Final report for the Albemarle-Pamlico National Estuary Program (APNEP) project. "Recycling fishing gear to enhance shellfish productivity and improve local water quality."

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Introduction:

Eastern oyster (*Crassostrea virginica*) harvests have declined dramatically over the last century due, in part, to the mechanical disturbance and removal of biogenic reef substrate which oyster larvae require to settle and grow. As oyster populations have decline, several of the ecosystems services provided by this foundation species have become diminished, such as water filtration (improved water clarity), nursery provision for fishes and decapods, shoreline/erosion buffering and carbon sequestration. To help maintain the oyster fishery in North Carolina, the state spends hundreds of thousands of dollars annually attempting to restore oyster substrate (using mostly shell and marl). Thus, there is an obvious incentive to identify and employ cost-effective materials that serve as suitable oyster settlement/growth habitat.

One potential resource that could be employed to increase the availability of oyster habitat is surprising: crab pots used by commercial and recreational fishermen. These gears are occasionally lost during storms or as they age (becoming disconnected from surface markers). Each winter, the North Carolina Division of Marine Fisheries sweeps coastal sounds and estuaries to remove these derelict pots (this occurs across several states, with several thousand pots cleared). Annually, hundreds of crab pots collected during these sweeps are crushed and discarded if they cannot be returned to their rightful owners. This may waste of a novel resource for enhancing oyster populations.

Our observations and anecdotal experience suggest that crab pots, if located in the right conditions, could serve as ideal settlement and feeding habitat for eastern oysters in shallow water environments (Fig. 1). Mechanistically, the vertical structure provided by crab pots raises spat off the bottom where small predators (mud crabs, drills) are less likely to forage effectively, and enhanced flow equates to enhanced oyster growth. Moreover, crab pots are likely unsuitable habitat for biogenic borers that can flourish in marl or scattered shell (Niels Lindquist, pers. comm.).

Figure 1. Derelict crab pots found in Middle Marsh already colonized by oysters.

Therefore, we proposed an experimental restoration project to quantify the environmental and fishery benefits that can be accrued by refurbishing derelict crab pots so they no longer ghost fish, and redeploying these recycled pots in targeted locations to facilitate oyster settlement and growth.

Summary of work performed:

During January and February, 2011, we worked with the North Carolina Division of Marine Fisheries (Marine Enforcement winter sweep for derelict pots in Albemarle Sound) and Dr. Kirk Havens (VIMS: www.ccrm.vims.edu/research/mapping_surveying/marine_debris.html) to

collect ~ 320 derelict crab pots (50% of the pots were obtained from the debris removal program in VA, while the remaining 50% were obtained from the NC sweep). These pots were transferred to UNC-IMS and refurbished prior to deployment. All pots were cleaned (powerwashed) and refurbished by removing all entry funnels, leaving 4 easy-to-access holes in the lower chamber, and cutting a 15cm hole in the roof of the upper parlor. Thus, crabs, fishes and turtles should be able to access pots without becoming entrapped. All pots were assigned a unique ID number and labeled with a permanent plastic tag. Individual pot characteristics were documented, such as overall condition (e.g., decay level, physical damage), color, and coating type (see attached Excel file). One third of the pots (evenly distributed among VA and NC style pots) were given two coats of concrete to further test for effects of material type on oyster settlement (Fig. 2).

Figure 2. Examples of refurbished, recycled crab pots deployed as oyster settlement substrate. Note the removal of entrance funnels (both images) and addition of 1. Exit portal at top (left); 2. settlement plates (left), concrete coating (right), ID tags (both), and rebar anchor (left).

Refurbished crab pots were deployed in sets of 36 across 8 different sites in the coastal waters of North Carolina (Fig. 3). At each site, groups of 12 pots were deployed at three depths, set at -0.4 m NAVD88, -0.6 m NAVD88 and -1.0 m NAVD88 (for comparisons to cultch-based restored reefs in the Middle Marsh region; refer to synergistic work cited below). Within each group of 12 pots deployed at each depth at each site, 4 pots originated from VA and were not dipped in concrete, 2 pots were from VA and were dipped in concrete, 4 pots were from NC and were not dipped in concrete, and 2 pots were from NC and were dipped in concrete. Along the "medium" depth line of pots, 4 pots were fitted with three standard settlement tiles that are currently be used to evaluate seasonality and inundation-related effects in/on oyster settlement (Fig. 2). Table 1 includes the complete description of our deployment sites, as well as the ID numbers of refurbished crab pots that we deployed. Pots were deployed in May and early June of 2011, prior to the onset of oyster settlement in our region (Figs. 4-7).

