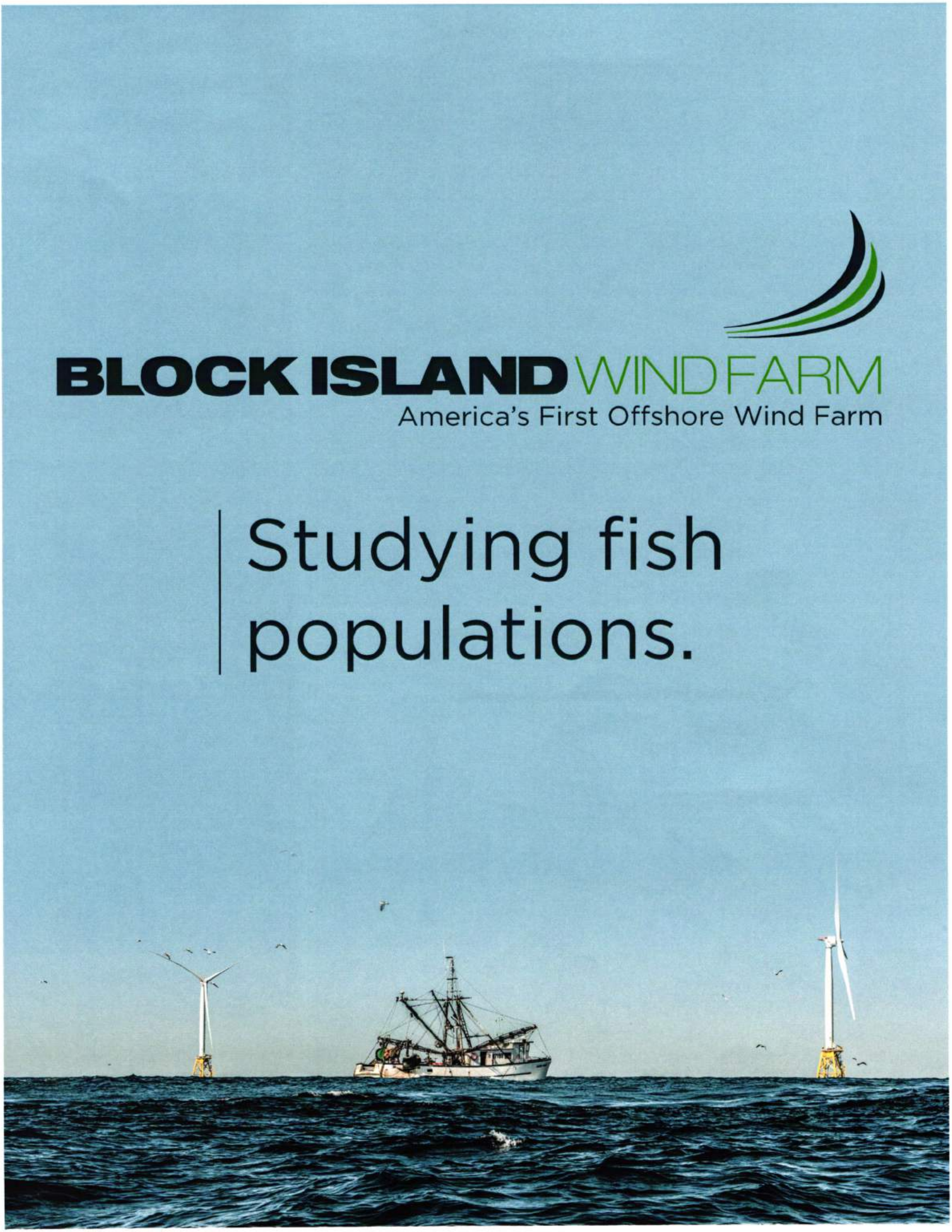
BLOCK ISLAND WIND FARM

America's First Offshore Wind Farm

Studying fish populations.



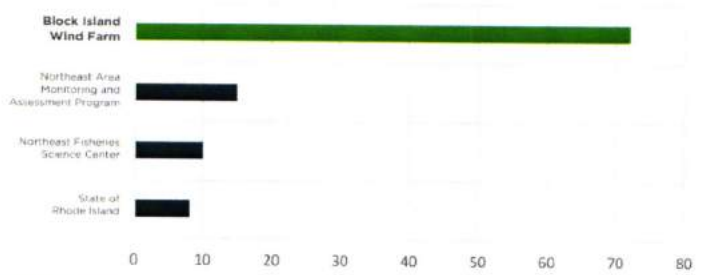
The study.

Every month for nearly 5 years, a crew made up of local fishermen and scientists has sailed out to the Block Island Wind Farm to assess the project's impacts to fish and shellfish. Aboard a local commercial fishing vessel, the researchers tow nets to catch sea life near or at the bottom of the seafloor. They collect samples at the wind farm and other locations near it. For every catch, scientists sort and count fish by species, measure their length and take their weight. The crew conducts over 70 trawls per year to support this study.

The study began prior to the start of offshore construction of the wind farm and continued throughout offshore construction. Post construction monitoring is currently underway and is scheduled to conclude in 2018. The studies were designed by scientists with input from fishermen using a similar methodology as other fisheries studies in New England so results could be compared across studies.

Because the researchers used the same methodology for collecting fish data before, during, and after construction of the wind farm, they aim to measure the impact of the wind farm on the abundance and variety of fish in the area.

Approximate # of Bottom Trawls per Year in Rhode Island Sound



What we're learning.

Data collected so far shows that fish populations are just as strong as they were before the start of offshore construction. We haven't seen an appreciable change in variety of species found near the wind farm to date. We have collected a great deal of information on specific species such as Atlantic cod, black sea bass, bluefish, founder, striped bass, and longfin squid, just to name a few.

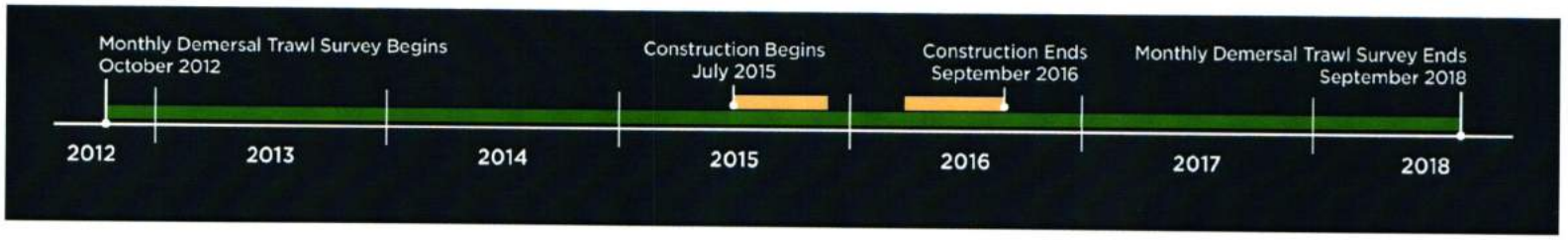
Total Weight of Fish Collected
311,579 lbs

Number of Trawls Planned
427 (355 so far)

Most Caught
Butterfish (54,424)

Most Caught by Weight
Dogfish (36,054 lbs)

Number of Species Collected
83 (59 fish species)



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Flatfish habitat use near North America's first offshore wind farm

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ABSTRACT

Use of offshore wind power as a renewable energy source is underway in North America with the construction of the pilot, five wind turbine, Block Island Wind Farm, off Rhode Island, USA. Demersal trawl monitoring was conducted in two reference areas and near the wind farm that allowed an examination of whether flatfish abundances, size, and condition differed between baseline, construction, and operation time periods. Seven flatfish, (American plaice *Hippoglossoides platessoides*, fourspot flounder *Paralichthys oblongus*, Gulf stream flounder *Citharichthys arctifrons*, summer flounder *Paralichthys dentatus*, windowpane flounder *Scophthalmus aquosus*, winter flounder *Pseudopleuronectes americanus*, and yellowtail flounder *Pleuronectes ferruginea*) were collected in the study area. Winter flounder, windowpane and fourspot flounder accounted for 83% of all flatfish collected. Flatfish exhibited spatial and temporal variation in abundance, size, and condition, but this variation was not consistent with either positive or negative effects of wind farm construction or operation. Lower winter flounder abundances during the pile-driving time period and higher abundances during the cable-laying time period in the reference and wind farm areas suggest regionwide population fluctuations occurred. Although noise from pile driving may have been detectable in the reference areas, other flatfish abundances were not lower during this time period. Although no artificial reef effect was found for flatfish, negative impacts from construction activity and wind farm operation also were not evident.

