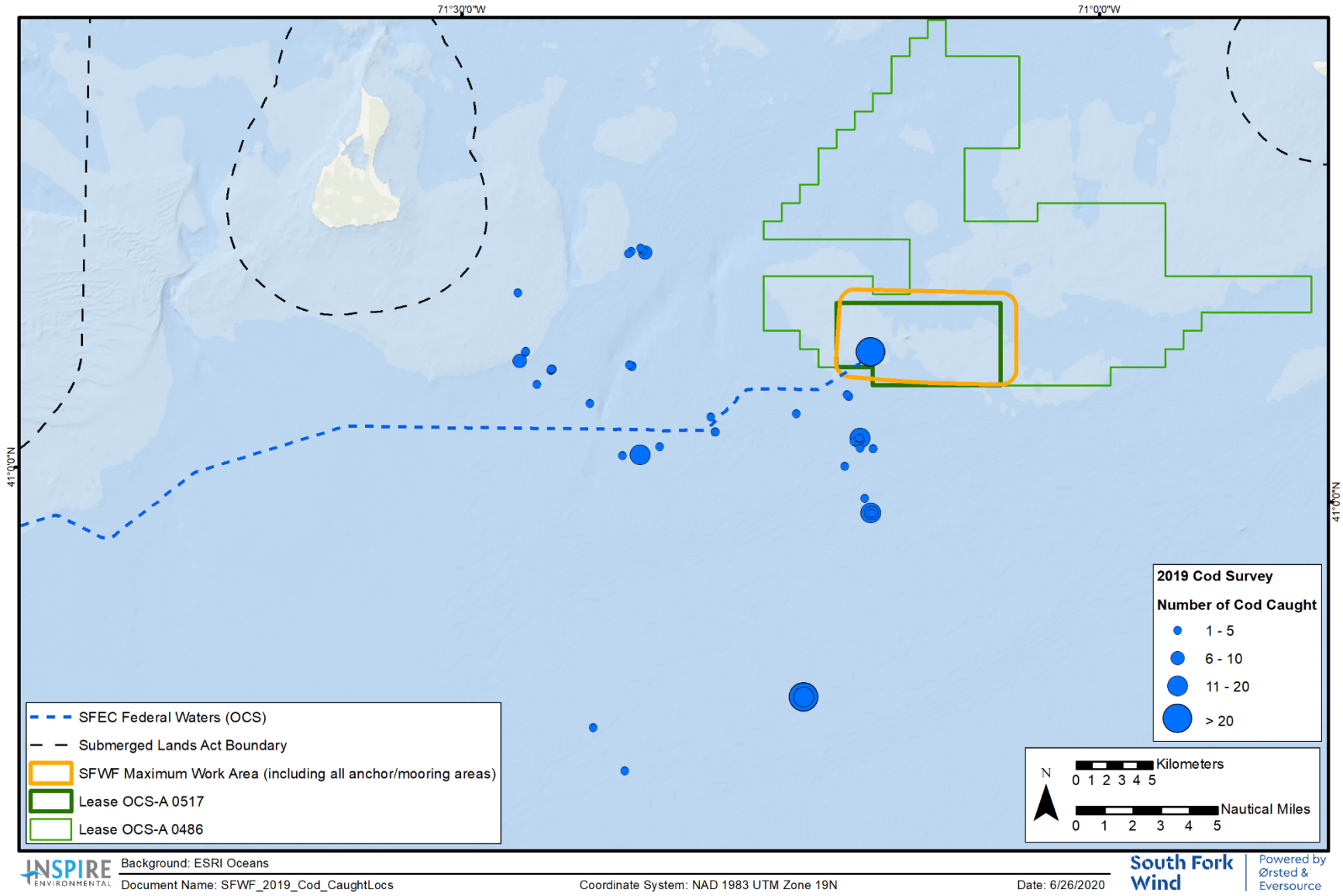


Figure 4-3. Fishing locations where Atlantic cod were caught