THE EXPOSED SURFACE AREA TO VOLUME RATIO: IS SHELL MORE EFFICIENT THAN LIMESTONE IN PROMOTING OYSTER RECRUITMENT?

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INTRODUCTION

Current Local Restoration Projects:

- $11 million in MS Sound
  - Fall 2012

    20,372 cuyd over 200 ac
  - Spring 2013

    54,162 cuyd over 542 ac

    86,703 cuyd over 688 ac
- DWH Oil Spill Restoration Funds: $1 Billion

Limestone is selected over shell:

- Price
- Availability
- Ability to attract spat

- After planting cultch only a portion is available for recruitment
- Available recruitment area = Exposed Surface Area = Surface Area/Number of faces
- Shell vs Limestone

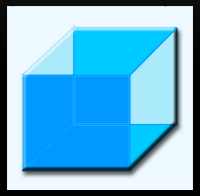
Different surface area to volume properties = differential settlement opportunities

- No available studies quantified expSA of shell and limestone

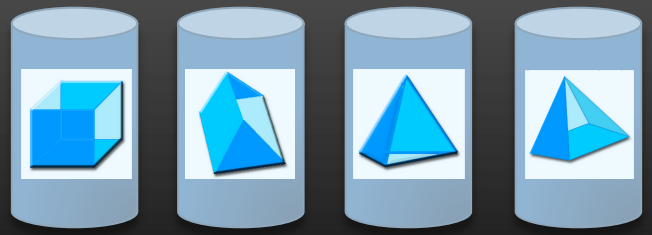
Shell **VS** **Limestone**

? **How does the exposed surface area (expSA) of shell compare to that of limestone?** ?

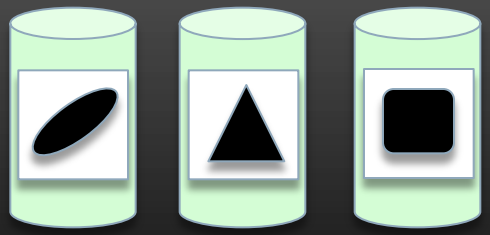
Cultch Material

- Limestone
  - **Cube**
    
    $2(W\,H + L\,W + L\,H)$
  - **Triangular prism**
    
    $B\,H + 2(L\,S) + L\,B$
  - **Square-base pyramid**
    
    $2(B\,S) + B^2$
  - **Triangular-base pyramid**
    
    $(0.5 * Apothem * H)+((3/2)\,H\,S)$
- Shell
  - Fragment
    - *Subquadrilateral*
      
      $2(Length*Width)$
    - *Subtriangular*
      
      $Base*Height$
  - Whole
    
    $2(Length*Width$ [illegible])

Measurements were made with calipers



#57 Limestone
#4 Limestone



Random sampling with replacement

N = 1,000

expSA
expSA
expSA
\+ expSA

Total expSA/cuyd

vol+voidvol
vol+voidvol
vol+voidvol
\+ vol+voidvol

Total Volume (1cuyd)

Cubic yards with a mixture of shapes

As a piece is selected and added to the cuyd, its expSA, volume and associated void volume is summed

Limestone has been reported to weigh 1.2 MT cuyd $^{-1}$
Our program yields weights 1.2 – 1.6 MT cuyd $^{-1}$ depending on the mix of particles chosen

SIMULATION RESULTS

Metric	Oyster Shell		Limestone
Mean Surface Area (m^2yd^{-3})	85.2	<	163.1
Mean Exposed Surface Area (m^2yd^{-3})	42.6	>	32.0

N = 1,000

- expSA of shell = 1.35(expSA of limestone)
  - Shell contributes more exposed surface area
  - Limestone contributes more total surface area

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SIMULATION RESULTS

How does limestone perform?

Particle Type	Mean SA (m^2yd^{-3})	Mean expSA (m^2yd^{-3})	Mean Weight ($MTyd^{-3}$)	Void Volume (yd^3)
#57 (Smaller)	194.2	38.2	1.45	0.56
#4 (Larger)	137.1	26.7	1.29	0.61
All Pyramidal	111.0	24.9	1.27	0.61
All Prismatic	211.5	42.3	1.63	0.50
All Cubic	235.3	39.2	1.37	0.50

Conclusion: size and shape matter

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SIMULATION RESULTS

How does whole oyster shell perform?

