FESC
Florida Energy Systems Consortium

FESC Project Update:
Southeast National Marine Renewable Energy Center

Thrust Area 6: Developing Florida's Ocean Energy Resources

Marine Renewable Energy (MRE) is the availability of energy in ocean currents, waves, tides, and thermal gradients. Tapping MRE resources will reduce our reliance on fossil fuels and help Florida along the road to energy self-sufficiency, energy security, and prosperity. Research areas of focus include improving understanding of ocean current and thermal-gradient resources, implementing testing capabilities to expedite commercial development of these resources, and understanding potential environmental impacts and how to mitigate them.

1. Project Description

Title: Southeast National Marine Renewable Energy Center (SNMREC)

PI: Susan H. Skemp, **Co-Investigators (at FAU):** Howard P. Hanson, James VanZwieten, full list appended.

Note: Student listing is appended

Budget: $8,750,000; Funding **Leveraged:** U.S. Dept. of Energy, National Science Foundation and Industry - $5.766M

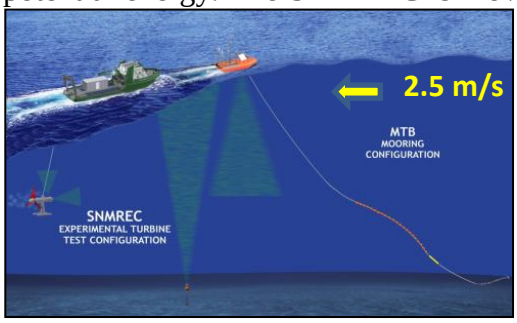
Description: The Southeast National Marine Renewable Energy Center (SNMREC) at Florida Atlantic University (FAU) was established by an award from the US Department of Energy in 2010 as an extension of FAU's Center for Ocean Energy Technology, which was originally founded in 2007 by the 2006 Florida State University System Center of Excellence Program. The SNMREC is investigating harnessing power from ocean currents, such as the Gulf Stream, as well as ocean thermal energy conversion to generate base-load electricity, thereby making a unique contribution to a broadly diversified portfolio of renewable energy for the nation's future. Key drivers for investigation are determined by the regulatory process at State and Federal levels and by market and technology gaps needed to commercialize MRE. The SNMREC's role is to bridge the gap between concept and commercial deployment of ocean energy technologies by providing at-sea testing facilities and technology development for both ocean current and thermal energy systems. Research areas span environmental, resource, economic, education, and technology topics.

Universities: Florida Atlantic University, collaborating with the University of Central Florida, Florida State University, University of South Florida, Embry-Riddle Aeronautical University, University of Miami, Oregon State University, University of Washington, Pennsylvania State University, University of New Hampshire, University of Hawaii, University of Edinburgh, Heriot-Watt University, Nova Southeastern University, Virginia Polytechnic Institute and State University, Stellenbosch University and Florida Institute of Technology.

External Collaborators: Numerous industry partners, state and federal government agencies, FFRDCs such as the National Renewable Energy Laboratory, Oak Ridge National Laboratory, Woods Hole Oceanographic Institution, U.S. Department of Energy (Office of Energy Efficiency and Renewable Energy), U.S. Department of Interior (Bureau of Ocean Energy Management, Regulation, and Enforcement), U.S. Department of Commerce (National Oceanic and Atmospheric Administration), the Florida Fish and Wildlife Conservation Commission, and Florida Departments of Agriculture and Environmental Protection.

2. Project Description

The Southeast National Marine Renewable Energy Center is developing an open-ocean energy laboratory and test capability to advance research on *marine and hydrokinetic* (MHK) ocean current energy and thermal potential energy. The SNMREC is moving forward with strategically selected research, developing and testing key technology, infrastructure and systems as well as standards criteria to meet this need. The successful implementation of an in-water testing infrastructure for MHK off the coastline of Florida will be the first and only such capability globally. Already, companies from both the U.S. and internationally have expressed a desire to work with the SNMREC in defining not only their test requirements based on their design, but also are exploring both short term occupancy in Florida and potentially longer term manufacturing and grid connection in developing arrays for commercial enterprises.



