COASTAL RECREATIONAL FISHING LICENSE
FINAL PERFORMANCE REPORT

Principal Investigator: Hans W. Paerl, Kenan Professor of Marine and Environmental Sciences, UNC-CH Institute of Marine Sciences, Morehead City, NC 28557 (252) 726-6841, Ext. 133 (hpaerl@email.unc.edu)

Grant Award #: 2013-H-012

Grant Title: FerryMon: NC DOT Ferry-based automated monitoring of water quality and fisheries habitat condition in the Pamlico Sound System, NC

Grant Award Period: July 1, 2013 – December 31, 2016

This is a final report on the Ferry-based Water Quality Monitoring Program for Pamlico Sound System, FerryMon. Included is information on monitoring, assessment, research, reporting, educational and public informational outreach from the July 1, 2013 – June 30, 2016 funding period.

Project Costs:

Expenditures for the Period: 07/01/2013 – 12/31/2016

Category	Expenditures
Personnel	$187,931.18
Fringe	$58,809.67
Travel	$0.00
Equipment	$3,000.00
Supplies	$43,794.04
Communications	$1,310.80
Graduate Assistant Tuition	$2,085.75
Miscellaneous Services	$85,493.60
Total Direct	$382,425.04
Indirect	$56,707.19

Total Cumulative Expenditures for the Grant Award Period: $439.132.23

Total Remaining Balance: $12.95

Description of Work:

The NC Coastal Habitat Protection Plan (CHPP; Deaton et al 2010) identified the need to increase the coverage of continuous water quality monitoring so that water quality standards specific to fishery communities can be developed. In addition, the CRFL Strategic Plan highlighted the objective to "identify, designate, and conserve fish habitat and SHAs". This project specifically addressed Strategy H.2.3, which aims to inventory and conduct research and monitoring to determine status of and trends in the six basic fish habitats, the water column in particular. The FerryMon program utilized two NC-DOT ferries outfitted with continuous, flow-thru water quality measurement systems that operate along routes that are near to or go through areas nominated as SHAs in Region 2. Many of the parameters included in FerryMon's arsenal of water quality indicators address this strategy.

The project objective, therefore, was to use FerryMon to establish the status and trends in water column habitat conditions in the Pamlico Sound and Neuse River. The continuous nature of the FerryMon data collection capabilities also serves as an early warning system for significant changes in water quality conditions. Specific objectives included:

1. Use FerryMon's flow-thru detection system to monitor surface salinity, temperature, dissolved oxygen, pH, turbidity and chlorophyll *a* (Chl *a*, an indicator of algal biomass and potentially-harmful blooms) conditions in the APES, adding to an over ten year database.

2. Use time series analysis of historic data to establish trends in water quality parameters that specifically impact fishery species growth, reproduction, and survival (e.g., temperature, salinity, and pH). These trends will be then compared to trends in

fishery-dependent and independent data for determining relationships that can be utilized to help refine stock assessment models.

3. Use the real-time data collection to provide rapid detection of significant changes in water column physical-chemical conditions pertinent to fish health. For example, FerryMon is able to monitor wintertime temperatures and warn of potential cold stun or kill events.

Other, secondary objectives included updating and maintaining the FerryMon web site, www.ferrymon.org, which is used for communicating key findings to NCDENR (DMF, DWR), NGO's, educational institutions (K-12, universities) and the public, collecting nutrient and other samples using on-board automated water samplers, providing data for remote sensing algorithm development and calibrations.

Work Accomplished:

Year 1, 1 July 2013 – 30 June 2014

The components which made up the FerryMon flow-thru systems had been offline for almost two years due to a lapse in state funding, so the primary task to meet the first objective was to return the systems to working order. This task entailed fixing and replacing corroded fittings, calibrating and replacing bad sensors on YSI sondes, and loading and reconfiguring data collection software on computers. This work was completed quickly on the M/V Lupton, which crosses the Neuse River, but took longer on the M/V Carteret, which crosses Pamlico Sound, due to scheduling limitations and unknown data logger problems.

Cellular modems were installed on the ferry computers that allow wireless remote communication to the data collection platform. Real-time conditions can be monitored by project staff from anywhere, although the current software still requires manual downloads of data files for quality control.

The data collected was subjected to quality control checks and entered into the existing relational database. Almost 18,000 records of data collected from the M/V Lupton (Neuse River) during Year 1 were added. Data from the M/V Carteret on the Pamlico Sound were also checked for accuracy and suitability. On 3 December 2013, NC-DOT set up an emergency ferry route because of the closure of the Bonner Bridge over Oregon Inlet. The M/V Lupton was moved to that route until 15 December, 2013 and the FerryMon sampling and sensing system was able to operate during most of the period collecting water quality data from the inlet route.

On 19 May 2014, the M/V Lupton was moved by the Ferry Division from its normal Neuse River route to the Hatteras-Ocracoke ferry route to accommodate summer time traffic and the longer route necessitated by shoaling in Hatteras inlet. The flow-through system continued to operate on this new, temporary route, although it made servicing and troubleshooting more difficult and more dependent on Ferry Division staff. On the other hand, we collected data from an area rarely monitored.

A temperature time series generated from the FerryMon database was shared with a member of the Marine Fisheries Commission Finfish Advisory Committee for use in an analysis of red drum morality (see “Collaborations” below).

During Year 1 there were no major events (i.e., no major tropical cyclones or nor’easters) noted that would have significant impact on fish health. Late in January 2014, the system on the M/V Lupton recorded temperatures below 5 °C, conditions which have in the past led to cold stun events for spotted seatrout (*Cynoscion nebulosus*) (Fig. 1). The DMF contact for cold stun events, Chip Collier, was contacted and made aware of the conditions on the ferry route. The Division closed coastal and inland waters to commercial and recreational spotted seatrout harvest through June.

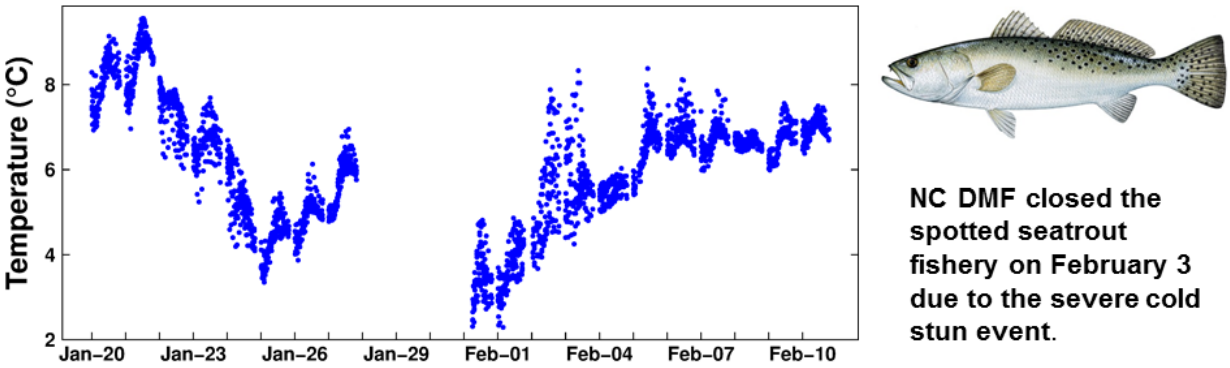

Figure 1. Data from FerryMon program collected during February 2014 seatrout cold stun event

The existing FerryMon web site was updated to include customizable plots of several water quality variables (Fig. 2). Visitors to the page can adjust the date range window and can change which variables are shown. In the example, the spatial variation in water quality can be seen. Higher salinity, temperature, and chlorophyll values were recorded on the northern, Minnesott Beach end of the route. The chlorophyll values (fluorescence) were at times quite high (above the 40 µg L-1 TMDL acceptable water quality criterion), which corresponded to a dinoflagellate bloom (*Prorocentrum minimum* and *Heterocapsa triquetra*) identified by Dr. Nathan Hall at IMS a few days earlier.

