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Paper Title: Forward Scouting: Use of Sediment Profile Imagery in Conjunction with Multibeam Echosounder Mapping for Offshore Wind Cable Routes and Site Characterization

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Abstract

Selection of cable routes and wind turbine site assessments for offshore energy projects in the often-complex geology of the North American Atlantic coast entails very high risks for developers as well as state agencies: limited desktop data, patchy distribution of critical or sensitive habitats, and use conflicts, are a sampling of the risks encountered. The costs required to conduct multi-disciplined geophysical spreads including weather delays during marine mammal transit windows does not support exploring multiple or alternative routes. A novel approach was developed by Fugro and INSPIRE Environmental to reduce the risks and costs of required geophysical and benthic assessment surveys for offshore wind projects. Collection of field data is required by the Bureau of Ocean Energy Management (BOEM) as part of the Site Assessment Plan (SAP) for geophysical and biological characterization in offshore wind development. Collection of Sediment Profile Imagery (SPI) and Plan View (PV) imagery was integrated with multibeam echosounder (MBES) acoustic data collection to optimize route selection, provide ground-truth of acoustic data, and characterize benthic habitats in survey campaigns at three offshore wind projects. The SPI/PV data were downloaded daily and combined with on-board processed MBES data to provide near real-time guidance for optimizing survey operations. BOEM requires the mapping of sensitive habitats such as deepwater corals, eelgrass beds, and hard bottom environments including bedrock, boulder and cobble habitats as well as habitat characterization for a full benthic assessment.

The data presented from these three projects using the Forward Scouting approach illustrates the utility of rapid data acquisition and interpretation to support project-critical acoustic surveys. The SPI/PV data will be presented in an innovative visualization that integrates the profile and plan view imagery and processed MBES data. The visualization of the ground-truthed and benthic assessment data with landscape-scale seabed features has provided valuable decision-making support for archeological, benthic, fisheries, and engineering assessments. These combined technologies demonstrated the success of a collaborative approach to cable route and site characterization and led to development of the Forward Scouting approach to further reduce risk to schedules and assets, reduce site investigation costs, and incorporate multi-discipline (engineering and environmental) site data during early stages of project planning that is beneficial to stake-holder engagement activities.

Cable routing and site assessment is optimized when engineering and restricted-habitat constraints are minimized prior to full geophysical and geotechnical (G&G) survey operations with large assets. The SPI/PV Forward Scouting survey team can be deployed with high-frequency (>200 kHz) acoustic reconnaissance tools on small vessels that do not require permits or protected species observers (PSOs). The acoustic data collection for reconnaissance can utilize wider swath data retention without the requirement to meet International Hydrographic Organization standards and ‘sweep’ the proposed cable routes prior to defining the accepted centerline for full spread surveys. The SPI/PV photographic data provides ground-truth for the acoustic reconnaissance and if collected along the accepted centerline prior to demobilization will also provide baseline data acceptable for benthic assessment.

The Forward Scouting approach offers the offshore wind industry critical advantages in cost and time by utilizing seasonal survey windows often inaccessible to the full-complement of geophysical equipment or vessels and reducing the scope of survey plans based

on desktop data review. The potential for Forward Scouting is optimized with close collaboration between geophysical and SPI/PV providers.

Introduction

Offshore renewable energy projects in North American and European waters require extensive baseline geophysical, geotechnical, and environmental surveys prior to engineering and permitting. Collection and review of information on seabed properties must be coordinated between geophysical survey teams, engineering groups, marine archeologists, environmental scientists, permitting groups, and numerous stakeholders. Cable routing and platform siting is often an iterative process balancing engineering optimization with environmental effects and conflicting uses including safe navigation, fishing activities, cultural artifacts, and presence and timing of protected species.