1. Introduction

Offshore wind farms are increasingly established as an alternative to carbon emitting energy sources and have been in operation on a commercial scale in Europe since 2002 (Bailey et al., 2014). Although the environmental benefits of moving to renewable energy sources are widely acknowledged, the potential ecological impacts of offshore construction activities and altered coastal habitats are less clear (Vandendriessche et al., 2015; Heery et al., 2017). Disturbances to the marine environment from offshore wind farm construction and operation include increased noise and vibration especially during the pile-driving phase of construction, elevated suspended sediments and sedimentation caused by cable installation, altered benthic and pelagic habitat, and the introduction of novel electromagnetic fields (Bailey et al., 2014). The increased habitat complexity created by the turbines and scour protection structures may enhance biodiversity through colonization of the structures (Wilhelmsson and Malm, 2008; Maar et al., 2009) and by attracting fish that aggregate near the new hard structures (e.g., Wilhelmsson et al., 2006; Bergstrom et al., 2013; Reubens et al., 2013b; van Hal et al., 2017). Turbine structures, therefore, may provide foraging habitat (e.g., Derweduwen et al., 2012; Reubens et al., 2014) and refuge for appropriately-sized fish (Vandendriessche et al., 2015), potentially affecting prey consumption and fish size distributions.

The first offshore wind farm in North America, Block Island Wind Farm (BIWF) in Rhode Island, USA, was constructed on a pilot scale, becoming operational in 2016. BIWF's five wind turbine generators were sited based on coordination with state and federal resource agencies in an attempt to minimize environmental impacts to marine habitat. The surrounding marine area supports commercial and recreational fisheries and provides a linkage between nearshore and offshore habitats for fish such as winter flounder (*Pseudopleuronectes americanus*). Other uses of Rhode Island's offshore waters include artificial reefs and potential aquaculture leases (Malek et al., 2014), therefore, understanding how demersal fish respond to BIWF construction and operation is necessary for future effective fisheries management in this changing seascape (Bishop et al., 2017). Of particular interest are the potential BIWF impacts to flatfish because they spend the majority of their juvenile and adult phases on the substrate, and therefore may not respond like pelagic fish to disturbances such as noise and vibrations that are transmitted differently through the substrate than through the water column. Likewise, electromagnetic fields that may repel pelagic fish from the vicinity of wind farms (Gill, 2005; Ohman et al., 2007) may affect flatfish differently. In the present study, we investigate whether the construction and operation of the BIWF

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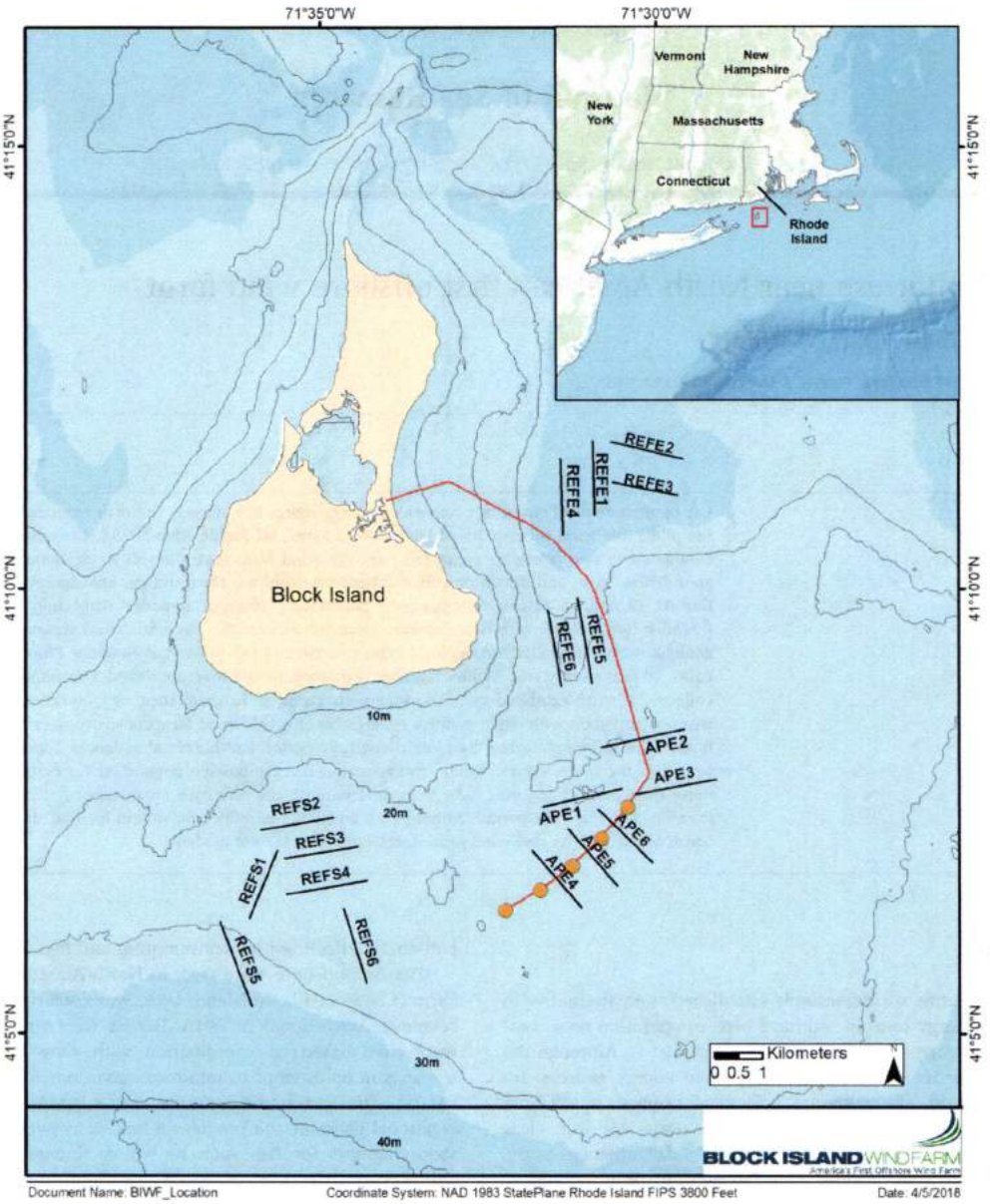

Fig. 1. Location of the five turbine (yellow circles) Block Island Wind Farm and the six bottom trawl tow lines located in each of two reference areas (REFE and REFS) and the Area of Potential Effect (APE). The cable location is denoted in red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

affected flatfish assemblage composition, abundances, size distributions, and condition. Impact assessments typically use abundance data collected in a before-after-control-impact (BACI) design (Underwood, 1992), however, highly variable fish abundance data can result in low statistical power (e.g., Wilber et al., 2003). Therefore, examinations of fish condition and size provide additional mechanisms by which potential impacts from the wind farm can be detected (e.g., Reubens et al., 2013a).

