“Determining the ecological impacts of shellfish relay in North Carolina”

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Project Summary

***Abstract**:* Shellfish relaying is the regulated practice of transplanting oysters or clams from closed polluted waters to private leases where they can depurate. This provides shellfishers (and ultimately the consumer public) access to an otherwise inaccessible resource. While representing a modest component of lease production (~14% of NC’s wild harvest, 2002-2017), relaying is a contentious practice among shellfishers and coastal stakeholders. Critics argue that the removal of shellfish from defacto sanctuaries disturbs and further degrades areas that are dependent on the water filtration services shellfish provide. Advocates believe this disturbance becomes a net benefit over time, suggesting that periodic reef disaggregation increases the abundance and health of oysters by creating space for recruitment and growth while reducing predator refugia. In this study, we tested the disturbance-recovery-driven ecological impacts of shellfish relay by comparing designated relay subsites to paired sanctuary reef patches. After one year, relayed reefs (576 ± 159.46 oysters/m^2) had not yet recovered to pre-relay levels (986.67 ± 87.93 oysters/m^2). The density of oysters in relayed reefs was less than before but still substantially exceeded the basic ecological threshold for a healthy reef (10 oysters/m^2) and closely resembled the unrelayed pairs (625.07 ± 235.81 oysters/m^2). Overall, oyster recruitment and predator load did not differ between relayed and unrelayed sites, suggesting that the proposed ecosystem recovery drivers did not manifest within one year. The modest recovery of relayed reefs indicates that typical relaying activity constitutes a moderate pulse disturbance that neither bolsters nor decimates reef health in this time frame.

***Introduction**:* Shellfish relay, the practice of transplanting oysters or clams from polluted waters to private leases where they can depurate in cleaner water, provides shellfishers and growers, and ultimately the consumer public, access to what would otherwise be an inaccessible resource. Supporters of the practice point to its value in diversifying product supply for shellfish lease holders and as a source of supplemental income for shellfishers contending with ever-expanding closure of formerly approved shellfishing waters. Indeed, shellfish relay has contributed to the productivity of North Carolina's oyster fishery, with shellfishers transplanting an average of 15,252 bushels of oysters (min: 8,130 bu; max: 21,518 bu), annually, between 2002 and 2017 (NCDMF data), amounting to ~14% of annual oyster harvest. However, the ecological impacts of relaying oysters from closed waters, a defacto sanctuary, and arguably areas in greatest need of the water filtration ecosystem services provisioned by oysters, to leases for private economic gain remains unstudied in North Carolina. As such, arguments between proponents and opponents of shellfish relay have been based on a few studies from systems with biophysical and relay practice characteristics that generally do not represent conditions in North Carolina.

Proponents of shellfish relay argue that breaking up aggregated reefs has the potential to increase substrate available for future larval settlement, reduce refugia for oyster predators, and lower boring sponge load (Kennedy and Breisch 1981, Manzi 1985, Allen and Turner 1989), while those opposed cite studies showing negative effects of relay on subsequent substrate availability, recruitment, or mortality (Drobeck and Johnston 1982, Johnson 2002, Mackenzie Jr 2007, Green et al. 2009, Mercaldo-Allen and Goldberg 2011). Without information specific to the unique attributes of our estuarine system and fishery, policy makers have been unable to incorporate ecological impacts into their analysis of the benefits (i.e., economic benefits to fishers, cultural value) and costs (i.e., administrative, supervision by marine patrol, impediment to shellfish hatchery development by diminishing reliable in-state demand for seed) of the program. Understanding how shellfish relay influences the ecology of reefs in closed waters is necessary to holistically evaluating the value of the practice to North Carolina, which remains a highly contentious issue for a myriad of state coastal stakeholders (Fodrie et al. 2019).

Provided the magnitude at which shellfish relay is occurring in North Carolina, the divergent findings of the practice's impacts on recruitment in areas other than North Carolina, and general controversy surrounding the issue, a study that examines the ecological impacts of shellfish relay in North Carolina is clearly merited. Our study evaluated the ecological impacts of oyster relay practices in North Carolina to inform policy decisions regarding the future of the practice. Our specific research questions and hypotheses are as follows:

Research Question 1: Does relaying oysters from sites/reefs in closed waters increase the subsequent recruitment and productivity of the area compared to unrelayed control sites?

Hypothesis 1: Relaying oysters from otherwise closed sites will increase subsequent recruitment rate and productivity of sites if relay practices result in the disaggregation of reefs. Conversely, relay from unaggregated reefs will decrease recruitment and productivity.

