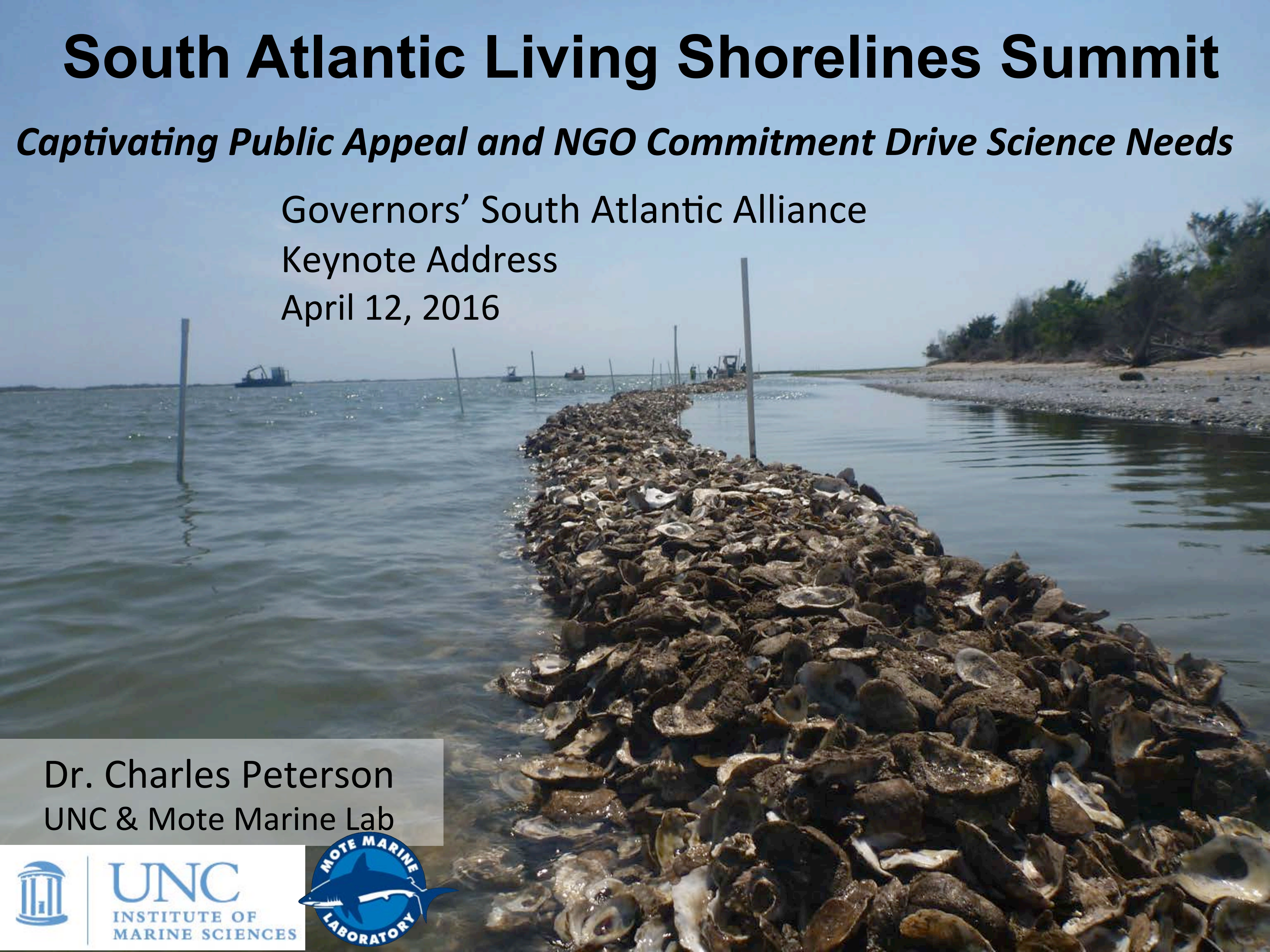
South Atlantic Living Shorelines Summit
Captivating Public Appeal and NGO Commitment Drive Science Needs
Governors' South Atlantic Alliance
Keynote Address
April 12, 2016
Dr. Charles Peterson
UNC & Mote Marine Lab
UNC
INSTITUTE OF MARINE SCIENCES
MOTE MARINE LABORATORY