2. Methods

2.1. Field collections

The BIWF consists of five, 6-MW wind turbine generators located approximately 3.5 km southeast of Block Island, Rhode Island, USA (Fig. 1). Power is exported via a 34 km, bi-directional submarine cable connecting the wind farm to Block Island and the mainland. Demersal trawl surveys were conducted monthly during activity time periods that are characterized in this study as baseline, pile driving, turbines installed (i.e., steel jacket foundations in place, but turbines not operational), cable installation, and turbine operation (Table 1). For each monthly survey, two replicate (20 min) tows were conducted in each of two reference areas and two tows were conducted in the area of potential effect (APE), resulting in six independent trawl tow lines (Fig. 1). Each of these areas was surveyed with a Sediment Profile Imaging and Plan View system (Germano et al., 2011). Substrate classifications were based on measurements of grain size major mode and observations of sedimentary features visible on the surface. The reference areas are

Table 1
Timeline of baseline sampling, Block Island Wind Farm construction activities, and commencement of wind farm operation. The total number of tows conducted in all areas for each time period and the corresponding seasons are given.

Activity	Time period	Tows	Seasons
Baseline	October 2012 to June 2015	171	Fall, Winter, Spring, Early Summer, and Late Summer
Pile driving	July 2015 to October 2015	45	Fall, Early Summer, and Late Summer
Turbines installed	November 2015 to March 2016	30	Fall, Winter
Cable laying	April 2016 to September 2016	36	Spring, Early Summer, and Late Summer
Turbine operation	October 2016 forward	60	Fall, Winter, Spring, and Early Summer

denoted as REFE which had silty-sand and silt sediments and REFS, which had sand and gravel sediments. The APE sediments were comprised of silty-sand, sand, and gravel. Each area (REFE, REFS, and APE) contained six pre-determined tow lines that were accessible for trawling, but subject to seasonal location of fixed fishing gear (e.g., gill nets and lobster trawls). Two tow lines were randomly selected each month and if a tow line was obstructed by fixed gear or was not deemed towable due to other conditions, an additional random selection determined the tow line (but tow lines were not repeated in any month). When construction activity was underway in the APE, tow lines 4, 5, and 6, which are located between the turbine foundations, were not accessible for sampling. Trawling was conducted using a 412 × 12 cm, four-seam whiting trawl with 1.67 m otter doors and 2.54 cm knotless cod end liner. Trawl catches were sorted by species and size categories within each species, all flatfish were counted and the total lengths (TL) of fifty individuals of each species within a size category were measured to the nearest 0.5 cm. A subsample (up to 10 individuals species per station per sampling event) were individually weighed (whole body) to the nearest 10 g (gm) and sexed via visual observation of the gonads during dissections for a separate stomach content study. Gonads were not weighed and maturity class was not consistently recorded, preventing use of this parameter as a covariate in statistical analyses. Bottom water temperature, dissolved oxygen, and salinity data were collected at the end of each tow using a YSI model 650 MDS water quality meter.

2.2. Statistical methods

2.2.1. Flatfish assemblages

Multivariate analyses were conducted to determine whether the taxonomic composition of flatfish assemblages differed among reference areas (REFS, REFE) and the APE and among activity time periods using the PRIMER Version 7.0.1 computer program (Clarke et al., 2014; Clarke and Gorley, 2015). These analyses were conducted separately by season because fish abundances are strongly influenced by temperature. Seasons were defined based on monthly groupings of similar temperature variation (Fig. 2) as: Fall - declining water temperatures (October through December), Winter - low temperatures (January through March), Spring - initially rising temperatures (April and May), Early Summer - (June and July), and Late Summer (August and September). Flatfish abundances were square-root transformed to reduce the importance of abundant species and permit species with low or rare occurrences to contribute to similarity groupings of the samples. Analysis-of-Similarities (ANOSIM) tests used ranked similarity matrices based on Bray-Curtis similarity measures to distinguish flatfish assemblages on a scale of $R = 0$ (fish assemblages were indistinguishable from each other) to $R = 1$ (there was no similarity in flatfish assemblages). If flatfish assemblages differed among areas or activity time periods, SIMPER (similarity percentages, Clarke et al., 2014) analysis

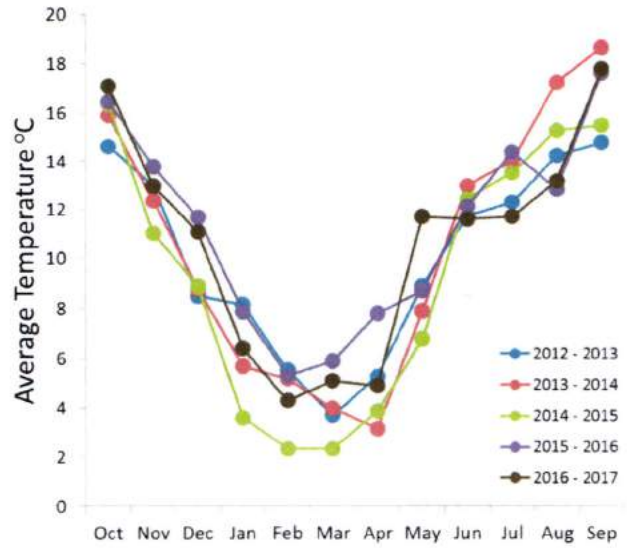

Fig. 2. Mean monthly bottom water temperatures across all areas for each year of sampling.

was used to identify the species that contributed the most to distinguishing these assemblages. Non-metric multidimensional scaling (nMDS) ordinations were used to depict the relative similarities in composition of flatfish assemblages among areas and activity time periods within seasons for those seasons in which significant dissimilarities occurred.

2.2.2. Abundances

Potential impacts of wind farm construction activities on individual species abundances were examined for those species with sufficient sample sizes using two-factor Analysis of Variance (ANOVA) tests conducted separately by season. Independent factors were area (APE, REFE, and REFS) and activity time period, which depending on the season, could include baseline, pile driving, turbines installed, cable laying, and operation time periods. Abundance data were square-root transformed to satisfy the normality and homogeneity of variance assumptions of the test.

2.2.3. Size

Separate two factor ANOVAs (area × activity time period) were conducted by species (winter flounder, windowpane, fourspot flounder, summer flounder, and Gulf stream flounder) to examine potential differences in flatfish size related to wind farm operation. Time periods were restricted to baseline and operation due to sample size constraints for construction activity time periods.

2.2.4. Condition

Condition indices were estimated for subsamples of winter flounder (male $n = 84$; mature female $n = 264$) and summer flounder ($n = 182$). An individual's condition index was calculated as its residual from the log-log regression of mass to length (Le Cren, 1951; Jakob et al., 1996). In winter flounder, fluctuations in condition indices can reflect energy depletion and accumulation during and after the spawning season, respectively. Because winter flounder condition varies by season and this variation is more pronounced for females (Wuenschel et al., 2009), the sexes were analyzed separately. Only mature females (> 300 mm TL; Winton et al., 2014), were included in condition analyses to reduce variation related to maturity status. Mature female winter flounder condition was examined using two-factor (area × time period) ANOVAs for the fall, a non-reproductive season and for the spring, the end of the reproductive season. Low sample sizes during the baseline time period

prevented similar tests in the winter and early summer. Male winter flounder and summer flounder conditions were analyzed using separate two-factor (area × time period) ANOVAs across all seasons.

3. Results

3.1. Environmental conditions

Water quality parameters were similar among areas, with dissolved oxygen concentrations above 6 mg/L for all samples and oceanic salinities recorded between 30 and 34 psu. Bottom water temperatures varied seasonally and were similar among years with the exception of lower winter temperatures in 2014–2015 (Fig. 2), which coincided with the "turbines installed" time period. Water depths sampled within each area ranged from 28 to 40 m in the REFE, 22–37 m in the REFS, and 25–30 m in the APE.

3.2. Flatfish assemblages

Seven flatfish species (American plaice *Hippoglossoides platessoides*, fourspot flounder *Paralichthys oblongus*, Gulf stream flounder *Citharichthys arctifrons*, summer flounder *Paralichthys dentatus*, windowpane flounder *Scophthalmus aquosus*, winter flounder *Pseudopleuronectes americanus*, and yellowtail flounder *Pleuronectes ferruginea*) were collected totaling 17,263 individuals (Table 2) during the five survey years. Winter flounder were numerically dominant, and along with windowpane and fourspot flounder, accounted for 83% of all flatfish collected (Table 2). American plaice were uncommon ($n = 3$) and were collected in the APE in April and May of 2013 and are not included in subsequent analyses. Fall flatfish assemblages were dominated by winter flounder and windowpane. In the winter, flatfish abundances declined. Winter flounder and fourspot flounder were numerically dominant in the spring and early summer, with fourspot flounder and winter flounder and windowpane most abundant in the late summer (Fig. 3).

