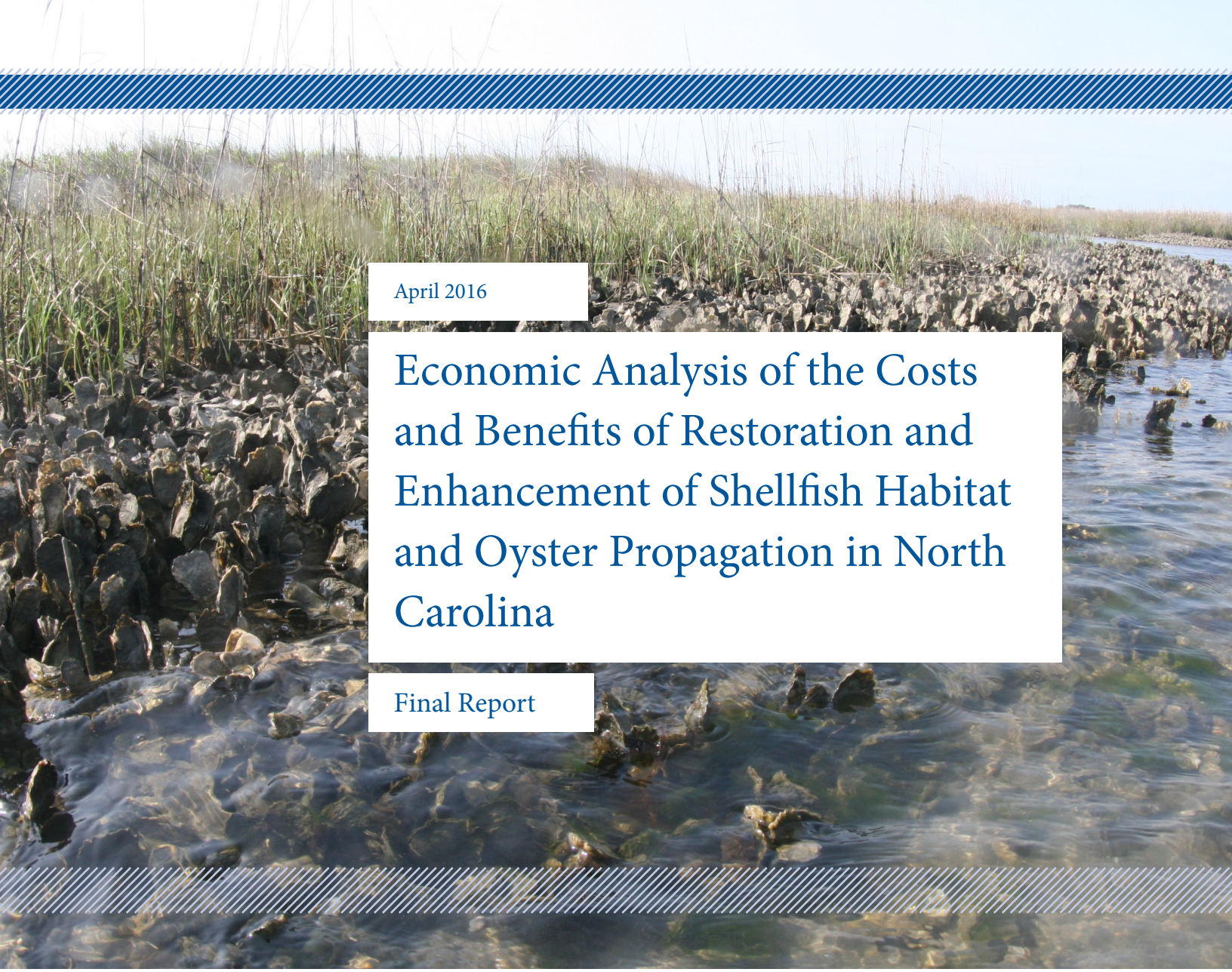

April 2016

Economic Analysis of the Costs and Benefits of Restoration and Enhancement of Shellfish Habitat and Oyster Propagation in North Carolina

Final Report

Prepared for—

Albemarle-Pamlico National Estuary Partnership
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Executive Summary

North Carolina began oyster enhancement activities in coastal waters in 1915. Recognizing the commercial and ecological values of the oysters, North Carolina continues to enhance oysters with support from the Coastal Habitat Protection Plan[1] (Deaton et al., 2010), which recommends expanding shell bottom enhancement activities. The North Carolina Division of Marine Fisheries (NCDMF) manages three separate programs for habitat enhancement: 1) Shellfish Rehabilitation Program, 2) Oyster Sanctuary Program, and 3) Artificial Reef Program. All three programs provide submerged structures to promote settlement, growth, and proliferation of oysters. The Artificial Reef Program, while undertaken to expand recreational fishing opportunities, also provides expanded oyster habitat when reefs are constructed within oyster-growing areas.

North Carolina continues to pursue shellfish habitat enhancement, and the NCDMF has created a strong network of partners to assist with habitat enhancement projects, including federal agencies (U.S. Army Corps of Engineers and National Oceanic and Atmospheric Administration) and environmental nonprofits (The North Carolina Coastal Federation and The Nature Conservancy).

To better document how habitat enhancement projects in North Carolina improve the coastal economy and environment, the Albemarle-Pamlico National Estuary Partnership contracted with RTI International to assess the benefits and costs of the three oyster programs under the NCDMF habitat enhancement programs. Key findings include the following:

- With just over $20 million[2] in government and private investments between 2010 and 2015 that RTI evaluated, North Carolina restoration and habitat enhancement activities
  - supported over 500 acres of habitat;
  - provided market and nonmarket benefits, including
    - commercial fishing (including oyster harvest services from oyster cultch planting activities only),
    - recreational fishing, and
    - water quality services such as nitrogen removal and shoreline stabilization services (oyster cultch planting activities only);
  - produced expected benefits valued at $82 million. In other words, every $1.00 invested in habitat enhancement activities provided North Carolina with about $4.05 in benefits;
  - produced expected benefits ranging from $2.00 to upwards of $12.28 for every dollar invested; and
  - provided an expected benefits contribution by benefit type as follows: recreational fishing (38%), water quality (33%), and commercial fishing (29%).
- Increases in commercial fishing ($8.2 million between 2010 and 2015) brought about by enhancement activities
  - created 696 jobs over multiple years, with an average of over 100 jobs per year,
  - generated $32 million in revenue to North Carolina businesses, and
  - added $13 million to household income.
- Previous studies also show that grant funding of just over $5 million for coastal restoration in oyster sanctuary sites
  - created over 50 jobs,
  - generated $7.9 million in revenue to North Carolina businesses, and
  - added $1.9 million to household income.
- Grant funding amounts included salaries and benefits, supplies (oyster shells and other materials), equipment (boat rental), and disbursements to local project partners and contractors.
- Generally, it is more cost-effective for NCDMF to complete smaller-scale projects while contracting out the larger ones. Deployment costs, timelines, and the cost of monitoring contractors should all be considered when making this decision.

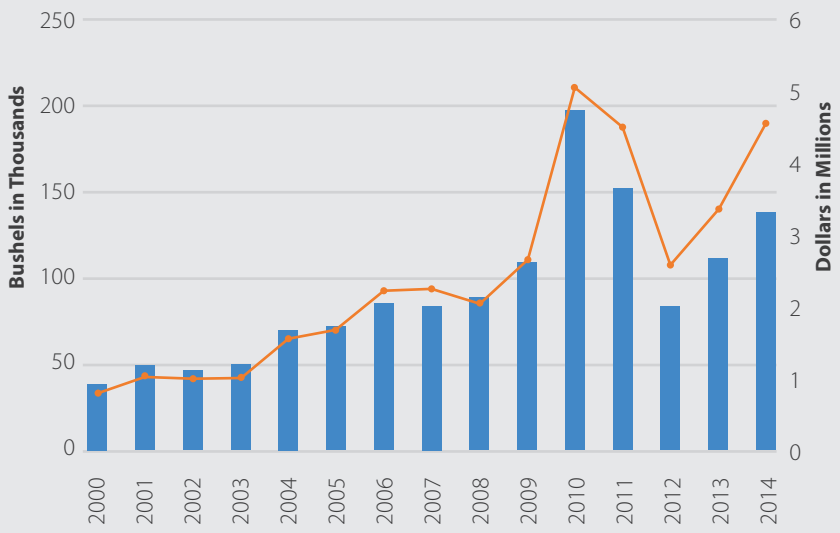
[1] The Draft 2015 Coastal Habitat Protection Plan was released in December 2015: http://portal.ncdenr.org/web/mf/habitat/chpp/downloads.

[2] This number reflects the present value of investments expressed in today's dollars (2016).

1
Background

The North Carolina Division of Marine Fisheries (NCDMF) is responsible for stewardship of estuarine resources (G.S. 113-131) and enhancement of shellfish habitat (G.S. 113-201). Shellfish, particularly oysters and clams, are important commercial species and also provide benefits to recreational fishermen and citizens of North Carolina. Not only do shellfish provide revenue from direct harvest and associated jobs, but they also provide recreational fishing opportunities and many beneficial ecosystem services. In response to an effective fishery management plan and numerous enhancement activities, the commercial oyster harvest has grown significantly in the past 15 years with a peak value of over $5 million in 2010 (see Figure 1-1).