Trail-blazing Heros of Living Shorelines

- NGO -Tracy Skrabal, Todd Miller, Lexia Weaver (NCCF): Mike Beck (TNC) with Pew Trust
- Fed Gov Science - Carolyn Curran (NOAA)
- Academic Science - Rachel Gittman, Jon Grabowski (UNC, NEU); Rochelle Seitz, Donna Bilkovic (VIMS); Sean Powers (UNC, DISL)
- Entreprenuer – Shimrit Perkol-Finkel (ISR)
- Fed Gov Regulation - USACE District-specific
- State Gov Regulation – MD, NC Agencies

Estuarine habitats of most value for their ecosystem services and contributions to resilience abut shore and have suffered the greatest percentage losses

- Intertidal coastal marsh (Gedan et al. 2009) >40% NA
- Intertidal mangrove forest (Alongi 2002) 30%WW
- Intertidal oyster reef (zu Ermgassen et al. 2012) 65-85% WW
- Nearshore seagrass meadow (Waycott et al. 2009) 30% WW
- Intertidal flat (evident but unquantified and ignored)

What are “Living Shorelines”?

- Shorelines harboring life, designed for resilience to change and to deliver sustainable net gains in natural ecosystem services
- First option: restore the natural habitat of “ecosystem engineers” (e.g., replant coastal marsh; mangroves; oyster reefs; seagrass(?))
- Second option: introduce structures that with their associated biota stabilize shorelines and create ecosystem services (e.g., install an oyster shell breakwater developing into oyster reef)

Complications in Defining Living Shorelines

State or federal permitting may define by statute what is considered a living shoreline (e.g., a rock revetment may be included and a vertical bulkhead excluded despite limited evidence of differential performance).

A shoreline may be considered living based upon expectation of its colonization despite initial absence of life (e.g., a structurally complex concrete harbor wall that includes horizontal platforms, tide pools, and variously sized niches expected to promote and sustain life).

Intent is Pure: Science is Incomplete

- Estuarine shoreline property owners, private and public, typically demand protection for their assets against flooding and storm damage
- Vertical bulkheads the historic choice - 87% in NC
- If engineered hard barriers are replaced by effective living habitat barriers - marsh, mangrove or oyster reef, are expected ecosystem services delivered?
- Emotionally appealing so NGOs advocate for them and an engaged public participates in installation
- But what structures are durable under what levels of water height and wave energy?
- Are erosion and sedimentation merely redirected?

Technical Basis for Living Shorelines

Engineering performance of alternative living shorelines

- Durability across a range of water levels/wave heights?
- Capacity for repairs/construction and repair costs?

Sedimentary geology in response to structures

- Sedimentation and erosion- where and how much?
- Breakwaters, groins, jetties, sand bags, tombalos

Biology/ecology/economic value of living shorelines

- Quantify ecosystem services by habitat restored
- Assess temporal change in habitat and its services

Living shorelines: marsh sills

Granite sill

Oyster bag sill

Marl sill

PNAS

Oyster reproduction is affected by exposure to polystyrene microplastics

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Edited by Marguerite A. Xenopoulos, Trent University, Durham, ON, Canada, and accepted by the Editorial Board December 22, 2015 (received for review September 25, 2015)