Any progress in efficiencies of survey design and review of interpreted data has the potential to reduce costs and timelines for competitive development projects including critical path elements during site assessment, construction, and operations. Critical path elements include submission and approval by federal, tribal, and state agencies of a Site Assessment Plan (SAP) (https://www.boem.gov/Site-Assessment/) and a Construction and Operations Plan (COP) (https://www.boem.gov/Construction-and-Operations/); issuance of Incidental Harassment Authorizations (IHAs) and scheduling of supply chains for surveys and construction. Constraints on efficiency include the process of tendering bids for surveys, lack of clarity of permitting requirements, and need for integration of engineering requirements with environmental survey design. Bid tenders are often first offered for broad geophysical survey needs and not combined with environmental survey needs. Permitting requirements can be difficult to interpret and result in slower adoption of innovative approaches. Because cable routing and turbine siting evolve as data are available, the tendering and survey designs may require multiple efforts rather than a single adaptive approach.

We present three case studies of offshore wind surveys in the Northeast Atlantic that contain lessons learned for improving survey efficiencies, and we propose a 'Forward Scouting' approach to minimize risk to schedules and assets.

The southern New England near-shore continental shelf is an ideal area for offshore wind exploration and development. A slowly sloping shelf in concert with relatively high average wind conditions and large urban population centers proximal to the coastline provide a substantial number of prime locations for offshore wind energy production. The Bureau of Ocean Energy Management (BOEM) has produced regulations and guidelines for preparing SAPs and COPs for the proposed development of all offshore wind projects in U.S. federal waters. BOEM requires all seabed data to be classified in the Coastal Marine Ecological Classification System (CMECS, FGDC 2012). The Forward Scouting approach generates data contributing to:

- BOEM's Guidelines for Information Requirements for a Renewable Energy Construction and Operation Plan (BOEM 2016),
- Guidelines for Providing Geophysical, Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585 (BOEM 2015),
- Guidelines for Providing Archaeological and Historic Property Information Pursuant to 30 CFR Part 585, prepared by BOEM July 2015 and March 2017 (BOEM 2017), and
- Guidelines for Providing Benthic Habitat Survey Information for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585 (BOEM 2013).

The Forward Scouting approach utilizes a SPI/PV camera system combined with acoustic data collection (MBES and side scan sonar, Figure 1). The camera system collects high-resolution images of the surface of the seafloor and a cross section of the near surface sediment profile (Figure 2) and is used widely for environmental assessment (Germano et al. 2011). Full geophysical and geotechnical (G&G) surveys ideally follow this reconnaissance approach (Fugro 2017). The SPI/PV images provide high-resolution, *in-situ* ground-truth data for interpretation of acoustic data (Figure 3).

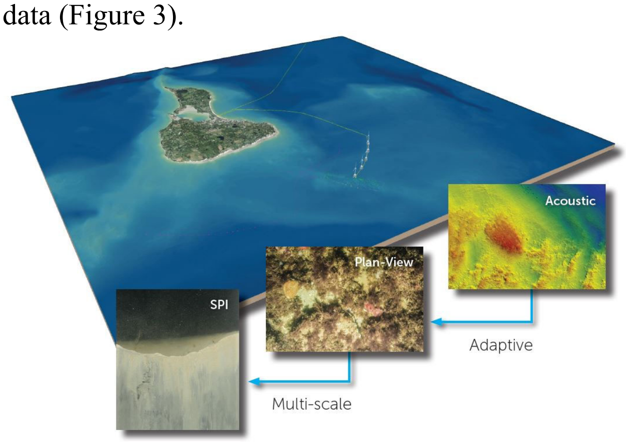

Figure 1. Multi-scale site assessment approach used in Forward Scouting.

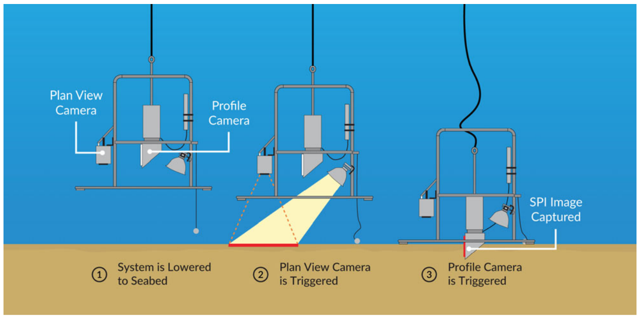

Figure 2. Operation of Sediment Profile Imaging (SPI) and Plan View (PV) camera system.