Figure 1-1. North Carolina Commercial Oyster Harvest



Source: Division of Marine Fisheries Harvest Statistics, 2015

The NCDMF manages three separate programs for habitat enhancement: 1) Shellfish Rehabilitation Program, 2) Oyster Sanctuary Program, and 3) Artificial Reef Program. Each is described below.

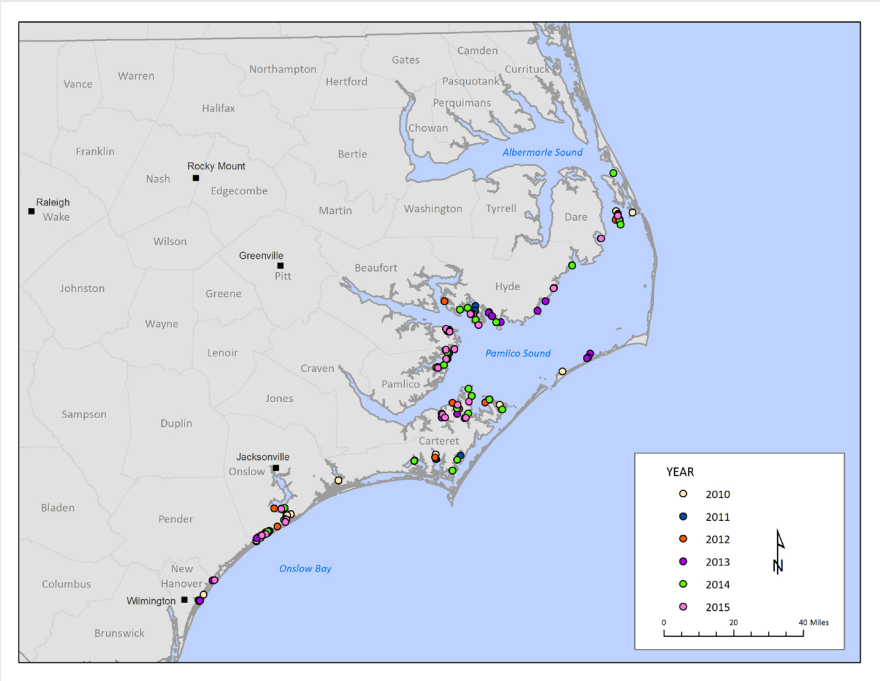
1.1 SHELLFISH REHABILITATION PROGRAM

The Shellfish Rehabilitation Program has been operational in North Carolina since 1915 through various agencies and divisions. Between 1915 and 2013, an estimated 20 million bushels of cultch material, oyster shell, and limestone marl were planted in coastal North Carolina (NCDMF, 2013). The cultch material provides hardened substrate to facilitate oyster larvae settlement and growth. Oyster larvae settle on a hard surface and grow into spat, eventually growing into adult oysters of harvestable size. In addition to the commercial opportunity associated with the oyster harvest, oyster reefs provide numerous ecosystem services, including improved water quality and essential habitat for both commercially and recreationally targeted fish and crustacean species.

The North Carolina oyster population status is monitored by the Division through the development of the Oyster Fishery Management Plan. Shellfish Rehabilitation Program staff assist the Fisheries Management Section with population monitoring through various sampling programs. Spatfall sampling measures oyster spat recruitment and growth at cultch sites planted in the past 3 years. Dermo sampling is a surveillance program that monitors the presence and intensity of infection of the protist Perkinsus marinus, a lethal oyster disease, in North Carolina's oyster population. These activities assist the Division in monitoring the oyster population in North Carolina and have led to the population being labeled as a "species of concern." Commercial landings have increased over the last 15 years, as seen in Figure 1-1, but recreational harvest levels are unknown. Historical overharvesting and degraded habitat have contributed to the current need for expanded restoration efforts and research to boost the overall population.

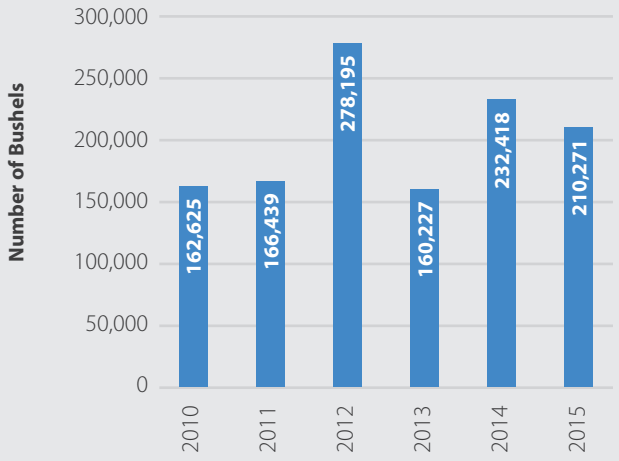
The Shellfish Rehabilitation Program is mandated by Session Law 1997-443 to report on annual program expenditures, and included in these reports is the amount of bushels planted. Figure 1-3 displays bushels of cultch material planted between 2010 and 2015.

Figure 1-2. Cultch Planting Sites in Coastal North Carolina, 2010 – 2015



Source: Wright, G. North Carolina Division of Marine Fisheries. Personal communication with Tim Sartwell, RTI, February 4, 2016.

Figure 1-3. Bushels of Cultch Material Planted, 2010–2015



Source: Wright, G. North Carolina Division of Marine Fisheries. Personal communication with Tim Sartwell, RTI, February 26, 2016.

North Carolina Division of Marine Fisheries. 2010. "Division of Marine Fisheries Shellfish Rehabilitation Report 2010 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2011. "Division of Marine Fisheries Shellfish Rehabilitation Report 2011 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2012. "Division of Marine Fisheries Shellfish Rehabilitation Report 2012 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2013. "Division of Marine Fisheries Shellfish Rehabilitation Report 2013 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2014. "Division of Marine Fisheries Shellfish Rehabilitation Report 2014 Annual Report." Morehead City, NC.

Cultch is deployed April through September in prime shellfish-growing areas to enhance the existing oyster fishery by creating harvestable reefs. Numerous criteria qualify an area as a prime growing area, including factors such as salinity, oxygen, tidal flow, depth, the availability of hard substrate for larval settlement, and the absence of shellfish in the vicinity. As described in the North Carolina Coastal Habitat Protection Plan, optimal oyster growth occurs between a salinity of 14 and 28 parts per thousand (ppt) and with oxygen availability above 1 to 2 milligrams per liter (mg/l) (Deaton et al., 2010). These prime areas are designated by the NCDMF through sampling surveys and consultation with various stakeholders, including commercial fishermen, the general public, and research partners. The Division hosts eight public meetings a year in coastal areas to facilitate input. Oysters and reef-associated organisms can be removed from the cultch planting sites in accordance with their specific regulations (e.g., size limit, season, gear).

1.2 OYSTER SANCTUARY PROGRAM

The primary objective of the Oyster Sanctuary Program is to establish a network of no-harvest oyster reefs, which serve as larval sources for other reefs throughout Pamlico Sound, including the Neuse River. The sanctuaries are also developed in areas that are conducive to oyster growth and proliferation (i.e., optimum salinity and oxygen levels, ample flow and depth, available substrate for continued larval settlement). As of 2015, 15 permitted sites, including 14 completed or under development, and two in design are under the direct management of the Oyster Sanctuary Program. Table 1-1 outlines the current and planned oyster sanctuaries in North Carolina. Figure 1-4 locates all sanctuaries in coastal North Carolina.

Table 1-1. Current and Planned Oyster Sanctuaries

SANCTUARY	YEAR ESTABLISHED	PERMITTED ACRES	DEVELOPED ACRES	MATERIAL
Croatan Sound	1996	7.7	5.4	1800 tons limestone marl riprap, Pallet Reef Balls (added 2013)
Crab Hole	2003	30.5	30.5	38,076 tons limestone marl riprap
Gibbs Shoal	2009	30.0	30.0	16,075 tons limestone marl riprap, 2674 Ultra Reef Balls; reef cube
Deep Bay	1996	17.2	5.7	1,300 tons limestone marl riprap, 290 Bay Reef Balls (added 2014)
West Bluff	2005 (USACE Expansion Proposed 2016)	19.9	9.1	8,400 tons limestone marl riprap, 10 Ultra Reef Balls, 75 Pallet Reef Balls and 125 Bay Reef Balls
Clam Shoal	1996	58.2	31.4	38,359 tons limestone marl riprap
Middle Bay	2004	4.6	0.4	900 tons limestone marl riprap
Ocracoke	2004	76.0	25.4	11,347 tons limestone marl riprap, Reef Balls, precast concrete, processed recycled concrete, three 65'–130' vessels
Neuse River	2005	5.7	5.3	7500 tons limestone marl riprap
West Bay	1996	6.7	2.2	2,000 tons limestone marl riprap, 100 Mini Bay Reef Balls (added 2014)
Long Shoal	2013	10.0	6.6	880 Ultra Reef Balls
Raccoon Island	2013	10.0	7.0	1,169 Ultra Reef Balls, 150 tons precast concrete, 157 tons processed recycled concrete
Little Creek (Under Construction)	2016	20.7	9.8	Limestone marl riprap, Reef Balls, precast concrete, processed recycled concrete, concrete blocks, reef pyramids, granite riprap; basalt riprap
Pea Island	2015	32.0	18.6	360 Ultra Reef Balls, 900 tons precast concrete, 1,800 tons processed recycled concrete
Cape Fear River (Proposed)	TBD	TBD	TBD	TBD
Gull Shoal (Proposed)	TBD	TBD	TBD	TBD