Following deployment, pots have been allowed to collect oyster spat and other fouling organisms naturally (ongoing, see preliminary observations below). We also began conducting stratified random surveys within the North River–Straits–Back Sound region (including all to the Rachel Carson NERRS) to document the occurrence, condition and oyster coverage of intertidal derelict crab pots. We have randomly identified ten 1km sections of shoreline for surveying. All pots encountered during these shoreline surveys are being imaged using a standardized photoquad. Using these images, we will evaluate how salinity, depth, habitat context and pot type/condition affect the settlement and growth of oysters (Fig. 8).

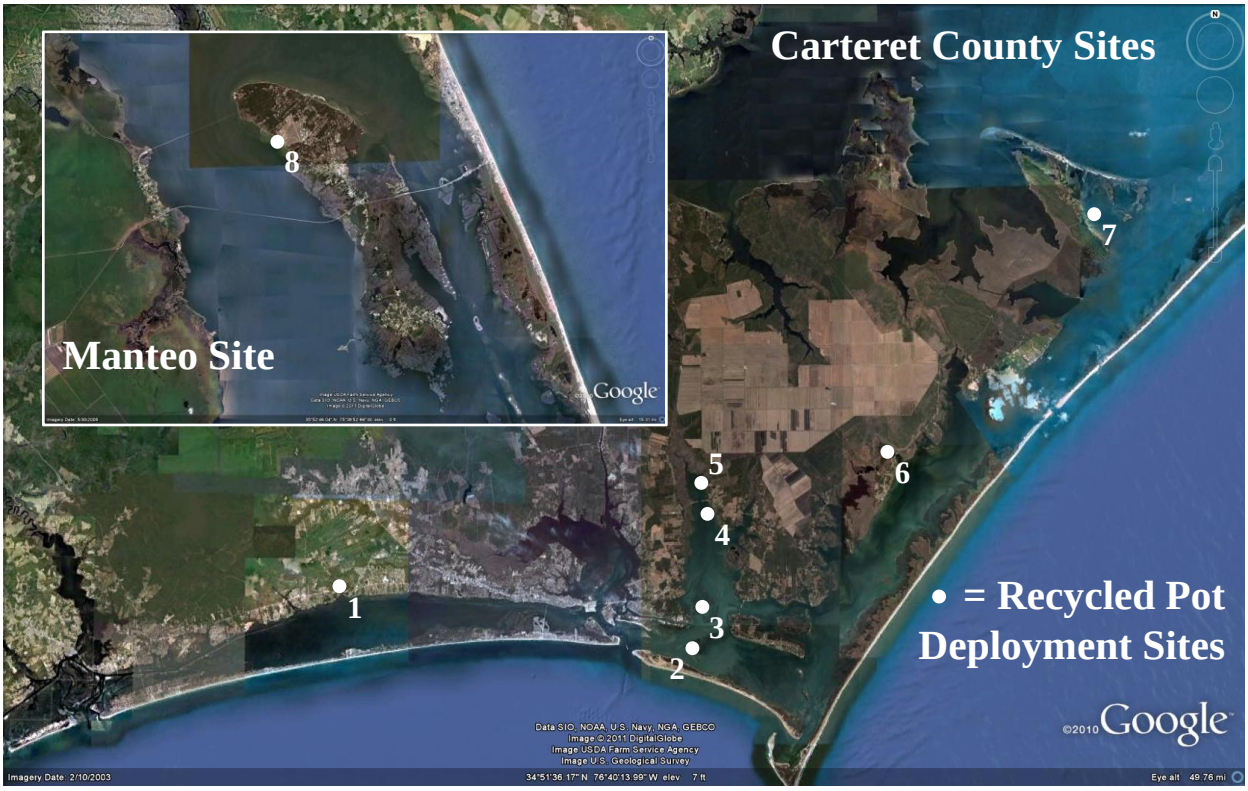

Figure 3. Map of the 8 sites in which sets of 36 crab pots were deployed to serve as settlement substrate for eastern oysters. 1. Gales Creek. 2. Middle Marsh (Rachel Carson National Estuary Research Reserve). 3. North River Marshes. 4. North River – South Causeway. 5. North River – North Causeway. 6. Oyster Creek. 7. Cedar Island Bay. 8. Manteo (North Carolina Aquarium).