In the fall, winter, and late summer, flatfish assemblages did not differ among areas or time periods (ANOSIM $R \leq 0.17$; p-values $> .3$). In the spring, flatfish assemblages differed spatially, with the greatest dissimilarity in assemblage composition between the reference areas ($R = 0.31, p = .001$; Fig. 4a), with higher winter flounder and fourspot flounder abundances at the REFE area and windowpane and summer flounder abundances at the REFS area (Table 3). In the early summer, flatfish assemblages in the APE differed from those in the REFE ($R = 0.47, p = .001$) and the REFS ($R = 0.37$, p = .001; Fig. 4b). Early summer flatfish distributions reflected the overall trend of lower abundances in the APE compared to the reference areas (Table 3). In both the spring and early summer, flatfish assemblages did not differ by activity time period across all areas (Fig. 4).

Table 2
Total abundances of flatfish collected in monthly bottom trawl sampling at the two reference (REFE and REFS) areas and the area of potential impact (APE) for the Block Island Wind Farm from October 2012 through September 2017.

Common name	Species	APE	REFE	REFS	Total
American plaice	*Hippoglossoides platessoides*	3	0	0	3
Fourspot flounder	*Paralichthys oblongus*	104	2505	735	3344
Gulf stream flounder	*Citharichthys arctifrons*	19	430	98	547
Summer flounder	*Paralichthys dentatus*	384	398	910	1692
Windowpane	*Scophthalmus aquosus*	961	1409	1623	3993
Winter flounder	*Pseudopleuronectes americanus*	2128	2490	2935	7553
Yellowtail flounder	*Pleuronectes ferruginea*	67	8	56	131
Total flatfish		3666	7240	6357	17,263

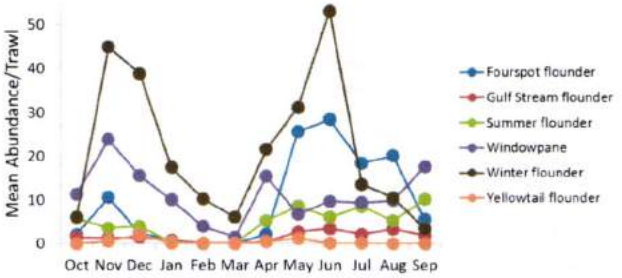

Fig. 3. Mean monthly flatfish abundances per trawl across all areas and years of sampling.

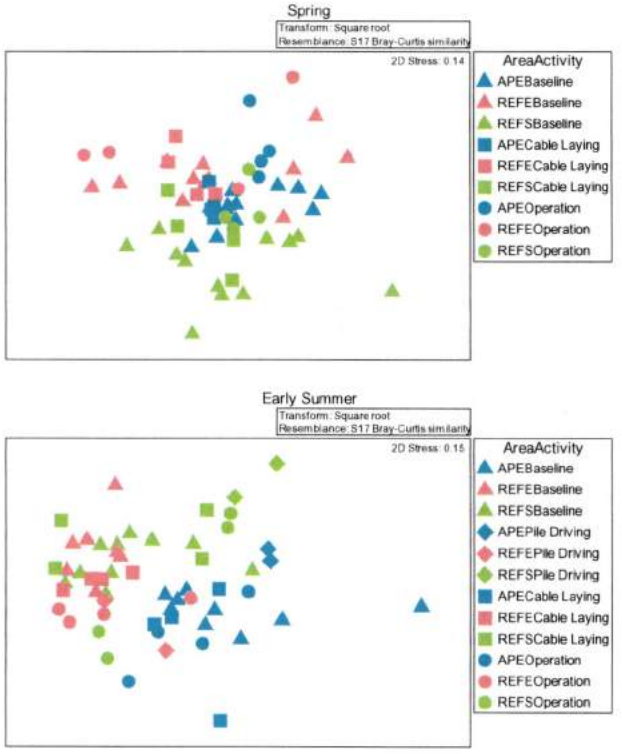

Fig. 4. Non-metric multi-dimensional scaling plots of (a) Spring and (b) Early Summer flatfish assemblages depicted by area (color) and activity time period (shape).

Table 3
Mean abundances per trawl of flatfish species contributing at least 5% to dissimilarities among areas (SIMPER) in the spring and early summer.

	Spring			Early summer		
Species	APE	REFE	REFS	APE	REFE	REFS
Winter flounder	21.6	35.6	22.0	10.2	31.1	60.2
Fourspot flounder	1.3	32.2	8.0	1.7	48.7	20.1
Windowpane	7.2	3.3	22.9	6.4	7.8	14.3
Summer flounder	5.8	3.3	11.8	3.8	3.1	14.2
Gulf stream flounder				0.3	6.3	2.1

3.3. Abundances

Individual flatfish species abundances exhibited different area and activity time period effects by season. Winter flounder abundances in the fall were lower in all areas during the pile driving time period

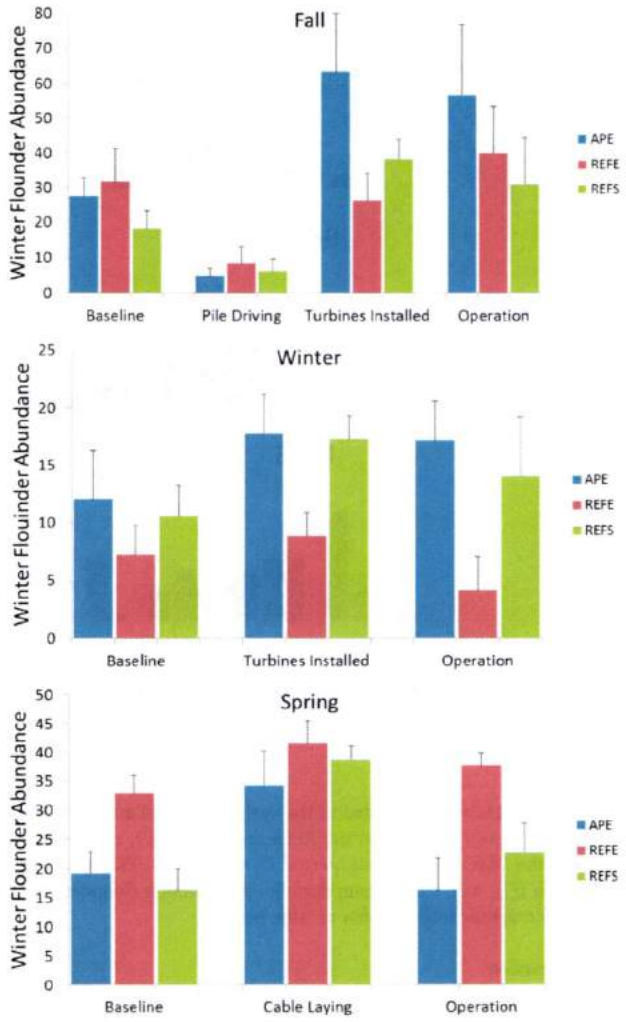

Fig. 5. Mean (+ standard error) winter flounder abundances that differed significantly either by activity time period or area within seasons.

($F = 6.94, p < .001$; Fig. 5). In the winter, winter flounder abundances were consistently lower in the REFE area regardless of the activity time period ($F = 5.41$; $p = .006$), and spring winter flounder abundances were higher during the cable laying time period in all areas ($F = 3.37$, $p = .04$; Fig. 5). In all seasons, interaction terms for winter flounder abundances were not significant. Summer flounder abundances differed significantly by the area × activity interaction in the fall ($F = 3.34$, $p = .005$) when abundances were high at the REFS area during the turbines installed (but not operating) time period and in late summer ($F = 6.14$, $p = .001$), when abundances were high at REFS during the pile driving time period (Fig. 6). Windowpane abundances in the spring were consistently high in the REFS area ($F = 11.9$, $p < .001$) and lower in all areas during the operation time period ($F = 4.5$, $p = .02$) with no interaction. In the early summer, windowpane abundances again were consistently higher at the REFS area ($F = 3.6$, $p = .03$; Fig. 7). Fourspot flounder abundances were significantly higher in the REFE area in the early summer ($F = 38.6$, $p < .001$).