Oyster sanctuaries also provide structure for commercial and recreational fishing activities, except for the direct harvest of oysters and the use of trawl nets, long-haul seines, or swipe nets (Rule 15A NCAC 03K.0209). Through these protections, recreational and commercial fishermen derive direct and indirect benefits from the oyster reef. Commercial finfish and crustacean fishermen benefit from the natural recruitment and utilization of the reef by commercially valuable species. Commercial shellfish fishermen benefit from the unfished biomass of oysters providing larval supplement that provides untold amounts of natural recruitment to natural reefs and cultch planting sites. Recreational fishermen benefit from the increased opportunity to target and catch reef-associated species. The list below contains a few of the relatively common oyster sanctuary–associated species in North Carolina that have an existing commercial or recreational fishery (Deaton et al 2010):

- black drum
- blue crab
- red drum
- sheepshead
- Southern flounder
- spotted seatrout
- stone crab
- striped bass

Figure 1-4. Oyster Sanctuaries in Coastal North Carolina

The General Assembly encourages shellfish cultivation and authorizes the closure of public bottom for the propagation of shellfish (G.S. 113-201 and G.S. 113-204). Session Laws 2014-120 and 2015-241 provide for the further enhancement of shellfish habitats and sanctuaries in the Senator Jean Preston Oyster Sanctuary Network. The Marine Resources Fund is encouraged to support the Oyster Sanctuary Program (G.S. 113-175.1 (c)). Sanctuaries are delineated in Marine Fisheries Commission Rule 15A NCAC 03R .0117.

1.3 INSHORE ARTIFICIAL REEF PROGRAM

The Artificial Reef Program develops and maintains a successful system of artificial reefs to enhance fishing, diving, biological, and ecological opportunities (Table 1-2). Although they are not constructed with oyster restoration as the primary benefit, inshore estuarine artificial reefs do serve as potential oyster settlement areas. The Artificial Reef Program is responsible for coordinating all aspects of inshore and offshore reef planning and construction, permit compliance, research on materials and ecology, and effective public communication.

As of 2015, the NCDMF maintains eight estuarine reefs. It is illegal to interfere with artificial reef markers in North Carolina jurisdictional waters (G.S. 113-266), but artificial reefs experience no other protections. Marking requirements and closure authority for artificial reefs are established by Marine Fisheries Commission Rule 15A NCAC 03I .0109.

All inshore estuarine artificial reefs are open to both commercial and recreational harvest. According to Rule 15A NCAC 03I .0109, the Director of the Division of Marine Fisheries may close an artificial reef for harvest for no more than 1 year, and any economic effect will be published in writing prior to closure.

Table 1-2. Estuarine Artificial Reef Information

ARTIFICIAL REEF NAME	LATITUDE AND LONGITUDE	REEF MATERIAL
AR-191 Black Walnut Point Reef	36° 00.000′ N 76° 40.000′ W	219 tires, 12 boat molds, 10 trash boxes
AR-291 Bayview Reef—Pamlico River	35° 25.941′ N 76° 48.421′ W	28,000 tires
AR-292 Quilley Point—Pungo River	35° 28.250′ N 76° 34.250′ W	19,200 tires
AR-296 Hatteras Island Business Association Reef	35° 17.333′ N 75° 37.500′ W	16,280 tires, limestone marl
AR-298 Ocracoke	35° 10.653′ N 75° 59.800′ W	104 foot barge, 130 foot barge, 75 tons concrete rubble
AR-392 New Bern	35° 05.000′ N 77° 00.617′ W	105,000 tires
AR-396 Oriental	35° 01.833′ N 76° 39.500′ W	Scrap metal, 22,000 tires, limestone marl
AR-398 New River	34° 39.598′ N 77° 22.499′ W	Concrete rubble

Figure 1-5. Map of North Carolina Estuarine Artificial Reefs

2
Benefit-Cost Analysis

2.1 INTRODUCTION

As described in their mission statement, "the Division of Marine Fisheries is dedicated to ensuring sustainable marine and estuarine fisheries and habitats for the benefit and health of the people of North Carolina." What facts help determine whether this mission is being accomplished? Although benefit-cost analysis should never be the only basis for public policy, counting and comparing existing benefits and costs can help decision makers understand the trade-offs associated with existing and future program choices. In this section, we discuss the benefits and costs of three important habitat enhancement activities carried out by the NCDMF between 2010 and 2015.

With just over $20 million in investments between 2010 and 2015 that RTI International evaluated, North Carolina restoration and habitat enhancement activities produced expected benefits valued at $82 million. In other words, every $1.00 invested in habitat enhancement activities provided North Carolina with about $4.05 in benefits. Even when conservatively high cost estimates are used in combination with conservatively low benefit estimates, the examined activities still passed the cost-benefit test, with every $1.00 invested in habitat enhancement activities providing North Carolina with about $2.00 in benefits.

2.2 ESTABLISHING A BASELINE AND TIME HORIZON

In the first step of the analysis, we established a "baseline" scenario. The baseline scenario describes what the habitat sites would look like without human enhancement activities. Without appropriated financial support for the activities, we assumed that human enhancement activities would not take place, while acknowledging that some natural enhancement may still occur in these areas. However, it is unlikely that natural enhancement would provide noticeable results in a truncated time period because many natural reefs take tens to hundreds of years to form. Anecdotal information in southern areas suggest harvests were sustained when higher amounts of cultch were planted annually. With reduced funds and low amounts of shell planted, the natural reefs were degraded. In addition, spatfall counts on cultch sites were declining prior to oyster sanctuaries established in Pamlico Sound. This pattern may have continued without the broodstock sites.

The second step of the analysis identified the time horizon. In other words, this step marked the start and endpoint years considered. In this analysis, the time horizon began in 2010 and considered how many acres the enhancement activities covered during a 6-year activity interval (2010 through 2015). The interval offers two advantages. First, enhancement activities often occur in ebbs and flows that are influenced by unusual circumstances that take place in a given year. Choosing a single year does not account for this variation and may bias the conclusions. In other words, we would be more likely to understate or overstate actual net benefits of enhancement activities if we select a single year. A second advantage relates to transparency. The NCDMF prepares an annual legislative report that provides a complete time series of annual expenditures for most of the activities during this 6-year activity interval. These reports provide a standardized set of financial statistics and are widely available to the public.

We chose the endpoint year for the analysis to be 2040, or 25 years beyond the last year of activity (e.g., 2015). Because the enhancement activities provide benefits beyond the initial year of deployment, we selected this endpoint to capture the stream of post-deployment benefits and costs. We also report the results for a shorter endpoint year—2025, or 10 years beyond the last year of activity.

2.3 HABITAT ENHANCEMENT ACTIVITIES

To quantify the benefits for three enhancement activities, we estimated area measurements (total acres) by site. The estimated acreage for oyster cultch planting, oyster sanctuary enhancements, and artificial reef enhancements was provided by the NCDMF (Table 2-1). As shown, cultch planting acreage ranged from 30 acres in 2011 to 81 acres in 2010. The cumulative total planted was 309 acres.

Table 2-1. Number of Bushels and Acreage of Cultch Planted per Year

YEAR PLANTED	YEAR BENEFITS BEGIN TO ACCRUE	BUSHELS PLANTED	ACREAGE
2009	2010	206,364	49.59[a]
2010	2011	208,309	81.36[b]
2011	2012	166,439	30.12[b]
2012	2013	276,370	69.47[b]
2013	2014	157,677	39.43[b]
2014	2015	232,418	39.08[b]

[a] Denotes estimated acreage from using the average bushels per acre from total bushels planted divided by the total acres during 2010 through 2015.

[b] Denotes actual acreage developed from known coordinates.

Table 2-2 summarizes the annual acres and cumulative acres for the enhancement activities used in the benefit-cost analysis. We included cumulative acres because we assumed that acres planted each year continue to provide benefits each year thereafter for the study period. As shown, cultch planting at oyster sites had the highest cumulative acres (349 acres), followed by oyster sanctuary enhancements (123 acres) and artificial reef enhancements (73 acres).

Table 2-2. Summary of the Estimated and Cumulative Acres Covered by Enhancement Activities by Year

CULTCH PLANTING AT OYSTER SITES		
YEAR	ESTIMATED ACRES	CUMULATIVE ACRES
2009	50	50
2010	81	131
2011	30	161
2012	70	231
2013	39	270
2014	39	309
2015	41	350
OYSTER SANCTUARY SITES		
YEAR	ACTUAL ACRES	CUMULATIVE ACRES
2009	28	28
2010	34	62
2011	5	67
2012	15	82
2013	27	109
2014	1	110
2015	12	122
ARTIFICIAL REEF SITES		
YEAR	ACTUAL ACRES	CUMULATIVE ACRES
2009	4	4
2010	20	24
2011	13	37
2012	8	45
2013	12	57
2014	6	63
2015	10	73

2.4 HABITAT ENHANCEMENT BENEFITS

Once we determined the acreage associated with the enhancement activities, we used nonmarket valuation methods to monetize the value of benefits using the values reported in the peer-reviewed study prepared by Grabowski et al. (2012). In addition, we used Grabowski, Piehler, and Peterson (2011)[1] to estimate benefits accruing from recreational fishing on the habitat enhancement sites. Both studies focused on North Carolina sites.