An MHK lease application on the outer continental shelf (OCS) was submitted to the U.S. Department of Interior, Bureau of Ocean Energy Management (BOEM). This is the first national application which will form the model for future lease applications. BOEM released the Final Environmental Assessment (EA) with a Finding of No Significant Impact (FONSI) on 12 August 2013. The EA and FONSI can be found on the Department of Interior's website at http://www.boem.gov/Florida-Revised-EA-FONSI-August2013/.

The DOE NEPA office is in the process of writing their FONSI required by law based on the EA. The Department of Environmental Protection, as the State of Florida's lead Coastal Zone Management Act agency, conducted a consistency determination review of the BOEM EA and FONSI. They notified the BOEM on 25 September 2013 that the issuance of a lease to SNMREC for hydrokinetic technology testing is consistent to the maximum extent practicable with the provisions of the Florida Coastal Management Program. It is anticipated that a lease will be granted to FAU and SNMREC in Q1 of CY2014.

The SNMREC is engaged in sensor and instrument acquisition, deployment, and analysis to more fully characterize offshore energy resources, and the benthic and pelagic environment. Second, fabrication of a small-scale hydrokinetic turbine system is in the final stages of completion. Testing is ongoing for components, sub-systems, and major systems of the turbine. Assembly and tow testing of the prototype prior to deployment of the test infrastructure will begin in November. Discussions are ongoing with over 40 companies to determine testing/validation requirements for open-ocean testing of their proposed experimental devices at the SNMREC's test facility. A centralized, standardized testing capability will be provided for testing current energy conversion prototypes; initially, scaled versions and eventually full-scale devices. In addition, critical environmental measurements will be obtained from the observational platform.

Sea trials were successfully conducted of a mooring and telemetry buoy to ready it for at-sea deployment. In-lab technology testing is underway with a scaled generator dynamometer which provides a platform to test offshore electrical systems before use and simulate offshore grids. Aerial surveys are being conducted to determine offshore turtle and marine mammal distribution and activity prior to install/test of MHK devices. Sub-sea surveys of installation sites are helping to identify deep water coral distribution and determine appropriate anchor areas.

Over fifty upper-division graduates and Principle Investigators have been engaged in research in marine renewable energy (MRE) to date. The Center developed a curriculum for upper-division high-school students to introduce the topic within secondary education.

To date, with the State of Florida funding, the SNMREC has successfully leveraged $5,717M of U.S. Department of Energy funds. Industry sponsored funding is at a level of $177,000.

3. Annual Progress Report 10/12 – 9/13

3.1 Introduction

SNMREC is developing and installing the first open-ocean current energy conversion test facility in the U.S. consisting of at-sea equipment (Figure 1) for the purpose of investigating current energy conversion devices in the Florida Current, approximately 12 miles offshore Fort Lauderdale, Florida. Initially, the capability will be limited to scaled devices (⅛ – ¼ scale, or up to 7 meter diameter rotors or 100kW instantaneous maximum power production). The SNMREC facility will provide a centralized, standardized approach to testing for current energy conversion prototypes. In addition, the facility will serve as an observational platform from which critical environmental measurements can be obtained.

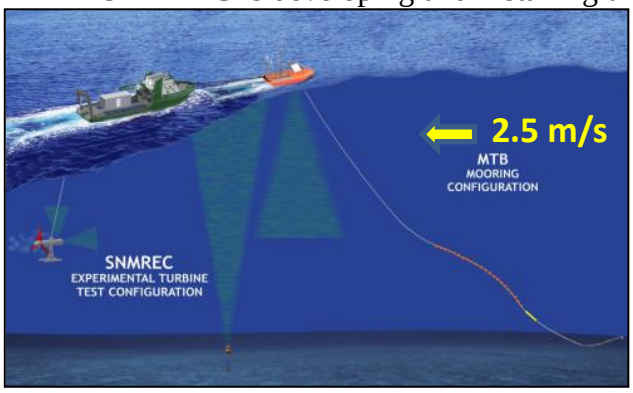
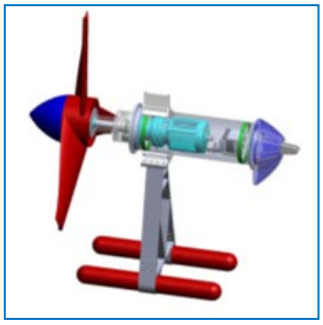


Figure 1. SNMREC Ocean Current Test Facility setup



A 3-meter rotor diameter, 20kW generically designed experimental research turbine (Figure 2) will provide a non-proprietary platform for component development at small scales. The test procedure/plan is laid out to incorporate monitoring and failure prediction systems, to gain experience in at-sea operations of this nature, and to support standards and protocol development. Industrial beneficiaries will be able to use the results of testing to enhance and accelerate prototype development. A major challenge, obtaining an outer continental shelf lease, is nearly met.