during the survey

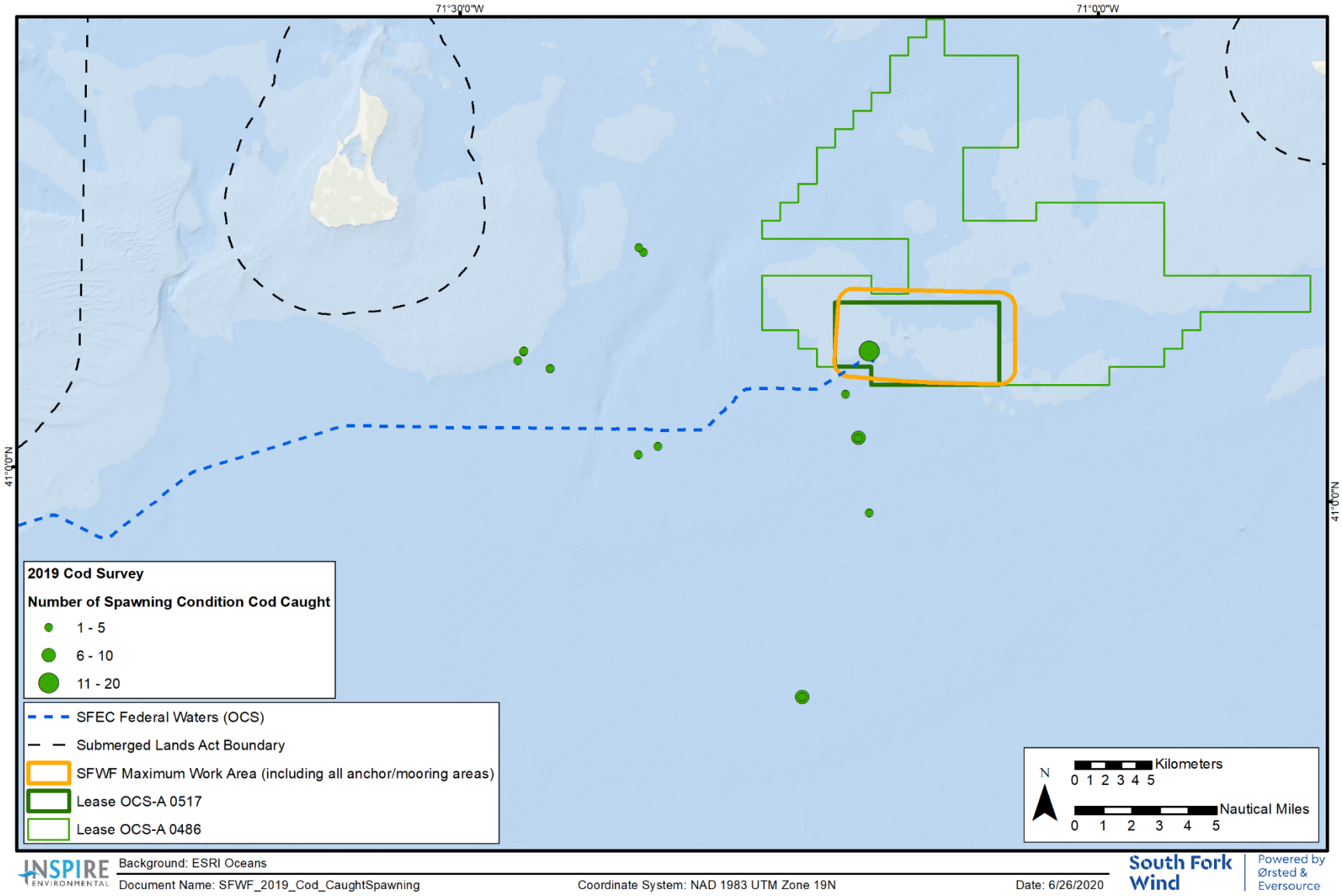
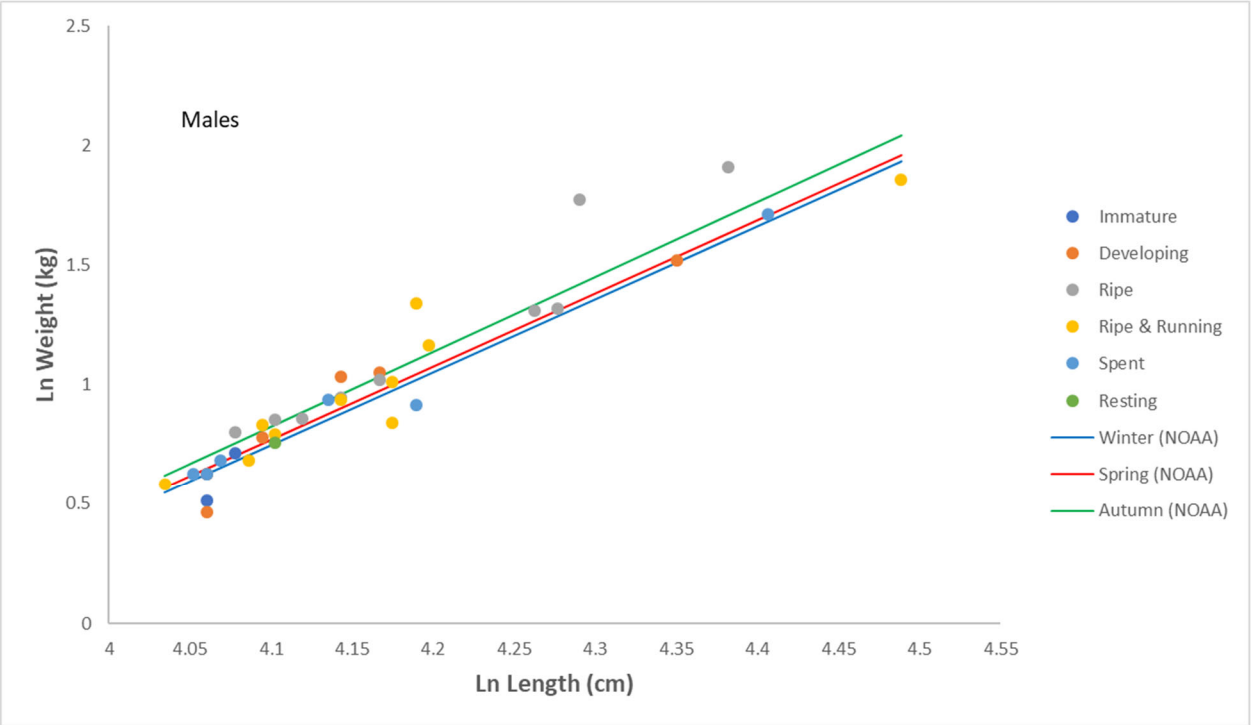