3.4. Size

Flatfish size varied by area and time periods in different ways for each species. Winter flounder were significantly larger at the APE

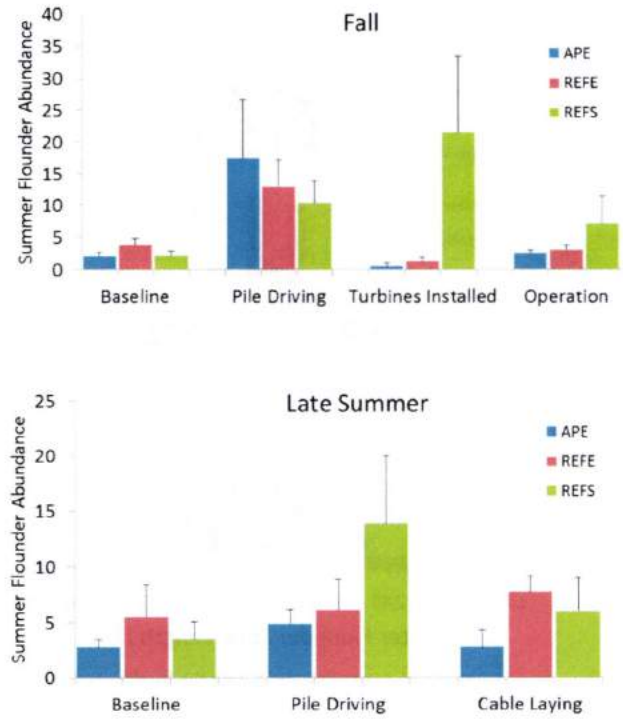

Fig. 6. Mean (+ standard error) summer flounder abundances that differed significantly by the area × activity interaction in the fall and late summer.

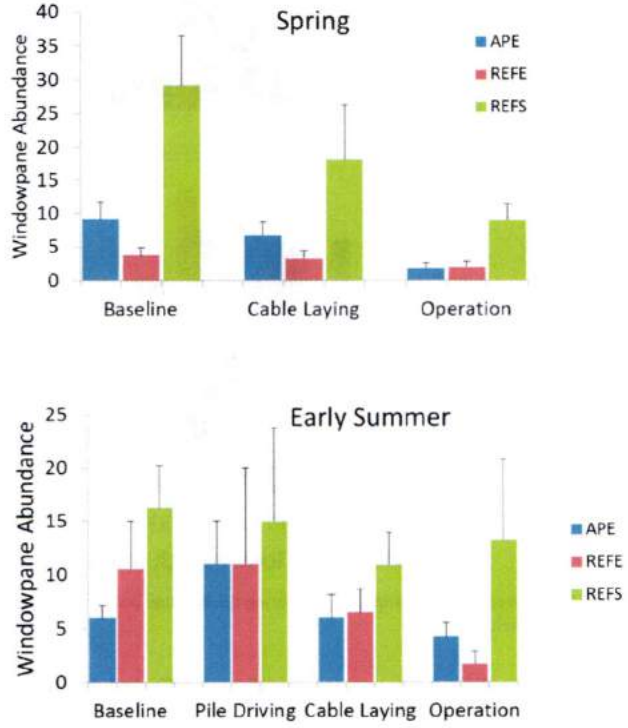

Fig. 7. Mean (+ standard error) windowpane abundances that differed significantly by either area or activity time period interaction in the fall and late summer.

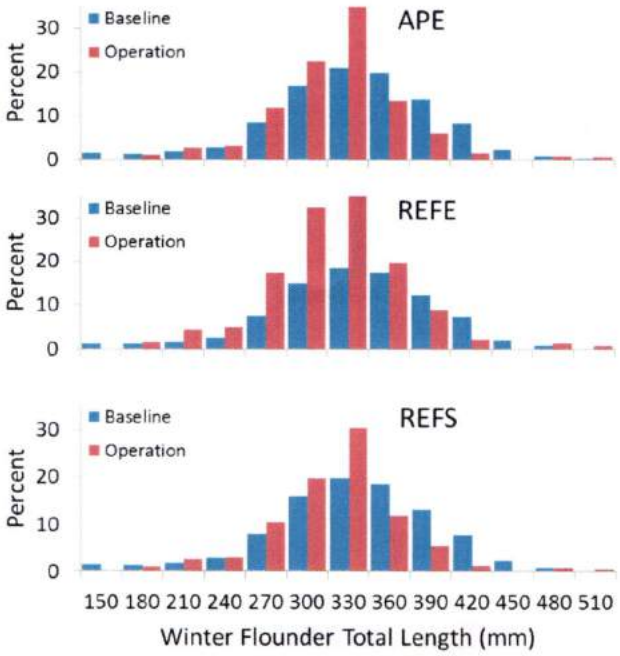

Fig. 8. Size frequencies of winter flounder during the baseline and operation time periods in each area.

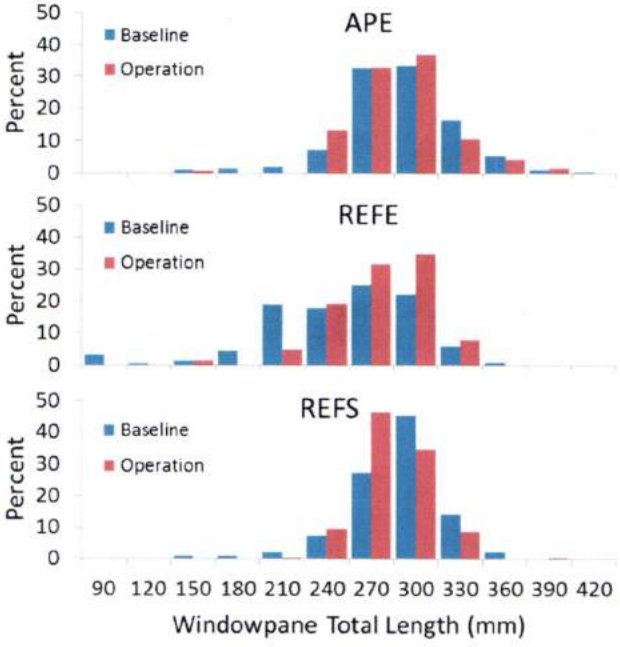

Fig. 9. Size frequencies of windowpane during the baseline and operation time periods in each area.

compared to the reference areas (F = 3.5, p = .030) and during baseline compared to operation time periods (F = 21.6, p < .001), with no interaction. Juvenile (< 150 mm TL) winter flounder were collected in all areas, but only during the baseline time period (Fig. 8). Although the smallest winter flounder (70–90 mm TL) were collected in the fall, most other juveniles were collected in the winter and spring. Windowpane size was significantly smaller at the REFE area during the baseline sampling period (F = 9.7, p < .001; Fig. 9), where juveniles

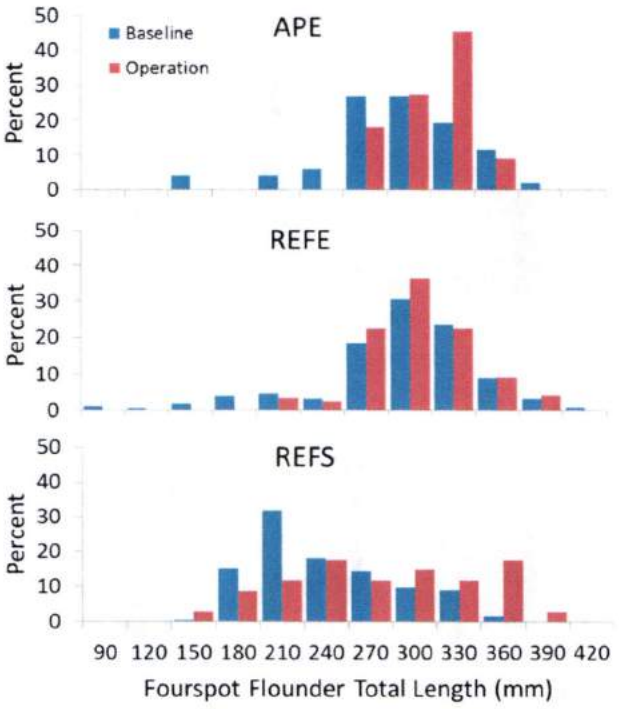

Fig. 10. Size frequencies of fourspot flounder during the baseline and operation time periods in each area.