Figure 2. SNMREC 3-meter diameter Rotor, 20kW Instantaneous Max Power Prototype Turbine

3.2 Areas of Significant Progress

3.2.1 Resource Assessment

The global analysis of ocean thermal energy conversion (OTEC) potential, a DOE-funded project undertaken jointly with the Lockheed-Martin Marine Systems and Sensors Division, has been completed, producing a publically available GIS database that is accessible at http://maps.nrel.gov/mhk_atlas. This GIS tool provides information pertinent to both OTEC and sea water air conditioning (SWAC). A screenshot of this tool is shown in Figure 1. Detailed assessments of both the OTEC and SWAC resources off Florida have also been conducted. Using the Hybrid Coordinate Ocean Model (HYCOM) results produced in data-assimilation mode by the Naval Research Laboratory (NRL) and *in situ* data, estimates of the net electric power that could be created utilizing a representative 100 MW OTEC plant have been made. It is estimated that such a plant could produce an average up to 112 MW of power if located off Key West, with power production decreasing with latitude up the east coast of Florida (Figure 3).

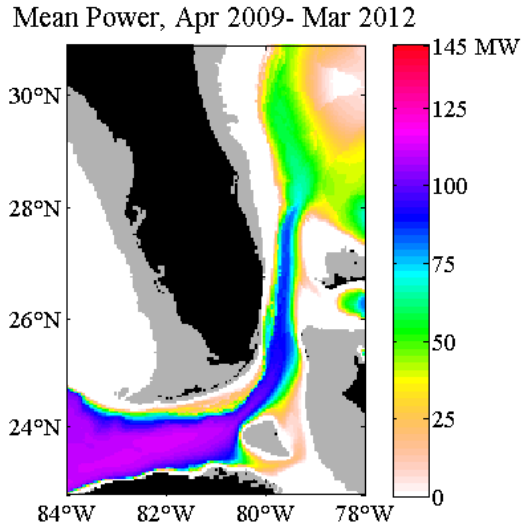


Figure 3. Average net electric power produced from a single representative 100 MW OTEC plant

OTEC plants create power by using the temperature difference between the warm surface water and cold deep water to produce electricity. For this reason they run large amounts of both cold and warm water through heat exchangers. Therefore, a first step in assessing the environmental impact of locating an OTEC plant in the Florida Straits is quantifying the percentage of the resource that will be used by a plant. It is calculated that an OTEC plant located along the transect line "A" in Figure 4 would use approximately 0.009% of the cold water (<9° C Figure 4, right) flowing past this line. To help put this into perspective Florida utilized approximately 26 GW of power in 2005. If this entire 26 GW of power were produced using OTEC (meaning 260 of the 100 MW OTEC plants discussed here) then these plants would utilize less than 2.5% of the cold water that flows between Florida and Cuba.