Figure 4-4. Fishing locations where ripe, ripe and running, and/or spent Atlantic cod were caught during the survey



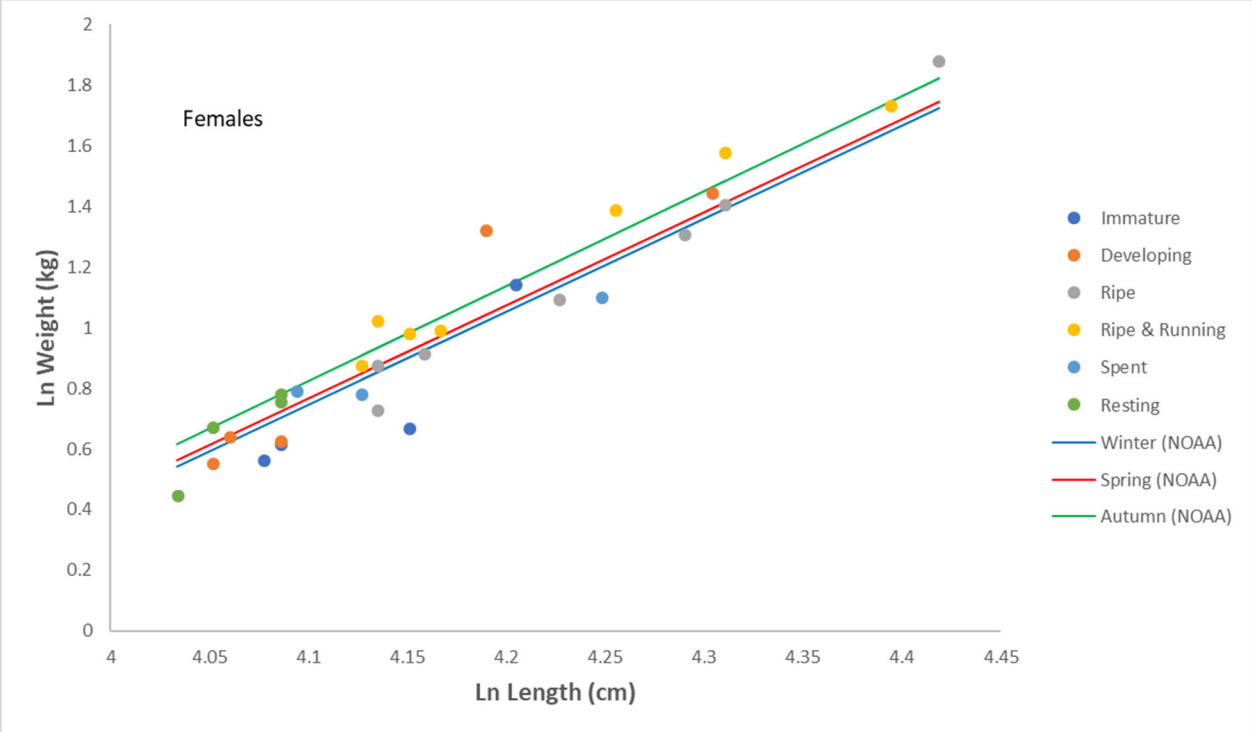


Figure 4-5. Condition of male and female Atlantic cod plotted by spawning status as the log-log relationship of weight (kilograms) to length (cm). Length-weight relationships for cod derived from NOAA Fisheries' NEFSC bottom trawl survey data plotted for reference from Wigley et. al, 2003.

Figure 4-6. Cod gonad developmental stages: (a) female immature, (b) developing, (c) ripe, and (d) ripe/running; (e) male developing, (f) ripe, (g) ripe/running, and (h) spent