Using preexisting estimates to measure benefits at another project site is known as the benefit transfer approach to nonmarket valuation. This method transfers a point estimate and range of benefits from the original study site (referred to as the "study site") to the site of interest (referred to as the "policy site"). The main advantage of benefit transfer is its low cost relative to other approaches; it is commonly used when time or resources are insufficient to develop customized project site benefits using other nonmarket valuation approaches. We acknowledge disadvantages of this approach due to differences in the policy and study sites, as well as problems due to violations of economic theory (Barton, 2002; Costanza et al., 1997; Chattopadhyay, 2003; Delavan and Epp, 2001; Downing and Ozuna, 1996; Loomis et al., 1995).

The following benefits identified by Grabowski et al. (2012) and Grabowski, Piehler, and Peterson (2011) are monetized in this report (Table 2-3):

- commercial fishing, including oyster harvest services from oyster cultch planting activities only
- recreational fishing
- water quality services, including nitrogen removal/water quality improvement, value of submerged aquatic vegetation (SAV) enhancement (all activities), and shoreline stabilization (oyster cultch planting activities only)

To calculate the stream of benefits for each year, the Grabowski et al. benefit per acre was multiplied by the cumulative acres reported earlier in Table 2-2. For the analysis, we adjusted the benefit values (Table 2-3) expressed in 2011 dollars to 2015 dollars to adjust for inflation using the Consumer Price Index. We also converted dollars per hectare to dollars per acre using the following conversion factor: 2.47 acres/hectare. Table 2-4 provides the benefit streams for the three enhancement activities.

[1] We used values reported in Table 10 of the report.

Table 2-3. Total Annual Value of Ecosystem Services Provided by Oyster Reefs in 2011 Dollars per Hectare per Year

ECOSYSTEM SERVICE VALUES	MINIMUM	MAXIMUM	AVERAGE	INCLUDED IN BENEFIT-COST ANALYSIS
Commercial fishing oyster harvest value state				
Year 1 no-low harvest levels	NA	NA	$0	Yes
Year 2 no-low harvest levels	NA	NA	$880	Yes
Year 3 moderate-intense harvest levels	NA	NA	$12,186	Yes
Year 4 + no-low harvest levels	NA	NA	$880	Yes
Recreational fishing *Grabowski, Piehler, and Peterson (2011)*				
Recreational	NA	NA	$6,469	Yes
Other commercial fishing *Grabowski et al (2012)*				
Commercial	$4,123	$4,123	$4,123	Yes
Water quality services				
Chlorophyll *a* removal[a]	$0	$0	$0	No
Nitrogen removal[b]	$1,385	$6,716	$5,050	Yes
Recreational use	NA	NA	NA	No
SAV enhancement[c]	$0	$2,584	$1,292	Yes
Bacterial removal	NA	NA	NA	No
Carbon burial	NA	NA	NA	No
Shoreline protection[c]	$0	$85,998	$860	Yes
Habitat for epibenthic infauna	$0	$0	$0	No
Landscape processes	$0	$0	$0	No
Nonoyster harvest service total	**$5,508**	**$99,421**	**$10,325**	

Note: NA represents insufficient data to assess the economic value of the service. There are 2.47 acres per hectare. To express annual values on a per-acre basis, divide each value in Table 2-3 by 2.47.

Sources: Grabowski et al. (2012). Table 4 and Grabowski, Piehler, and Peterson, 2011. Table 10.

[a] The value of chlorophyll a removal was not included in the summary table because this service is considered potentially redundant if nitrogen removal through denitrification is also considered.

[b] The value of nitrogen removal was estimated by quantifying the value of enhanced denitrification rates on oyster reefs.

[c] The average SAV enhancement and shoreline stabilization was valued assuming that 1% of the linear length of reefs perform this function.

Table 2-4. Annual Value of Benefits by Enhancement Activity, Monetized Benefit Type, and Year (expressed in 2015 dollars)

OYSTER CULTCH PLANTING ENHANCEMENTS			
YEAR	COMMERCIAL FISHING	RECREATIONAL FISHING	WATER QUALITY[a]
2010	$105,090	$137,234	$119,844
2011	$504,398	$362,387	$316,466
2012	$713,588	$445,740	$389,257
2013	$626,364	$637,989	$557,144
2014	$889,964	$747,106	$652,434
2015	$835,336	$855,255	$746,879
OYSTER SANCTUARY ENHANCEMENTS			
YEAR	COMMERCIAL FISHING	RECREATIONAL FISHING	WATER QUALITY[a]
2010	$49,841	$78,234	$64,778
2011	$109,027	$171,134	$141,700
2012	$117,454	$184,362	$152,653
2013	$143,864	$225,817	$186,978
2014	$191,996	$301,366	$249,534
2015	$194,481	$305,268	$252,764
ARTIFICIAL REEF ENHANCEMENTS			
YEAR	COMMERCIAL FISHING	RECREATIONAL FISHING	WATER QUALITY[a]
2010	$6,735	$10,571	$8,753
2011	$41,502	$65,144	$53,940
2012	$64,439	$101,147	$83,751
2013	$79,055	$124,089	$102,746
2014	$100,864	$158,321	$131,091
2015	$111,539	$175,078	$144,966

[a] Nitrogen removal and average SAV enhancement. 36% of oyster cultch planting also includes benefits from shoreline protection.

2.5 HABITAT ENHANCEMENT COSTS

As discussed earlier, the NCDMF prepares an annual legislative report that provides time series of annual expenditures for 2010 through 2014. Because 2015 data are not currently available, we assumed expenditures are similar to 2014 values (see Table 2-5). To account for artificial reef enhancements, we multiply the average cost per acre (approximately $16,000) by the estimated number of acres. Also included in the oyster sanctuary costs is a $3.7 million dollar grant provided by National Oceanic and Atmospheric Administration for oyster sanctuary improvements.

Table 2-5. Annual Habitat Enhancement Costs, 2010–2015 ($ million)

YEAR	CULTCH PLANTING ACTIVITIES	OYSTER SANCTUARIES[a]	OYSTER SHELL RECYCLING	ARTIFICIAL REEFS	TOTAL COSTS (NOMINAL DOLLARS)	CONSUMER PRICE INDEX RATIO	TOTAL COSTS (2015 DOLLARS)	PRESENT VALUE @ 3% DISCOUNT RATE	PRESENT VALUE @ 7% DISCOUNT RATE
2010	$2.24	$4.04	$0.03	$0.31	$6.63	1.086	$7.20	$8.35	$10.10
2011	$1.60	$0.26	$0.04	$0.21	$2.10	1.057	$2.22	$2.50	$2.91
2012	$1.42	$0.33	$0.01	$0.14	$1.90	1.032	$1.96	$2.14	$2.40
2013	$1.57	$0.80	$0.00	$0.21	$2.57	1.017	$2.61	$2.77	$2.99
2014	$1.57	$0.49	$0.00	$0.10	$2.16	0.999	$2.16	$2.22	$2.31
2015	$1.57	$0.49	$0.00	$0.15	$2.21	1.000	$2.21	$2.21	$2.21
Totals	**$9.97**	**$6.40**	**$0.08**	**$1.12**	**$17.57**		**$18.37**	**$20.20**	**$22.93**

[a] In 2010, we have included the $3.7 million dollar grant provided by National Oceanic and Atmospheric Administration for oyster sanctuary improvements.

2.6 COMPARISON OF BENEFITS AND COSTS: BENEFIT-COST RATIO

After calculating the annual value of benefits and costs, we compared the two. Because the benefits and costs take place over multiple years, we used discounting procedures to calculate the net present value (NPV) for the enhancement activities. NPV is estimated by multiplying the benefits minus costs in each year (Tables 2-4 and 2-5) by a discount factor (d) and summing the values across the time horizon (2010 through 2025). The discount factor is defined as:

$$d_t = \frac{1}{(1+r)^t}$$

where r is the interest rate and t is the analysis year (t = 0 in 2015). A 3% interest rate approximates the real rate of return on long-term government debt over the last 30 years (Office of Management and Budget [OMB], 2011).

As shown in Table 2-6, with just over $20 million in investments between 2010 and 2015 that RTI evaluated, North Carolina restoration and habitat enhancement activities produced expected benefits valued at $48.0 million through 2025. In other words, every $1.00 invested in habitat enhancement activities will provide North Carolina with about $2.38 in commercial fishing, recreational fishing, and water quality benefits.

If we look at the potential benefits over a longer time horizon (Table 2-7), the expected benefits from North Carolina restoration and habitat enhancement activities grow to $81.8 million through 2040.

In other words, every $1.00 invested in habitat enhancement activities will provide North Carolina with about $4.05 in commercial fishing, recreational fishing, and water quality benefits.

In summary, a comparison of the benefits and costs for activities by the NCDMF's Habitat Enhancement Section indicates that the benefits substantially exceed costs. The investment in state enhancement activities provides a net improvement in the welfare of North Carolina citizens. The activities pass the benefit-cost test even though some known and likely substantial benefits are not monetized. [1]

Table 2-6. Present Value of the Benefits and Costs of Habitat Enhancement Activities (3% discount rate; million 2015 dollars) through 2025

ENHANCEMENT ACTIVITY	COMMERCIAL FISHING	RECREATIONAL FISHING	WATER QUALITY	TOTAL
Oyster cultch planting	$10.6	$11.6	$10.2	$32.3
Oyster sanctuaries	$2.5	$3.9	$3.3	$9.7
Artificial reefs	$1.5	$2.4	$2.0	$5.9
Total monetized benefits	**$14.6**	**$18.0**	**$15.4**	**$48.0**
Total costs				**$20.2**
Benefit-Cost Ratio: Over 15 years, every $1 invested produces benefits of				**$48.0 ÷ $20.2 = $2.38**

[1] Table 2-3 identifies which possible benefits were not monetized and excluded from the benefit-cost analysis.

