St. Mary's River Oyster Reef Monitoring Report

Robert W. Paul, Christopher E. Tanner, Elaine F. Szymkowiak, John Spinicchia

February 2, 2016

In 2012 when we (Paul and Tanner) proposed the design of the 3-dimensional oyster reefs to the St. Mary's River Watershed Association (SMRWA), we included an estimate of costs that in our estimation would be necessary for 3 years of monitoring. We have appended that section of the report to this document (Attachment 1). Because of renewed interest in monitoring now that the SMRWA 3-dimensional reefs have been completed, because of developments in reef restoration elsewhere in Maryland (Harris Creek), and because new assessment criteria and methods are available, we believe that reef monitoring can now begin. The purpose of this report is to revisit our initial thoughts about assessing the success of the reefs in light of our better understanding of reef ecology and assessment over the last 3 years. Here we include a brief analysis of two recent publications that suggest best management practices for assessing oyster restoration initiatives, an evaluation our current capacities, and some suggestions.

RECENT PUBLICATIONS

1. Restoration goals, quantitative metrics and assessment protocols for evaluating success on restored oyster reef sanctuaries (Allen et al., 2011)-
http://www.chesapeakebay.net/channel_files/17932/oyster_restoration_success_metrics_final.pdf
This report by the Oyster Metrics Workgroup and submitted to the Chesapeake Bay Program was an attempt to standardize operational goals, minimal thresholds, and protocols for judging the efficacy of efforts to restore oyster reefs in Chesapeake Bay as outlined in Executive Order 13508. The Chesapeake Bay Program accepted all the metrics, monitoring and assessment protocols and designated them as being suitable for assessing sanctuary reefs. Subsequently, the metrics, protocols, goals, and endpoints have been incorporated into *Oyster Habitat Restoration: Monitoring and Assessment Handbook,* and are relevant to the efforts of the SMRWA in evaluating our experimental reefs in the upper St. Mary's River.

Restoration Goals- *Tributary Level*
This section is divided into tributary level approaches and reef level approaches. While recognizing the overall goal of achieving thriving, highly functioning oyster reefs, specific challenges to this overall goal were acknowledged. These challenges to restoration include high natural depletion rates associated with disease, predation, siltation and poaching as well as 'negative shell budgets' all of which limit recolonization sites and recruitment.

At the tributary level, the overall goal was to "dramatically increase oyster populations and recover a substantial portion of the ecosystem functions provided by oyster reefs within the tributary". USACE estimates that 8-16% of historic bottom needs to be restored to notice any real change in functionality. Based on this analysis by USACE, the accepted goal was **50-100% of currently *restorable* oyster habitat.** Therefore, **an ideal candidate tributary for restoration is one where 50-100% of the currently restorable bottom is equivalent to at least 8% of the historic bottom.**

Restoration Goals- *Reef Level*
First, the workgroup recognizes that reef persistence depends on oyster densities at some minimal level, supplying not only propagules, but colonization sites as well. Thus, the importance of having a positive shell budget is stressed. It was noted that many restoration activities do not use adaptive management to determine if reapplication of shell/substrate is occasionally required.
Achieving high reproductive success was also recognized as depending on population structure: age class distribution to ensure a sufficient number of males in light of the protandric nature of the animal. The target goal of restoration on a reef level is **a mean density of 50 oysters/m^2 AND 50 grams dry weight/m^2 containing at least two year classes covering at least 30% of the reef area.** This workgroup notes that the literature supports this combination of minimum biomass, abundance and coverage in order for restoration to be deemed successful.

A minimum threshold was also defined as **a mean density of 15 oysters/m^2, 15 grams dry weight/m^2, containing at least 2 year classes covering at least 30% of the reef area.** The work group noted that using adaptive management to track the height, spatial extent, and shell budget of restoration reefs is crucial to understanding whether the reef is expanding, shrinking or static and able to respond in a timely manner. The work group recommended that the spatial extent, reef height, and shell budget should grow or remain neutral to be considered a successful restoration. The remainder of this report suggests general approaches for assessing the density and minimum threshold goals stated above. Detailed protocols are included in the *Oyster Habitat Restoration: Monitoring and Assessment Handbook*.

