Ecologically engineering living shorelines for high energy coastlines

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Ocean ship traffic up 300% worldwide

Large container ships & fishing vessels

Tournadre 2014, Geophysical Research Letters
Small boat traffic in estuaries also on the rise
Rarely monitored & ecological effects unknown

Studies examining the effects of wakes on turbidity & wetland erosion
Sorenson 1973; Zabawa & Ostrom 1980; Nanson et al. 1994; Osborne & Boak 1999; Castillo et al. 2000; Parnell & Kofoed-Hanson 2001; Bauer et al. 2002; Grizzle et al. 2002; McConchie & Toleman 2003; Glamore 2008; Houser 2010; Tonelli et al. 2010; Bilkovic et al. 2017

*Black text= primary literature/ Grey text = grey literature*
Intracoastal Waterway (ICW)

3,000 miles of natural waterways & manmade channels

Artery for commerce & recreation

New Orleans

Ponte Vedra, FL

America's Great Loop Cruise Routes
Boat highway through coastal wetlands
Dredging & hardening are common

Mulberry Island, LA

Little River, SC

Palm Valley, Florida

Wilmington, NC
Intracoastal Waterway (ICW) shoreline

Cordgrass (*Spartina alterniflora*)

Eastern oyster (*Crassostrea virginica*)

Intracoastal Waterway (ICW) shoreline
Salt marsh retreating \( \sim 1 \text{m per year} \)

No intertidal oysters

**Loss of habitat & ecosystem services**

**Intracoastal Waterway (ICW) shoreline**

Silliman et al. *in review*
Many living shoreline designs fail

In < 3 weeks, wakes blew apart these oyster bags & coir logs
1) What is wake climate in this Florida estuary?
2) Can we engineer ‘living shorelines’ to dissipate boat wakes & protect shorelines?
Measuring boat activity in ICW

Tracked boats:
- Automatic Identification System (AIS) boat transponder data
- # boats per day

All boats (tracked & non-tracked):
- Nortek Vector Acoustic Doppler Velocimeter
- Wakes characterized (Sheremét et al. 2012)
- # wakes per day, max. wake height
Boat traffic recorded by AIS & Vector: Nov. 17 – Dec 5, 2017

Also field experiment sites 4 & 5
Large, tracked boats common on ICW

9 boats!

197 ft passenger vessel on 12/01/17
- Speed: ~ 10.5 knots
- Max wave produced: ~0.2m
AIS boats small % of all boat traffic

How big are these wakes?

Max: 143 boats!
Maximum wake height

Number of wakes

Max Wake Ht (m)
More than 90% are less than 0.3m wakes.

Wakes >0.3m can erode fine, marsh sediment (Nanson et al. 1994)
Can we protect shorelines from incessant boat traffic without armoring?
Two lines of defense: breakwall & oyster restoration structures

Semi-permeable branch-filled break walls

Paired living shoreline & unmanipulated controls at 5 sites of varying channel width
1 year pre-treatment + 1 year of post-treatment monitoring
Dutch brush-filled ‘groynes’ used for salt marsh creation & land reclamation in fetch-dominated systems

De Groot & van Duin 2013

Strong waves & currents

Sediment deposition & salt marsh formation
Are the break walls dissipating wakes?
Sensor deployment: March 2018
Channel-to-intertidal Vector array

Channel

Salt marsh edge

Diagram showing sensor deployment in a channel leading to an intertidal area, with various markers indicating the positions of Vector instruments.
Nortek Vector array deployment: March 2018
Identify wakes in flow velocity & pressure records as *chirps*

Chirp = signal in which frequency increases or decreases with time

Next: analyses of this highlighted wake
Quantify energy flux of chirp, 2\textsuperscript{nd} harmonic & infragravity in each wake at each sensor.
Chirp

2nd harmonic

Infragravity

In front of break wall

Behind break wall

A (chirp) monochromatic

B (chirp) HF LF monochromatic

C (breakwall) HF LF monochromatic

HF = high frequency waves
LF = low-frequency waves
Bathymetry scans using autonomous Teledyne Q-boat indicate significant erosion of channel bed in 5 months.
FUNWAVE TVD model

Fits field data from study site
Simulates wake generation and transformation (shoaling)
Explore effects of:
  - boat size & shape
  - bathymetry
  - tidal height
  - ebb/flood current speed

Model Details: fully nonlinear Boussinesq wave model initially developed by Kirby et al. (1998)

Movie Details: 30 fps, 0.5 sec plotting interval, 0.5 m contour lines, Red=dry land, average boat speed=5.6 m/s
Study Take-Home Messages

1) Boats impose an artificial wave climate that is driving loss of coastal ecosystems & services
   • Most damaging stress in some waterways
2) Semi-permeable breakwalls can dissipate wakes
   • Stimulate oyster growth & marsh progradation
   • Shipworms pose a threat to long-term durability
3) Quantifying nature of artificial wake climate may be essential for successful shoreline management
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Gabions: Great Recruitment!
Two lines of defense: breakwall & oyster restoration structures

Bird’s Eye View of One Experimental Living Shorelines Treatment

1) Semi-permeable breakwalls
2) Oyster restoration structures

Paired living shoreline & unmanipulated controls at 5 sites of varying channel width
1 year pre-treatment + 1 year of post-treatment monitoring
mean oyster density (# m\(^{-2}\))

Site

Increasing submergence time
Tracking salt marsh response: 15 poles, 1m apart
Post breakwall construction, overall trend of progradation
Especially in breakwall treatments
AIS-tracked boats

83 boats recorded over 19 days

Herbert et al. *in preparation*
BESE versus Gabions

Not a single oyster in 2017!
Larger, tracked boats common on ICW

- 197 ft passenger vessel on 12/01/17
  - Speed: ~10.5 knots
  - Max wave produced: ~0.2m
Bathymetry scans using Teledyne Q-boat indicate significant erosion of intertidal bed.
Shipworm Damage:
Far higher close to mud line & in softer woods

Varied between sites & years
Field experiment: understanding shipworm dynamics

4 common tree species
Multiple distances from sediment
Replicated at 2 estuaries & 2 years
Measured wood volume lost to shipworm burrows

Bersoza Hernandez & Angelini, submitted