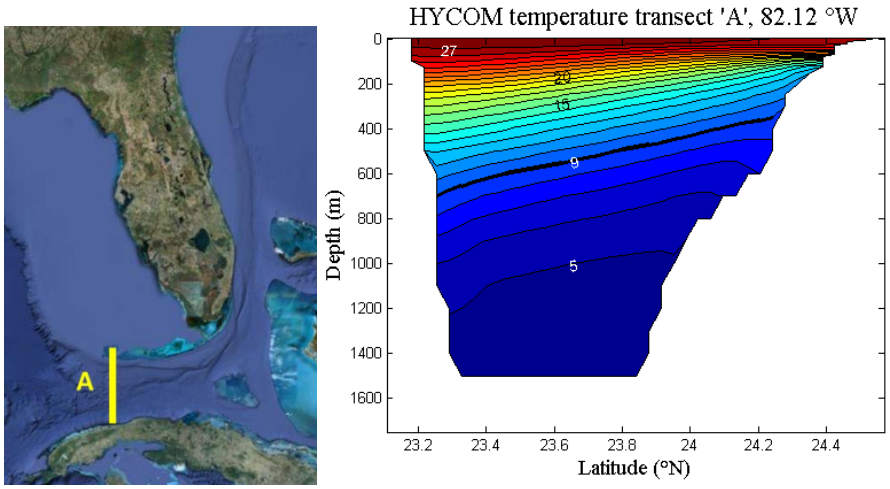


Figure 4. Thermal energy resource for (a) summer, (b) winter, (c) annual average

The DOE-sponsored global OTEC resource study relied on model results, from a data-assimilation version of the global HYCOM. Recently, the NRL has adopted a more recent version of HYCOM for its simulations of the Gulf of Mexico and the Straits of Florida, which version includes both very high resolution (~4 km horizontally and more vertical layers) and improved physics. Because of this, comparisons between SNMREC field datasets and HYCOM results such as those shown in Fig. 4 have improved markedly. These results will continue to be useful for ongoing OTEC assessments for Florida's future.

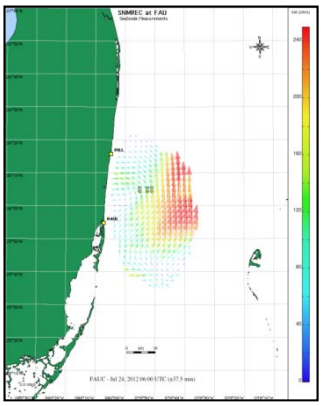


Fig 5. CODAR Installations

Finally, on May 22nd three Acoustic Doppler Current Profiler (ADCP) buoys were deployed. The ADCP measurements combined with a SeaSonde® ocean surface current measurements system will allow for estimations of the Florida Current's volumetric flow and power potential. The SeaSonde® system, manufactured by CODAR Ocean Sensors, consists of two pairs of antennas installed on land within close proximity to the shore at Hillsboro and Haulover Beach (Figure 5). At each site one antenna transmits a high frequency radar signal that is reflected on the ocean surface and received by the second antenna. At offshore locations where at least two radar signals intersect the total current speed and direction can be calculated.

Concurrently as of mid-July 2012, SNMREC's 12 MHz SeaSonde® radar system has been collecting ocean surface current measurements (see figure 5 for location of

ADCP buoys in relation to SeaSonde® coverage area). Fortuitously, the ADCPs were operating during the passage of Hurricane Sandy and were recovered in December 2012. With the passage of Hurricane Sandy, however, wave action at the Hillsboro site caused serious beach erosion and, in the process, the northern of the two antennas was destroyed. However, data were obtained before the unit's loss to allow initial attempts to validate the SeaSonde® data by comparing to data collected from the ADCPs. Early results suggest that, at least during periods of variable winds, such as during the passage of the storm, there is no correlation between CODAR-measured surface currents and currents throughout the water column. It appears that it will be necessary to adopt other strategies for continuous monitoring of the current.

Eventually, wind data within the coverage area (which will be collected from the MTB anemometer when permission to deploy the MTB is granted) will be available to quantify the wind effects and improve the accuracy of the current profile prediction algorithms. In May 2013, four ADCPs were deployed in a modified diamond configuration to measure both latitude and longitudinal effects of variability in the current. Recovery of the ADCPs is planned for December 2013.

Finally, in July, notification came from a fisherman, that a buoy had been spotted floating in the current off Graciosa, the Azores and recovered. The buoy was equipped with two ADCPs, a 75 kHz and a 300 kHz. Serial numbers from the ADCPs were sent to the manufacturer and finally traced back to equipment purchased by SNMREC and deployed in February 2009. At the time of retrieval of the first four ADCPs in March 2010, it was discovered that the one located furthest east at an approximate depth of approximately 2,165 ft. in the core of the current was missing. Three years later, it turned up in the Azores. The instruments were recovered by SNMREC and the data is undergoing evaluation. Changes were made to the ADCP buoy design and a GPS monitoring device was installed to provide tracking data should ADCP buoys slip their mooring in the future.