A webcam was mounted on the bridge of the M/V Lupton, which served to inform the public (via the New Bern-Ch.12 WCTI and Washington-Ch. 7 WITN TV stations and the FerryMon website) of water conditions on the Neuse crossing. Images from the webcam were retrieved at one minute intervals and posted to the FerryMon website. An example of the webcam page is shown in Figure 3. The images were used to assess weather and sea state conditions on the river.

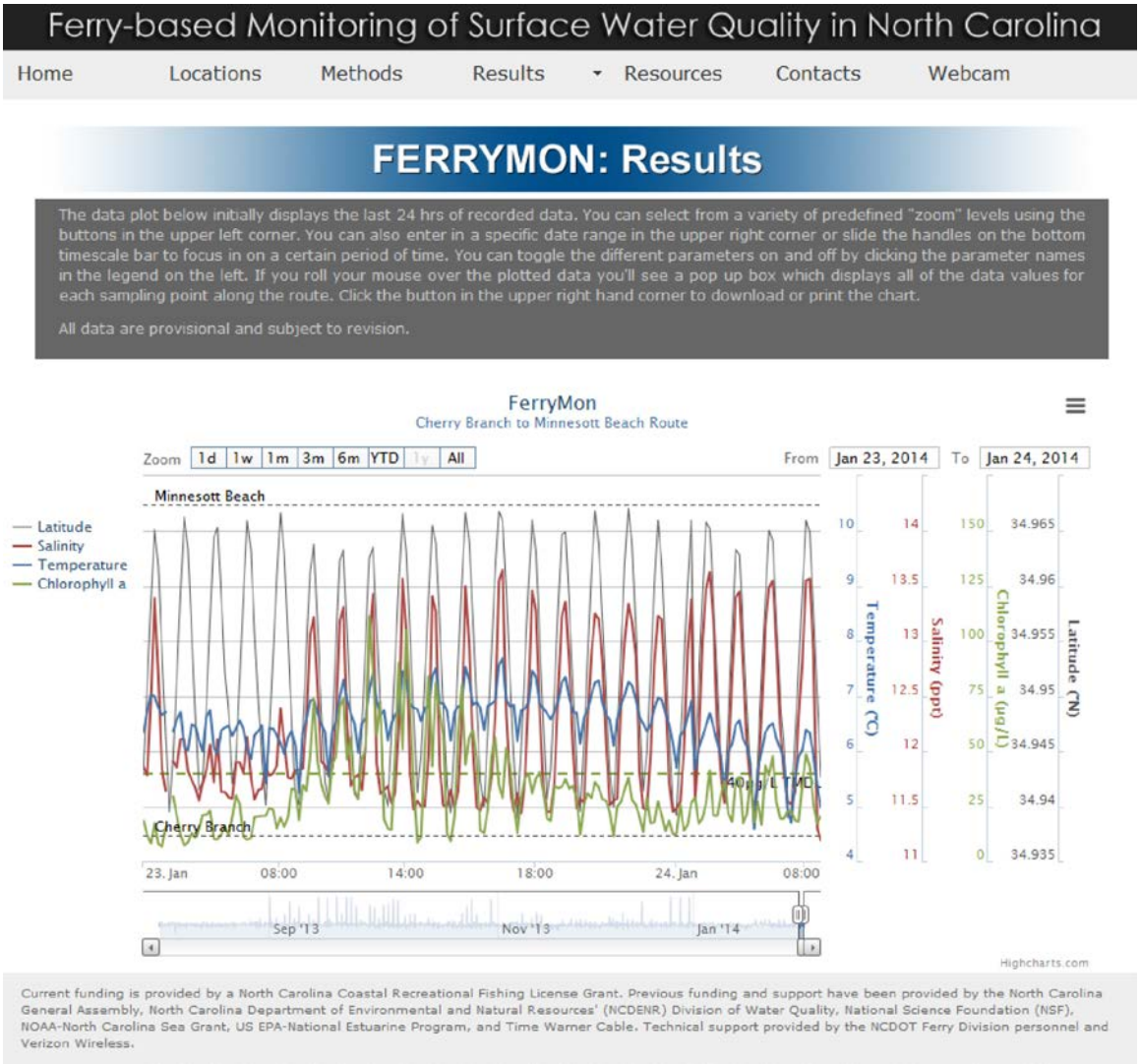

Figure 2. Example of FerryMon results from updated website (www.ferrymon.org).

Figure 3. Example of FerryMon webcam page from updated web site (www.ferrymon.org).

Year 2, 1 July 2014 – 30 June 2015

The objective to monitor surface water quality conditions using FerryMon was met during the Year 2 by the collection of over 22,500 data records from the M/V Lupton on four separate routes and while the ship moved between routes. These data were subjected to quality control checks and entered into the existing relational database and are routinely shared with NCDEQ-DMF and DWR. Additional data collected were collected from the M/V Carteret (Cedar Island to Ocracoke and Ocracoke to Swan Quarter, 2), but were suspect because of water flow issues (see Deviations below).

Starting in May 2014, the DOT Ferry Division moved the M/V Lupton from its normal Neuse River route to the Hatteras-Ocracoke route (Fig. 4) in response to the increase in summer traffic and the longer route necessitated by shoaling in Hatteras inlet. The flow-through system operated intermittently on this new, temporary route, providing water quality data from an area rarely monitored. Data collection on the Neuse River route resumed on 18 November. Sampling along the Neuse River route continued until 14 December, when the Ferry Division reassigned the M/V Lupton to the Bayview-Aurora route traversing the Pamlico River (Fig. 4). In April 2015, prior to being moved to the Fort Fisher to Southport route, the M/V Lupton was temporarily assigned to the Hatteras-Ocracoke route; unfortunately no data were collected because ferry personnel had shut the system off. The Lupton operated on the Cape Fear River along the Fort Fisher to Southport route until it moved back to the Hatteras to Ocracoke route on 4 May. On 7 June the Lupton was taken offline and moved to Ferry Division shipyard for scheduled maintenance. Some data collection continued aboard the M/V Lupton during these various reassignments.