Table 2-7. Present Value of the Benefits and Costs of Habitat Enhancement Activities (3% discount rate; million 2015 dollars) through 2040

ENHANCEMENT ACTIVITY	COMMERCIAL FISHING	RECREATIONAL FISHING	WATER QUALITY	TOTAL
Oyster cultch planting	$17.2	$20.2	$17.7	$55.1
Oyster sanctuaries	$4.2	$6.7	$5.5	$16.4
Artificial reefs	$2.7	$4.2	$3.5	$10.3
Total monetized benefits	**$24.1**	**$31.1**	**$26.6**	**$81.8**
Total costs				**$20.2**
Benefit-Cost Ratio: Over 25 years, every $1 invested produces benefits of				**$81.8 ÷ $20.2 = $4.05**

2.7 SENSITIVITY ANALYSIS

In our last section, we evaluate how robust the findings in Section 2.6 are under alternative assumptions. In other words, we provide lower- and upper-bound estimates of the benefit-cost ratios to illustrate the precision by which we can measure the ratios given existing data and assumptions.

In our first sensitivity analysis (Table 2-8), we used conservatively low benefits by using the minimum values from the monetized benefits from Grabowski et al. (2012) and also used a higher 7% discount rate consistent with the historical average pretax rate of return to U.S. private capital (OMB, 2011). The assumptions will tend to lower the present value of the benefit stream and raise the present value of the cost stream. As shown below, even under this scenario using conservatively low benefit estimates with conservatively high cost estimates, the examined activities still passed the benefit-cost test, with every $1.00 invested in habitat enhancement activities providing North Carolina with about $2.00 of benefits.

Table 2-8. Sensitivity Lower Bound: Present Value of the Benefits and Costs of Habitat Enhancement Activities (Low Benefits and Higher (7%) discount rate; million 2015 dollars): 25-Year Horizon

ENHANCEMENT ACTIVITY	COMMERCIAL FISHING	RECREATIONAL FISHING	WATER QUALITY	TOTAL
Oyster cultch planting	$13.2	$14.9	$3.2	$31.3
Oyster sanctuaries	$3.2	$5.0	$0.8	$9.0
Artificial reefs	$2.0	$3.1	$0.5	$5.5
Total monetized benefits	**$18.3**	**$23.0**	**$4.5**	**$45.8**
Total costs				**$22.9**
Benefit-Cost Ratio: Over 25 years, every $1 invested produces benefits of:				**$45.8 ÷ $22.9 = $2.00**

In our second sensitivity analysis, we used optimistically high benefits by using the maximum values from the monetized benefits from Grabowski et al. (2012) and also used a 3% discount rate (Table 2-9). The assumptions will tend to raise the present value of the benefit stream and lower the present value of the cost stream. As shown below, under this optimistic scenario, the benefit-cost ratio is much higher; every $1.00 invested in habitat enhancement activities provided North Carolina with about $12.28 of benefits. The primary driver of the large difference is the value of shoreline protection assumed under this scenario ($85,998 per hectare versus $860 per hectare).

Table 2-9. Sensitivity Upper Bound: Present Value of the Benefits and Costs of Habitat Enhancement Activities (High Benefits and 3% discount rate; million 2015 dollars): 25-Year Horizon

ENHANCEMENT ACTIVITY	COMMERCIAL FISHING	RECREATIONAL FISHING	WATER QUALITY	TOTAL
Oyster cultch planting	$17.2	$20.2	$125.9	$163.3
Oyster sanctuaries	$4.2	$6.7	$41.1	$52.0
Artificial reefs	$2.7	$4.2	$25.8	$32.6
Total monetized benefits	**$24.1**	**$31.1**	**$192.8**	**$248.0**
Total costs				**$20.2**
Benefit-Cost Ratio: Over 25 years, every $1 invested produces benefits of				**$248 ÷ $20.2 =$12.28**

3

Other Contributions to the State Economy: A Macroeconomic Perspective Case Study

According to one view of economic contributions, the size of the economy increases when more spending is attracted to the economy than leaves it. Other studies of coastal restoration and community economic development in North Carolina have already documented and illustrated economic impacts associated with coastal restoration expenditures. For example, RTI (2015) prepared a report for the North Carolina Coastal Federation that examined the job impacts of a $5 million grant entitled Putting Private Industry to Work Rebuilding North Carolina's Oyster Habitat. The grant included expenditures for reef construction and site preparation; site design research; and planning, administration, transportation and other support for oyster sanctuary sites Crab Hole and Clam Shoal. The study concluded that the economic impact of the grant resulted in $7.5 million in business revenue, $1.9 million in household income, and over 50 jobs during the restoration period. Funding amounts for the industries included salaries and benefits, supplies (oyster shells and other materials), equipment (boat rental), and disbursements to local project partners and contractors.

In the case study below, we complement the previous report findings by examining how additional commercial fishing sales brought about by habitat restoration ripple through the state economy. The approach adds new and additional information associated with ongoing longer term effects of economy-wide spending patterns created by additional commercial fishing sales.

3.1 HOW THE STATE ECONOMIC IMPACT IS MEASURED

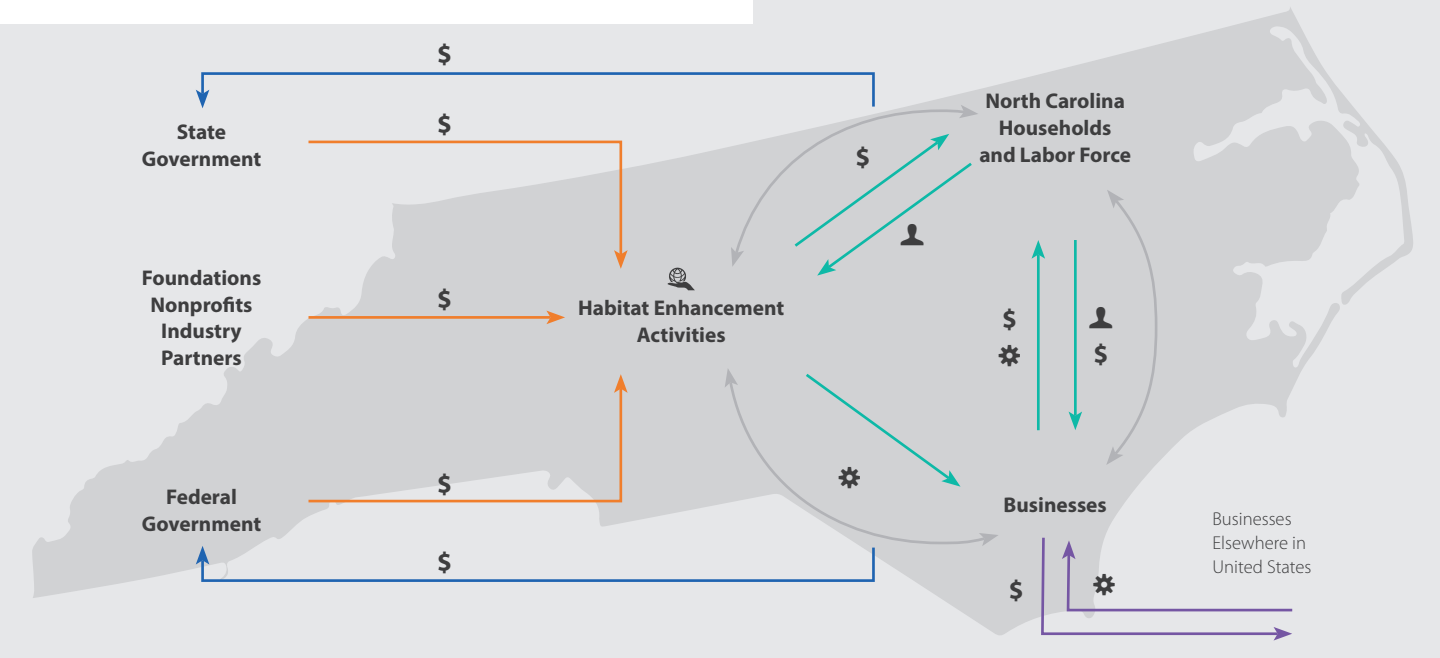
RTI examined the effects of spending patterns created by additional commercial fishing sales using input-output analysis. Input-output analysis is a well-known and reliable methodology for calculating these types of far-reaching spillover effects. The methodology has a long history in economics, and the economist who created this analysis framework received the Nobel Prize in Economic Science for it. The statewide economic effects were measured using the Commercial Fishing Economic Impact Model developed by the NCDMF, which examines economic impacts generated by commercial seafood harvesters, dealers, wholesalers, and retailers (NCDMF License and Statistics Section, 2014).