Research Question 2: Does relaying oysters from sites/reefs in closed waters reduce oyster predator and bioeroder load from shellfish reefs?

<u>Hypothesis 2</u>: Oyster relay that reduces structural complexity of reefs will decrease the density of oyster predators and boring sponge load by decreasing structural refugia for predators and reducing the reservoir of "old growth" shell that is more susceptible to infection, respectively.

Methods: Beginning in November 2020, we worked with a team of local shellfishers (Steve Weeks, Ira Long, Christian Bayer) to determine which exact spots they would like to relay. Once the relay areas were announced for Spring 2021, we set up paired 25m^2 boxes for relay and no relay at 5 sites. Three were in the Newport River and two were in Wards Creek. During relay season, we observed these shellfishers harvesting from relay treatment boxes while leaving controls undisturbed. These same shellfishers ensured cooperation from other local shellfishers. We then sampled before, 1 month after, 7 months after, and 1 year after relaying activity, constituting an mBACI design (multiple before-after control-impact). Sampling consisted of excavating three 0.25m x 0.25m quadrats per box (treatment and control at five sites) by hand down to the mud layer. The contents were placed in typical onion/oyster bags and brought to the lab on ice for enumeration and measurements. Samples were kept frozen until processing. Quadrat locations were chosen via grid patterned random number generator, with no repeats across or within sampling efforts. Processing of excavated quadrats included the following parameters taken: overall oyster count, LVL and width of each oyster (in mm), whether the oyster was in a cluster or solitary, # of oysters in cluster. Then, if the oyster was perfectly sealed and its shell was intact, its whole mass was taken, the oyster was shucked, and the shell and contents were separated and massed. Each shucked oyster was then examined for evidence of sponge infestation and the shell interiors were photographed for blister worm infestation analysis. The body/viscera of the shucked oyster was placed in an aluminum weigh boat and cooked in a drying oven at 60°C until it reached a constant mass (~48 hours). Condition index was then calculated using the formula of: body dry mass / total wet mass. In addition to oysters, clams and gastropods were also identified and enumerated. Mobile species found in excavated quadrats were not counted as the very process of excavation likely excluded many mobile organisms and the remaining individuals would be an inexact count, at best. We then compared treatment (relay) to control (non-relay) using linear models of the interaction between relay and time, pairing "before" sampling effort with each of the "afters" (1 mo, 7 mo, 1 yr).

*Figure SEQ Figure * ARABIC 2. Nick Funnell (R) excavates oysters in the Newport River for processing*

Results:
Research Question 1: Does relaying oysters from sites/reefs in closed waters increase the subsequent recruitment and productivity of the area compared to unrelayed control sites?
Answer and relevant findings: In short, no. For the purposes of this study, we defined productivity as the abundance and health of oysters. As of one year post-relay, overall oyster counts on relayed reefs (576 ± 159.46 oysters/m^2) had not yet rebounded to pre-relay levels (986.67 ± 87.93 oysters/m^2) (Figure 3). Though we note the abundance of oysters on relayed reefs still far exceeds the traditional ecological threshold for a reef of 10 oysters/m^2. Additionally, there was no significant impact between relaying and time at any time point, as there was a decline in oysters on non-relayed sites between 1 month and 7 months post-relay ($p=0.14$ at 1 month, $p=0.54$ at 7 months, $p=0.35$ at 1 year). One proposed mechanism for any robust recovery of a pulse disturbance would be the freeing of space, allowing for increased oyster recruitment. After one year, relaying did not promote oyster recruitment, as spat (oysters ≤ 25mm) counts between relay (238.936 ± 87.74 oysters/m^2) and non-relay (217.6 ± 109.02 oysters/m^2) sites did not differ from each other at any time point (interaction of relay and time: $p=0.58$ at 1 month, $p=0.8$ at 7 months, $p=0.81$ at 1 year) (Figure 4). Perhaps explaining the lack of boosted recruitment was the lack of disaggregation from relay activity, as there was no interaction between relaying and time for proportion of oysters found in clusters ($p=0.29$ at 1 month, $p=1$ at 7 months, $p=0.61$ at 1 year) (Figure 5). Oyster health, as estimated by condition index (dry body mass/wet body mass) (Figure 6) and consumer appeal (condition index * [width/LVL]) (Figure 7) also did not change between relay and non-relay activity at any time scale. In all, relaying constituted a moderate pulse disturbance that did not disaggregate reefs at a level to trigger enhanced recruitment and subsequent boosts to oyster health and abundance.