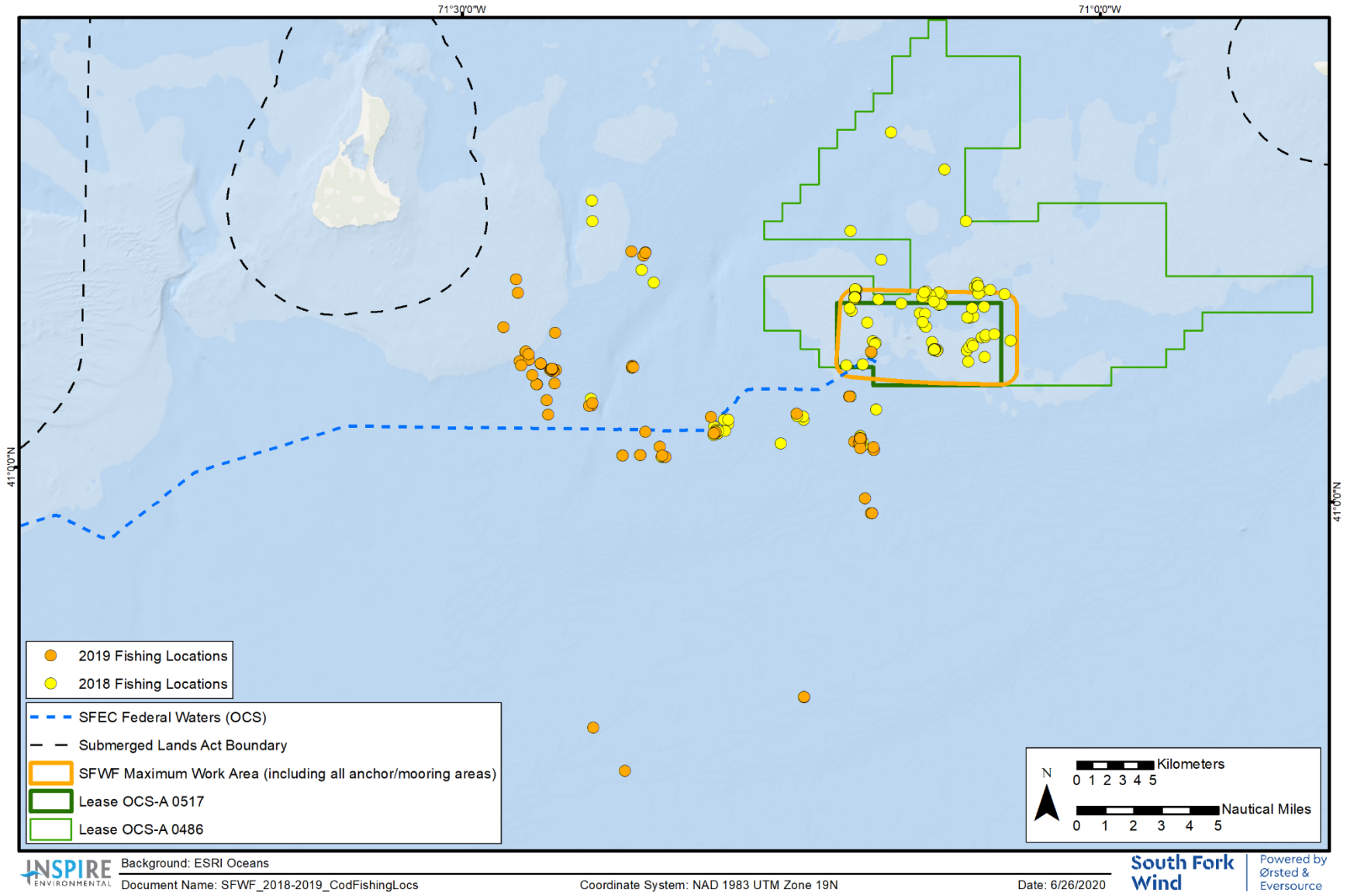


Figure 4-7. All fishing locations for both the 2018 and 2019 Atlantic cod spawning surveys

South Fork Wind Farm

Observational Atlantic Cod Spawning Survey

December 2018 - April 2019

Final Report

APPENDICES

Prepared for:

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June 2020

Appendix A: Sampled Atlantic Cod

Cruise ID	Location ID	Weight (kg)	Total Length (cm)	Sex	Spawning Stage	Gonad Weight (kg)
19-01	05	2.50	66.0	M	Spent	0.0100
19-01	05	4.24	74.0	F	Developing	0.0600
19-01	05	4.00	70.5	F	Ripe and Running	0.4000
19-01	05	2.69	64.5	F	Ripe and Running	-
19-01	05	3.82	66.0	M	Ripe and Running	0.0900
19-01	05	1.74	57.5	F	Developing	0.0700
19-01	05	3.75	66.0	F	Developing	0.1000
19-01	05	2.55	63.0	M	Ripe and Running	0.1000
19-01	05	2.40	62.5	F	Ripe	0.1500
19-01	05	5.65	81.0	F	Ripe and Running	0.8700
19-01	05	-	60.0	F	Immature	-
19-01	07	2.40	62.0	F	Ripe and Running	0.2000