The estimated annual commercial fishing sales inputs for the model range from $0.2 million in 2010 to $2.0 million in 2014, for a total of $8.2 million between 2010 and 2015 (Table 3-1). These are the direct commercial benefits from habitat enhancement activities. However, additional benefits above and beyond the direct sales benefits ripple through the economy through supply chain and household income linkages that the commercial fishing sector has within the state. [1]

Table 3-1. Estimate of Additional Commercial Fishing Sales Brought about by Habitat Enhancement Activities: 2010–2015

YEAR	FISH AND CRUSTACEANS	OYSTERS	TOTAL
2010	$0.1	$0.1	$0.2
2011	$0.4	$0.8	$1.2
2012	$0.5	$1.3	$1.8
2013	$0.6	$0.7	$1.3
2014	$0.8	$1.2	$2.0
2015	$0.9	$0.9	$1.8

Figure 3-1. Ties between the Habitat Enhancement Activities and the Regional Economy



[1] In input-output modeling, the additional supply chain and income effects are referred to as the indirect and induced effects.

3.2 SUMMARY OF RESULTS

We estimated that, from 2010 to 2015, the increases in commercial fishing sales ($8.2 million) rippled through the state economy and generated up to $31.8 million in business revenue (Table 3-2). Two other measures illustrate the economic impact on jobs and labor income. Commercial fishing sales supported up to 696 jobs across the entire North Carolina economy over the time frame. These jobs paid a total of $13.2 million in annual wages and salaries.

In addition to the quantified economic impacts from additional commercial fishing, we acknowledge there are additional unquantified economic impacts (jobs, income, business revenue) generated by the oyster restoration activities (e.g., material suppliers, transportation services, employees, partners, contractors), as well as the recreational fishing that occurs on the sites (e.g., gas stations, boat builders/dealerships/mechanics, tackle shops, restaurants). As a result, Table 3-2 presents a lower-bound estimate of total economy-wide impacts.

Table 3-2. State-Wide Total Economy Impacts Associated with $8.2 million in Commercial Fishing Sales, 2010–2015

	ECONOMY-WIDE IMPACTS		
ADDITIONAL COMMERCIAL FISHING SALES	BUSINESS REVENUE	WAGES AND SALARIES (MILLION)[a]	NUMBER OF JOBS
$8.2	$31.8	$13.2	696

Source: RTI analysis based on NCDMF Commercial Fishing Economic Impact model results.

[a] Value of wages and salaries earned.

4
Cost-Effectiveness

4.1 BACKGROUND

The NCDMF has relied on both its own resources and the use of contractors to complete projects related to developing shellfish habitat and oyster propagation in North Carolina. In this section of the report, RTI explores whether NCDMF should continue using its own resources, use contractors for all services, or use a combination of both to accomplish its goals.

As shown in Section 2.1, the NCDMF has two programs with the primary purpose of shellfish habitat enhancement and oyster propagation: the Shellfish Rehabilitation Program and the Oyster Sanctuary Program. The Artificial Reef Program is NCDMF's third habitat enhancement program with a secondary function of oyster habitat in oyster-growing areas. This section of the analysis focuses on the Shellfish Rehabilitation Program, which is responsible for deploying cultch and oyster sanctuary material to develop harvestable and no-take oyster reefs.

4.2 INTERNAL RESOURCES AND COSTS

The Shellfish Rehabilitation Program uses a variety of internal resources, including marine and land equipment and a qualified staff of research biologists, field technicians, and vessel crews. The Shellfish Rehabilitation Program has 12 full-time staff positions who participate in cultch planting: one biologist supervisor, one biologist, four research vessel captains, two research vessel engineers, three technicians, and a deckhand. At the time of writing, 10 of these positions are filled and 2 are vacant. Cultch planting occurs from April through August, with the planning of these activities occurring from January through March and sampling these areas from September through December. Oyster sanctuary construction and planning occurs year-round with sampling occurring August through October.

Appendix A shows the equipment owned by NCDMF and used for cultch planting activities, including the year of purchase, model, purchase price, and number of years owned by the program. For cultch planting, the Program owns five research vessel barges and associated equipment such as tractors, loaders, motors, dump trucks, trucks, trailers, and GPS units used for deploying cultch material within North Carolina's coastal waters. However, not all equipment in the list is used for the sole purpose of cultch planting and may be used for other activities such as noncultch planting sampling, artificial reef construction, mapping, habitat monitoring, and facility maintenance. Additionally, the Shellfish Rehabilitation Program occasionally loans equipment and staff to other programs and sections to accomplish their tasks.

Table 4-1 shows the total operational expenditures (including fuel and maintenance), bushels planted, and cost per bushel for each vessel from 2010 to 2015. The cost-per-bushel estimates do not factor in labor costs, depreciation, or the cost of vessel deck replating, which occurs every 15 years. Since 2013, two vessel decks have been replated with costs ranging from $18,400 to $25,000. As shown in Table 4-1, the cost-per-bushel ranges from $0.04 per bushel (in 2010 for the Stone's Bay vessel and 2014 for the Cape Fear vessel) to $1.57 per bushel (in 2014 for the Stone's Bay vessel).

Table 4-1. Operational Expenditures, Bushels Planted, and Cost per Bushel by Vessel, 2010–2015 (not including labor costs or depreciation)

VESSEL	2010	2011	2012	2013	2014	2015
R/V Shell Point[a]						
Expenditures	$15,060.71	$12,666.35	$16,013.59	$16,351.56	$43,813.83[b]	$8,960.50
Bushels planted	57,517	20,138	31,969	28,725	69,046	77,923
Cost per bushel[c]	$0.26	$0.63	$0.50	$0.57	$0.37	$0.11
R/V Cape Fear						
Expenditures	$1,986.05	$1,361.29	$3,448.16	$1,147.31	$578.00	$3,909.53
Bushels planted	21,014	3,940	24,591	18,794	13,648	13,050
Cost per bushel	$0.09	$0.35	$0.14	$0.06	$0.04	$0.30
R/V Stones Bay						
Expenditures	$1,139.84	$3,099.66	$1,556.33	$2,279.32	$27,852.36[b]	$8,251.13
Bushels planted	32,399	10,846	34,354	18,794	1,820	22,135
Cost per bushel[c]	$0.04	$0.29	$0.05	$0.12	$1.57	$0.37
R/V Crab Slough						
Expenditures	$6,928.27	$12,061.44	$12,779.00	$19,747.48	$16,597.91	$11,425.32
Bushels planted	62,447	114,625	63,089	71,348	68,613	67,526
Cost per bushel	$0.11	$0.11	$0.20	$0.28	$0.24	$0.17
M/V Jones Bay						
Expenditures	$-	$-	$69.78	$2,924.31	$1,261.32	$-
Bushels planted	0	0	0	4908	0	0
Cost per bushel	$-	$-	N/A	$0.60	N/A	$-

[a] The R/V Shell Point was used to deploy reef balls from 2011 to 2013.
[b] Includes deck replating costs.
[c] Cost per bushel estimates do not factor in deck replating costs.

The program also operates the M/V West Bay, which is the Division's primary vessel for construction of oyster sanctuaries and artificial reefs. It is also the secondary vessel for cultch planting and can plant cultch in deeper water sites, where a large amount of material must be transported a long distance. This vessel is capable of transporting 150 tons of material and is staffed by a crew of four: a captain, two research vessel engineers, and a deckhand. To provide more detail on the types of operational expenses a vessel requires, we present the operational costs of using the M/V West Bay in Table 4-2. The detailed operational costs of other vessels were not provided.

In Example 1, a contractor was hired in 2009, 2012, and 2015 to develop small patch oyster reefs at a site in Onslow County. Table 4-3 shows the bushels that were planted, the contracted deployment costs, the acres planted, and the number of reefs developed. For the first project in 2009, the contract was made based on the assumption that the contractor could only take one trip per day. For the subsequent projects in 2012 and 2015, the contractor rented a temporary stockpile site closer to the project site and was able to make four to five trips per day, thus lowering the overall costs. This site was within 1 mile of a reliable stockpile site; costs would be higher if the reef site were farther from the stockpile site.

Table 4-2. Operations Cost Estimates of M/V West Bay

ITEM	INTERVAL (IN YEARS)	COST PER INTERVAL	COST PER YEAR	COST PER DAY (AVG. 72 DAYS/YEAR)
Oil	1	$1,425	$1,425	$14.26
Haul out	3	$162,876	$54,292	$754.06
Life raft inspection	1	$900	$900	$12.50
Spud removal	1	$1,100	$1,100	$15.28
General purchases	1	$13,360	$13,360	$185.56
Engine rebuild	10	$100,000	$10,000	$138.89
Clutch rebuild	10	$30,000	$3,000	$41.67
Deck replating	15	$100,000	$6,666	$92.59
Vessel Only			**$90,744**	**$1,254.79**
Staff salaries w/fringe	1	$199,327	$199,327	$2,768.44
Total			**$290,071**	**$4,023.23**

4.3 CONTRACTING SERVICES

The NCDMF uses contractors for some projects, both small and large scale. In this section, we present three examples of projects that used contractors and the costs for four hypothetical projects that the NCDMF might complete in the future.

One advantage to working with a contractor is the potential use of temporary private stockpile sites that are in close proximity to the project site.