2. Oyster Habitat Restoration: Monitoring and Assessment Handbook (Baggett, et al., 2014)-
http://www.habitat.noaa.gov/pdf/Oyster_Habitat_Restoration_Monitoring_and_Assessment_Handbook.pdf

This handbook is quite detailed and is the result a recent analysis of oyster restoration projects from 1990 to 2007 in the Chesapeake Bay in which 78,0000 records from 1035 sites were examined (Kramer and Sellner, 2009, Kennedy et al., 2011). The analysis found that relatively few of the restoration activities were monitored, and that the restoration goals of many of the projects were not well-defined, with only 43% of the datasets including both a restoration and monitoring component. The authors concluded that the monitoring of this large body of work was inadequate, and they were unable to assess changes in oyster populations on the constructed reefs. To address this critical gap, a working group was formed that consisted of restoration scientists and practitioners from the Atlantic, Pacific, and Gulf coasts of the US. With additional expert input, the working group developed recommendations for a set of Universal Metrics that should be monitored for all oyster restoration projects.

The set of Universal Metrics and Universal Environmental Variables is given in a table in Appendix I starting on page 69, and these are reproduced here. In addition, the report also includes Restoration Goal-Based Metrics (Brood stock and oyster population enhancement, Habitat enhancement for resident and transient species, Enhancement of adjacent habitats, and Water clarity improvement goals) but we have not included these here.

Universal Metrics

Metric	Methods	Units	Frequency	Performance Criteria
Reef Areal Dimension: Project Footprint.	Measure maximal aerial extent of reef using GPS, surveyor's measuring wheel or transect tape, or aerial imagery; subtidal use sonar, or SCUBA.	m^2	Footprint Pre-construction, within 3 months post-construction, and minimum 1-2 years post-construction; preferably 4-6 years. After events that could alter reef area	None
Reef Areal Dimension: Reef Area	Measure area of each patch reef using GPS, surveyor's measuring wheel or transect tape, or aerial imagery; subtidal use sonar or depth finder with ground trothing, or SCUBA. Sum all patches to get total reef area.	m^2	Pre-construction, within 3 months post-construction, and minimum 1-2 years postconstruction; preferably 4-6 years. After events that could alter reef area.	None
Reef Height	Measure using ruler, graduated rod and transit, or survey equipment; subtidal use sonar or depth finder.	cm	Pre-construction, within 3 months post-construction, and minimum 1-2 years postconstruction; preferably 4-6 years. After events that could alter reef area.	Positive or neutral change
Live Oyster Density/ Recruitment Density	Utilize quadrats. Collect substrate to depth necessary to obtain all live oysters within quadrat, and enumerate number of live oysters, including recruits. If project involved the use of seed oysters, enumerate all seed oysters present in quadrat.	ind/m^2	Immediately after deployment if using seed oysters. Otherwise, annually at the end of oyster growing season (will vary by region), 1-2 years at minimum; preferably 4-6 years.	Based on short and long-term goals developed using available regional and project-type data, as well as current and/ or historical local/regional densities.
Size Frequency Distribution.	Measure shell height of at least 50 live oysters per oyster density sample	mm (size), number or % per bin (size dist.)	Annually at the end of oyster growing season (will vary by region) in conjunction with oyster density sampling, at a minimum.	None

Universal Environmental Variables

Metric	Methods	Units	Frequency
Water temperature	Measure above substrate close to reef using *in situ* instrumentation, a thermometer, or other handheld instrumentation	°C	Continuous (preferred), otherwise as often as possible
Salinity	Measure above substrate close to reef using *in situ* instrumentation, a refractometer, or other handheld instrumentation	ppt or psu	Continuous (preferred), otherwise as often as possible
Dissolved oxygen (subtidal only)	Measure above substrate close to reef using *in situ* instrumentation or handheld instrumentation	mg/L	Continuous (preferred), otherwise as often as possible

WHERE WE ARE NOW AND WHAT NEEDS TO BE DONE?

The SMRWA science team (Paul, Spinicchia, and Szymkowiak) met with Chris Tanner on Thursday, January 28, 2016, to review oyster reef monitoring. Over the past several years some St. Mary's College of Maryland students (Liz Lee, Hanna Coe, and Adrienne Silver) have conducted research projects (their St. Mary's Projects) using the SMRWA reefs. In addition, Ken Gill and other high school students have done some survey work on the reefs in the summer. While these projects have been admirable and yielded results, they really do not systematically assess the reefs using the universal metrics given in the table above. Therefore, these studies were primarily educational because they either do not directly address the metrics or because the studies lack scientific rigor. It is clear that both high school and college students may be useful and contribute to assessing and monitoring the reefs in the future, but their activities must be carefully monitored and tied to the Universal Metric goals and methods above.