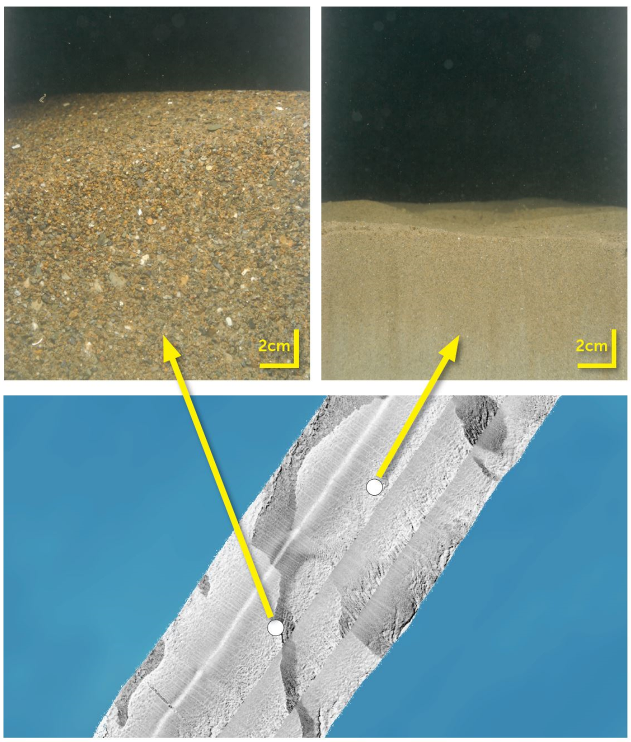

Figure 3. Use of SPI/PV to ground-truth side scan sonar data.

Block Island Wind Farm

The first offshore wind farm in North America, Block Island Wind Farm (BIWF) in Rhode Island, USA, was constructed by Deepwater Wind on a pilot scale (30 MW), becoming operational in 2016. BIWF's five wind turbine generators were sited to minimize environmental impacts to marine habitat and maximize engineering efficiencies of power generation and cable length. The surrounding marine area supports commercial and recreational fisheries and contains areas with Pleistocene glacial moraine deposits as well as Holocene marine transgression deposits of sand and silt. The project was sited in Rhode Island state waters consistent with the process defined in the Ocean Special Area Management Plan (SAMP) but prior to promulgation of BOEM survey guidelines (Ocean SAMP 2019).

Prior to full G&G surveys, a benthic habitat characterization study was conducted in October 2009 to investigate engineering constraints and potential impacts to Essential Fish Habitat (EFH) from installation of the subsea transmission cables connecting the offshore turbines to shore landings. The survey was conducted as a reconnaissance study with flexible station locations to determine initial route planning of subsea cables relative to potential EFH impacts and engineering design.

The habitat study sampled over 204 stations in four days with a SPI/PV system. A station in this study represented a single camera drop or in some cases replicate sampling with multiple drops within a watch circle. The approach was presented to the U.S. National Marine Fisheries Service Habitat Protection Division (responsible for evaluating EFH assessments) with concurrence that the data were sufficient to provide site specific assessment information for formal review of the proposed project.

Stations were collected over the entire routes of proposed transmission cables including two alternative locations for the planned 5-8 wind turbine generators (Figure 4). There are several shallow ridges south of Block Island formed by Pleistocene glacial moraine deposits that have the presence of key habitats for managed species (American lobster and longfin squid). These habitats are comprised of cobble and boulder sized rocks with extensive coverage by algae and marine life and are considered sensitive habitats in this region under EFH standards (Figure 5). The presence of these hard bottom areas had implications for cable burial engineering feasibility and permitting. The mapped locations of undisturbed cobble habitat precluded viable cable routes from turbine locations directly south of Block Island to the preferred landing site (Alternative 2, Figure 4). As a result, the Block Island Renewable Energy Zone was expanded by the State of Rhode Island to allow the turbine site ultimately used for construction (Figure 6). Other portions of the cable route were re-routed prior to the full geophysical survey to avoid similar habitats closer to the mainland.