3.2.2 Regulatory Environment

Continuing evolution of state and federal agency requirements is a challenge obtaining permits for open-ocean deployment of even experimental test systems. Pursuing any research and development in renewable energy on the Outer Continental Shelf (OCS) must comply with the federal Outer Continental Shelf Lands Act. With respect to the SNMREC deployments of prototype devices/systems, the major permits, approvals, and authorized actions necessary to construct, operate, maintain, and decommission project facilities while falling outside of State of Florida waters (i.e., greater than 3 miles offshore), will involve interaction with the Florida Fish and Wildlife Conservation Commission due to its agreements with the U.S. Fish and Wildlife Service. Shore-side activities in support of the offshore deployment will be conducted within State waters, at a commercial marina under the purview of the Florida Department of Environmental Protection. These activities also engaged agencies such as the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration's Marine and Fisheries Service, the U.S. Coast Guard, the U.S. Navy, etc.

SNMREC submitted the first lease application in the nation to the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) to deploy equipment related to marine hydrokinetic energy conversion device on the outer continental shelf (OCS). The initial phase of a standalone testing and evaluation infrastructure without transmission of power to shore required an Environmental Assessment (EA) which was conducted by BOEM. BOEM released the Final Environmental Assessment (EA) with a Finding of No Significant Impact (FONSI) on 12 August 2013. The EA and FONSI are located on the Department of Interior's website at: http://www.boem.gov/Florida-Revised-EA-FONSI-August2013/. As required by law, the Department of Environmental Protection, as the State of Florida's lead Coastal Zone Management Act agency, conducted a consistency determination review of the BOEM EA and FONSI. They notified the BOEM on 25 September 2013 that the issuance of a lease to SNMREC for hydrokinetic technology testing is consistent

to the maximum extent practicable with the provisions of the Florida Coastal Management Program. It is anticipated that a lease will be granted to FAU and SNMREC in Q1 of CY2014.

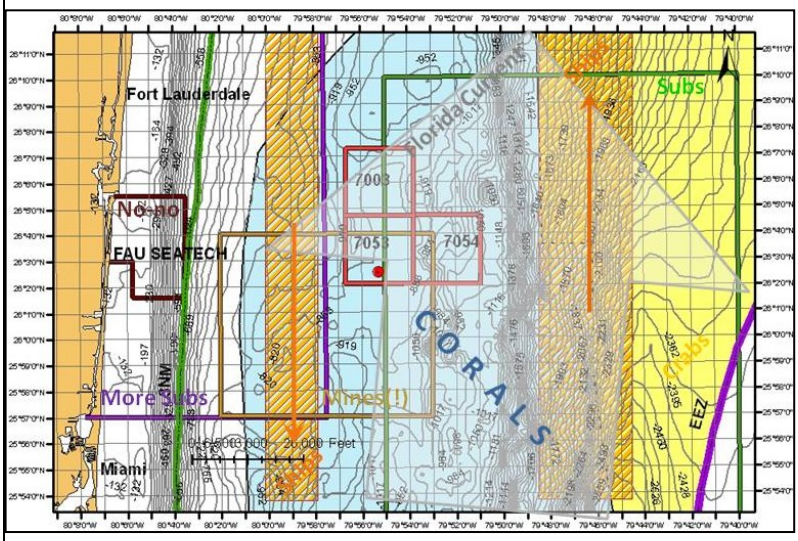


Figure 6. Map of SNMREC requested OCS Lease BOEM Blocks (7003, 7053 and 7054).

Efforts are underway to develop the Project Plan required by the EA. The Project Plan will include any specifics that were not detailed in the original lease application as well as any information necessary to comply with lease and EA stipulations. As this is the first such application for MHK on the OCS, there are still areas being worked out by the agencies.

The three-block area of interest requested in the application includes BOEM defined blocks 7003, 7053 and 7054, as shown with red outlines in Figure 6. The map is a compilation of other identified areas of primary interests and potential user conflicts that were considered during selection of the final BOEMRE blocks.

Recent research results, some of which were supported by the SNMREC, have provided additional information about a newly discovered genus of corals that inhabit the outer parts of the Miami Terrace in the Florida Straits. The vulnerability of these corals to deep-trawl commercial fishing led the National Oceanic and Atmospheric Administration to designate a large part of the sea-bed offshore of Florida and Georgia as a Coral Habitat Area of Particular Concern. While this designation will result in relatively little disruption of the SNMREC's operations – the Center's two or three anchor systems can easily be deployed on the large, sandy patches that exist between coral beds – there will likely be significant challenges for commercial-scale deployments in the future.

