COASTAL AQUACULTURE PLANNING AND ENVIRONMENTAL SUSTAINABILITY

James Morris and Kenneth Riley

NOAA National Ocean Service
National Centers for Coastal Ocean Science
James.Morris@noaa.gov
Science serving coastal communities

- Science to manage threats of harmful algal blooms
- Advancing research on climate impacts to coastal communities
- Understanding impacts of coastal pollution
- Science to support coastal and marine spatial planning
Our Mission
We develop decision support tools enabling coastal managers to safeguard the environment while supporting aquaculture development in the coastal zone.

Program Focus
Coastal Planning
Environmental Interactions
Innovative Technology
Climate Change
The CAPES Staff

Dr. James Morris, Marine ecologist, CCFHR

Dr. Suzanne Bricker, Marine ecologist, CCMA

Dr. Ken Riley, JHT Biologist, CCFHR

Dr. Carol Price, JHT Biologist, CCFHR

Lisa Wickliff, PhD, JHT Biologist, CCFHR

Robert Farnell, JHT Physiologist, CCFHR

Troy Rezek, JHT Biologist, CCFHR

Gary Fisher, Biological Tech, CCFHR

Myranda Gore, JHT Physiologist, CCFHR

Zaina Idarara, Morocco foreign guest
We are working with coastal managers in every region
NOAA has established the goal of tripling aquaculture production by 2050.
Aquaculture, the farming of fish, shellfish, seaweed, and other products, represents the fastest growing sector of global food production.

The World Bank
Marine Aquaculture Species
Environmental sustainability
Research and development
Feeds initiative
National shellfish initiative
Genetics and conservation
Site selection and MSP
Aquatic animal health
Best Management Practices
Science outreach
Why NOS is doing aquaculture?

- Aquaculture is the fast growing food production sector in the U.S.
- Rapidly growing global middle class = high demand
- Global markets for aquaculture products >$100 billion annually
- Coastal aquaculture occurs in every state
- Aquaculture is occupying increasing coastal space
- NOS specializes in coastal planning
- NOS can provide strong support by building coastal intelligence for aquaculture managers and industries
NOAA: Coastal ocean aquaculture can be environmentally sustainable

Little to no effects on coastal ocean environment seen with proper safeguards, planning

December 18, 2013

Specific types of fish farming can be accomplished with minimal or no harm to the coastal ocean environment as long as proper planning and safeguards are in place, according to a new report from researchers at NOAA’s National Ocean Service.

The study, led by scientists at National Ocean Service’s National Centers for Coastal Ocean Science (NCCOS), evaluated the environmental effects of finfish aquaculture, including interactions with water quality, benthic habitats, and marine life across various farming practices and habitat types.

“We did this study because of concerns that putting marine finfish farms in the coastal ocean could have adverse effects on the environment,” said Dr. James Morris, NCCOS ecologist. “We found that, in cases where farms are appropriately sited and responsibly managed, impacts to the environment are minimal to nonexistent.”

“This report provides coastal and farm managers with a global perspective on a range of potential environmental effects and their relative intensity,”
Marine Cage Aquaculture

- USA
- Norway
- USA
- Scotland
- Spain
- Ireland
- China
- Mexico
- Australia
Where in the world is all the Aquaculture?

91% of all aquaculture is produced in Asia.

<table>
<thead>
<tr>
<th>Continent</th>
<th>Production 2008</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>40,508,119</td>
<td>61.5</td>
</tr>
<tr>
<td>Asia</td>
<td>19,401,808</td>
<td>29.5</td>
</tr>
<tr>
<td>Europe</td>
<td>2,341,846</td>
<td>3.6</td>
</tr>
<tr>
<td>South America</td>
<td>1,461,061</td>
<td>2.2</td>
</tr>
<tr>
<td>North America</td>
<td>965,792</td>
<td>1.5</td>
</tr>
<tr>
<td>Africa</td>
<td>962,183</td>
<td>1.4</td>
</tr>
<tr>
<td>Oceania</td>
<td>176,181</td>
<td>0.3</td>
</tr>
</tbody>
</table>
United States Exclusive Economic Zone

U.S. ranked #1 for highest opportunity for offshore aquaculture development

(FAO 2013)
Aquaculture In Norway

Norway produces 33% of world’s farmed salmon

Aquaculture occupies 0.1% of space in coastal waters

Total Norwegian salmon production
- 1.3 million tonnes
- 59 km$^2$ cages
- 420 km$^2$ anchorage

![Graph showing area (km$^2$) from 1990 to 2010 for Farm, Traffic, Fishing, and Anchorage.]
Gulf of Mexico Aquaculture Opportunity at a Glance

The FMP for Regulating Offshore Marine Aquaculture in the Gulf of Mexico provides the first regulatory framework for aquaculture in federal waters.