Bob Paul and Chris Tanner spoke with Dr. Lora Harris from the University of Maryland's Chesapeake Biological Laboratory about assessing the oyster reefs through modeling. Lora is a mathematical modeler and heavily involved with the Harris Creek oyster restoration project on the Eastern Shore. She told us that it is possible to model the SMRWA reefs, but that we needed baseline data on water quality, chlorophyll concentrations, the reef metrics from the table above, and accurate water velocity measurements. Following that fall 2015 meeting, Chris investigated and priced YSI water instruments that could provide continuous measurements of the Universal Environmental Variables in the second table above. He responded to an initiative from SMCM's Provost for equipment augmentation by generating the attached proposal (Attachment 2). The estimate for a marginally useful instrument is $16,000 and a fully-functional, highly capable instrument is $23,000. We expect that water velocity/currents can be measured with instruments costing about $1,000. Where do we get roughly $25,000? Rotary clubs in Leonardtown and Lexington Park MAY contribute, the Secretary of DNR, sounded interested, but that would have to be actively pursued. We were not there when they did the "drive-by" of the site, but Joe Anderson, spoke with the entourage and should have a notion of height of interest. There may be other sources of funds (grants) to support the acquisition of instruments, but of course proposals would have to be written.

Presuming that the cost of instrumentation can be met, this leaves the universal metrics on reef sizes, measurements, mapping, and other physical metrics. This probably can be accomplished by hiring at least two students during the summer or fall to take all these measures, but they need to be very carefully trained and supervised and need to be responding to a specific set of quantifiable criteria. We do not believe that oyster density and frequency distribution can be quantified during the summer because the water is too murky. Yet, Bob Lewis was able to take excellent photographs in the fall, so a GoPro camera positioned on a grid may be the best way to obtain these oyster metrics in an October-November time frame. Again, this cannot be an educational student project, but rather requires serious, professional assessment, or a commitment from someone trained to take on a project like this.

LITERATURE CITED

Allen, S., A.C. Carpenter, M. Luckenbach, K. Paynter, A. Sowers, E. Weissberger, J. Wesson, and S. Westby. 2011. Restoration goals, quantitative metrics and assessment protocols for evaluating success on restored oyster reef sanctuaries. Report of the Oyster Metrics Workgroup, Chesapeake Bay Program, United States Environmental Protection Agency, Annapolis, Maryland.

Baggett, L.P., S.P. Powers, R. Brumbaugh, L.D. Coen, B. DeAngelis, J. Greene, B. Hancock, and S. Morlock. 2014. Oyster habitat restoration monitoring and assessment handbook. The Nature Conservancy, Arlington, Virginia.

Kennedy, V.S., D.L. Breitburg, M.C. Christman, M.W. Luckenbach, K. Paynter, J. Kramer, K.G. Sellner, J. Dew-Baxter, C. Keller, and R. Mann. 2011. Lessons learned from efforts to restore oyster populations in Virginia and Maryland, 1990 to 2007. Journal of Shellfish Research 30:1-13.

Kramer, J.G. and K.G. Sellner (Eds.), 2009. ORET: Metadata analysis of restoration and monitoring activity database., native oyster (*Crassostrea virginica*) restoration in Maryland and Virginia. An evaluation of lessons learned 1990-2007. Maryland Sea Grant Publication #UM-SG-TS-2009-02; CRC Publ. No. 09-168, College Park, Maryland.

Attachment 1

This was Paul and Tanner's original estimate of monitoring when the reef project was proposed in 2012.

We recommend three years of monitoring beginning after the complete of the construction of the reefs. Water quality monitoring will take place twice a month from early March through October. We recommend 6 monitoring stations, so this is a total 96 samples for each parameter per year (16 sampling periods x 6 stations). Oyster monitoring, reef community characteristics and oyster disease can be monitored less frequently (twice a year is adequate). While the monitoring will be planned and supervised by SMCM faculty, much of the actual monitoring will be done by SMCM students and community volunteers trained by SMCM faculty members. Estimated costs are described in Table 5.

Table 15. Monitoring costs over a three year period.