19-01	07	2.35	60.5	M	Ripe	0.2000
19-01	07	4.84	74.5	F	Ripe and Running	0.5900
19-01	07	6.41	89.0	M	Ripe and Running	0.2200
19-01	07	2.67	63.5	F	Ripe and Running	-
19-01	07	1.85	59.5	F	Immature	0.0100
19-01	07	1.87	58.0	M	Spent	0.0100
19-01	07	5.90	73.0	M	Ripe	0.4000
19-01	07	2.78	62.5	F	Ripe and Running	0.4000
19-01	07	2.78	64.5	M	Ripe	0.2000
19-01	07	6.54	83.0	F	Ripe	0.8200
19-01	07	6.75	80.0	M	Ripe	0.6000
19-01	07	4.58	77.5	M	Developing	0.2200
19-02	01	3.71	71.0	M	Ripe	0.2000
19-02	01	2.07	62.5	F	Ripe	0.1800
19-02	01	3.13	67.0	F	Immature	0.0300
19-02	02	1.59	58.0	M	Developing	0.0700
19-02	02	2.18	60.0	M	Developing	0.0600
19-02	02	2.23	59.0	M	Ripe	0.1500
19-02	02	1.95	63.5	F	Immature	0.0300
19-02	04	2.36	61.5	M	Ripe	0.2000
19-03	06	1.76	59.0	F	Spent	0.3000
19-04	05	2.58	63.0	M	Ripe	0.2280
19-04	07	5.53	82.0	M	Spent	0.1030
19-04	07	1.67	58.0	M	Immature	0.0110
19-04	07	1.90	58.0	F	Developing	0.1060
19-05	10	2.30	60.0	M	Ripe and Running	0.0838