(35–70 mm TL) were collected in the early summer. Fourspot flounder were significantly smaller at the REFS area (F = 29.9, p < .001) and during the baseline sampling period (F = 9.9, p = .002) with no interaction (Fig. 10). Gulf stream flounder and summer flounder size did not differ significantly by area or time period.

3.5. Condition

The log-log regression of mass (M; gm) to length (L; cm) for mature winter flounder females was significant (r^2 = 0.71, p < .001), yielding the following equation: logM = 2.732 ∗ logL − 1.513. The condition index (residuals) varied temporally, both seasonally and between time periods in some seasons. In the fall non-reproductive season, mature female winter flounder condition was relatively high, did not differ among areas, and was greater during the baseline time period (F = 37.9, p < .001; Fig. 11). During the operation time period, mature female winter flounder condition decreased in the winter and increased successively in the spring and early summer. In the spring, mature female winter flounder condition differed significantly by the area × time period interaction (F = 8.4, p < .001), with females in the lowest condition occurring in the REFS during the baseline time period (Fig. 11). The weight × length regression for male winter flounder was significant (r^2 = 0.86, p < .001) and described by the equation: (log (gm) = 2.581 ∗ log(cm) − 1.296). The resultant condition indices did not differ by area or activity time period (all p-values > .18).

The significant log-log regression (r^2 = 0.83, p < .001) of mass to length for summer flounder is explained by the equation: log (gm) = 3.322 ∗ log(cm) − 2.489. Summer flounder condition did not differ by area or time period (all p-values > .49).

4. Discussion

Although flatfish abundance, size, and condition differed spatially near the Block Island Wind Farm and temporally between the baseline and operation time periods, these differences were not consistent with

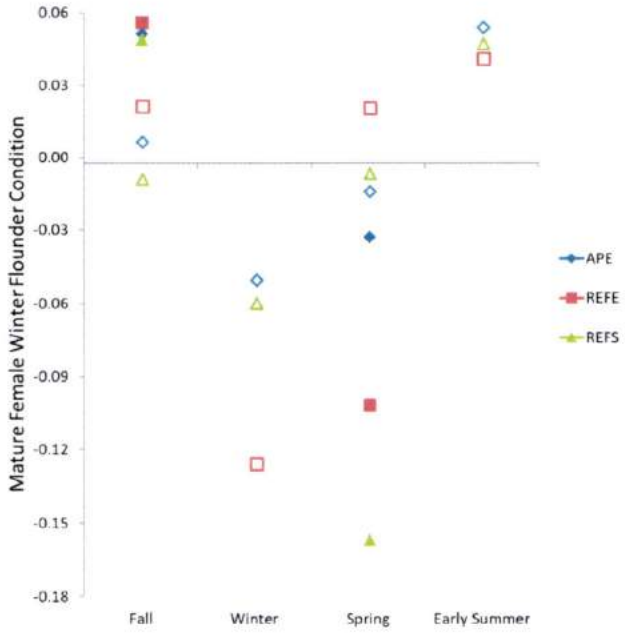

Fig. 11. Mature female winter flounder mean condition indices by season, area and time period (baseline – solid symbols and operation – open symbols).

impacts from wind farm construction or operation. In cases where flatfish abundances differed during phases of construction activity, these differences occurred across all areas. For instance, lower winter flounder abundances in the fall during the pile driving time period occurred in all three areas, which could reflect either a regional trend in population fluctuations or perhaps that reference areas were within the spatial zone where winter flounder could detect pile driving noise. The reference areas were approximately 2–3 km from the wind farm, which is within the distance at which noise levels produced by pile driving cause the displacement of marine mammals (Bailey et al., 2010). For instance, the harbour porpoise *Phocoena phocoena* exhibited displacement distances up to 18 km during pile driving on monopile foundations (Brandt et al., 2011) and up to 12 km when bubble curtains were used to attenuate the noise (Dahne et al., 2017). Although marine mammals and fish with swim bladders are most sensitive to underwater noise, all fish can detect noise-induced particle motion via their otoliths (Andersson et al., 2017). It is difficult to predict the flight or avoidance noise thresholds of fish species that have not been tested based on the responses of other species. Response thresholds are species-dependent and can be influenced by the activity state (e.g., feeding, migrating, etc.) of the individual (Mueller-Blenkle et al., 2010). Other factors that influence detection distances include background noise levels, water depth, and sea bottom type (Wahlberg and Westerberg, 2005). One flatfish that has been tested for response to pile driving noise is the Dover sole *Solea solea*, which increased its swimming speeds in response to recorded pile driving sounds in mesocosm experiments (Mueller-Blenkle et al., 2010). The lower winter flounder abundances during pile driving, therefore, could reflect flight from all areas, whereas other flatfish (summer flounder and windowpane) did not appear to respond to pile driving activity. Low winter flounder abundances during pile driving and relatively high abundances in all areas in the spring when undersea cables were being installed, also are consistent with possible regional population fluctuations that included the entire study area. Other spatial differences in flatfish abundances, such as higher spring and early summer windowpane abundances at the REFS and lower winter flounder abundances in the REFE in the winter for all time periods, are consistent with known habitat preferences and appear unrelated to wind farm activities. For instance, windowpane are more commonly collected on sandy bottom habitat (Hanson and Wilson, 2014), which was prevalent at the REFS, whereas winter flounder spawn over sandy habitat (Schultz et al., 2007; Wilber et al., 2013a), making the siltier REFE area less preferred in the winter, although recently-spawned females (low condition indices) were collected in all areas.

There was no indication that the presence of turbine structures attracted flatfish to the BIWF, either increasing flatfish abundances compared to the reference areas or the baseline time period. It is possible that bottom trawl sampling in the vicinity of BIWF turbines was not conducted close enough to the foundations to collect flatfish attracted to the structures. Higher fish abundances around wind turbines reported for pelagic species are sampled using hook and line and fyke nets (e.g., Couperus et al., 2010; Reubens et al., 2011; Krone et al., 2013; Stenberg et al., 2015). Attraction of fish that aggregate near the new hard structures may result in no net increase in the local population or fish production may be increased by the addition of new habitat that enhances fish settlement, survival and growth. These attraction/production mechanisms are not mutually exclusive (Bohnsack, 1989; Brickhill et al., 2005) and may be less relevant to understanding flatfish population responses to windfarm structures, because flatfish have more limited interactions with the turbine structures, primarily experiencing the structures near the bottom. Demonstrations of impacts of European wind farms on flatfish are equivocal. For instance, higher flounder (*Platichtys flesus*), as well as other fish, abundances were detected at the Lillgrund wind farm in Sweden during its operational phase compared to the baseline period using fyke net sampling, however, fish abundances also increased at reference areas, suggesting a larger regional trend in fish population fluctuations (Bergstrom et al., 2013). At the OWEZ wind farm (Netherlands) a tagging study revealed that sole were neither attracted to nor avoided the wind farm turbines (Winter et al., 2010). Another study at OWEZ using gillnets and DIDSON sonar documented higher abundances of Atlantic cod (*Gadus morhua*), pouting (*Trisopterus luscus*), and crab (*Cancer pagurus*) near the turbines and higher flounder (*Platichthys flesus*) and whiting (*Merlangius merlangus*) abundances in sandy habitat away from the turbines (van Hal et al., 2017). At the Horns Rev. wind farm (Denmark), seven years after construction, pelagic fish densities decreased at both the wind farm and control sites (Leonhard et al., 2011), indicating interannual variation in fish populations more strongly influenced abundances than any attraction effect of the wind farm.