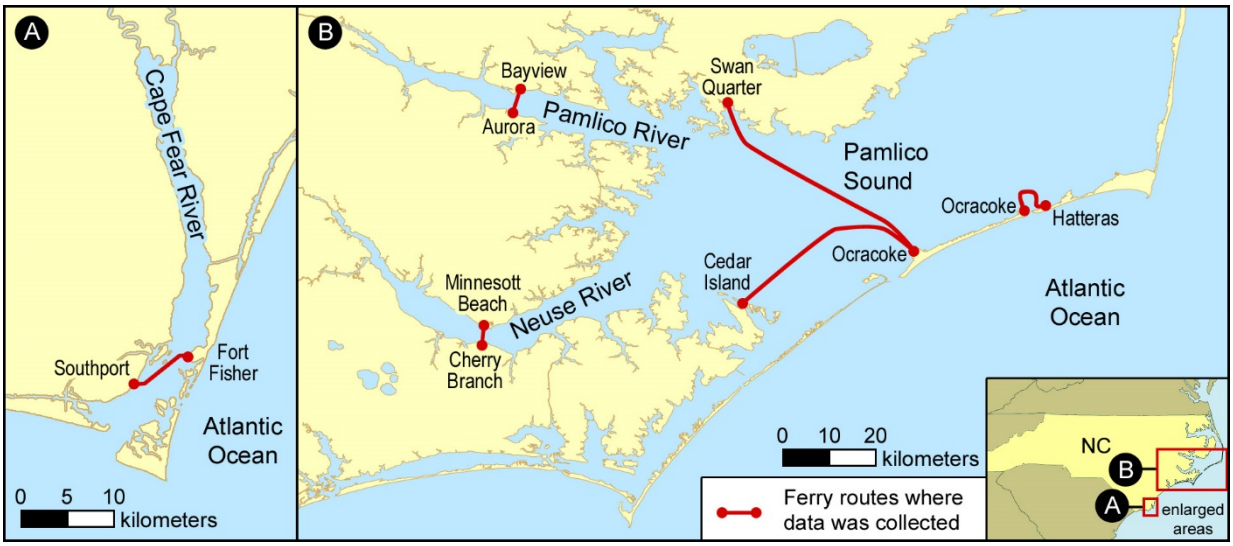

Figure 4. Map showing NCDOT ferry routes where data was recorded during July, 2014, to June 2015.

The time series analysis of ferry-based data was complicated by the aforementioned shuffling of the ferry fleet. However, this shuffling provided opportunities to collect surface water quality data from areas not previously sampled by FerryMon. We processed and sorted the data collected from the different routes and made interactive

plots for the newly sampled routes available in the results section of our website, www.ferrymon.org.

Neuse and Pamlico River salinity data were provided to the NCDOT Ferry Division so they could determine maintenance schedules for ferries that operate along those rivers. A temperature time series generated from the FerryMon database was shared with a member of the Marine Fisheries Commission Finfish Advisory Committee for use in an analysis of red drum mortality.

The effect of wind on the spatial distribution of salinity was examined using the time series collected on the Pamlico River route (Fig. 5). Over a period of nine days, salinity varied between a pattern of a south to north increase to one of a south to north decrease, depending on the wind direction and strength. When the wind was from the north, less saline water was pushed to the south shore and higher salinity water was upwelled to the north shore. The pattern was reversed when the wind came from the south and west (Fig. 5, 2 Feb). A lack of a spatial salinity gradient was noted when wind speeds were low. This system behavior is similar to salinity spatiotemporal patterns on the Neuse River based on FerryMon data and related parallel research (Reynolds-Fleming and Luettich, 2004).

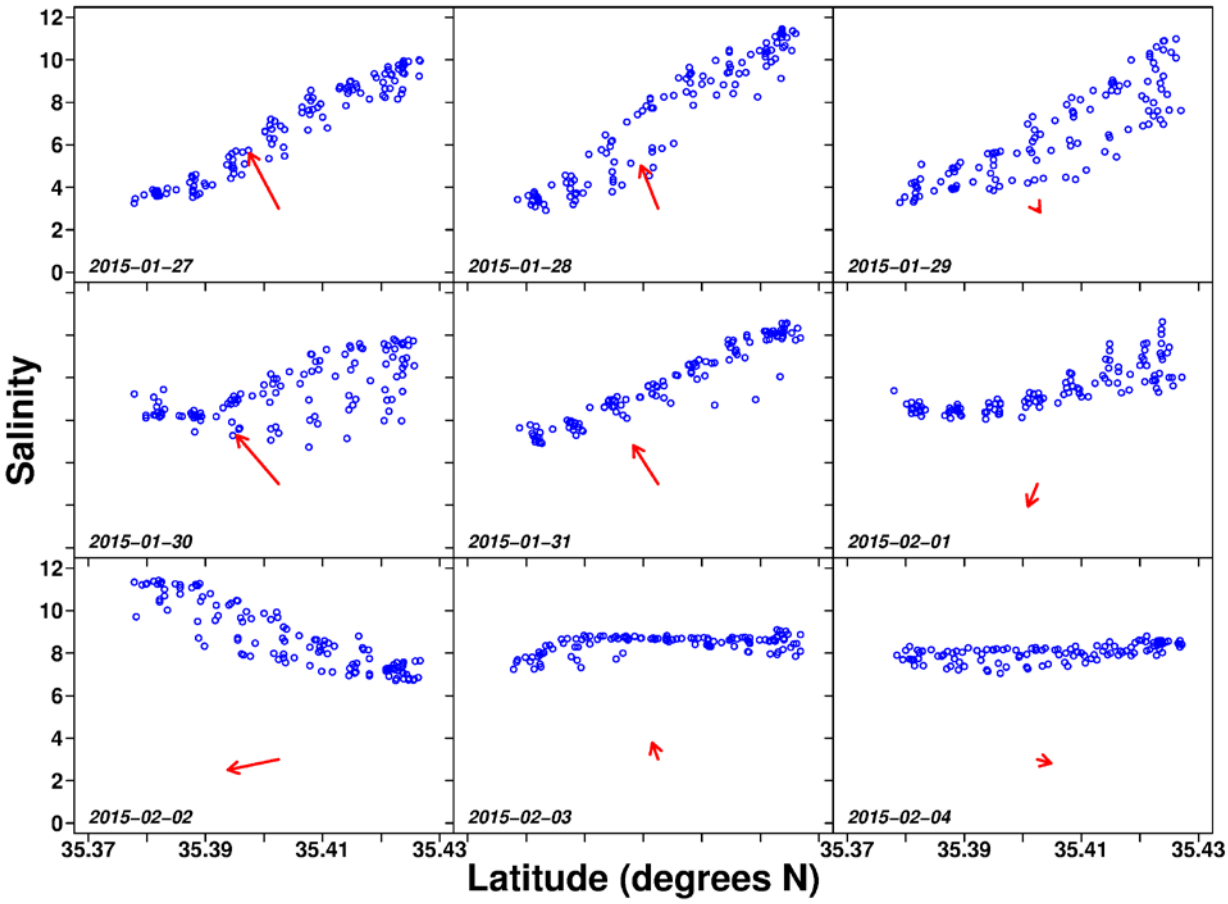

Figure 5. Salinity (blue circles) versus latitude by day for the Bayview-Aurora route across the Pamlico River. Each panel represents salinity for all crossings during a single day. The south shore is to the left (Aurora) and the north shore is to the right (Bayview). The red arrows are daily mean

wind direction and speed, where the arrow points in the direction the wind came from and the length of the arrow indicates relative speed.