Cruise ID	Location ID	Weight (kg)	Total Length (cm)	Sex	Spawning Stage	Gonad Weight (kg)
19-05	10	2.18	59.5	F	Resting	0.0102
19-06	05	2.21	60.5	M	Ripe and Running	0.0857
19-06	06	1.96	57.5	F	Resting	0.0272
19-08	03	2.75	65.0	M	Ripe and Running	0.1234
19-08	03	2.21	60.0	F	Spent	0.0277
19-08	03	3.74	72.0	M	Ripe	0.0290
19-08	03	1.87	57.5	M	Spent	0.0086
19-08	03	2.13	59.5	F	Resting	0.0116
19-08	03	1.79	56.5	M	Ripe and Running	-
19-08	03	2.32	65.0	M	Ripe and Running	-
19-09	01	1.87	58.0	M	Developing	0.0406
19-09	01	1.56	56.5	F	Resting	0.0087
19-09	01	3.20	66.5	M	Ripe and Running	0.0677
19-09	01	1.98	59.5	M	Ripe and Running	0.0911
19-10	01	2.18	62.0	F	Spent	0.0487
19-10	01	2.55	62.5	M	Spent	0.0114
19-10	01	1.87	59.5	F	Developing	0.0242
19-10	01	3.69	73.0	F	Ripe	0.1286
19-10	05	2.04	59.0	M	Immature	0.0045
19-10	05	1.98	58.5	M	Spent	0.0154
19-10	07	2.49	64.0	F	Ripe	0.0977
19-11	01	2.81	63.0	M	Developing	0.0262
19-11	02	2.86	64.5	M	Developing	0.0199
19-11	03	4.08	74.5	F	Ripe	0.0732
19-12	01	3.00	70.0	F	Spent	0.0463
19-12	01	2.98	68.5	F	Ripe	0.1238
19-12	01	2.13	60.5	M	Resting	0.0044

Hyphen indicates value not collected.

Appendix B: Sea State and Water Temperature

Cruise ID	Wind Speed (knots)	Wind Direction	Air Temperature (F)	Swell Height (ft)	Swell Direction	Average Water Temperature (F)
19-01	5-10	SE	37	3-4	SE	47.2
19-02	5-10	W	32	2-3	SW	-
19-03	15	NW	28	4	NW	43.6
19-04	1-10	W	25	1-2	W	42.9
19-05	0-5	NE	34	2-4	NE	38.6
19-06	0-5	SW	42	0-2	SW	38.6
19-07	0-1	N	40	0-1	N	39.7
19-08	3-7	SW	-	2-5	SW	40.4
19-09	0-7	SW	40	1-2	SW	39.7
19-10	5-9	S	38	1-2	S	37.7
19-11	5	NE	40	1-2	NE	39.0
19-12	1-5	NE	44	1	NE	41.6
19-13	1-5	NE	46	1	NE	42.2

Hyphen indicates value not collected on the cruise.

Appendix C: Fishing Locations

Cruise ID	Location ID	Fishing Start Time	Fishing End Time	Latitude (N) NAD1983	Longitude (W) NAD1983	Depth at Start of Fishing (ft)	Drift or Anchor	Cod Caught?
19-01	01	8:15	8:23	41.03	71.18	137	Anchor	Yes
19-01	02	8:35	8:47	41.02	71.17	145	Anchor	No
19-01	03	8:53	10:18	41.03	71.17	147	Anchor	Yes
19-01	04	10:25	10:55	41.03	71.17	146	Anchor	Yes
19-01	05	11:11	12:15	41.03	71.18	132	Anchor	Yes
19-01	06	12:25	12:35	41.02	71.17	146	Drift	No
19-01	07	13:01	14:05	41.08	71.17	118	Anchor	Yes
19-02	01	8:25	9:30	41.08	71.44	97.1	Anchor	Yes
19-02	02	10:00	11:30	41.07	71.45	104	Anchor	Yes
19-02	03	12:15	12:24	41.07	71.44	108	Anchor	No
19-02	04	12:33	12:49	41.08	71.44	98	Drift	Yes
19-02	05	13:00	13:12	41.08	71.44	103	Anchor	No
19-02	06	13:37	13:50	41.09	71.46	80	Anchor	No
19-02	07	14:10	14:33	41.11	71.45	90	Anchor	Yes
19-03	01	6:51	7:16	41.07	71.42	124	Anchor	No
19-03	02	7:35	8:34	41.06	71.43	134	Anchor	Yes
19-03	03	9:12	9:41	41.05	71.39	140	Anchor	No
19-03	04	10:44	11:25	41.03	71.18	142	Drift	Yes
19-03	05	11:35	11:58	41.03	71.18	135	Anchor	No
19-03	06	12:17	13:08	41.06	71.19	123	Anchor	Yes
19-04	01	7:14	8:32	41.03	71.18	141	Anchor	No
19-04	02	8:37	8:56	41.03	71.18	140	Drift	No
19-04	03	9:01	9:17	41.03	71.18	141	Drift	Yes
19-04	04	9:26	9:41	41.03	71.17	146	Drift	No
19-04	05	9:50	10:15	41.03	71.18	136	Anchor	Yes
19-04	06	10:17	10:26	41.03	71.18	136	Anchor	Yes
19-04	07	10:53	11:40	40.99	71.17	175	Anchor	Yes
19-04	08	12:16	12:27	41.03	71.29	144	Drift	No