Although flatfish size differed among reference and BIWF areas, there was no indication wind farm operation was related to these differences. Juvenile winter flounder were collected in all three areas during baseline sampling. Inshore winter flounder populations once were thought to spawn exclusively in estuaries and shallow embayments, where juveniles would spend their first year before migrating to offshore habitat (Bigelow and Schroeder, 1953). More recently, however, nearshore coastal winter flounder spawning has been reported for New Jersey (Wuenschel et al., 2009) and the Gulf of Maine (DeCelles and Cadrin, 2010; Fairchild et al., 2013; Fairchild, 2017). Juvenile winter flounder movement within estuaries is limited (Buckley et al., 2008; Manderson, 2008; Sagarese and Frisk, 2011) and a positive correlation between egg and juvenile production within an estuary (Wilber et al., 2013b) further indicates estuarine populations are localized. Therefore, juvenile winter flounder collected near BIWF (smallest TL = 70 mm) were most likely spawned near this offshore habitat. Other differences in flatfish size suggest the REFE area is preferred by juvenile windowpane and the REFS by juvenile fourspot flounder.

Flatfish condition indices can be a sensitive metric that reflect energy depletion and accumulation in adults related to relative habitat value (Pereira et al., 2012) or spawning activity (Wuenschel et al., 2009). During a non-reproductive period (fall), female winter flounder condition was similar among areas and exhibited inter-annual variation, with higher condition during the baseline time period. Condition can be affected by prey availability. The introduction of wind farm

turbine structures to sedimentary environments can be beneficial to pelagic fish by increasing prey via colonizing invertebrates, such as mussels, amphipods, and polychaetes. Food availability for fish around Danish offshore turbines was estimated to increase by a factor of 50 following wind farm construction (Lindeboom et al., 2011). Invertebrate colonization of turbine structures tends to be high near the surface (Maar et al., 2009; Kerckhof et al., 2012) and thus, these prey organisms are more accessible to pelagic fish predators. Flatfish, feed on benthic invertebrates, therefore their dietary habits are less likely to be affected by vertical habitat created by wind farm structures. However, benthic prey availability may be temporarily increased during wind farm construction and cable laying as bottom habitat is disturbed and prey are suspended. Seasonal fluctuations in mature female winter flounder condition are consistent with spawning activity in all areas in the winter and spring, which coincides with their spawning season. The lower spring condition for females during baseline time period may result from later spawning during the winter of 2014, which was colder than other years examined. A longer time series, however, is needed to more fully understand potential factors influencing spawning activity.

This study provides the first direct examination of potential impacts from offshore wind energy on biological resources in North America. Although no changes to flatfish communities were observed, further studies are needed to effectively manage coastal construction while protecting valuable marine resources.

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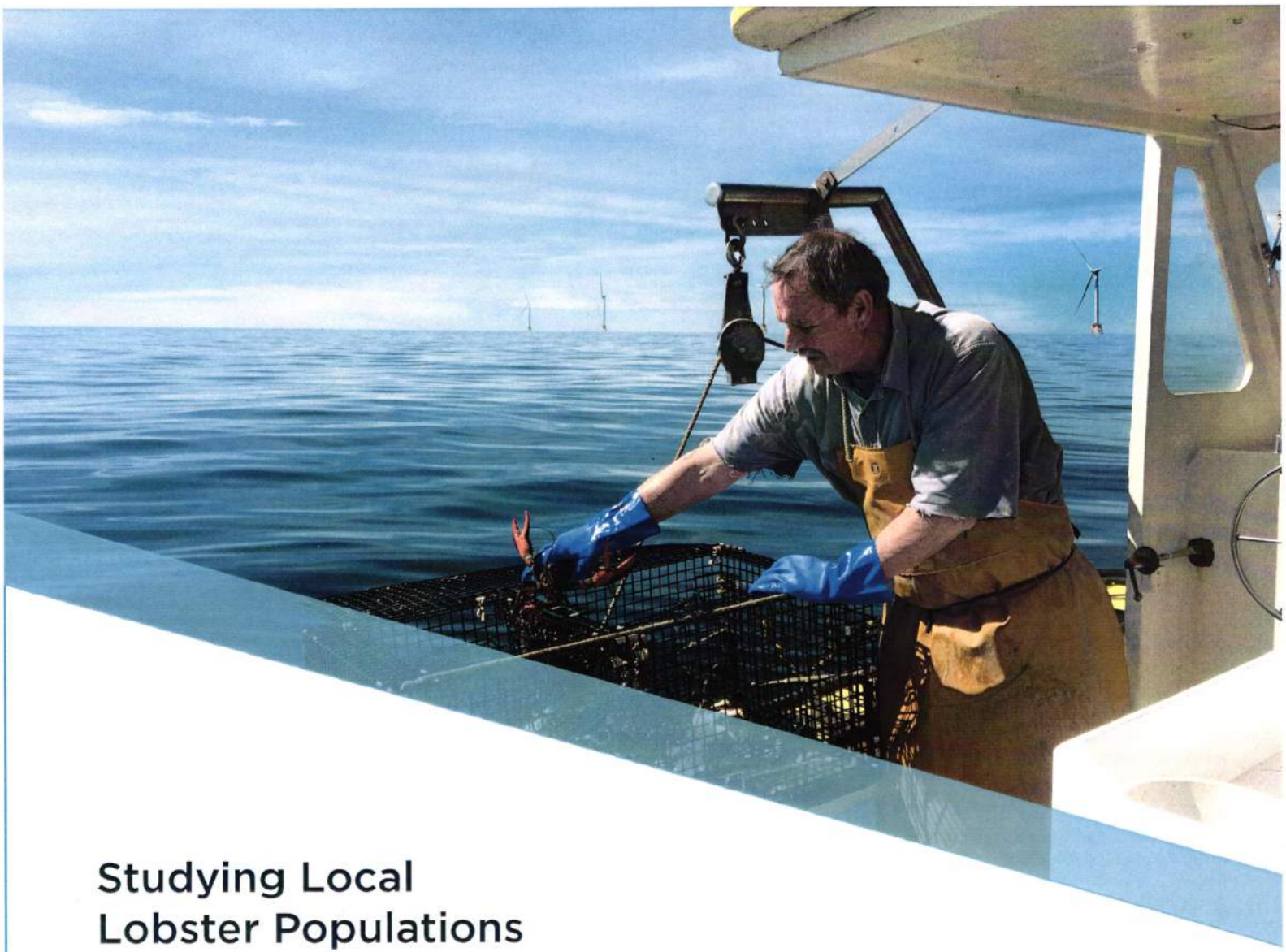

Studying Local Lobster Populations

In preparation for construction of the first offshore US wind farm, Deepwater Wind conducted a series of monitoring studies designed to assess effects on the environment, including potential impacts on lobster populations.

From the start, Deepwater Wind partnered with Rhode Island lobstermen and the local scientific community to study the issue. It was clear that local knowledge of lobsters and lobstering was essential to designing solid, scientific studies that are now adding to our understanding of local lobster populations. These studies allow an unbiased assessment of effects related to construction and operation of the wind farm.

Deepwater Wind hosted a series of public meetings and workshops and adopted an approach to:

- Partner with local lobstermen to collect data
- Provide lobstermen with support to engage in the survey design and analysis process
- Invite peer review and input from state and federal agencies
- Provide a fishing liaison to work with lobstermen

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What have we learned?