During Year 2, two tropical storms passed through or near the ferry sampling area. Hurricane Arthur made landfall and crossed the Pamlico Sound during 3 and 4 July 2014. The FerryMon system was offline during the storm passage, since ferries are removed from service for safety reasons. Pre- and post-storm data, however, were collected from the Hatteras Inlet area. While the storm did produce several inches of rain, wind and storm surges were the dominant impacts from Arthur and no major change in salinity was evident (Fig. 6, top). A much larger difference in salinity was evident when comparing data from September 2014 with the pre- and post-storm data (Fig. 7). Pamlico Sound salinity was significantly lower in September due to higher rainfall totals in the watershed and on the sound itself. A similar examination of data collected in May 2015 captured the effect of Tropical Storm Ana on Hatteras Inlet salinity. Ana was quite weakened when it passed far inland of the inlet, but the storm did generate significant rainfall. A decrease in salinity near the inlet was noted in the FerryMon data, although the effect was short-lived (Fig. 6, bottom).

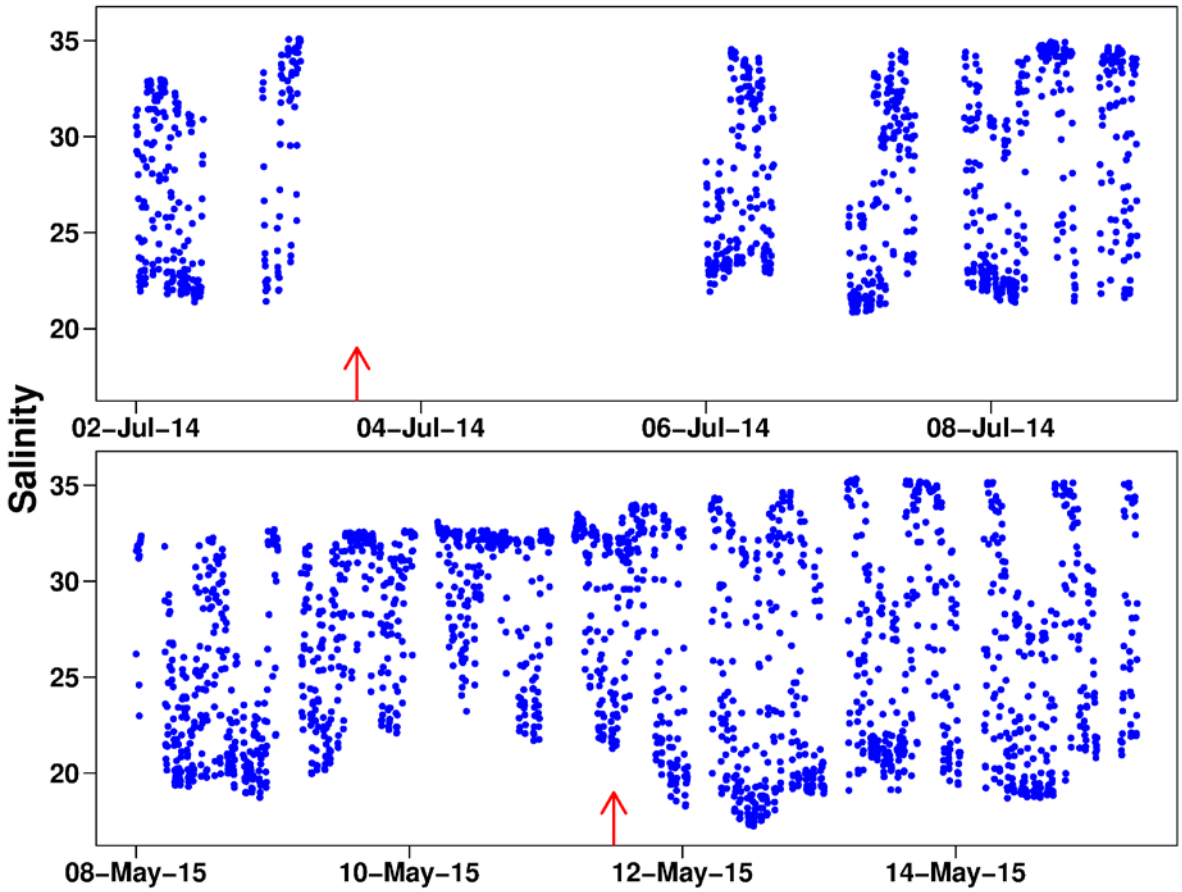

Figure 6. Salinity data collected aboard the M/V Lupton along the Hatteras to Ocracoke route during two periods spanning tropical storm passage. Top is during the 2014 landfall of Hurricane Arthur, which passed close to the ferry route. Bottom is during the 2015 passage of Tropical Storm Ana inland and upstream of Pamlico Sound. Arrows represent dates when storms were closest to ferry route.

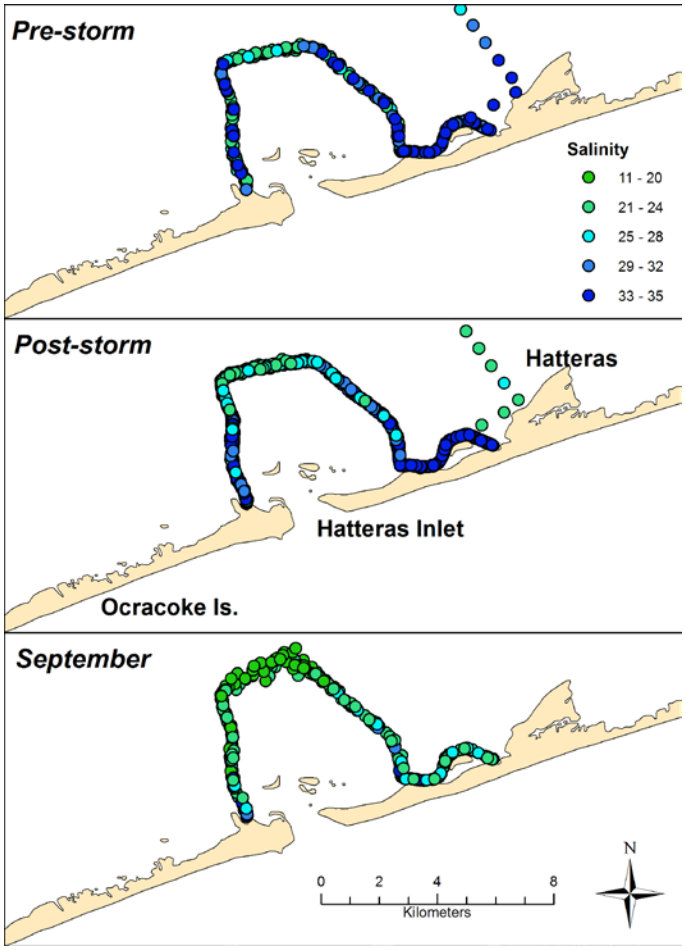

Figure 7. Salinity data from the FerryMon program collected before and after Hurricane Arthur (3 July 2014), as well as in September 2014. Each point represents an independent measurement, with the color representing salinity range. Data were collected from 2 to 3 July (Pre-storm), 4 and from 6 to 9 July (Post-storm), and 23 to24 September.