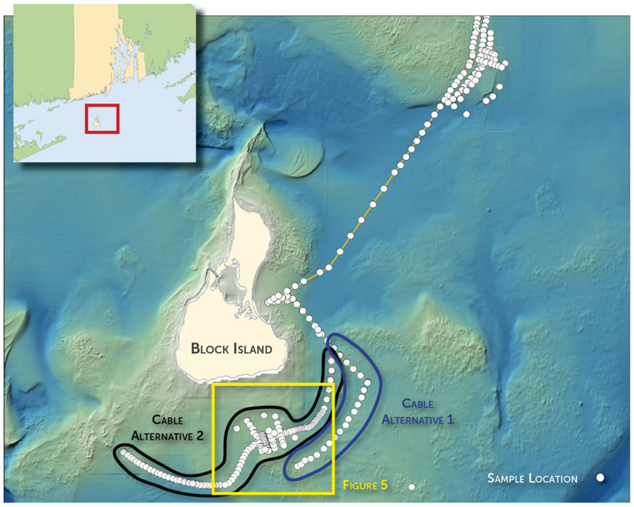

Figure 4. Stations sampled with the Sediment Profile Imaging (SPI) and Plan View (PV) camera system.

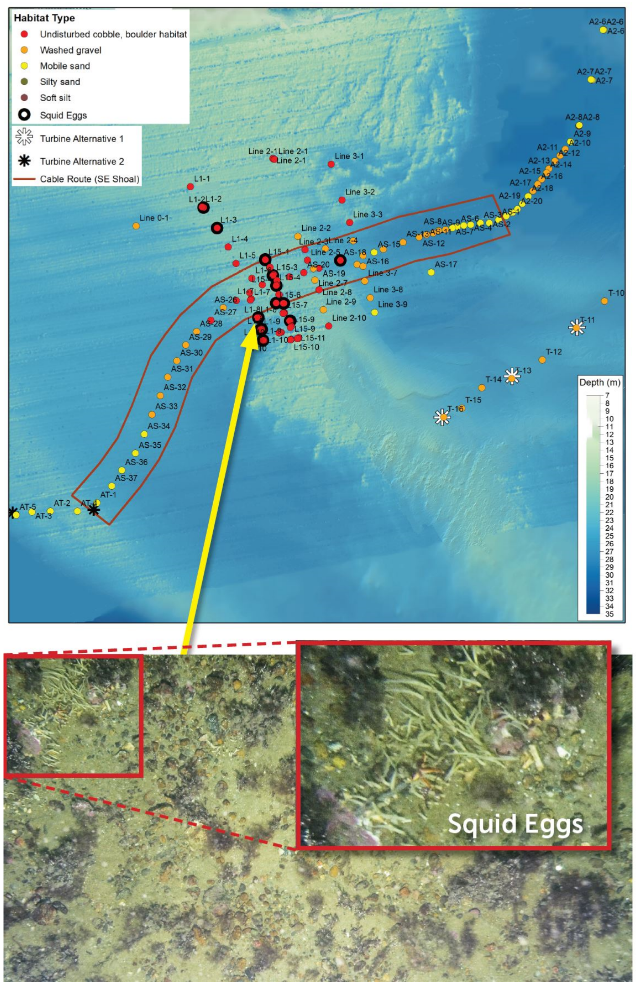

Figure 5. Habitat types mapped for transmission cable route from proposed Turbine Alternative 2 location to landfall on Block Island. The presence of squid eggs and undisturbed cobble triggered an Essential Fish Habitat problem for cable installation.

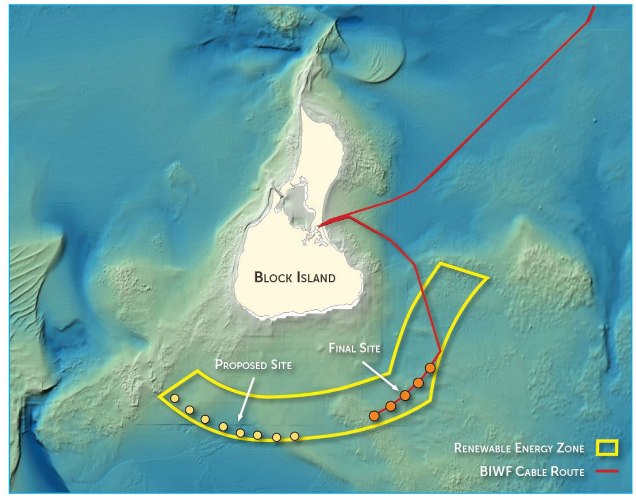

Figure 6. Optimization of the site of BIWF to ensure permitting of cable within the designated Renewable Energy Zone.