Particle Type	Mean SA (m^2yd^{-3})	Mean expSA (m^2yd^{-3})	Mean Weight ($MTyd^{-3}$)	Void Volume (yd^3)
Oyster Shell	85.2	42.6	0.57	0.81
#57 (Smaller)	194.2	38.2	1.45	0.56
#4 (Larger)	137.1	26.7	1.29	0.61
All Pyramidal	111.0	24.9	1.27	0.61
All Prismatic	211.5	42.3	1.63	0.50
All Cubic	235.3	39.2	1.37	0.50

Conclusion (assuming same cost by weight or volume):

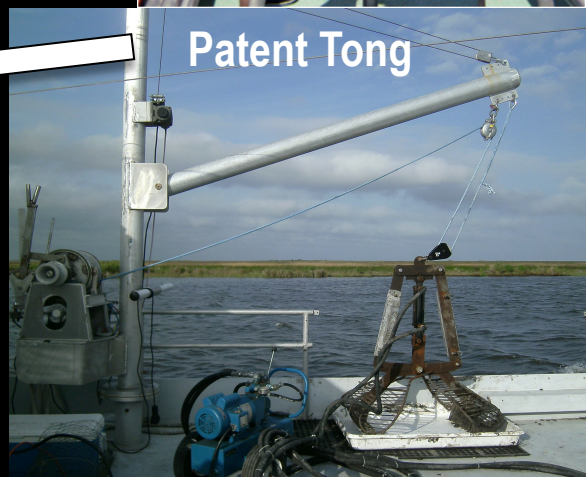
- By weight, oyster shell always performs better
- By volume, performance is similar **IF** limestone particle shape/size chosen wisely

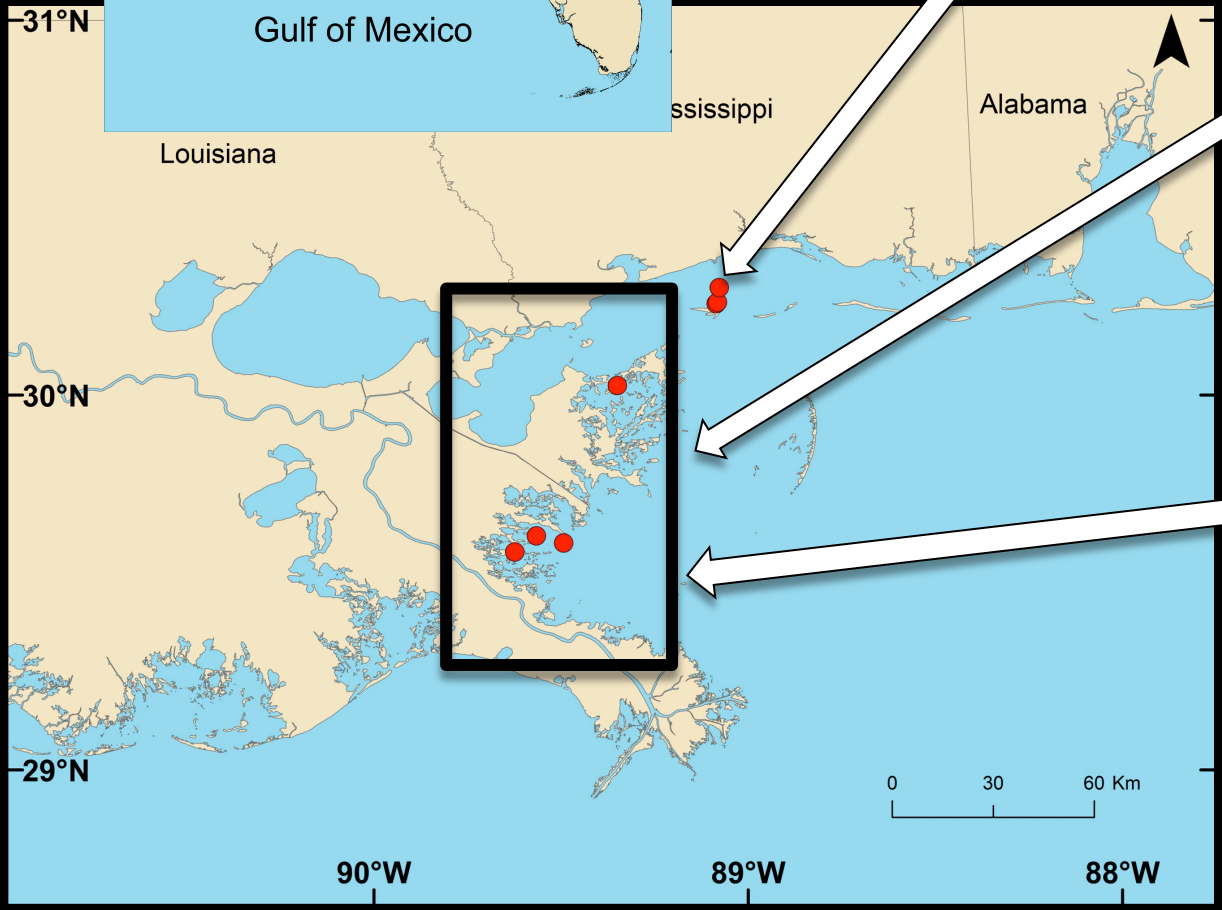
CAVEATS

- Assumption: exposure of only 1 surface of the shell
  - shell has a lower degree of packing
  - some portion of both faces very likely available
    - ➢ expSA underestimated for oyster shell

- Assumption: no sedimentation
  - even a dusting of sediment prevents recruitment
  - higher packing of limestone = more susceptible to sedimentation