In mid-February 2015, the sensor on the M/V Lupton recorded temperatures below 1 °C on the Pamlico River route (Fig. 8), conditions which have in the past led to cold stun events for spotted seatrout. Ice was evident on the water surface and there were unofficial reports of stunned fish in the area. A report of the low temperatures was sent to Chip Collier, who had been the species lead for Spotted Seatrout. The fishery was not closed due to this event. A similar event was captured by the FerryMon system in February 2014. At that time, stunned fish were reported and a proclamation to close the fishery was made by the Division of Marine Fisheries.

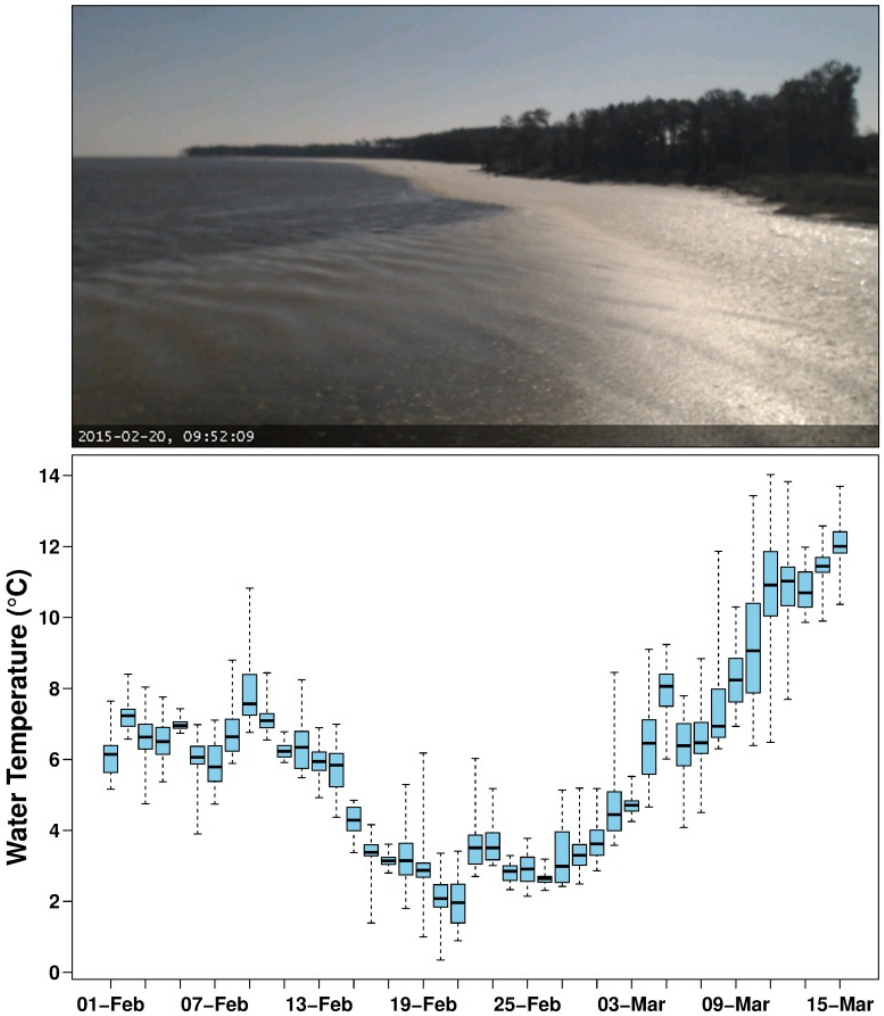

Figure 8. Top is image captured from web cam on 20 February 2015 aboard the M/V Lupton while on the Pamlico River (Bayview-Aurora route). Ice is visible on water surface and shoreline. Bottom is daily water temperature data collected during February and March 2015 at the same location. Horizontal line is daily median, box is interquartile range, and whiskers are daily minimum and maximum.

Year 3, 1 July 2015 – 31 December 2016

Both vessels were in the shipyard for scheduled maintenance at the beginning of the reporting period. In March, we were informed that the M/V Carteret had returned to its usual Pamlico Sound route and the M/V Lupton was put on the Hatteras to Ocracoke route. Monitoring equipment was restored on the M/V Carteret, but it took some time to get the data collection platform and GPS systems working properly. By June, water quality data with associated GPS coordinates were being stored.

The Ferry Division had agreed to help remove probable blockages in the water supply and waste lines on the M/V Carteret. Once data was being collected, it soon became apparent from the lack of change in the data that there was still a problem with water flow. The water supply pressure was quite sufficient, so the assumption is that a blockage

still exists in the waste line that joins the A/C water thru-hull discharge. We notified the ferry division of the blockage and it was cleared in October. We reinstalled the onboard instrumentation, but the power supply to the onboard computer was faulty. After replacing the onboard computer, we are now able to collect water quality data along the Cedar Island to Ocracoke route, as well as the Ocracoke to Swan Quarter route. We also installed the webcam to visually monitor weather conditions along this routes. The live shot from the webcam is featured on the FerryMon website: http://www.unc.edu/ims/paerllab/research/ferrymon/images/webcam.html. Since gaps in cellular coverage prevent continuous communication with the vessel, webcam images and data are not always available on demand. An external antenna for the cellular modem was installed, with only marginal improvements.

With data collection proceeding again, we were able to observe the effect on Pamlico Sound from Hurricane Matthew, which passed the southern Outer Banks during 9 October 2016. Valid data was not available from immediately before the storm, but by comparing salinity measurements during the two months following the storm to those from December 2013, a time with average freshwater discharge, the freshening effect from the massive inland flooding is quite evident (Fig. 9). The last time salinity was this low was after three hurricanes (Dennis, Floyd and Irene) impacted the area during a 6 week period in in 1999 (Paerl et al. 2001). The area of reduced salinity is widespread across the sound and reflects the elevated discharge from both the Neuse and Pamlico rivers. This effect has been persistent and higher salinity values are only just appearing in the vicinity of Ocracoke Inlet.