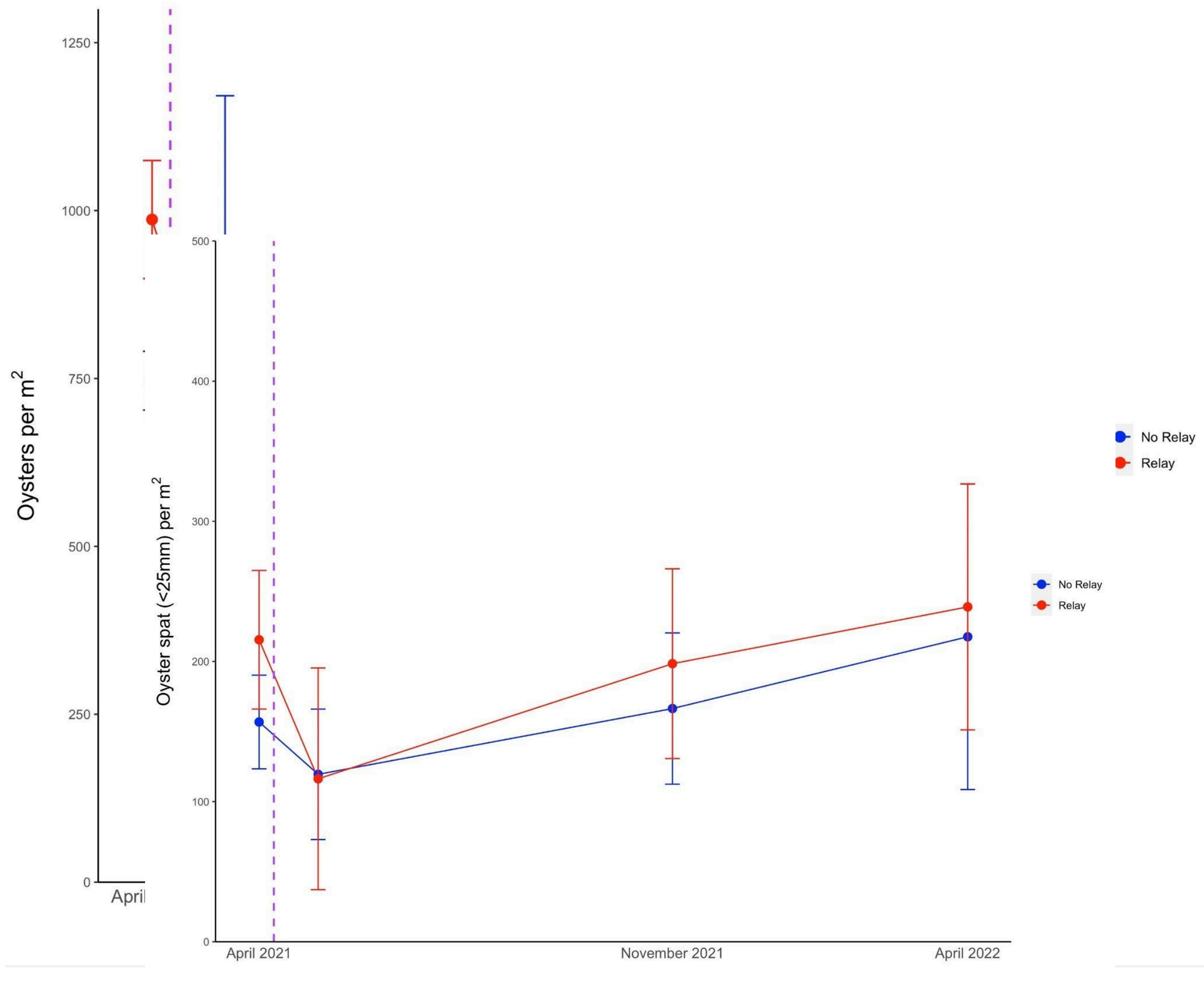
Research Question 2: Does relaying oysters from sites/reefs in closed waters reduce oyster predator and bioeroder load from shellfish reefs?
Answer and relevant findings: No, relay activity did not reduce predator or bioeroder load. Predators and bioeroders on all surveyed reefs were very low. *Urosalpinx cinerea*, or the oyster drill—a prolific oyster predator, was observed just once across all quadrats. *Pyramidelliade sp.*, an ectoparasitic gastropod thought to be a common vector for *Perkinsus marinus* (the pathogen causing dermo), was observed in similar numbers between relayed and non-relayed sites. Given the typical placement of relay areas in up-estuary positions, boring sponge (thrives at salinities above 30) was also not a major pest at any reef. Neither the occurrence (ratio of oysters with signs of sponge infestation) (Figure 8) nor the intensity (% of LVL with sponge evidence) (Figure 9) differed between relay activity and time.