Cruise ID	Location ID	Fishing Start Time	Fishing End Time	Latitude (N) NAD1983	Longitude (W) NAD1983	Depth at Start of Fishing (ft)	Drift or Anchor	Cod Caught?
19-04	09	12:43	12:51	41.04	71.30	141	Drift	Yes
19-05	01	6:55	7:55	41.14	71.35	125	Anchor	No
19-05	02	8:05	8:22	41.14	71.35	140	Drift	No
19-05	03	8:48	8:58	41.07	71.36	142	Drift	Yes
19-05	04	9:03	9:24	41.07	71.36	143	Drift	No
19-05	05	9:35	9:47	41.07	71.36	141	Drift	Yes
19-05	06	10:03	10:24	41.05	71.39	147	Drift	No
19-05	07	10:55	11:19	41.04	71.42	143	Drift	No
19-05	08	11:31	11:44	41.06	71.43	132	Anchor	No
19-05	09	12:00	12:20	41.06	71.44	134	Anchor	No
19-05	10	12:34	12:58	41.07	71.42	128	Drift	Yes
19-05	11	13:05	13:20	41.07	71.42	130	Drift	No
19-05	12	13:24	13:34	41.07	71.42	120	Drift	No
19-06	01	7:01	7:18	41.07	71.42	134	Drift	No
19-06	02	7:23	7:38	41.07	71.42	132	Drift	No
19-06	03	7:52	8:12	41.07	71.42	131	Drift	No
19-06	04	8:23	8:36	41.07	71.42	134	Drift	Yes
19-06	05	8:39	8:46	41.07	71.42	134	Drift	Yes
19-06	06	8:50	8:56	41.07	71.42	131	Drift	Yes
19-06	07	9:01	9:12	41.07	71.42	132	Drift	No
19-06	08	9:16	9:25	41.07	71.42	133	Drift	No
19-06	09	9:29	9:42	41.07	71.42	130	Anchor	Yes
19-06	10	9:48	10:16	41.07	71.42	130	Anchor	No
19-06	11	10:27	10:45	41.06	71.42	134	Drift	No
19-06	12	10:52	11:04	41.05	71.43	141	Drift	No
19-06	13	11:13	11:24	41.07	71.42	130	Drift	Yes
19-06	14	11:26	11:43	41.07	71.42	130	Drift	No
19-06	15	11:59	12:16	41.07	71.45	125	Drift	No

Cruise ID	Location ID	Fishing Start Time	Fishing End Time	Latitude (N) NAD1983	Longitude (W) NAD1983	Depth at Start of Fishing (ft)	Drift or Anchor	Cod Caught?
19-06	16	12:24	12:32	41.07	71.43	128	Drift	No
19-06	17	12:43	13:01	41.09	71.42	120	Anchor	No
19-06	18	13:15	13:30	41.12	71.45	86	Drift	No
19-07	01	6:46	7:09	41.07	71.42	131	Drift	No
19-07	02	7:12	7:52	41.07	71.42	132	Drift	Yes
19-07	03	8:05	8:20	41.07	71.42	132	Drift	No
19-07	04	8:27	8:36	41.07	71.43	132	Drift	No
19-07	05	8:40	8:49	41.07	71.42	132	Drift	No
19-07	06	9:08	9:27	41.05	71.39	148	Drift	No
19-07	07	9:52	10:01	41.03	71.29	145	Drift	No
19-07	08	10:34	11:04	40.99	71.17	164	Drift	Yes
19-07	09	11:08	11:28	40.99	71.17	175	Anchor	Yes
19-07	10	11:44	12:01	41.03	71.18	140	Drift	No
19-07	11	12:15	12:38	41.06	71.19	121	Anchor	No
19-08	01	7:16	7:35	41.03	71.29	146	Anchor	Yes
19-08	02	7:55	8:23	41.03	71.29	145	Anchor	Yes
19-08	03	9:11	9:50	40.88	71.22	178	Drift	Yes
19-08	04	10:47	11:14	40.83	71.36	198	Anchor	Yes
19-08	05	11:34	11:51	40.86	71.38	192	Anchor	Yes
19-08	06	12:52	13:12	41.07	71.42	130	Drift	No
19-08	07	13:14	13:32	41.07	71.42	128	Drift	No
19-09	01	7:48	9:26	40.88	71.22	176	Anchor	Yes
19-09	02	10:17	-	41.00	71.18	178	Anchor	Yes
19-09	03	11:08	11:36	41.03	71.18	135	Anchor	No
19-09	04	11:43	11:55	41.03	71.18	135	Drift	No
19-09	05	12:11	12:29	41.04	71.23	140	Drift	Yes
19-09	06	12:48	12:57	41.03	71.29	145	Drift	No
19-10	01	7:31	8:33	41.14	71.35	161	Anchor	Yes