Results from the reconnaissance survey provided critical path information to state and federal regulators and for the initial planning of both turbine siting and cable routing. This information led to re-routing the full geophysical survey reducing risk to timetables and assets and saving survey costs. The reconnaissance level quantitative data collection and habitat classification methods proved to be a cost-effective, rapid assessment approach that successfully reduced some risks of wind farm siting. The key innovation was to precede geophysical surveys with a rapid assessment. The traditional approach is to perform a full geophysical survey followed by grab sampling and benthic community assessment and laboratory analysis. This innovative approach provided scientifically-sound information that was presented in a visually understandable format that provided timely, critical information for siting as soon as the survey was completed; and used the national habitat classification standard ultimately required by BOEM. This Forward Scouting approach, first used at BIWF, has since been successfully applied to other projects.

New York Offshore Wind Survey

A Forward Scouting survey was conducted in 2017 for the New York State Energy Research and Development Authority (NYSERDA) to provide planning-level characterization of the geophysical, geotechnical, and benthic characteristics of potential offshore wind energy areas within previously identified water depth zones offshore New York State. This objective was accomplished with the collection and analysis of broad area reconnaissance MBES data products (primarily high-resolution bathymetry and backscatter) and SPI/PV photographic data used to ground-truth the acoustic data and provide an initial assessment of benthic habitat types within the study area. The SPI/PV imagery provided ground-truth data of surface sediment characteristics (grain size, shear strength, biological activity) that were used to identify areas with potential sensitive habitats. Backscatter is a measure of amount of sound energy reflected to the MBES transducer and provides a measurement of relative hardness and roughness of the sediment surface (Fugro 2017). The penetration depth of the camera provides a replicable measurement of the resistance of surface sediments that can be loosely related to geotechnical properties of the surface sediments (Germano et al. 2011).

When the State embarked on planning studies, it began by looking at a study area identified by the New York State Department of State (NYSDOS) in its two-year Offshore Atlantic Ocean Study (NYSDOS 2013). This study area, referred to as the "offshore study area (OSA)," is a 16,740 nm² (43,356 km²) area of the Atlantic Ocean extending from New York City and the south shore of Long Island to beyond the continental shelf break and slope into oceanic waters to an approximate maximum depth of 2,500 m (Figure 7). The MBES and SPI/PV survey was conducted offshore New York State within selected areas of the OSA. The planning area for the survey was initially defined by a subset of the OSA to exclude areas closer than 15 nm from shore and water depths greater than 62 m. Based on feedback from advisory groups and NYSERDA staff, the proposed suitable planning area was defined to additionally exclude major known shipping lanes, the sensitive habitat area of the Hudson Shelf Valley, and existing lease blocks. By restricting the survey area to exclude areas based on objective criteria (depth, distance from shore, intense use, habitat quality) it was possible to survey the remaining area with higher data density than would have been possible across the entire OSA. During the field survey, further consultation between NYSERDA and stakeholders occurred and resulted in the survey area adjacent to the western New Jersey/New York OSA boundary being modified. Several additional MBES lines and SPI/PV stations were added to the New Jersey side of the OSA (Figure 7).

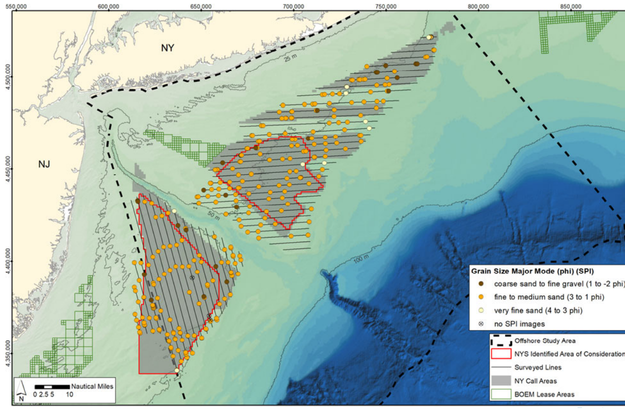

Figure 7. Map showing MBES lines and grain size results from the 300 SPI/PV station locations occupied during this survey superimposed on areas considered for development.