Monitoring Type		**Year 1**	**Year 2**	**Year 3**
Oyster Monitoring				
	SCUBA rentals & air	$500	$500	$500
	Miscellaneous supplies	$100	$100	$100
Oyster Disease				
	Stains & reagents	$100	$100	$100
Water Quality Monitoring				
	Service to YSI 6600 Sonde	$2,000		
	Onset HOBO Salinity/Temperature Logger (underwater)	$1,200		
	TSS Samples ($4.25 per sample x 96 samples)	$408	$408	$408
	Chlorophyll a ($6.75 per sample x 96 samples)	$648	$648	$648
	Phaeophytin ($1.50 per sample x 96 samples)	$144	$144	$144
	Nitrogen (NH3, NO2, NO3) ($12.00 per sample x 96 samples)	$1,152	$1,152	$1,152
	Miscellaneous supplies for current flow rate and sedimentation	$200	$200	$200
Boat Use				
	Gas and maintenance	$1,000	$1,000	$1,000
Planning and Supervision by SMCM Faculty		$2,000	$2,000	$2,000

Student Intern (Summer)	$4,000	$4,000	$4,000
TOTAL	**$13,452**	**$10,252**	**$10,252**
TOTAL FOR ALL 3 YEARS			**$33,956**

Attachment 2

Proposal for a Water Quality Monitoring Instrument to Support Courses and Faculty/Student Research in Biology and Environmental Studies

Rationale

The location of St. Mary's College of Maryland on the banks of the St. Mary's River estuary, surrounded by a variety of aquatic, wetland and terrestrial ecosystems, has led to a campus ethos of environmental stewardship as reflected in past and currently discussed strategic plans. Interest in course, research, outreach and volunteer opportunities related to the environment have grown over the years as a result of the implementation of the St. Mary's Project, externally funded programs such as the St. Mary's River Project (funded from 1999 through 2008) and, most recently, reflected by the approval of the Environmental Studies major.

Not long ago we had equipment to monitor the water quality of the St. Mary's River estuary and other aquatic ecosystems that was unsurpassed by almost any other small liberal arts college as a result of the St. Mary's River Project (SMRP). SMRP was a large scale environmental monitoring, research and education program that was funded by a variety of federal, state and nongovernmental organizations from 1998 through 2008 and co-directed by Bob Paul and Chris Tanner. The focus of SMRP was the St. Mary's River estuary and watershed, and spin-offs of the program include the SMRP Environmental Education Club (students teach environmental education in local schools) and the St. Mary's River Watershed Association (see http://www.smrwa.org/). During its decade of external funding, SMRP had a full time coordinator, involved 20 to 40 SMCM student volunteers a year and hired several students to help monitor the St. Mary's River over the summer. SMRP accumulated a substantial amount of scientific equipment (as well as a research vessel and truck) that was also available for courses and student research projects. Instruments specifically used to monitor the water quality of the river and other aquatic ecosystems, YSI Sondes, are now all over a decade old, no longer functional, and are being phased out by YSI as newer, easier to use technology is now available. Additionally, research in this area has suffered further from the relatively recent loss of the weather and water quality monitoring station mounted on the pier in front of the River Center that posted real-time weather and water quality information on a website (hosted by YSI's EcoNet website; see http://www.ysieconet.com/). We were forced to give up this station because of exhaustion of left over SMRP funds to pay YSI to host the data on their website and because our instruments were aging and no longer supported.

At this time we no longer have the ability to monitor several important water quality parameters in the field including chlorophyll (a measure of the amount of phytoplankton in aquatic ecosystems) and turbidity (a measure of water clarity, which is considered to be the key indicator of the water quality of aquatic ecosystems). At the same time that our ability to monitor the local environment is being reduced by the lack of functional equipment, there is a renewed interest on campus in environmental research and courses in part due to construction of artificial oyster reefs in front of the campus but also because of the growth of the Environmental Studies program.

A primary example of how important this instrument will be to the research capabilities of programs at St. Mary's is the on-going research on the impact of the constructed oyster reefs in front of the campus.

Oyster reefs have an enormous capacity to filter water (see https://www.youtube.com/watch?v=p4eLoDbdoEQ) and were once thought to be able to filter the volume of the entire Bay in a week, removing phytoplankton and suspended sediments. Decimation of oyster populations to less than 1% of historic numbers has adversely affected the water quality of the Bay. One of the strategies to improve water quality is to restore oyster populations. In the St. Mary's River three dimensional oyster reefs (built to resemble oyster reefs that existed prior to large scale harvesting of oysters) have been constructed just north of the River Center with a primary goal of understanding how constructed reefs can improve water quality. While we have basic instruments to measure some parameters such as temperature, salinity and oxygen, we lack the capability to measure parameters such as chlorophyll, turbidity and pH in the field...parameters that are critical for research on how these reefs are improving water quality in the river. Chris Tanner and Bob Paul recently met with Dr. Lora Harris at the Chesapeake Biological Laboratory to discuss collaborative research on the St. Mary's reefs. Dr. Harris is an ecological modeler who can help us develop a mathematical model for how the oyster reefs are improving water quality by reducing phytoplankton, suspended sediments and nutrients. Collecting data for the previous mentioned parameters will be important for developing the model.