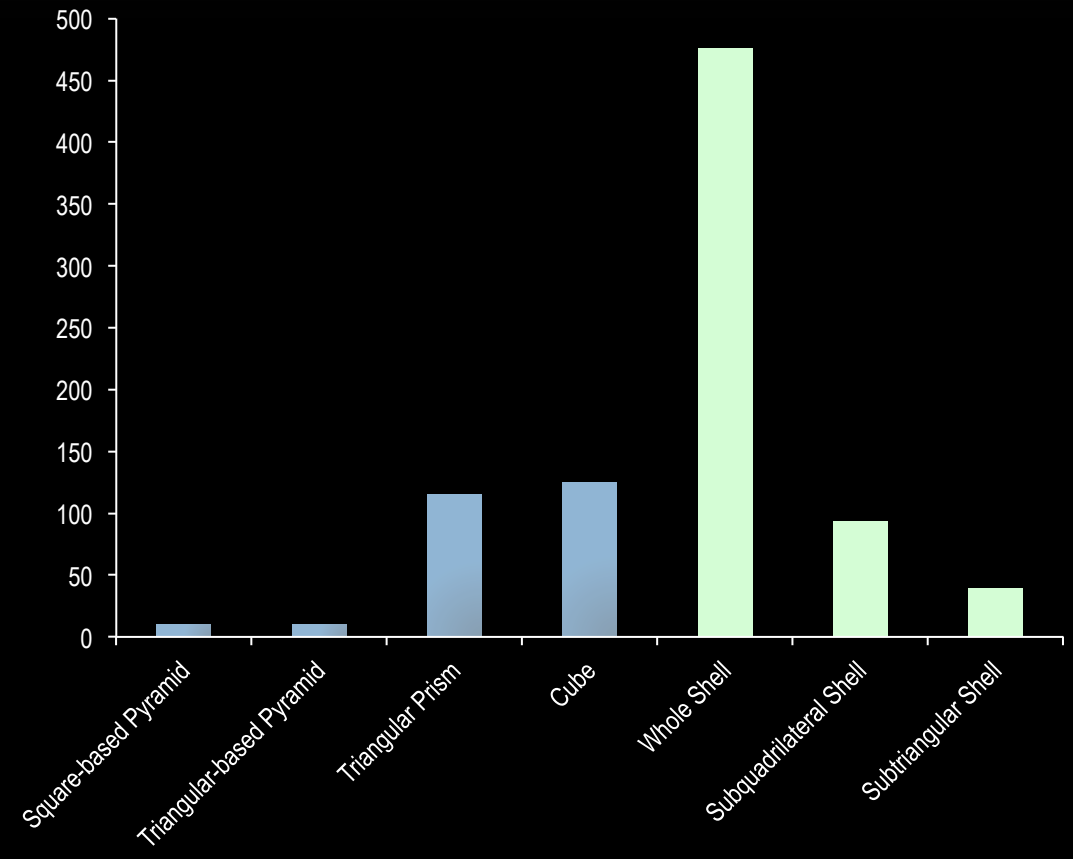
EXPERIMENTAL APPROACH





EXPERIMENTAL APPROACH

What does a real plant look like?



RESULTS

How did **limestone** perform at Three Mile?

Particle Type	Mean SA (m^2yd^{-3})	Mean expSA (m^2yd^{-3})	Mean Weight ($MTyd^{-3}$)	Void Volume (yd^3)
Whole Oyster	89.1	44.5	0.54	0.81
Limestone ≥5 cm3	276.6	48.9	1.61	0.51
All Limestone	441.4	79.9	1.64	0.50

Conclusion:

- Limestone performance ≈ Oyster shell performance
  - better if all small limestone particles are included
- Limestone particles were small and mostly cubes and prisms (The Perfect Plant)

RESULTS

How would **oyster shell fragments** have performed at Three Mile?

Particle Type	Mean SA (m^2yd^{-3})	Mean expSA (m^2yd^{-3})	Mean Weight ($MTyd^{-3}$)	Void Volume (yd^3)
Shell Fragments	630.8	315.5	2.01	0.41
Whole Oyster	89.1	44.5	0.54	0.81
Limestone ≥5 cm3	276.6	48.9	1.61	0.51
All Limestone	441.4	79.9	1.64	0.50

- Shell fragments
  - add significant expSA and weight to the cubic yard
  - outperform all limestone shapes and sizes and also whole oyster shell
- performance differential is highly significant by weight or volume

CONCLUSIONS

- What to plant to enhance recruitment?
  - Always plant **shell fragments** if you can
- Whole shell and limestone can perform similarly
  - Limestone can perform less well than shell
  - Choose limestone wisely
- Remember: Limestone packing suggests performance declines faster than shell if sedimentation occurs

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CONCLUSIONS

- What to plant to expand a reef?
  - Limestone is taphonomically resistant
  - Only shell yields surface complexity
- We suggest a limestone base but shell ultimately is necessary

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FUTURE RESEARCH

- Sensitivity of the model to composition change
  - manipulate proportions of shape types selected
- Taphonomic and degradation effects of cultch material
  - use of dissolution trays/containers
- Alternative deposition of cultch materials
  - use of shell vs limestone suspended strings

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