The overall survey plan was predicated on a two-part objective; 1) collecting quality MBES data over as large a representative set of environments within the OSA as possible, and 2) ground-truthing the MBES data with an efficient means of sediment sampling. The survey was conducted from June 21 to August 11, 2017 and collected data along 51 lines within four survey areas. Lines were spaced 1.9 nm apart (3.5 km). In addition to the main survey lines the survey continued to collect ancillary MBES data during opportune transits. The MBES survey collected a total of 2,498 linear nm (4,626 km) of high-resolution acoustic data of seafloor topography and relative seafloor hardness/softness data (backscatter) (Figure 7). All MBES data collected within the survey areas covered 229 nm² (787 km²) or 9% of the seafloor within the survey areas, which covered a total of 2,598 nm² (8,910 km²) of seafloor.

The SPI/PV survey occupied 300 stations throughout the four survey areas and collected up to four replicate image-pairs at each station. A total of 1,181 SPI images and 1,177 PV images were collected (Figure 7). Stations were distributed among cohesive regions of backscatter values (and clustered in areas where steep gradients in backscatter values were observed. Further placement of SPI/PV stations occurred in areas where an existing regional model indicated higher degrees of uncertainty regarding the composition of seafloor surface sediments. On-board processing of acoustic data and review of SPI/PV images allowed ground-truth station planning and field-interpretation of the data in near real-time. These data were processed onboard and assessed by our scientists within 24 hours of collection.

All data collected for this study were representative of soft-bottom substrata and were evaluated as suitable for offshore wind farm planning with respect to seafloor surface geology and benthic habitats. Data revealed a range of bedforms and surface sediment features, as well as associated benthic biotic communities, all of which can be characterized as soft-bottom substrata subject to episodic sediment transport events (Figure 8). No sensitive habitats (e.g., hard bottom with attached epifauna and flora) were observed in the acoustic and optical data collected. Additionally, surface sediment grain size data from this study will help fill data gaps and improve an existing regional grain size model. The interpretations of surface sediments and benthic biological communities are believed to be representative of the surveyed areas, given the survey design and collection of images across a range of seafloor features and textures (INSPIRE 2017).

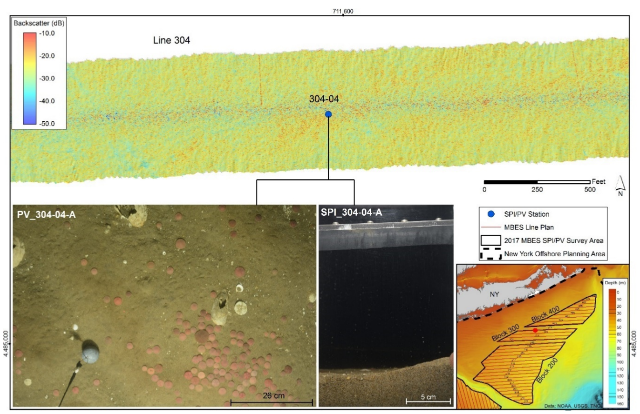

Figure 8. Data sample from SPI/PV station. Top panel shows a sample of MBES backscatter data, and location of the SPI/PV station. Lower left and middle panels show example plan view and profile view image of the seafloor.

The utility of combining SPI/PV ground-truth data with reconnaissance-level MBES allowed NYSERDA to proceed with evaluation of large areas of potential offshore wind lease areas and resulted in the "New York State's Area for Consideration" in October 2017. In April 2018 BOEM issued a "New York Bight Call for Information and Nomination" delineating four potential offshore wind lease areas for stakeholder input (Figure 7). Full detailed geophysical, geotechnical, and benthic assessment surveys will be required of each successful bidder on BOEM leases (BOEM 2015).