Another line of research affected by the loss of water quality data is the hedonic pricing research conducted by Dr. Henderson (Economics and Environmental Studies) and her students. The detailed data collected by the SMRP spans the 1999-2007 period for the 15 non-tidal stations throughout the watershed and the 1999-2002 period for 10 tidal stations; a subset of the tidal stations reported data through 2006. The historic nature of this rich data set limits the ongoing potential for research in this area. Hedonic pricing is a statistical methodology that makes use of market prices and environmental quality data to estimate values for environmental amenities that are not directly traded in markets. This line of research is ideally-suited to the Environmental Studies major, as majors whose depth is in the policy track would be able to conduct meaningful research which also motivates understanding of key scientific measurements which are critical inputs into the analysis. Such cross-disciplinary research is central to the purpose of the ENST major. Reliable water quality data collected at multiple points throughout the watershed and adjacent to the oyster reef project would facilitate valuation projects that would be both contribute to the literature and inform policy making. The equipment request made here represents a first step in developing a data collection program that would support a sustainable line of research in this area.

See other uses of this instrument below.

Requested Equipment

We are requesting a water quality monitoring system to replace the no longer functional and discontinued instruments originally purchased by SMRP. The instrument (YSI EXO2 Sonde with associated probes and accessories; see https://www.ysi.com/EXO2) is cable of measuring up to 6 water quality parameters at once, either providing that information on a hand display or logging data over time (for up to a couple months) with the instrument left submerged in the environment. The parameters that we are most interested in monitoring are chlorophyll, turbidity, and pH/ORP as we currently do not the capacity of monitoring these in the field. These parameters give a good picture of the characteristics of a body of water and are critical in assessing whether water quality is improving or degrading. Other parameters that we would like to eventually integrate into the data collected with this instrument include salinity, temperature and oxygen. Attached is a quote for the instrument with probes and required accessories. Note that the listed prices include a 5% discount for trading in our discontinued and no longer functional SMRP YSI instruments. Ideally, we would like to be able to purchase the entire system as priced in this quote (a total of $22,558.60). However, considering the high cost of the instrument, we are hoping for funds that will cover the instrument with probes and accessories that will allow us to monitor parameters that we currently do not have the capacity to monitor in the field (chlorophyll, turbidity, pH/ORP). These items are highlighted on the quote and come to a total of $16,151.80. If only partially funded, we will seek outside funds to add additional sensors to the instrument. It is unlikely that we will be able to find external funds for the entire system.

Who will use the equipment?

This instrument is to be shared between the Environmental Studies and Biology programs. Faculty and students will have access to it; however, as it is an expensive instrument that requires careful calibration, use will be limited to those have been appropriately trained. The local YSI representative, Tom Wasniak, will provide the initial training of faculty, who will then train students as needed. In addition, YSI provides free on-line training modules.

Primary uses will be for environmental/ecological research of the St. Mary's River estuary, local streams and ponds. In particular, the instrument will be used to assess the ecological services of the three dimensional reefs built in front of the College and to measure water quality in the river to support the hedonic pricing research conducted by Dr. Henderson. We already have had quite a few biology and environmental studies students working on the reefs and/or oysters for their SMPs. The collaborative project with Dr. Lora Harris and Dr. Henderson's project will increase the number of students conducting research that will utilize the requested instrument. In addition courses such as Environmental Field Methods (ENST350), Limnology (BIOL 432), Ecology Coastal Systems (BIOL 463) and lower level courses in biology and environmental studies (BIOL 101, Contemporary Bioscience; ENST 250, Introduction to Environmental Science) will have access to this instrument.

In addition this instrument is compatible with the continuous monitoring weather and water quality station that we had on the St. Mary's pier. If additional funds can be found to reinstall and maintain this station, the instrument may be deployed as a key component of the station when not in use for research or courses. Weather and water quality data will be provided to the college community and beyond by posting it on a website.

Where will the instrument be housed?

When not in use, the instrument will be housed in the River Center River Research Laboratory, along with all of the materials required to calibrate and maintain the instrument. This space was originally designed as a water quality research laboratory for the St. Mary's River Project. It is a space that is now shared by Biology and Environmental Studies and is an ideal location for the storage and calibration of this instrument, particularly because of its close location to the St. Mary's River.