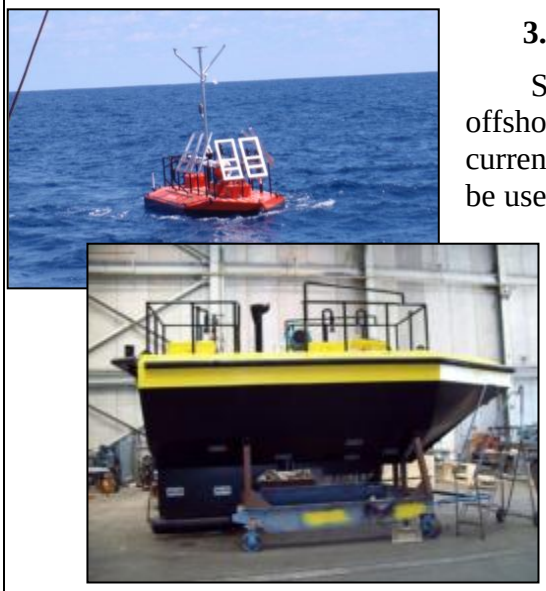


Figure 7. Mooring and Telemetry Buoy (MTB) during open-ocean sea trials.

3.2.3 Infrastructure

SNMREC's proposed initial deployment, approximately 12 miles offshore Fort Lauderdale, Florida which regularly experiences 3-4 kts of current, will consist of an anchored mooring and telemetry buoy (Figure 7), to be used as an attachment point for work boats to deploy prototype systems for testing, and as an observational platform for a variety of environmental and met-ocean studies. The SNMREC's buoy, a design based on the familiar NOMAD weather buoys originally developed by the U.S. Navy in the 1940s, is undergoing final tune-up modifications following a series of successful sea trials earlier this summer. The initial deployment will provide testing capabilities for devices in the 100kW class and smaller.

One of the biggest unknowns in the operation of ocean current turbine (OCT) systems concerns the behavior of the generator sub-system as it experiences both variable loads and the torque differentials associated with changing currents acting on the rotor. In order to provide a capability to test generators under conditions as realistic as possible without actually having to go to sea, SNMREC has

developed a computer-controlled dynamometer system, located at the FAU SeaTech facility in Dania Beach. This capability is further being developed in conjunction with oceanographic measurements and modeling to simulate rotor behavior as it would behave in the current. The 20 kW dynamometer (Figure 8) has been fitted with the SNMREC's experimental research turbine power and health management systems, and is generating data for Prognostics and Health Monitoring (PHM) research. In addition, preliminary work has been completed to emulate rotor behavior in wave conditions and from collected offshore measurements. Testing will continue to include optimization of *in situ* data integration and 20kW research turbine electrical and sensor system testing.

Figure 8. Dynamometer for generator testing (left) and full-up data acquisition and control system (right)

3.2.4 Environmental Monitoring / Demonstration

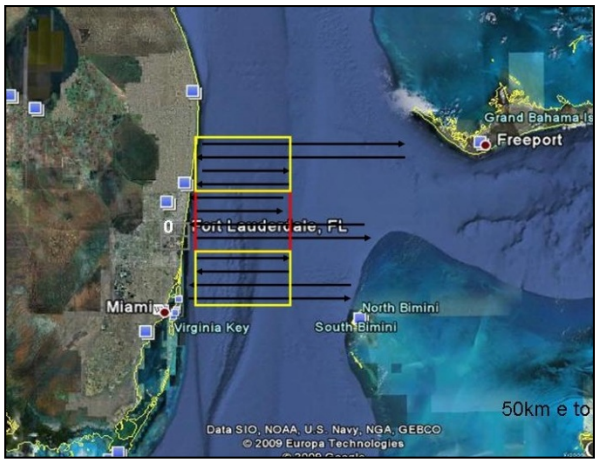


Figure 9. Aerial survey areas offshore Ft. Lauderdale, to determine sea turtle and marine mammal population

Monthly aerial diversity and distribution surveys are being conducted to assess sea turtle and marine mammal populations. The surveys employ the currently accepted protocol – human observers viewing transect areas from a plane flying approximately 500 ft. from the ocean surface. Twenty-four cross-channel and 20+ coastal surveys were completed. Additional along-shore surveys with available historical data are underway. Because preliminary data suggests significant population activity near shore, these transects will provide higher resolution data to support analysis efforts. The research team is working with the National Oceanic and Atmospheric Administration's, National Marine Fisheries Service to evaluate the SNMREC's enhanced approach as an expansion of currently accepted methods. The survey areas currently being assessed are depicted in Figure 9.