Figure 4. Commercial oystermen David Cessna (left) and Adam Tyler (right) who were intimately involved in the overall study design, as well as crab pot collection, refurbishing, deployment and ongoing monitoring. Picture taken by Jim Hawhee during crab pot deployments within the Rachel Carson National Estuary Research Reserve.

Figure 5. Sets of 12 crab pots deployed at "shallow" (~ -0.4 m NAVD88; left) and "medium" depths (~ -0.7 m NAVD88, center) in the Rachel Carson National Estuary Research Reserve. This photo shows the PI and commercial fishermen deploying the 12 "deep" pots (~ -1.0 m NAVD88; submerged).

Figure 6. The 36 Middle Marsh crab pots deployed in proximity to one of the 32 cultch shell oyster reefs (foreground) constructed in the spring of 2011 by Lindquist, Fodrie and Rodriguez utilizing APNEP funding. Photo by Jim Hawhee.

Figure 7. Crab deployed against the marsh bank within Oyster Creek. Only the "shallow" set of crab pots (N = 12) are visible. The remaining 24 crab pots deployed in oyster creek are in 2 lines that run parallel to the "shallow" set, but are submerged at the time this picture was taken.

Figure 8. Commercial Fishermen handling a derelict crab pot covered in oysters during a recent survey of intertidal shorelines in the Back Sound area.

Early results and discussion:

By late June, we were able to revisit all 8 deployment sites and make observational notes on the condition of recycled pots. Initially, all pots had been heavily settled by barnacles (with the deepest pots also heavily colonized by several algal species), and initially we were concerned for the potential of barnacles or algae to exclude oysters via space competition.

During July, however, oysters began to settle on refurbished pots – in some cases on top of barnacles and in some cases on bare space provided by the foraging of sheepshead (suspected).

By August, clear patterns were emerging in which juvenile oyster density was noticeably higher on the inside of crap pots (i.e., on the bait well) possibly related to predation refugia or alteration of flow (food flux). Additionally, crab pots dipped in concrete hosted greater abundances of oysters. Patterns related to pot depth were not as immediately clear. Surprisingly, some oyster on the inside of pots had already reached lengths of ~ 5 cm. We note however, that oyster densities and sizes have not yet been rigorously quantified to determine relationships with pot type, depth, etc.

We were especially concerned for the potential of major storms to displace intertidal crab pots, and this concern was tested with the passage of hurricane Irene in August. Although the eye passed direct over at least 6 of our sites (all but perhaps Gales Creek and Manteo), we have only documented the loss of 6 pots (we have yet to revisit the Oyster Creek and Manteo sites).

The "concern" status of oyster stocks coupled with an emerging understanding of the services provided by oysters (e.g., sediment stabilization, improved water clarity/quality) makes it imperative to assess the benefits of various restoration programs and implement findings to direct policy decisions. Ultimately, this restoration project should provide APNEP and NC-DMF with data concerning a novel use of derelict fishing gear to enhance, rather than disrupt, inshore fisheries. Should targeted deployments of recycled pots increase oyster production, we expect this approach could be used to benefit oyster stocks, coastal fisheries and estuarine health (an obvious requisite would be that pots be refurbished, as we will do in our study, so they no longer ghost fish).

Synergistic Activities:

Our APNEP-funded restoration effort using recycled fishing gear is intimately linked with several ongoing projects in the central North Carolina region to improve our understanding of oyster reef ecology and restoration. These projects involve collaborative work between the PI (Fodrie) and other faculty members at UNC and NCSU.

For instance, our site in the middle marsh region of the Rachel Carson National Estuarine Research Reserve augments ongoing restoration work from the 1997-2000 (reefs constructed by J. Grabowski (NEU) during his graduate thesis (and revisited in 2010-2011 by Fodrie, N. Lindquist [UNC] and T. Rodriguez [UNC]). The present-day patterns of success and decline among these reefs underpinned a recently completed APNEP oyster reef building project (#3154) testing the "critical substrate elevation" hypothesis. Recycled crab pots have been strategically placed at three depths at each of our 8 deployment sites to further test the "critical substrate hypothesis".