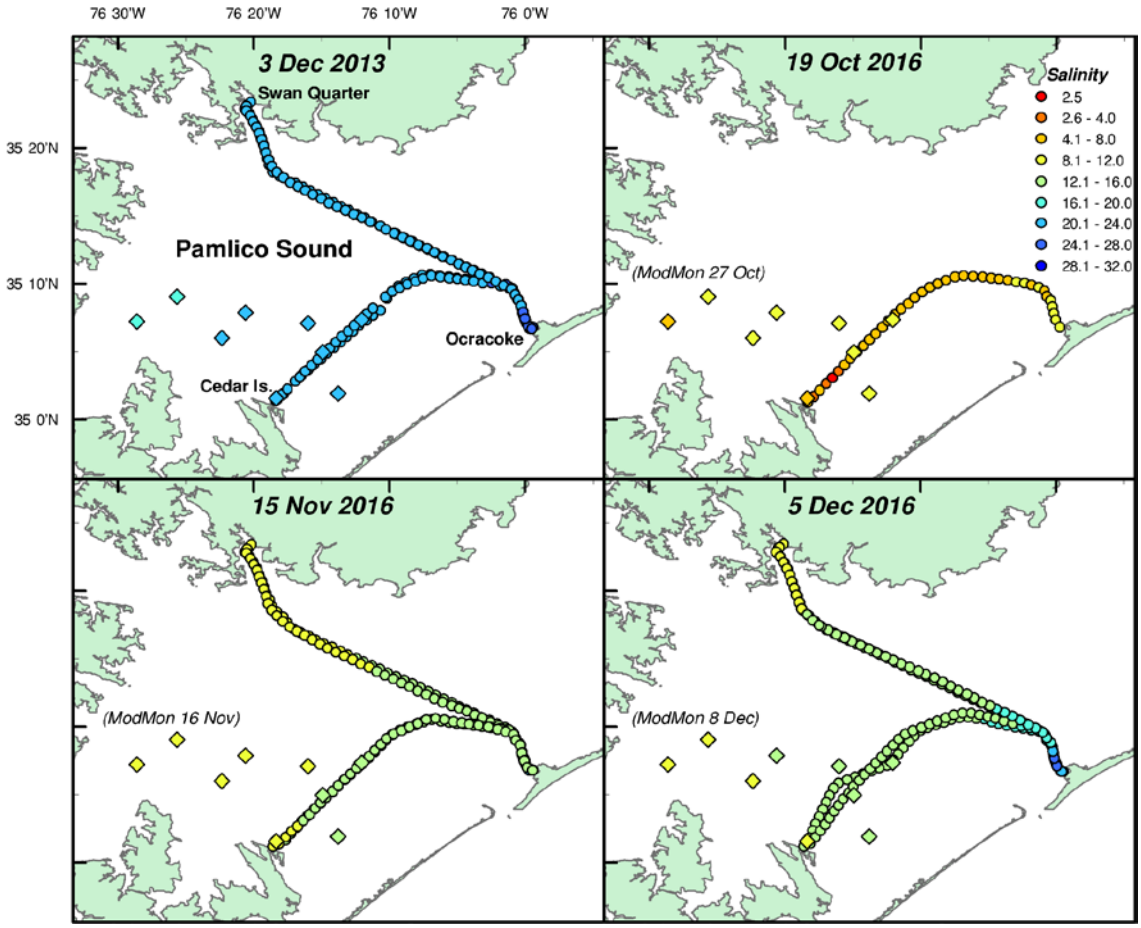

Figure 9. Salinity data collected by FerryMon (circles) and ModMon (diamonds) throughout Pamlico Sound in December 2013 (reference conditions) and after flooding from Hurricane Matthew in October 2016. Actual date for ModMon measurements noted in parentheses.

During Year 3 we also continued to refine our design for a new, more portable monitoring system that we can quickly install on an additional vessel, should one of our primary vessels be taken offline again in the future (Fig. 10). After estimating the cost to build this new system, we determined that we did not have adequate funding needed to build it. We applied for, and recently received, funding from the Duke Water Resources Fund to construct two of these systems. The first system is intended to be installed aboard the M/V Kinnakeet and the second system will be installed on a ferry that traverses the Ocracoke/Cedar Island and Ocracoke/Swan Quarter route. We hope to have both systems ready for installation this coming spring (2017).

The auditing of historical data continued during the reporting period. We previously uncovered records in the database that had been collected while the system was being flushed with freshwater for maintenance purposes. We have continued to search for similar invalid records, including readings collected while the ferries were at dock (added to the database prior to a location filtering procedure being implemented) or when the water supply to the system was shut off. These latter periods can be identified by salinity time series that show little variation along the ferry route.

Another data issue being considered is the separation of specific routes into separate databases. The original FerryMon database model had a separate database for each of three routes, each with its own vessel and data collection platform. Over time, the program was reduced to two outfitted vessels and two routes. The Ferry Division often changes the route a particular vessel travels, and the M/V Carteret has frequently done the route between Ocracoke and Swan Quarter along with the route between Cedar Island and Ocracoke. This has resulted in some of the data collected on the Ocracoke to Swan Quarter route to be part of the Cedar Island to Ocracoke database. The current objective is to maintain consistency through the separation of data by route, although this is complicated by the fact the two routes partially overlap.