South Fork Wind Farm

Deepwater Wind (now Ørsted USA Offshore Wind Power) and BOEM executed a commercial lease for the development of a wind energy installation in the waters offshore Rhode Island and Massachusetts (Lease OCS-A 0486). The South Fork Wind Farm (SFWF) will be located within the Lease Area and will consist of up to 16 wind turbine generators with a planned 120 MW capacity, one offshore sub-station, inter-array cables, and an export cable from the site to a location on Long Island, NY (Figure 9). As part of a geophysical survey for the SFWF, SPI/PV images were collected at stations inside the SFWF, along the proposed South Fork Export Cable (SFEC), and at reference stations. The SPI/PV surveys provide an interpretive assessment of discrete sampling stations to support interpretation of the remote sampling of the G&G survey required by BOEM. The stations occupied for the G&G survey were also analyzed for benthic conditions and provided technical data required for benthic assessment required by BOEM (BOEM 2013).

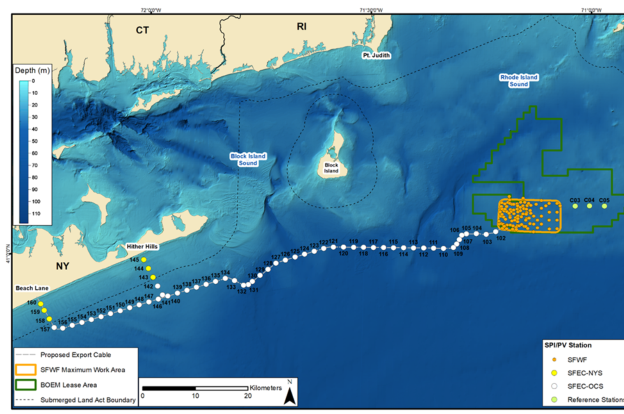

Figure 9. Survey area of the South Fork Wind Farm, proposed export cable and SPI/PV sampling stations.

The SFWF is in Rhode Island Sound on the southern New England outer continental shelf (Figure 8). To ground-truth the sediment types, bedform dynamics, presence of sensitive habitats and taxa, and benthic conditions in the SFWF and along the SFEC, the project team designed a survey of 98 stations within the SFWF, 60 stations along the SFEC, and three stations within a potential reference area to the east of the SFWF. The station distribution was consistent with BOEM guidelines for ground-truth of G&G surveys and benthic assessments. A total of 161 SPI/PV stations were sampled throughout the project. A 141-station SPI/PV survey was conducted November 11-15, 2017 and a 20-station SPI/PV survey was conducted on November 20, 2018.

Interpretation of the SPI/PV data provided detail on the physical sediment characteristics and benthic habitat whereas the MBES data, a remote sensing technique with lower resolution than the SPI/PV data, were used to map larger areas based on geomorphologic and backscatter interpretation. The power of the combined approach is to create greater confidence in interpreting geologic conditions and features in spatially expansive areas mapped using MBES data by incorporating sampling of *in-situ* ground-truth results (Fugro 2017). Sediments within the SFWF and reference area were spatially heterogenous ranging from fine-grained (silt and clay-sized) to cobbles and boulders on sand. This range of grain sizes is typical of outer Continental Shelf Pleistocene glacial moraine depositional environments that include Holocene marine transgressive deposits. The physical sediment characteristics within the SFEC were spatially heterogenous with types ranging from fine-grained (silt/clay) to pebbles and pebbles on sand. The sediment–water interface was often shaped by physical activity within the surveyed area. The physical sediment characteristics within the reference area were spatially heterogenous ranging from silt/clay to large cobbles. Benthic habitats were mapped and characterized by six discrete quantitative measurements (Germano et al. 2011). Three distinct benthic habitats were described and mapped: patchy cobbles and boulders on sand, sand with mobile gravel, and sand sheets (Figure 10).

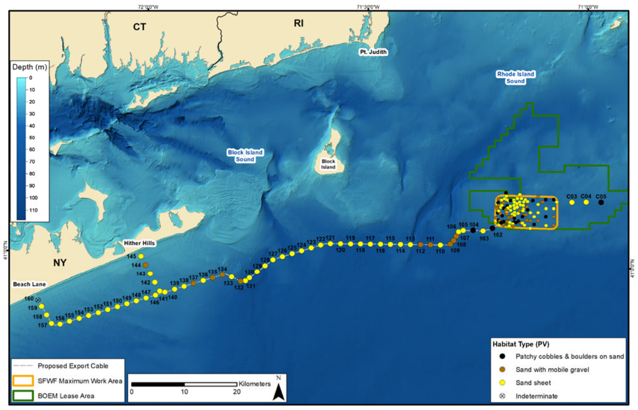

Figure 10. Habitat type distribution within the South Fork Wind Farm (SFWF) and South Fork Export Cable (SFEC).