During this project, addition research conducted with other federal and state dollars examined a

wide variety of processes and structural elements of nearby natural and restored reefs, including

• Coring natural and constructed reefs to examine long-term changes in reef condition and accretion rates (new North Carolina Sea Grant project to Rodriguez and Fodrie),
• Impacts of seasonal macroalgae blooms on natural and constructed reefs (North Carolina Sea Grant and National Estuarine Research Reserve funding to Fodrie),
• Faunal surveys of natural and constructed reefs across the intertidal gradient (recently completed Blue Crab / Shellfish funded project by Fodrie).
Additional concurrent and newly funded oyster projects that integrate with this APNEP project include:
• Lindquist, D. Eggleston (NCSU) and Tyler's (commercial fisherman) examination of the suitability and possible advantages of using non-carbonate substrates for oyster reef foundations in high salinity waters funded by the NC Sea Grant Fisheries Resource Grant program.
• We (Fodrie, Rodriguez, M. Piehler [UNC] and Grabowski have submitted three additional proposals to examine the capacity of oyster reefs to sequester carbon and mitigate the impacts of human-related climate change.

Lastly, we have received two years of funding from the Fishery Resource Grant program (North Carolina Sea Grant) to monitor succession patterns and fish utilization of the 288 crab pots deployed with APNEP funding. Together, these projects and future research on the structural and functional evolution of cultch- and pot-based oyster reefs in Middle Marsh should be exceptionally informative for oyster reef restoration efforts, both within and beyond the Albemarle-Pamlico estuarine system.

Media coverage:

"Estuarine research on the half shell" Coastwatch (NCSG); Summer 2011
"Fishermen and scientist working together to restore oyster reefs" ABC12; New Bern; May 15, 2011
"Fishermen, scientists build oyster reefs with crab pots" Carteret County News Times, April 24, 2011
"Abandoned crab pots become homes for baby oysters" Viginian-Pilot, January 23, 2011

Collaborating Institutions and Personnel:

University of North Carolina at Chapel Hill Institute of Marine Sciences
Faculty: Joel Fodrie, Niels Lindquist (for media [video, pictures] and logistical support)
Graduate Students: Sara Coleman
Technicians: Abigail Poray, Chris Baille, and Erin Voigt

Virginia Institute of Marine Sciences
Faculty: Kirk Havens (for access to VA fishermen that provided derelict crab pots)

North Carolina Division of Marine Fisheries, Marine Patrol
Harrold Knudsen (for provision of derelict crab pots)

Commercial Fisherman
Adam Tyler (NC license # F290312), David "Clammerhead" Cessna (NC license # F302711), Kevin Lawrence (NC license #F360180), Edward Hogge (VA Crabber – license # not provided), Mike Watkins (VA Crabber – license # not provided) and Richard Green (VA Crabber – license

not provided)

North Carolina Aquarium at Manteo
(for access to a deployment site adjacent to Aquarium property)

North Carolina Coastal Reserve and National Estuarine Research Reserve
(for access to Middle Marsh)

Table 1. Detailed description of recycled crab pot deployment sites, and list of crab pot IDs for each location and depth transect (refer to Excel data file for individual pot descriptions).