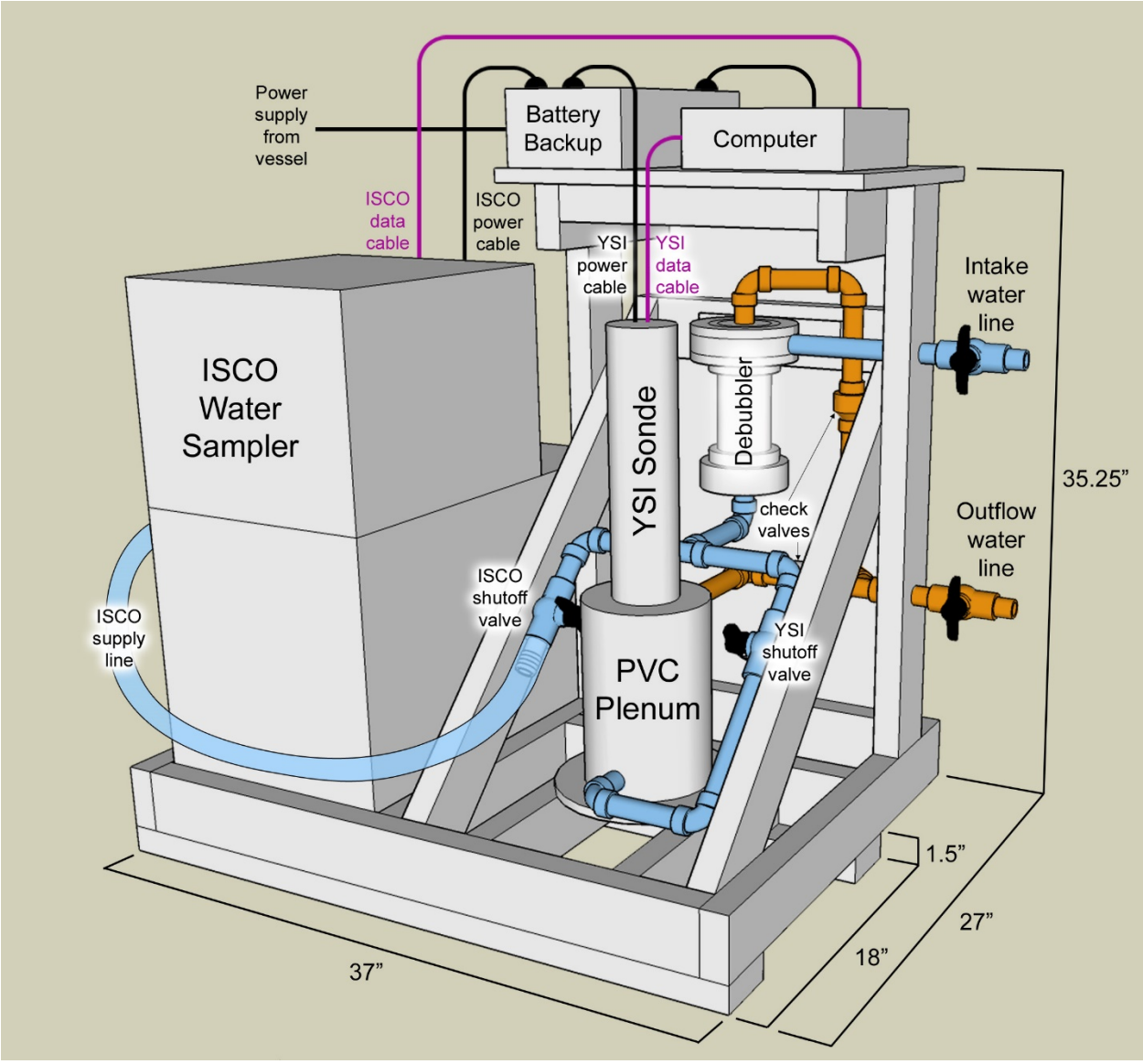

Figure 10. A diagram of the new onboard water quality monitoring system, designed in conjunction with the NC Ferry Division, for installation onboard the M/V Kinnakeet, which crosses the Neuse River. This system is more portable than our current onboard equipment, which should give us the ability to quickly move our equipment to a different vessel and avoid monitoring delays if vessels are taken offline for maintenance or reassigned to different routes in the future.

Other Accomplishments, Collaborations, and Outreach:

Collaborations

One of the secondary objectives for the project was to engage in local, national, and international collaborations in order to enhance and exchange the technology for unattended ferry-based water quality and habitat monitoring. Locally, FerryMon has provided data for NC DENR Division of Marine Fisheries (e.g., fish habitat condition and environmental stressors, such as cold stun and extreme variations in salinity) and the Division of Water Resources (as a critical data sources for the chlorophyll a-based TMDL and Ambient Monitoring Program for the Neuse Estuary). We made data available for Kenneth Seigle, who is assessing the effect of temperature on the mortality rates of captured (and released) red drum for Marine Fisheries Commission Advisory Committee discussions. In addition, we collaborated with several ongoing CRFL projects (Drs. Joel Fodrie, Niels Lindquist, Michael Piehler, P.I.s) by providing crucial environmental data (salinity, pH, temperature, DO, turbidity). We also collaborated with the Albemarle Pamlico National Estuary Partnership (APNEP) to provide environmental condition and educational information for researchers, educators, fishers, NGO's, tourists, environmental managers and decision makers.

Outreach Activities and Presentations

Several public presentations were given that featured FerryMon:

Paerl, H. W. 2014. "FerryMon: Keeping a watchful eye on water quality on North Carolina's Pamlico Sound System." Oral presentation at the EDUK8 4 Clean Water Workshop for NC Teachers organized by the Core Sound Waterfowl Museum and Heritage Center, 22 July 2014.

Paerl, H. W. 2014. Guest speaker at Lower Neuse Basin Association 20th Anniversary Reception. Cliffs of the Neuse State Park, 23 July 2014.

Paerl, H. W., B. L. Peierls, N. S. Hall, K. L. Rossignol and A. R. Joyner. 2014. FerryMon and ModMon: Keeping a watchful eye on North Carolina's Pamlico Sound System. APNEP Annual Conference, New Bern, NC. August, 2014.

Paerl, H.W., J, Crosswell, B. Peierls, N. Hall and K. Rossignol. 2014. FerryMon: Ferry-based, real-time assessments of human and climatically-driven environmental change in the Pamlico Sound Estuarine system, North Carolina, USA. Presented at the 248th American Chemical Society National Meeting, San Francisco, CA; August 10-14, 2014.

Paerl, H. W., N. S. Hall, B. L. Peierls, K. L. Rossignol, and A. R. Joyner. 2014. Coastal eutrophication dynamics and controls in a culturally and climatically stressed world. Keynote talk: Delta's in Time of Climate Change Conference, Rotterdam, Netherlands, September 2014.

Paerl, H.W. J.R. Crosswell, B.R. Van Dam, J.W. Stanhope, I.C. Anderson, B. Abare, K.L. Rossignol, B.L. Peierls. N.S. Hall. 2015. Impacts of human and climatic perturbations on green, black and blue carbon in our estuaries. Presented at the Atlantic Estuarine Research Society Meetings, Manteo, NC, March, 2015.

Paerl, H.W. I.C. Anderson, W.S. Gardner, M.J. McCarthy, N.S. Hall, B.L. Peierls, and K.L. Rossignol. 2015. Controlling eutrophication along the freshwater-marine continuum: Why the need for dual nutrient input constraints? Coastal and Estuarine Research Federation Conference. Portland, OR. Nov. 2015. Oral presentation.

Paerl, H.W. B. L Peierls, A.G. Hounshell and C.L Osburn. Poster presentation. The source and fate of bioavailable dissolved organic nitrogen in the Neuse River Estuary, NC. American Geophysical Union Meetings, San Francisco, CA, 13-16 Dec., 2015.

Paerl, H.W. Invited lectures, Coastal Eutrophication and harmful bloom dynamics. Austral Summer Ecology Course, University of Concepción, Chile, 8-25 January, 2016.

Paerl, H.W., H. Xu, B. Qin, G. Zhu, N.S. Hall, K.L. Rossignol, J.T. Scott and K.E. Havens. Controlling proliferation of harmful cyanobacterial blooms in a world experiencing human and climatic-induced change. Plenary Lecture, International Symposium 24th Anniversary of World Water Day, Seoul, S. Korea, 19 April, 2016.

Paerl, H.W., W.S. Gardner, M.J. McCarthy, T.G. Otten, N.S. Hall, K.L. Rossignol, H. Xu, G. Zhu, B. Qin and A.R. Joyner. Mitigating global proliferation of harmful algal blooms in a human and climate-impacted world: The need for dual nutrient (N & P) input reduction strategies. Invited talk, 5th International Ecosummit Symposium, Montpellier, France, 30 August, 2016

Publications Partially or Entirely Supported by FerryMon Project (since 2014)

Paerl, H.W., N.S. Hall, B.L. Peierls, and KL. Rossignol. 2014. Evolving paradigms and challenges in estuarine and coastal eutrophication dynamics in a culturally and climatically stressed world. Estuaries and Coasts 37(2): 243–258.