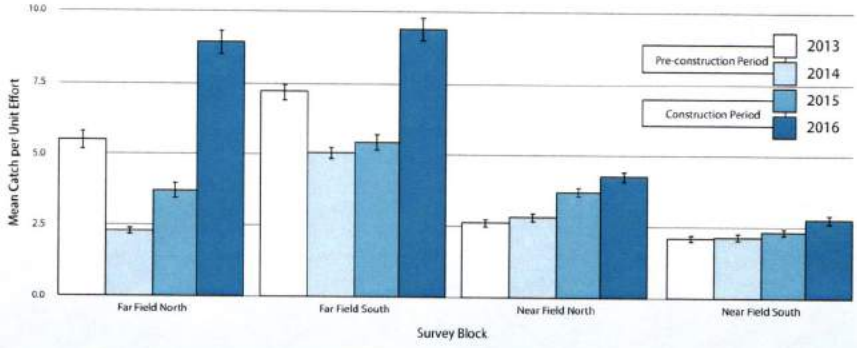
After collection and analysis over four years (May-October) before and during construction, the data indicate that lobster populations near the wind farm remain similar or have grown. Lobsters were found near the wind farm during construction at similar rates to their occurrence during pre-construction baseline years. Additionally, no consistent differences in abundance, bycatch, or size composition of lobster were found at sites near the turbine foundations during construction activities compared with pre-construction baseline years. Similar results were found at sampling sites identified by lobstermen as important lobster fishing grounds in Rhode Island Sound found at a distance (14 miles) from the wind farm.

The Block Island Wind Farm has become a model and source of knowledge for future offshore wind projects in the U.S. A hallmark of Deepwater Wind's approach is an ongoing commitment to working collaboratively with local lobstermen and to a rigorous scientific monitoring program. The data collected for this wind farm will be used to inform the next generation of U.S. offshore wind projects.

How do we know this?

Our data comes from sampling before, during, and after construction with local commercial lobster boats, scientific sampling gear, and at locations important to lobstermen. The sampling was designed to ensure that results can be compared with other lobster fishery studies in New England. Existing data were used to develop robust sampling designs capable of detecting effects of wind farm construction and operation on lobster populations. Post-construction monitoring will continue through 2018. Reports of our scientific results will be published at the conclusion of the study.

Lobster catch by year and location:



All species undergo inter-annual variability in local population size. These changes may be related to natural processes as well as human impacts, such as fishing pressure. Results from lobster monitoring display moderate inter-annual variability with the largest catches at each respective sampling site all occurring during 2016 (a construction year).

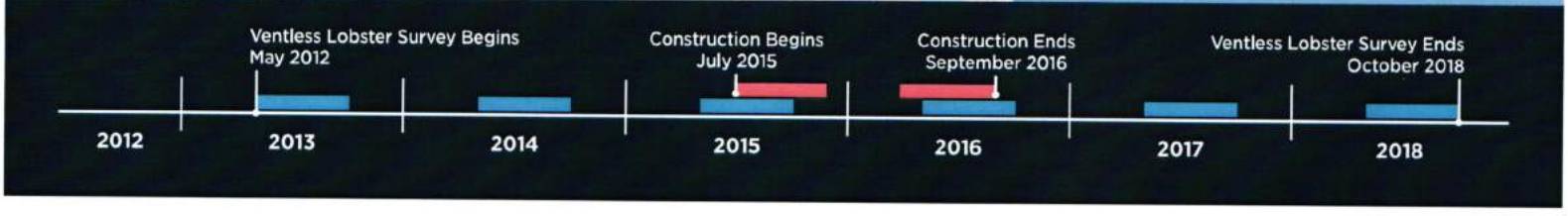
Number of Lobsters Sampled per Year:
~7,540 Lobsters

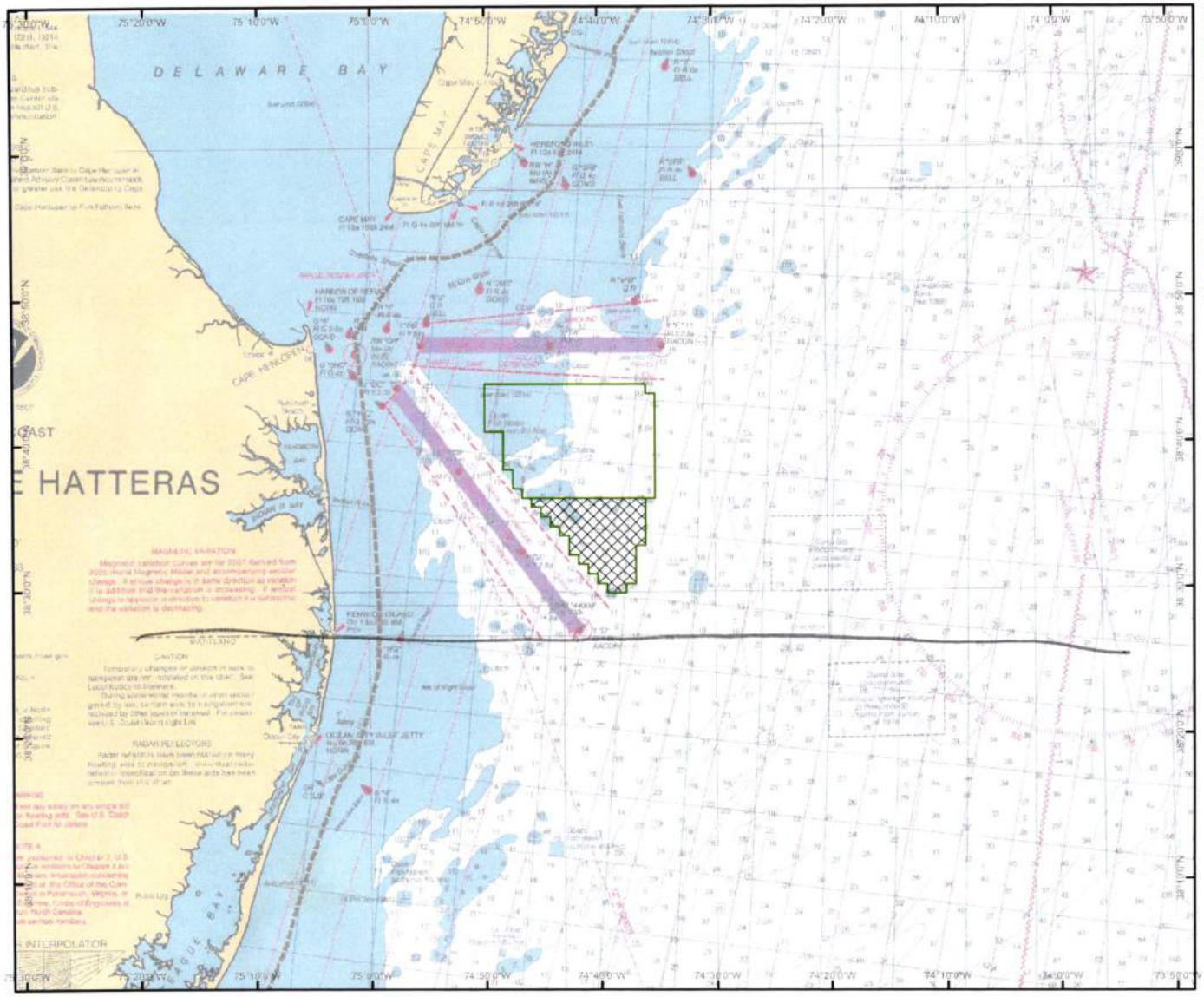
Number of Traps To Be Fished
10,368 (8,640 so far)

Largest Trawl Catch by Number:
270 Lobsters

Largest Lobster Collected:
3.6 lbs

Lobsters Returned Alive From Survey:
>99.99% of total





Location Map

BOEM Lease Area

Skipjack Wind Farm Area

State Waters (3 miles offshore)

Data Sources: BOEM, NOAA (2007)
Projection: NAD 83 UTM Zone 18N

N

0 5 10 20 Nautical Miles

0 5 10 20 Kilometers

SKIPJACK WINDFARM

SKIPJACK WINDFARM
PROJECT LOCATION
June, 2018