Table 4-3. Costs Incurred by Contractor for Developing Small Oyster Patch Reefs in Onslow County, NC (not including the cost of materials)

DATE COMPLETED	BUSHELS	DEPLOYMENT COST[a]	COST PER BUSHEL	TOTAL FOOTPRINT (ACRES)	NUMBER OF REEFS
12/15/2009	8,224.04	$30,000[b]	$3.65	0.87	5
5/3/2012	10,569.51	$9,000	$0.85	0.40	13
8/26/2015	6,885.71	$9,000	$1.31	0.34	
Totals	**25,679.26**	**$48,000**	**$1.87**	**1.62**	**18**

[a] Deployment costs include mobilization/demobilization but not material cost.

[b] Contract was based on the distance to an existing stockpile site at the time the project was planned. In later phases, the contractor was able to secure a temporary stockpile site close to the project site.

In Example 2, a contractor was hired in 2013 to develop artificial reefs. Although artificial reef development is different from oyster sanctuary development, this reef is sited in waters that are near oyster sanctuaries and built using similar materials. The total cost to deploy 2,000 tons of concrete was $165,000, as shown in Table 4-4. This deployment took the contractor 11 days to complete, including 3 days for mobilization and 8 days for deployment. Because the material used in this project was recycled concrete from a road construction project, there were no materials costs.

In Example 3, the North Carolina Coastal Federation, in partnership with NCDMF, hired a contractor for oyster sanctuary development. In this project, the contractor deployed 32,000 tons of marl rip rap on the Clam Shoal Oyster Sanctuary and 22,500 tons of marl rip rap on the Crab Hole Oyster Sanctuary. The large scale of this project required approximately 6 months of planning. Once underway, the project took 125 days to complete. The contractor used two tug boats (at a cost of $7,000 per day), six barges (at a cost of $26,000 per month), and several excavators. As shown in Table 4-5, the total cost of this project, including materials, was $3,762,745. Removing the cost of materials (i.e., factoring in only deployment costs) and dividing the total cost by the tons of materials deployed, the cost is $44.04 per ton.

Table 4-4. Contractor Costs for Artificial Reef Deployment, 2013[a]

ACTIVITY	COST
Fixed costs:	
Tug and barge mobilization	$12,500
Ocean barge rental	$30,000
Forklift rental	$10,000
Tug and barge demobilization	$12,500
Variable costs:	
Tug barge stand-by while loading	$40,000
Loading and lashing 2,000 tons of concrete	$20,000
Deployment	$40,000
Total	**$165,000**
Cost per ton	**$82.50**

[a] Total project timeline was 3 days for mobilization/demobilization and 8 days for reef deployment.

Table 4-5. Contractor Costs for Oyster Sanctuary Development

ACTIVITY	PRICE ($ PER TON)	TOTAL COST
Materials	$25	$1,362,500
Trucking material to port	$11	$599,500
Loading material on barge	$5	$272,500
Tug boat operation	$17	$926,916
Barge rental	$2.86	$156,000
Personnel and equipment for deployment	$5	$272,500
Mobilization and demobilization	$1.10	$60,000
Concrete barge decks	$0.73	$40,000
General expenses	$1.34	$72,829
Total	**$44.04**	**$3,762,745**

When using a contractor, NCDMF employees are required to monitor the contractors at all times throughout the project for permit compliance. The daily cost of monitoring contractors is $1,049.50 (see Table 4-6). This cost should be considered and added to the cost of the contracted work to represent the total cost of contracted projects. If the NCDMF were to use only contractors for deployment of cultch material, there would be a shift in staff responsibilities from development to contractor monitoring. Thus, all boat crew staff that are currently doing development work would be needed to monitor contractor deployments. Depending on the number of projects contracted, NCDMF may need to purchase additional boats from which the staff would monitor.

Table 4-6. NCDMF's Daily Cost to Monitor Contractors

ITEM	DAILY COST
Staff (11-hr day for two people)	$609.15
Vessel	$250.00
Small vessel fuel	$60.00
Per diem	$37.40
Vehicle ($0.65 per mile* 143 miles per day)	$92.95
Total	**$1,049.50**

Note: Cost will increase if overnight travel or workdays in excess of 11 hours are required.

4.3.1 Hypothetical Scenarios

Considering the NCDMF's need for contracting services in the future, we analyzed the costs of four hypothetical scenarios. All scenarios show the deployment and material cost for two different types of cultch material—oyster shell and marl. Because of the variability of cost and coverage, separate estimates were produced for oyster shell and marl. Each estimate was for development of cultch sites within 10 miles of Swan Quarter, one of the most costly sites to transport material to and one that takes the greatest amount of staff time. This location was chosen to provide an upper bound in cost estimates. We also present the detailed costs of these projects if NCDMF were to complete them. The cost of materials is presented in Table 4-7. We assumed the cost of materials would be equivalent regardless of whether the project is done internally or contracted.

Table 4-7. Cost of Materials for Four Hypothetical Scenarios

AMOUNT OF MATERIAL	MATERIAL COST
Scenario 1—275 tons of oyster shell	$21,656
Scenario 2—275 tons of marl	$10,862
Scenario 3—30,000 tons of oyster shell	$2,362,500
Scenario 4—30,000 tons of marl	$1,185,000

The first and second scenarios—both smaller projects—would involve the deployment of 275 tons of oyster shell or 275 tons of marl, resulting in 1 acre of oyster shell or 0.6 acres of marl. Assuming the NCDMF would use their R/V Crab Slough to complete these projects, their estimated deployment costs to complete this project are $4,648 for oyster shell and $3,338 for marl, as shown in Table 4-8. Adding the cost of materials and the deployment costs (from Tables 4-7 and 4-8, respectively) results in an overall total cost of $26,304 for Scenario 1 using oyster shell and $14,200 for Scenario 2 using marl.

The contractor was unable to estimate the costs to complete Scenario 1 or 2 because of the small size of the project. Because of the fixed costs of staging equipment, it would not be effective from a cost standpoint for a contractor to bid on a project of this size.

Table 4-8. Deployment Costs by NCDMF for Scenarios 1 and 2

	NUMBER OF TRIPS USING R/V CRAB SLOUGH	TOTAL DEPLOYMENT COST	DEPLOYMENT COST PER TON
Scenario 1—275 tons of oyster shell	8.51	$4,648	$16.90
Scenario 2—275 tons of marl	6.11	$3,338	$12.14

The third and fourth scenarios—both larger projects—would involve the deployment of 30,000 tons of oyster shell or 30,000 tons of marl, resulting in 109.2 acres of oyster shell or 66.6 acres of marl, depending on the material used.

The contractor would use two excavators—one on shore to load and manage the stockpile and one on a barge for deployment into the water. Similarly they would use two loaders, one on shore and one on the barge deck. In addition, they would use two or three barges and one tug boat. The contractor's estimated deployment cost of $35 per ton of material results in a deployment cost of $1,050,000. Adding the cost of materials results in a total cost of $3,412,500 for Scenario 3 using oyster shell or $2,235,000 for Scenario 4 using marl.

[2] Because oyster shell and marl have different weights per volume, the amount of acreage developed changes with material.

If this project were completed by NCDMF, they would use the M/V West Bay for an estimated deployment cost of $461,522, regardless of whether oyster shell or marl were used (see Table 4-9). This equates to $15 per ton. Adding the cost of materials results in an overall total cost of Scenario 3 to $2,824,022 using oyster shell and $1,646,522 for Scenario 4 using marl.

Table 4-9. Deployment Costs by NCDMF for Scenarios 3 and 4

	NUMBER OF TRIPS USING M/V WEST BAY	TOTAL DEPLOYMENT COST	DEPLOYMENT COST PER TON
Scenarios 3 and 4 —30,000 tons of oyster shell or marl	33.33	$461,522	$15.38

4.4 COMPARISON OF COMPLETING PROJECTS USING INTERNAL RESOURCES VERSUS CONTRACTORS

To compare the costs of using internal resources (i.e., NCDMF staff and equipment) versus external resources (i.e., hiring contractors), we highlight the overall costs and timelines for both options for a variety of projects (both actual and hypothetical) in Table 4-10. The costs shown in Table 4-10 include both materials and deployment costs. The internal resource costs and timeline were provided by NCDMF staff, and external resource estimates were provided by a contractor. [3]

Table 4-10. Comparison of Costs and Time Required for NCDMF versus Contractors, Including Materials and Deployment

PROJECT	AMOUNT OF MATERIAL DEPLOYED (TONS)	NCDMF COSTS	NCDMF TIMELINE	CONTRACTOR COSTS	CONTRACTOR TIMELINE
Example 2—Artificial Reef Development	2,000	$79,408	16 days	$165,000	11 days
Example 3—Oyster Sanctuary Development	54,500	$4,052,000	5.5 years	$3,762,745	125 days
Scenario 1 (Oyster Shell)	275	$26,304	5 days	N/A	N/A
Scenario 2 (Marl)	275	$14,200	3 days	N/A	N/A
Scenario 3 (Oyster Shell)	30,000	$2,824,022	3 years	$3,412,500	4 months
Scenario 4 (Marl)	30,000	$1,646,522	3 years	$2,235,000	4 months

[3] The contractor's estimate was a rough calculation and would require more planning and coordination with NCDMF to estimate an exact dollar amount to complete these projects.