Collection of SPI/PV imagery from the reference stations provided data on pre-construction physical and biological conditions outside the SFWF at intervals of 1.9 km. These data may be used to support a baseline reference to evaluate future construction and operation impacts to the benthic environment. Results indicate that the surface sediments along with the CMECS Biotic Subclasses and habitat types in the reference area proved to be representative of those found in the SFWF and along the SFEC.

The results and images from this survey allowed accurate ground-truthing of geophysical survey results and establishment of baseline large- and small-scale physical and biological features within the SFWF and along the SFEC. A visualization of geophysical data including MBES and seismic results combined with SPI/PV imagery was used to aid selection of geotechnical and cultural cores required by BOEM. These results will also allow Ørsted to broadly communicate the results of the G&G survey using seafloor and seabed images of pre-development conditions. Contributions from this survey will provide valuable information to address BOEM guidelines and regulations, as well as stakeholder concerns.

Summary

Three projects conducted over nine years in the emerging Atlantic coast offshore wind industry demonstrate the value of 'Forward Scouting' of geological and ecological seabed conditions to minimize risk to timelines, cost, and assets. Methods and approaches to Forward Scouting have improved over the nine years:

- Integration of data collection with tight coordination of geophysical and SPI/PV teams improved efficiency and interpretation of both datasets;
- Processing of SPI/PV imagery and navigation data onboard permitted near real-time adaptive sampling;
- Rapid production of visualization assisted consultation with Native Tribes and marine archeologists to select cultural cores and improve the efficiency of geotechnical survey planning.

The BIWF project benefited from a rapid assessment of environmental and engineering conditions for cable routing to reduce the time and effort required to conduct a geophysical survey. The design of the survey eliminated the need for IHAs and Protected Species Observers (PSOs) and was completed in four days with a small survey vessel. The results allowed the project to proceed with reduced scope for site assessment and cable route surveys by eliminating unsuitable routes prior to the geophysical survey. Estimates of time saved were three full survey days with MBES, side scan sonar, magnetometer and shallow seismic equipment on a large survey vessel.

The NYSERDA Offshore New York project was designed to coordinate geophysical MBES reconnaissance mapping and SPI/PV assessment. The design of the survey eliminated the need for IHAs and PSOs and was tailored to support a large area site reconnaissance assessment. The consistent results from geophysical and ecological ground-truth complemented a geophysical survey designed to characterize 'strips' of the survey area. The results were directly applicable to the New York State Offshore Wind Master Plan (INSPIRE 2017) and allowed NYSERDA to successfully petition BOEM for additional lease area designations.

The SFWF project is ongoing but has demonstrated the value of rapid collection and interpretation of ground-truth data and coordination with a geophysical survey. The integrated acoustic and SPI/PV results have also served as an integral part of pre-construction assessments and continue to support decision-making throughout the planning phases of the project. The results were integrated into a visualization that was used in consultation with indigenous peoples and marine archeologists to select locations of cultural cores. The visualization supported consultation with commercial fishermen and fisheries regulators regarding distribution of potential spawning habitats and Essential Fish Habitat.

Conclusion

The use of SPI/PV as part of site assessment studies can be conducted before, concurrent with, or after G&G surveys using vessels of opportunity that allows for IHA Permit-free and PSO-free surveying. The Forward Scouting approach offers the offshore wind industry critical advantages in cost and time by utilizing survey windows inaccessible to full-spread geophysical equipment and reducing the scope of survey plans based on desktop data review. The potential for Forward Scouting is dependent on close collaboration between geophysical and SPI/PV providers as exemplified in the case studies. The primary lesson learned from the surveys is that SPI/PV is most effective when used in a Forward Scouting mode in close integration with planning for G&G surveys.

Acknowledgments

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