Plastics are persistent synthetic polymers that accumulate as waste in the marine environment. Microplastic (MP) particles are derived from the breakdown of larger debris or can enter the environment as microscopic fragments. Because filter-feeder organisms ingest MP while feeding, they are likely to be impacted by MP pollution. To assess the impact of polystyrene microspheres (micro-PS) on the physiology of the Pacific oyster, adult oysters were experimentally exposed to virgin micro-PS (2 and 6 μm in diameter; 0.023 mg·L^{-1}) for 2 mo during a reproductive cycle. Effects were investigated on ecophysiological parameters; cellular, transcriptomic, and proteomic responses; fecundity; and offspring development. Oysters preferentially ingested the 6-μm micro-PS over the 2-μm-diameter particles. Consumption of microalgae and absorption efficiency were significantly higher in exposed oysters, suggesting compensatory and physical effects on both digestive parameters. After 2 mo, exposed oysters had significant decreases in oocyte number (−38%), diameter (−5%), and sperm velocity (−23%). The D-larval yield and larval development of offspring derived from exposed parents decreased by 41% and 18%, respectively, compared with control offspring. Dynamic energy budget modeling, supported by transcriptomic profiles, suggested a significant shift of energy allocation from reproduction to structural growth, and elevated maintenance costs in exposed oysters, which is thought to be caused by interference with energy uptake. Molecular signatures of endocrine disruption were also revealed, but no endocrine disruptors were found in the biological samples. This study provides evidence that micro-PS cause feeding modifications and reproductive disruption in oysters, with significant impacts on offspring.

and fecundity in copepods (20, 22) and reproductive disruption in *Daphnia* (21). At cellular and molecular levels, alterations of immunological responses, neurotoxic effects, and the onset of genotoxicity have been observed in mussels exposed to polycyclic aromatic hydrocarbon-contaminated polystyrene particles (17). Additional impacts may arise from harmful plastic additives and persistent organic pollutants adsorbed on MP, which are known to be taken up and accumulated by living organisms (23).

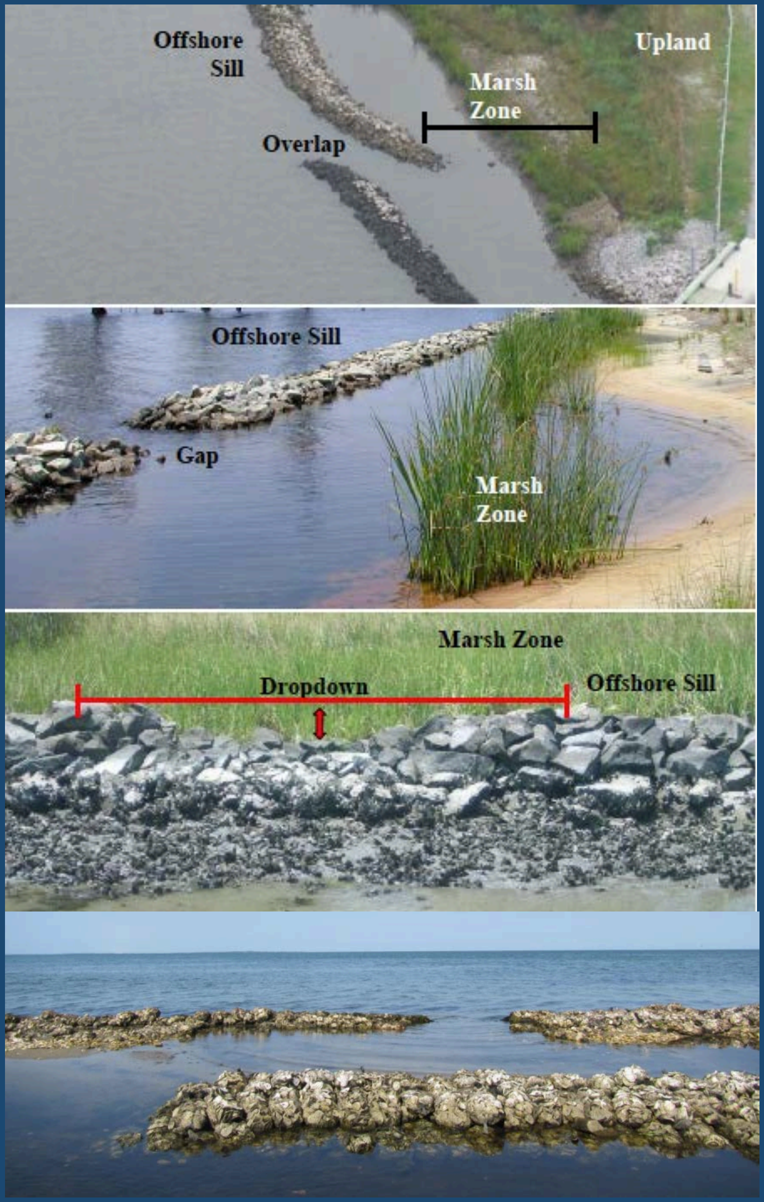
In this study, the effects of MP exposure were assessed on reproductively active *Crassostrea gigas* adults and their offspring. The Pacific oyster was chosen because of its world-wide production, economic importance as seafood, and important role in estuarine and coastal habitats (24). A 2-mo exposure of adult oysters to microsized polystyrene spheres (micro-PS, 2 and 6 μm, 0.023 mg·L^{-1}) was performed under controlled conditions suitable for germ-cell maturation. Polystyrene is one of the most commonly used plastic polymers worldwide, often found in microplastics sampled at sea (25, 26). In our study, toxic endpoints were investigated through an integrative approach, covering data from molecular and cellular parameters to ecophysiological behavior and energy budget modeling. Our results show that experimental