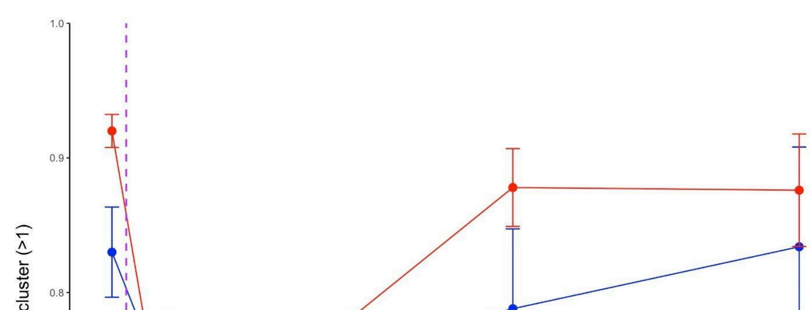
To summarize, the two major expected drivers of recovery from a pulse disturbance event are the reduction of competition (here, the mechanism is conspecific: freeing of space) and the alleviation of predation pressure. Our findings show that neither driver was triggered by relay activity, suggesting that relaying (as observed here) neither bolsters nor decimates reef health within a one-year period.

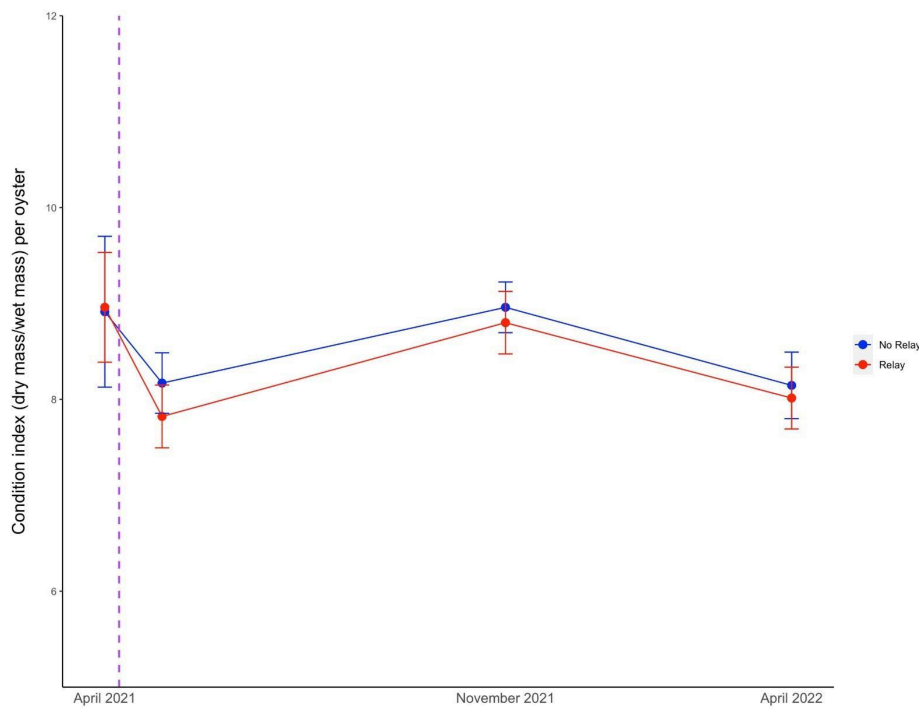
Dissemination Plan:

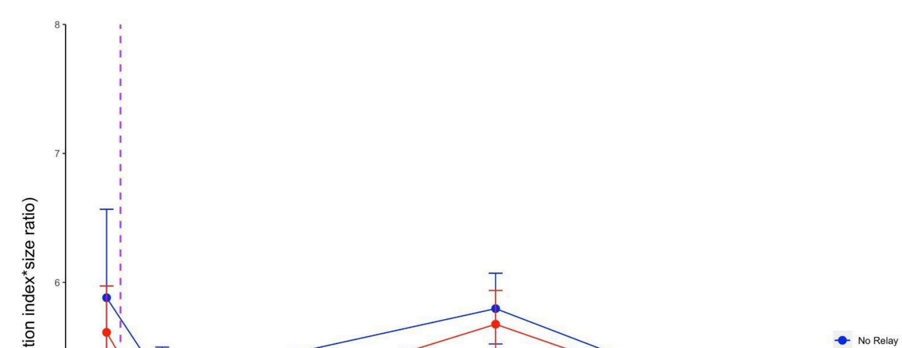
We are sharing this research in several different ways to reach diverse audiences:

1. To reach the general public, an article summarizing the study's progress appeared in NC Sea Grant's 2022 Autumn Issue of *Coastwatch.*
2. To reach North Carolina scientists and stakeholders, Nick will give a 20-minute presentation at the NC Sea Grant Coastal Conference in early November 2022.
3. To reach managers and shellfishers, we will share our findings directly with NC DMF and our network of shellfishers via meetings and phone calls.
4. To reach a broader scientific audience, we are preparing a manuscript for journal submission next year.
5. To satisfy University requirements, this project will serve as one chapter of Nick's graduate dissertation.






12
10
8
6
Condition index (dry mass/wet mass) per oyster
April 2021
November 2021
April 2022
No Relay
Relay


8
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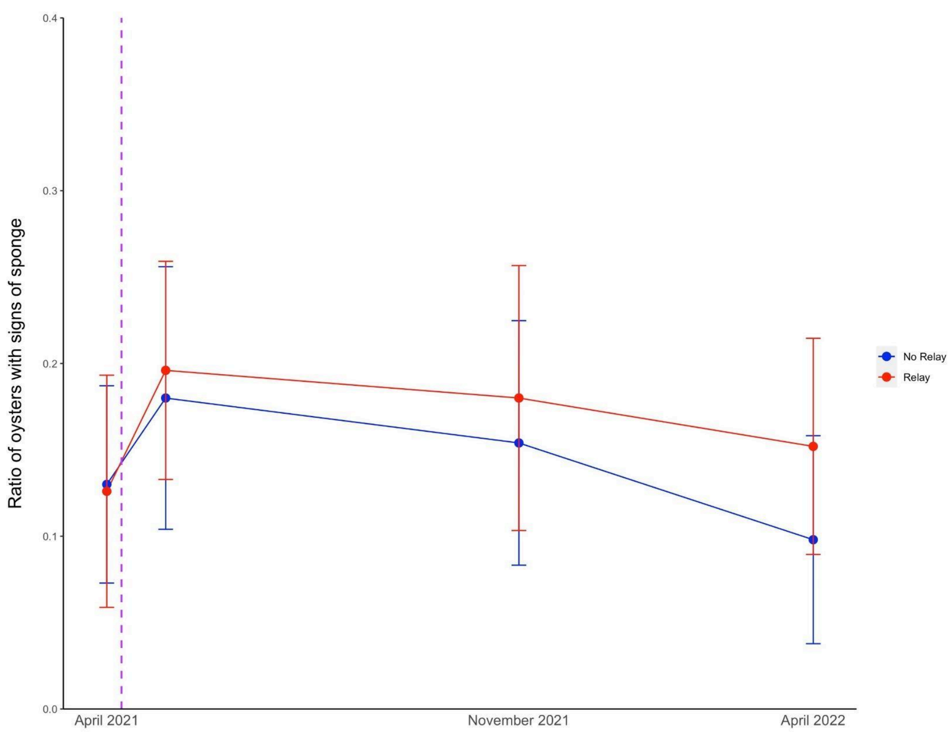
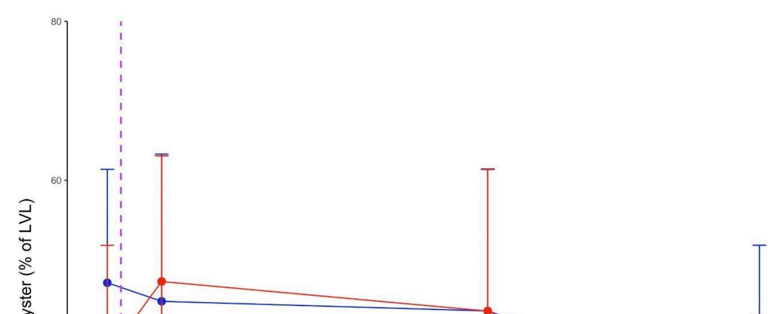


0.4
0.3
0.2
0.1
0.0
Ratio of oysters with signs of sponge
April 2021
November 2021
April 2022
No Relay
Relay



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