Crosswell, J.R. M.S. Wetz, B. Hales, and H.W. Paerl. 2014. Extensive CO2 emissions from shallow coastal waters during passage of Hurricane Irene (August 2011) over the Mid-Atlantic Coast of the U.S.A. Limnology and Oceanography 59:1651-1665.

Dixon, J.L., C.L. Osburn, H.W. Paerl and B.L. Peierls. 2014. Seasonal changes in estuarine dissolved organic matter due to variable flushing time and wind-driven mixing events. Estuarine, Coastal and Shelf Science 151 (2014) 210-220.

Hall, N.S, A.C. Whipple and H.W. Paerl. 2015. Vertical spatio-temporal patterns of phytoplankton due to migration behaviors in two shallow, microtidal estuaries: Influence on phytoplankton function and structure. Estuarine, Coastal and Shelf Science 162:7-21.

Thompson, P.A., T.D. O'Brien, H.W. Paerl, B.L. Peierls, P.J. Harrison, M. Robb. 2015. Precipitation as a driver of phytoplankton ecology in coastal waters: A climatic perspective. Estuarine, Coastal and Shelf Science 162:119-129.

Kimmel, D.G, B.D. McGlaughon, J. Leonard, H.W. Paerl, J.C. Taylor, E.K. Cira, M.S. Wetz. 2015. Mesozooplankton abundance in relation to the chlorophyll

maximum in the Neuse River Estuary, North Carolina, USA: implications for trophic dynamics. Estuarine, Coastal, and Shelf Science 157:59-69.

Cira, E. M.S.Wetz, and H.W. Paerl. 2016. Effects of Nitrogen Availability and Form on Phytoplankton Growth in a Eutrophied Estuary (Neuse River Estuary, NC, USA). PLoS One DOI:10.1371/journal.pone.0160663..

Other Products

Brochures describing the FerryMon Program were distributed to educators attending the DESTINY Traveling Science Learning Program from the Morehead Planetarium and Science, Chapel Hill, NC.

FerryMon brochures were also distributed to the general public during a National Estuaries Day event at the Beaufort Maritime Museum in September 2014. A hands-on demonstration of our water quality monitoring equipment was also featured at this event.

Staff associated with FerryMon joined SciREN (The Scientific Research and Education Network) to partner with educators to develop standards-based lesson plans that will effectively convey our research findings to students in the classroom. We designed a lesson plan and presented it to educators at a networking event at the NC Aquarium at Pine Knoll Shores on 12 February 2015 and again on 18 February 2016. This lesson plan is currently available for download through the SciREN online portal and being utilized by teachers in the classroom. Two UNC-Ch PhD students associated with the FerryMon program, Alexandria Hounshell and Bryce Van Dam, are also serving on the SciREN COAST organizational team.

On 19 March 2014, 28 April 2015, and 26 April 2016 FerryMon staff gave presentations about FerryMon to 11th and 12th grade students at the North Carolina School of Science and Math, Durham, NC.

FerryMon project members collaborated with April Smith at In Situ Explorers to write a chapter for an upcoming book designed to encourage kids to get outdoors and explore science in the world around them. This book will feature 30 – 50 current research sites around NC and identify ways that readers can get involved in the ongoing research. Our chapter featured the FerryMon program and highlighted the importance of water quality monitoring in NC estuaries.

Interactive data plots for the various ferry routes sampled were made available online at our website: www.ferrymon.org. A live webcam was in place and transmitting images onboard the M/V Lupton ferry. When the ferry is running, this live shot was shared with regional news stations and featured during on air broadcast, helping to raise public awareness of our ongoing water quality monitoring project. We also maintained a Twitter newsfeed to help communicate findings and raise public awareness for this project.

Deviations:

The major objectives for the project remained the same throughout the project period. Unfortunately, due to the aging ferry fleet, the Ferry Division frequently reassigned its vessels to different routes while taking other ferries offline to service them in the shipyard. This unpredictability with the ferries made it difficult to maintain continuous water quality monitoring efforts along the Neuse River, as the M/V Floyd J. Lupton, which is equipped with FerryMon instrumentation, was often operating along other routes. We were informed by the Ferry Division that the M/V Kinnakeet would be the consistently running along the Neuse. Since we preferred to continue monitoring the Neuse for reasons of the historical dataset, the existing parallel monitoring program (ModMon), and the proximity to our facilities, we began plans to outfit the M/V Kinnakeet with an onboard monitoring system. While we were able to work with the Ferry Division to design a new system that would be suitable to install aboard the M/V Kinnakeet, we did not have money budgeted in this project to build it. We submitted a proposal to the Duke Water Resources Fund and recently received funding from them to construct two new onboard water quality monitoring systems this winter. The new systems will be more portable than our existing systems, so we can easily transfer the system to another vessel if one of our primary ferries gets reassigned to different route. Once the new equipment is installed onboard, we will have a state of the art system that will provide the ability to remotely control the samplers' programming and activation to allow event-based sampling.

The shuffling of the ferries did allow us to collect valuable water quality data from the Pamlico River, a location we have not previously sampled, although it made servicing and troubleshooting more difficult and more dependent on Ferry Division staff. Having data from another tributary of the Pamlico Sound provided us with a broader understanding of habitat conditions in the Pamlico Sound System as a whole. In addition to the data collected along the Pamlico River route, the M/V Floyd J. Lupton also collected data along the Fort Fisher to Southport route across the lower Cape Fear River, and the Hatteras to Ocracoke route. Data collected along these routes were plotted and made available in the results section of our website, www.ferrymon.org.

During the project period, we encountered an inline blockage on the M/V Carteret which prevented seawater flow from reaching the sensors. We were able to remove the blockage and restored seawater flow to the sensors. However, we later discovered another blockage to seawater flow downstream of the sensors, preventing proper flow-through operation. Ferry Division staff were notified, but unfortunately this situation was not resolved before the completion of the project.

In addition, we experienced intermittent loss of remote connection to the system on the M/V Carteret because of gaps in Verizon's coverage area. Another issue with the data collection platform has been that the laptop computers do not automatically restart after a power loss. Restarting the system requires the physical presence of project or NC-DOT Ferry Division staff, once the problem has been identified. The current computer starts up when power is applied, thus eliminating that issue and the newly designed system will have similar hardware that avoids manual intervention after a power loss.

References:

Deaton, A.S., W.S. Chappell, K. Hart, J. O'Neal, B. Boutin. 2010. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources. Division of Marine Fisheries, NC. 639 pp.

Paerl, H. W., J. D. Bales, L. W. Ausley, and others. 2001. Ecosystem impacts of three sequential hurricanes (Dennis, Floyd, and Irene) on the United States' largest lagoonal estuary, Pamlico Sound, NC. Proceedings of the National Academy of Sciences of the United States of America 98: 5655–5660.

Reynolds-Fleming, J. V., and R. A. Luettich. 2004. Wind-driven lateral variability in a partially mixed estuary. Estuarine Coastal and Shelf Science 60:395–407.