3.2.5 Education and Outreach

3.2.4.1 Professional Community

The Southeast National Marine Renewable Energy Center (SNMREC) will provide a centralized, standardized testing capability for ocean current energy conversion prototypes; initially, scaled versions and eventually full-scale devices will be tested. Initial testing in the lease area will be with SNMREC's experimental prototype turbine components and subsystems. SNMREC is working with over forty individual companies as well as industry organizations on a research agenda that is compatible with strategic industry, government, and academic requirements. Balancing the portfolio to meet the diverse priorities is a challenge. Technology R&D, specifically in areas related to intelligent monitoring and environmental assessment will continue as Marine Hydrokinetic (MHK) commercial devices are developed to ensure safety and reduce risk.

The Center supports participation on two International Electrotechnical Commission (IEC) U.S. Technical Advisory Groups (TAG) in developing global standards and conformity assessment practices for marine renewable energy. The two areas of focus of the Technical Committees are wave, tidal and ocean current design, performance and operation (TC114) and mechanical vibrations, shock and condition monitoring (TC108).

Discussions are ongoing to determine testing/validation requirements for open-ocean testing of company's proposed experimental devices at the SNMREC's test facility. Further, critical environmental measurements will be obtained from the observational platform. Additional test berths will need to be installed as commercial devices progress through development gates (including grid-connection and moored stand-alone systems in the 1:4 and 1:1 scale). A future permanent ocean observing system co-located with offshore test facilities will provide real-time environmental measurements, resource characterization, and device performance data. The environmental measurements and assessments, in conjunction with device deployments, will allow for the investigation of interaction with installed MHK systems after baseline ecological activity information is gathered. Education and outreach programs will continue to be fostered in all levels of curricula to populate the growing economic sector, and a publicly available and useful data clearinghouse will provide related and integrated data specifically for MHK and Ocean Thermal Energy Conversion development.

3.2.4.2 Education

SNMREC created and implemented a summer internship program with HBOI, and the United States Coast Guard Academy for the summer of 2013. This ongoing initiative will ran from July 2012 - the summer of 2013, and will continue annually. The cadet selected to participate in the program this year used her research to submit a poster to the National Oceans Conference. This program will enhance cooperation between the U.S. Coast Guard and the SNMREC while educating future officers about projects which will be installed in coastal areas.

The SNMREC continues to partner with the South Broward High School's Marine Magnet Program and presents programs to the students using the SNMREC's curriculum as a basis. The focus of this program is technological while also highlighting interactions with the environment.

SNMREC staff worked with professors and students at FAU's School of Communications and Multimedia Studies' to create an interactive educational display game. In partnership with HBOI, the SNMREC is designing and installing a kiosk in their Ocean Discovery Center. The kiosk is anticipated to be installed by January 2014 and will create a hands-on experience which educates the public about future ocean energy projects. This effort will be leveraged to provide similar kiosks to science and discovery museums. The intent is to provide an opportunity to engage all ages in a hands-on, fun and educational experience about ocean renewable energy production. The kiosks will increase knowledge of real, cutting- edge research in renewable energy from the ocean as well as, incorporating valuable Science Technology Engineering & Math (STEM) content to foster a well- informed *constituency that* understands the importance of renewable energy production in the U.S.

In collaboration with Florida Atlantic University's Lifelong Learning Society (LLS), the SNMREC presented two lectures to members of the LLS. The LLS at FAU is a 20,000 member strong organization providing an opportunity to introduce MHK energy to a wider age spectrum of the population.

A seventh lesson is in development for the SNMREC curriculum for high school based on civics/social studies. This lesson instructs the students on the important role that the government has in renewable energy production and advancement. The lesson is based on the same educational model as the original curriculum, the "5E's"; Engaging, Exploring, Explaining, Elaborating and Evaluation. Appropriate activities and Sunshine State Standards are included.