Site	Description	Deployment date	Bottom Type	Depth	Start Coordinates		End Coordinates		Crab Pot Ids											
Middle Marsh		5/12/2011	Sandy	shallow	Lat	34°41.234	Lat	34°41.222	263	269	51	271	40	216	246	214	41	281	137	59
					Long	76°37.148	Long	76°37.140												
Middle Marsh		5/12/2011	Sandy	medium	Lat	34°41.225	Lat	34°41.216	53	280*	142*	272	211*	52	284	270	207	138*	43	135
					Long	76°37.164	Long	76°37.153												
Middle Marsh		5/12/2011	Sandy	deep	Lat	34°41.223	Lat	34°41.211	278	185	236	286	55	133	54	50	134	276	136	65
					Long	76°37.173	Long	76°37.163												
North River-1	South of Causeway	5/13/2011	sand/mud	shallow	Lat	34* 47.356	Lat	34*47.358	66	68	252	161	101	171	61	193	97	220	95	172
					Long	76*36.435	Long	76*36.417												
North River-1	South of Causeway	5/13/2011	sand/mud	medium	Lat	34*47.342	Lat	34*47.344	162	159*	108*	079*	57	205	167	72	63	212	49	198*
					Long	76*36.435	Long	76*36.418												
North River-1	South of Causeway	5/13/2011	sand/mud	deep	Lat	34*47.338	Lat	34*47.339	170	73	148	93	174	288	56	48	277	96	199	62
					Long	76*36.436	Long	76*36.418												
North River-2	North of Causeway	5/13/2011	sand/mud	shallow	Lat	34*47.608	Lat	34*47.621	22	209	229	12	124	147	210	13	144	10	117	267
					Long	76*36.275	Long	76*36.278												
North River-2	North of Causeway	5/13/2011	sand/mud	medium	Lat	34*47.593	Lat	34*47.604	067*	30	110	204*	154	016*	58	132*	241	187	14	273
					Long	76*36.308	Long	76*36.309												
North River-2	North of Causeway	5/13/2011	sand/mud	deep	Lat	34*47.571	Lat	34*47.587	69	131	265	11	114	163	215	18	168	197	26	166
					Long	76*36.365	Long	76*36.365												
North River-3	North River Marsh	6/3/2011	Sandy/marsh	shallow	Lat	34*43.213	Lat	34*43.227	222	81	116	195	234	208	74	126	141	275	266	84
					Long	76*36.491	Long	76*36.490												
North River-3	North River Marsh	6/3/2011	Sandy/marsh	medium	Lat	34*43.214	Lat	34*43.228	243	88	249	118	196*	87*	247	194	240*	70	139*	83
					Long	76*36.493	Long	76*36.494												
North River-3	North River Marsh	6/3/2011	Sandy/marsh	deep	Lat	34*43.215	Lat	34*43.229	71	242	123	90	82	127	89	235	237	206	274	213
					Long	76*36.500	Long	76*36.501												
Cedar Island		6/2/2011	soft sand/mud	shallow	Lat	34*59.585	Lat	34*59.567	225	192	224	189	42	219	233	92	46	245	99	35
					Long	76*18.413	Long	76*18.403												
Cedar Island		6/2/2011	soft sand/mud	medium	Lat	34*58.583	Lat	34*59.571	191	47*	34	223	98	230*	78	262*	105*	248	173	32
					Long	76*18.401	Long	76*18.393												
Cedar Island		6/2/2011	soft sand/mud	deep	Lat	34*59.593	Lat	34*59.584	228	45	231	37	186	91	109	44	102	158	20	188
					Long	76*18.392	Long	76*18.384												
Oyster Creek		6/2/2011	algae (soft)	shallow	Lat	34*49.574	Lat	34*49.580	264	103	113	160	128	106	157	5	149	17	4	146
					Long	76*27.432	Long	76*27.448												
Oyster Creek		6/2/2011	algae (soft)	medium	Lat	34*49.507	Lat	34*49.577	107*	76	143	251	287	129*	239	94	115	36	80*	232*
					Long	76*27.439	Long	76*27.452												
Oyster Creek		6/2/2011	algae (soft)	deep	Lat	34*49.562	Lat	34*49.573	64	120	60	283	2	218	145	100	282	121	7	130
					Long	76*27.445	Long	76*27.457												
Manteo		6/7/2011	hard sandy	shallow	Lat	35*55.057	Lat	35*55.049	77	260	285	180	261	151	31	217	181	190	155	140
					Long	75*42.348	Long	75*42.335												
Manteo		6/7/2011	hard sandy	medium	Lat	35*55.048	Lat	35*55.041	279*	221	184*	244	253	21	156	29	254	153	33*	258*
					Long	75*42.359	Long	75*42.344												
Manteo		6/7/2011	hard sandy	deep	Lat	35*55.041	Lat	35*55.034	256	268	3	259	1	255	85	257	15	169	86	27
					Long	75*42.374	Long	75*42.360												
Gales Creek		6/8/2011	silt/mud	shallow	Lat	34*43.905	Lat	34*43.900	25	28	75	175	24	183	202	39	119	104	164	176
					Long	76*54.453	Long	76*52.438												
Gales Creek		6/8/2011	silt/mud	medium	Lat	34*43.908	Lat	34*43.903	200*	226*	203	6	177	111*	306*	112	300	23	178	227
					Long	76*54.452	Long	76*54.438												
Gales Creek		6/8/2011	silt/mud	deep	Lat	34*43.910	Lat	34*43.905	19	238	38	9	122	150	182	8	165	125	201	152
					Long	76*54.438	Long	76*54.436												
Gales Small 1	Across creek	6/8/2011	silt/mud		Lat	34*43.917	Lat	34*43.919	308	304**	301	307**	310*	309						
					Long	76*54.368	Long	76*54.373												
Gales Small 2	Near bridge	6/8/2011	silt/mud		Lat	34*43.766	Lat	34*43.773	250	179	305**	302	311**	303						
					Long	76*53.965	Long	76*53.963												
Wards Creek	Southeast of Hell's Gate	6/10/2011	shelly/mud		Lat	34*46.269	Lat	34*46.263	WC1	WC2	WC3	WC4	WC5	WC6						
					Long	76*34.328	Long	76*34.324												