In the example of artificial reef deployment (Example 2), it would have cost the NCDMF $79,407 to complete this project internally compared with the contractor cost of $165,000 (see Table 4-4). Thus, it would have been more cost-effective for the NCDMF to complete this project internally, with a cost savings of $85,592, though it would have taken 5 more days to complete. In the example of oyster sanctuary development (Example 3), it would have cost the NCDMF an estimated $4 million to complete this project internally because of the project location compared with the actual contractor cost of $3.7 million (see Table 4-5). It was more effective to contract this project, with a cost savings of $289,255. In addition to monetary savings, the project was completed in a timelier manner by using a contractor. Because the NCDMF's largest vessel, the M/V West Bay, deploys material approximately 72 days per year, it would have taken 5.5 years to complete the oyster sanctuary development project in Example 3 versus the 125 days that it took the contractor to complete.

In Scenario 1, the deployment of 275 tons of oyster shell at a water depth of 5 feet for the planting site would cost the NCDMF an estimated total of $26,304 (including materials and deployment). This project could be completed in 5 days. For Scenario 2, the deployment of 275 tons of marl at a water depth of 5 feet for the planting site would cost the NCDMF an estimated total of $14,200. Scenario 2 would take NCDMF 3 days to complete. As explained in Section 4.3.1, the contractor did not estimate the costs for this scenario because of the small size.

In Scenarios 3 and 4, the deployment of 30,000 tons within 10 miles of a stockpile site at a water depth of at least 10 feet for the planting site would cost the NCDMF an estimated total of $461,522 to deploy compared with $1 million for deployment by a contractor. However, it is important to note that a distance over 10 miles away from the site would double NCDMF's deployment cost.

Factoring in the cost of materials, for Scenario 3 the cost increases to $2.8 million for NCDMF and $3.4 million for a contractor. Comparing costs in Scenario 4, the total cost for NCDMF is $1.6 million versus $2.2 million for a contractor. Although it would be more cost-effective for NCDMF to do these large projects, we must also consider the amount of time required to complete these projects. A contractor could complete these projects in 4 months, whereas it would take NCDMF at least 3 years to complete because of the lack of resources owned and other project obligations. Thus, it is not time effective for NCDMF to complete these projects internally.

As noted in Table 4-6, the daily cost of $1,049.50 to monitor contractors needs to be added to the contractor costs. For Scenarios 3 and 4, if we assume that each month has 22 working days and it takes 4 months to complete the project, then we should add $92,356 to the total cost of the project.

Through these examples, it is evident that the NCDMF should continue to complete some projects using internal resources and contract other projects. Deployment costs, timelines, and the cost of monitoring contractors should all be considered when making this decision. Generally speaking, it is more time and cost-effective for NCDMF to complete smaller projects and hire a contractor for larger projects. Moving forward, NCDMF will need to hire contractors to complete large-scale projects. It is recognized that it may be more cost-effective for NCDMF to complete larger projects but limited staffing and vessel availability may require the use of contractors to ensure that the projects are completed in a timely manner. More analysis should be completed to determine the breakpoint at which it becomes more effective to hire a contractor. This type of analysis may need to be done on a case-by-case basis given the wide variety of factors that influence costs.

Barton, D.N. 2002. "The Transferability of Benefit Transfer: Contingent Valuation of Water Quality Improvements in Costa Rica." *Ecological Economics* 42(1):147-164.

Chattopadhyay, S. 2003. "A Repeated Sampling Technique in Assessing, the Validity of Benefit Transfer in Valuing Non-market Goods." *Land Economics* 79(4):576-96.

Costanza, R., R. d'Arge, R. De Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. O'Neill, J. Paruelo, R. Raskin, P. Sutton, and M. van den Belt. 1997. "The Value of the World's Ecosystem Services and Natural Capital." *Nature* 387:253-260.

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.

Delavan W., and D.J. Epp. 2001. "Benefits Transfer: The Case of Nitrate Contamination in Pennsylvania, Georgia and Maine." In J.C. Bergstrom, K.J. Boyle, G.L. Poe, eds., *Valuation of Water Quality*, Brookfield, VT: Edward Elgar Publishers.

Downing, M., and T. Ozuna, Jr. 1996. "Testing the Reliability of the Benefit Function Transfer Approach." *JEEM* 30:316-322.

Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., Keeler, A.G., Opaluch, J.J., Peterson, C.F., Michael F. Piehler, M.F., Powers, S.P., and Smyth, A.R. 2012. "Economic Valuation of Ecosystem Services Provided by Oyster Reefs." *BioScience* 62(10):900-909.

Grabowski, J.H., M.F. Piehler, and C.H. Peterson. 2011. "Assessing the Long-Term Economic Value and Costs of the Crab Hole and Clam Shoal Oyster Reef Sanctuaries in North Carolina."

Loomis, J., B. Roach, F. Ward, and R. Ready. 1995. "Testing Transferability of Recreation Demand Models across Regions: A Study of Corps of Engineer Reservoirs." *Water Resources Research* 31:721-30.

North Carolina Coastal Federation. March 12–13, 2014. "North Carolina Oysters: A Workshop to Chart Future Restoration, Learning from the Past." Accessed December 2015. Available at http://nccoast.org/uploads/documents/Oyster%20Summit%202014/Presentations/Ted,%20summary%20of%20accomplishments.pdf.

North Carolina Division of Marine Fisheries. 2010. "Division of Marine Fisheries Shellfish Rehabilitation Report 2010 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2011. "Division of Marine Fisheries Shellfish Rehabilitation Report 2011 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2012. "Division of Marine Fisheries Shellfish Rehabilitation Report 2012 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2013. "Division of Marine Fisheries Shellfish Rehabilitation Report 2013 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries. 2014. "Division of Marine Fisheries Shellfish Rehabilitation Report 2014 Annual Report." Morehead City, NC.

North Carolina Division of Marine Fisheries, License and Statistics Section. 2014. 2014 *Annual Report*. Morehead City, NC.

North Carolina Division of Marine Fisheries. Division of Marine Fisheries Harvest Statistics (2000–2014). Morehead City, NC. Accessed December 2015. Available at http://portal.ncdenr.org/web/mf/statistics/comstat/oysters.

Office of Management and Budget (OMB). 2011. Regulatory Impact Analysis: A Primer. Available at https://www.whitehouse.gov/sites/default/files/omb/inforeg/regpol/circular-a-4_regulatory-impact-analysis-a-primer.pdf

RTI International. 2015. *Coastal Restoration and Community Economic Development in North Carolina*. Research Triangle Park, NC: RTI International.

Wright, G. North Carolina Division of Marine Fisheries. Personal communication with Tim Sartwell, RTI, February 4, 2016.

Wright, G. North Carolina Division of Marine Fisheries. Personal communication with Tim Sartwell, RTI, February 26, 2016.

Table A-1. Equipment Used for Cultch Planting Activities

ASSET	YEAR PURCHASED	MODEL	PURCHASE PRICE	YEARS OWNED BY SECTION
Barge R/V Shell Point	1987		$48,100.00	29
Marine diesel engine R/V Shell Point	2003	TFM50	$17,029.53	13
Marine diesel engine R/V Shell Point	2003	TFM50	$17,029.53	13
Marine Generator	2005	3LB1PM03	$7,280.17	11
Barge R/V Crab Slough	1991		$93,040.00	25
300 HP Marine Engine R/V Crab Slough	2003	RG6081AFM0	$20,622.66	13
300 HP Marine Engine R/V Crab Slough	2003	RG6081AFM0	$20,622.66	13
Marine Generator	2005	3LB1PM03	$7,280.17	11
LCU Deployment Vessel M/V West Bay	2003	LCU CLASS	$50,000.00	13
Barge R/V JONES BAY	2012	40 X 20 X 4	$86,809.47	4
200hp Outboard Motor R/V Jones Bay	2012	OPTI XL	$10,446.00	4
200hp Outboard Motor R/V Jones Bay	2012	OPTICXL	$10,728.00	4
Barge R/V Cape Fear	1981	BARGE	$62,427.00	35
Barge R/V Stones Bay	1983	BARGE	$52,111.00	33
Dump truck 2006 Ford F550	2006	F550	$29,461.00	10
Tractor loader	1995	5450	$30,793.00	21
Tractor loader	2005	LV80	$46,338.23	11
Shell conveyor	2008	4024-G	$29,440.00	8
Centrifugal stationary pump	2005	B3JQBMS	$3,492.00	11
Shell conveyor	2011	6530	$69,980.00	5
Dump truck 2012 Ford F750	2013	F750	$81,611.00	3
Tractor loader	2011	T4030	$29,836.00	5
Front end loader	2011	820TL	$5,933.00	5
Lowboy trailer	1999	HTD18B15T	$10,237.17	17
2003 Sterling dump truck	2003	STERLING03	$59,440.00	13
Dump body	2003	500TR42	$9,442.75	13
Lowboy trailer	2005	20TON HP	$11,176.35	11
Hyundai Wheel Loader	2007	HL757TM-7	$111,040.26	9
Lowboy trailer	2008	HP	$7,503.55	8

(continued)

Table A-1. Equipment Used for Cultch Planting Activities

(continued)

ASSET	YEAR PURCHASED	MODEL	PURCHASE PRICE	YEARS OWNED BY SECTION
2006 Silverado truck	2006	1500	$18,888.86	10
2001 Ford truck	2001	F-250	$21,959.60	15
2010 Ford truck	2010	F-250	$26,826.17	6
2006 Ford truck	2006	F-350	$28,800.00	10
2007 Ford truck	2007	F-350	$30,956.00	9
2010 Ford truck	2010	F-250	$24,063.71	6
Centrifugal stationary pump	2005	B3JQBMS	$3,492.00	11

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Final Report

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