Significance

Plastics are a contaminant of emerging concern accumulating in marine ecosystems. Plastics tend to break down into small particles, called microplastics, which also enter the marine environment directly as fragments from a variety of sources, including cosmetics, clothing, and industrial processes. Given their ubiqui-

Research gaps:

- What are the economic costs associated with different erosion protection structures and the costs of sustaining them in the long run?
- How do different shoreline stabilization mechanisms perform during storms of different magnitudes and durations?
- How do recreationally and commercially important nekton use modified shorelines?
- Does nekton behavior change along modified shorelines?
- How does structural complexity and marsh sill configuration affect fish use?



Fear and Bendell 2011

Ecosystem Services of Coastal Marshes
(from Millennium Ecosystem Assessment 2005)

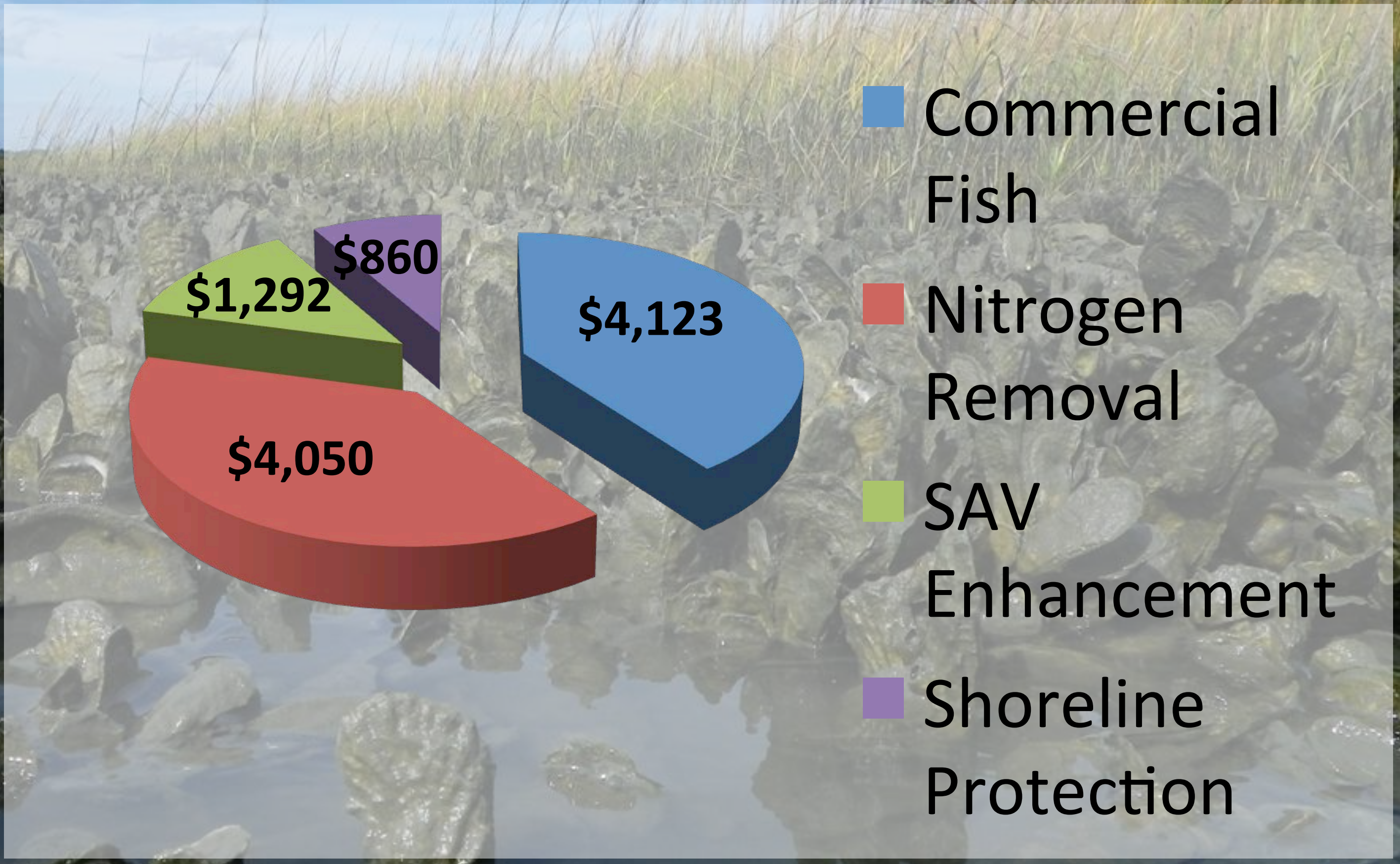
- Habitat and food web support
  - Vascular plants, microbes
  - Invertebrates, fishes, crustaceans
  - Birds, mammals, reptiles
- Water quality preservation (nutrients, sediments, pathogens, toxic metals and chemicals)
- Hydrologic services (flood water storage)
- Shoreline stabilization
- Biogeochemical processing (Blue C sequestration)
- Buffer against storm wave damage and flooding
- Human socioeconomic services
  - Consumptive uses
  - Non-consumptive uses

Ecosystem Services of Oyster Reefs – from Peterson et al. (2003), Piehler and Smyth (2011), Grabowski et al. (2013)

- Habitat and food web support
  - Extremely high benthic invertebrate biodiversity
  - Commercially and recreationally important fishes, crabs, and shrimps are enhanced in production on oyster reefs