- Production capped at 64 million pounds annually.
- Individual production cap of 20%, or 12.8 million pounds.
- Economic impact estimated at $264 million.
Marine Aquaculture Permitting
**Farm Siting and Design (1000 mt)**

Cage circumference: 120 m  
Surface footprint: 12 acres  
Anchoring footprint: 90 acres  
Lease boundary: 180 acres  

*(Gulf of Mexico Aquaculture Permit)*
LEASE BOUNDARY

MOORING GRID & CAGE ARRAY

TYPICAL ANCHOR LINE 4:1 SCOPE AT 200 FT. DEEP

SCREW MOORING

DEPTH ~ 200'

Figure Not Drawn To Scale
Aquaculture Coastal Planning Tools

Marine Spatial Planning
- Regional ocean mappers
- State siting atlases
- Habitat digitizer (delineate habitats from geo-referenced images)

Examples:
- NOAA Digital Coast
- Connecticut Shellfish Aquaculture Atlas
- North Carolina Shellfish Aquaculture Siting Tool

Environmental Models
AquaModel
- Gulf of Mexico
- Hawaii
- California

Farm Aquaculture Research Model (FARM)
- Long Island Sound
- Chesapeake Bay

Tool and Data Center
- Marine Cage Culture and the Environment
- Guidelines for Environmental Monitoring Offshore Aquaculture Operations
- Best Management Practices for Offshore Aquaculture in the US Caribbean
Coastal Aquaculture Planning Portal
Partnership with OCM

AquaModel – Environmental Simulation of Offshore Aquaculture Operations
NOAA National Ocean Service
AquaModel provides real-time, three-dimensional simulation of water column and benthic impacts related to offshore aquaculture operations.

Hawaii Aquaculture Marine Mapper
NOAA National Marine Fisheries Service
Interactive online map viewer designed to assist coastal managers and industry siting offshore aquaculture operations.

Shellfish Model – Coastal Spatial Planning and Aquaculture Siting
NOAA National Ocean Service
Ecological carrying capacity model used to evaluate shellfish aquaculture, eutrophication, and nutrient bioextraction.
Southeast, Gulf of Mexico, and U.S. Caribbean

- Environmental support for Gulf of Mexico Aquaculture FMP
- South Atlantic Fishery Management Council’s Policy on aquaculture interactions with EFH
- Gulf of Mexico AquaMapper
- Gulf of Mexico AquaModel to aid in site selection
- BMPs for marine cage culture in the U.S. Caribbean
Supporting policies and best practices for environmental stewardship

✓ Baseline and annual monitoring guidelines for Offshore Aquaculture in Gulf of Mexico

✓ South Atlantic Fishery Management Council’s Policy on aquaculture interactions with EFH
National Monitoring Guidelines

GUIDELINES FOR ENVIRONMENTAL MONITORING OF OFFSHORE MARICULTURE OPERATIONS

Carol Price, NOAA/NOS/NCCOS, Beaufort, NC
Other Co-authors?
Hawaii Subcommittee Review Team?

NOAA Technical Memorandum NOS NCCOS ###
Spatial Planning Tools for Marine Aquaculture

**Site screening**
- Proximity to ports
- Bathymetry
- Temperature
- User conflicts
- Protected species
- Viewshed
- Management areas
- ....

**Environ. modeling**
- Env. data required
- Pollution thresholds
- Production capacity
- Spatio-temporal dynamics
- Fish energetics
- Scenario simulations
- ....