Cruise ID	Location ID	Fishing Start Time	Fishing End Time	Latitude (N) NAD1983	Longitude (W) NAD1983	Depth at Start of Fishing (ft)	Drift or Anchor	Cod Caught?
19-10	02	8:44	9:15	41.14	71.36	128	Anchor	Yes
19-10	03	9:55	10:27	41.07	71.36	140	Anchor	No
19-10	04	10:52	11:09	41.03	71.35	154	Anchor	No
19-10	05	11:19	11:43	41.02	71.34	152	Anchor	Yes
19-10	06	11:50	12:00	41.02	71.35	152	Drift	No
19-10	07	12:13	12:27	41.02	71.35	152	Drift	Yes
19-10	08	12:31	12:47	41.02	71.37	153	Drift	Yes
19-10	09	12:51	13:04	41.02	71.37	152	Drift	No
19-10	10	13:15	13:38	41.02	71.33	153	Drift	No
19-10	11	13:44	13:53	41.02	71.33	154	Drift	No
19-11	01	7:33	8:24	41.14	71.35	125	Anchor	Yes
19-11	02	9:15	9:40	41.01	71.19	110	Anchor	Yes
19-11	03	10:05	10:26	41.06	71.19	123	Anchor	Yes
19-11	04	10:58	11:17	41.03	71.29	144	Drift	No
19-11	05	11:32	11:48	41.02	71.33	152	Drift	No
19-11	06	11:50	12:06	41.02	71.33	152	Drift	No
19-11	07	12:13	12:30	41.03	71.35	151	Anchor	No
19-11	08	12:51	13:14	41.05	71.39	144	Drift	Yes
19-11	09	13:36	13:56	41.07	71.42	132	Drift	No
19-11	10	14:02	14:15	41.07	71.44	126	Drift	No
19-12	01	7:45	9:11	41.14	71.36	125	Anchor	Yes
19-12	02	9:19	9:49	41.14	71.36	127	Anchor	Yes
19-12	03	10:02	10:29	41.13	71.35	124	Drift	No
19-12	04	11:00	11:40	41.07	71.36	141	Anchor	Yes
19-12	05	11:55	12:15	41.07	71.34	136	Drift	No
19-12	06	12:50	13:08	41.12	71.46	89	Drift	No
19-12	07	13:26	13:39	41.15	71.47	94	Drift	No
19-12	08	14:06	14:20	41.16	71.42	75	Drift	No

Cruise ID	Location ID	Fishing Start Time	Fishing End Time	Latitude (N) NAD1983	Longitude (W) NAD1983	Depth at Start of Fishing (ft)	Drift or Anchor	Cod Caught?
19-13	01	8:51	9:53	41.14	71.35	125	Anchor	No
19-13	02	10:03	10:20	41.13	71.35	122	Drift	No
19-13	03	10:48	11:03	41.08	71.40	127	Drift	No
19-13	04	11:23	11:31	41.07	71.42	129	Drift	No
19-13	05	11:40	12:05	41.07	71.44	110	Drift	No
19-13	06	12:38	12:58	41.16	71.45	80	Drift	No
19-13	07	13:04	13:19	41.17	71.45	56	Anchor	No
19-13	08	13:30	13:47	41.16	71.44	62	Anchor	No
19-13	09	14:06	14:32	41.21	71.45	106	Anchor	No