- Through filtration, clarifying the water column enhancing light penetration to benthic microalgae and SAVs
- Inducing net denitrification by discharge of pseudofecal and fecal particles onto sediment surface
- Fecal and pseudofecal particle discharge serving to fertilize SAVs and enhance their cover and production
- By extending structure up into the water column, slowing and buffering current flows, thereby inducing deposition of suspended organic detritus and burial, removing carbon from the biosphere
- By serving as a breakwater, protects against shoreline erosion and flooding by reducing energy in storm waves

Summary: Oyster Ecosystem Services

Average value of oyster services= $10,325 per hectare



Grabowski et al. 2012

NOAA March 2016: Encourages Living Shorelines

- To provide, maintain or improve habitat or ecosystem function and enhance coastal resilience
- Shoreline stabilization based on the softest approach feasible based on site conditions
- Careful consideration of regional and site-specific differences in factors such as wave energy, habitat type, and geologic setting
- Incorporation of best available science and practices
- Consideration of ecosystem services provided by each shoreline stabilization approach

Stressors interacting with climate change – least appreciated yet most serious

- Rising sea level interacts with growing use of bulkheads and other anti-erosion structures to:
- prevent transgression of shallow habitats land-ward and break their connectivity with uplands
- cause wave refraction leading to scour and potential loss of fringing marsh habitat
- steepen the slope of the shoreline losing intertidal zone and habitats
- lose ecosystem services of marsh, mangrove, SAV, oyster reef, and intertidal flat.

Current elevations reflect imminent risks