**Site selection**
- Abiotic and biotic considerations
- Validation process
- Permitting process
- Socio-economics
- ....
Gulf AquaView
A Planning and Siting Guide for Aquaculture in Gulf of Mexico

- Data for site-selection
- Identifies unsuitable areas
- Mapping for co-siting
- Identifies use conflicts
- Tool for industry and managers

Approximately 14% of Gulf of Mexico EEZ is suitable for aquaculture (28,700 nm²)
Aquaculture Areas of Concern

- Platform Safety Zones
- Dredged Material Disposal Areas
- Navigation Fairways
- Lightening Zones
- Tortugas Ecological Reserve
- Steamboat Lumps Marine Reserve
- Flower Garden Banks National Marine Sanctuary
- Seagrass
- Coral or Harboretom Areas
- Habitat Areas of Particular Concern
- Florida Keys National Marine Sanctuary

(Rester 2008)
Harmful Algal Blooms 1955-2008 within 25 to 100m

Cells per Liter
- 0 - 5000: Very Low
- 5001 - 10000: Very Low
- 10001 - 50000: Low
- 50001 - 100000: Low
- 100001 - 1000000: Medium

(Rester 2008)
Increasing depth using models as guidance for environmental monitoring

- Model evaluation: AquaModel, DEPOMOD, and Sed-Dep Model
- Locations: Gulf of Mexico and Hawaii
- Production format: marine cage operation (5,000 mt)
Gulf of Mexico Offshore Aquaculture Consortium

- 40 km south of Pascagoula
- 25-m depth
- Ocean Spar SS31 (3,100 m³)

(Bridger 2004)
Gulf of Mexico AquaModel

AquaModel provides real-time, 3D simulation of marine cage culture as well as associated flow and transformation of nutrients, oxygen, and particulate wastes.
Gulf of Mexico AquaModel

Output Results Example:

<table>
<thead>
<tr>
<th>Within or Under Cage</th>
<th>Flow Velocity</th>
<th>Growth Rate</th>
<th>Fish Biomass</th>
<th>Dissolved Oxygen</th>
<th>Nitrogen</th>
<th>Phytoplankton</th>
<th>Zooplankton</th>
<th>Fecal Carbon</th>
<th>Feed Carbon</th>
<th>Sediment Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>cm s⁻¹</td>
<td>1/d</td>
<td>MT</td>
<td>mg L⁻¹</td>
<td>μM</td>
<td>μg L⁻¹</td>
<td>μg L⁻¹</td>
<td>g m⁻³</td>
<td>g m⁻³</td>
<td>g m⁻²</td>
</tr>
<tr>
<td>Mean</td>
<td>8.4</td>
<td>0.01</td>
<td>483.9</td>
<td>5.47</td>
<td>1.06</td>
<td>0.06</td>
<td>0.09</td>
<td>0.02</td>
<td>0.06</td>
<td>0.75</td>
</tr>
<tr>
<td>SD</td>
<td>5.2</td>
<td>0.00</td>
<td>421.7</td>
<td>0.18</td>
<td>0.71</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.03</td>
<td>1.51</td>
</tr>
<tr>
<td>Change</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>-0.23</td>
<td>+0.91</td>
<td>-0.04</td>
<td>+0.04</td>
<td>+0.02</td>
<td>+0.06</td>
<td>+0.75</td>
</tr>
<tr>
<td>90th %</td>
<td>15.9</td>
<td>0.01</td>
<td>543.4</td>
<td>5.63</td>
<td>1.96</td>
<td>0.10</td>
<td>0.13</td>
<td>0.03</td>
<td>0.10</td>
<td>2.82</td>
</tr>
<tr>
<td>10th %</td>
<td>2.9</td>
<td>0.01</td>
<td>426.5</td>
<td>5.24</td>
<td>0.42</td>
<td>0.03</td>
<td>0.06</td>
<td>0.01</td>
<td>0.03</td>
<td>0.00</td>
</tr>
</tbody>
</table>
New Tool: CanVis for Coastal Aquaculture
in partnership with NOAA OCM

The Concern

Actual Coastal Planning

Cage location 5 miles offshore
CanVis: Aquaculture Image Library

Create Photo Realistic Simulations

For Demonstration Purposes – Images Are Not Drawn To Scale
Free Software Available (http://coast.noaa.gov/digitalcoast)
Best Management Practices
For Marine Cage Culture

TABLE OF CONTENTS

Introduction
1. Ecological Effects
2. Water Quality
3. Escapes
4. Fish Health
5. Feeds
6. Human Dimensions
7. Permitting
8. Siting
9. Environmental Monitoring
10. Recordkeeping and Reporting
We are building a nexus of scientific, industry, regulatory, and public partners committed to ecologically sound coastal communities that provide the nation with safe, environmentally sustainable, reliable, and profitable seafood industries.