OFFSHORE AQUACULTURE TECHNOLOGY IN THE PACIFIC NORTHWEST

by

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Purpose of this talk:

1. Explain the unique challenges associated with offshore aquaculture.

2. Describe recent technological advancements in offshore aquaculture.
   - Containment technology
   - Anchoring options
   - Feeding options
   - Automation

3. Discuss how these technologies can be applied in the U.S. Pacific Northwest.

4. Seed a visioning process for coastal economic development based on offshore aquaculture.
## Why business as usual won’t work.

<table>
<thead>
<tr>
<th>Near-Shore</th>
<th>Open-Ocean</th>
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<tbody>
<tr>
<td>Make full use of permitted site</td>
<td>Large area, very low-density</td>
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<tr>
<td>Multiple pens in array</td>
<td>Independent cages?</td>
</tr>
<tr>
<td>Fixed location, multiple anchors</td>
<td>Location less critical</td>
</tr>
<tr>
<td>Site rotation for fallowing</td>
<td>Little or no benthic impact</td>
</tr>
<tr>
<td>Rely on human intervention</td>
<td>Mechanization where possible</td>
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- Conventional technologies are suitable only in a narrow band of sheltered waters.
- These waters are full of conflicting uses.
- These waters are the most polluted.
- Currents are most variable in coastal waters.
- Temperatures are most variable in coastal waters.
- Wave energy increases with shoaling.

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Sheltered-water Aquaculture in Floating Pens

British Columbia salmon farm using rectangular gravity pens

Circular P.E. pens at a Lubec, ME salmon farm

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The Importance of Submergence for Structures and Fish

Gravity cage failures are typically related to moorings or netting attachment to flotation collars.

Wave energy decreases exponentially with depth - except in shallow water.

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Salmon aquaculture in Downeast Maine
Conventional collar-type gravity cages are unsuitable in the high-energy environment found in the Pacific northwest. To meet this challenge the emphasis in cage technologies to date has been on:

- Submersible cages
- Innovative anchoring methods
- Reducing the cost per cu. m.
- Automation
- Mobile systems
Offshore fish farm - normal view

Cage surfaced for servicing
USM/MIT project 22 miles offshore in Gulf of Mexico

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Sea Station™
developed by Ocean Spar Technologies LLC of Bainbridge Island, WA
http://www.oceanspar.com/
Available in sizes up to 15,000 cu. m.

The first affordable, submersible ocean cage.
Over 50 installations worldwide

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10 meter dia., 500 cu. m, Aquapod® submersible cage being launched in Portsmouth, NH.

Aquapod™ panels packed in a Hi-Cube shipping container.

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Cage Size

Is there an optimum?

As in sheltered-water fish farming, there is a trend in offshore aquaculture toward larger and larger cages. Much of that is driven by the realities of cage cost per unit volume. But there are other factors that might favor smaller cages:

- Water-quality issues in a large cage (LVHD)
- Risk management
- Novel harvest option
- Small, economical cage designs
Aquapod 115 m³ in Panama

OCAT 100 m³ in China

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Anchoring Options: Submerged Grid

Rectangular Array

Linear Array

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Anchoring Options: Submerged Grid

- A grid can be cost effective with multiple cages.
- Tolerant of off-axis currents.
- Failures can cascade.
- Concerns about self pollution and disease transmission.
Anchoring Options

Multiple anchors to independent cages
Anchoring Options
Multiple anchors to independent cages

- Most expensive option.
- Requires near-bidirectional current.
- Failure tolerant.
Anchoring

Conventional methods of cage anchoring can become impractical at depths over 150 feet

Area vs. Depth
(20m cage, 7/1 scope)

Solutions?

- Tension leg
- Single-point mooring
- Mobile operations

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Single Point Mooring

- Reduced benthic deposition
- Reduced overall loads
- Cage always has a bow
- Simplifies installation
- Can be self-submerging
Single Point Mooring

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Anchoring Options
Single Point Moorings (SPMs)
Anchoring Options
Single Point Moorings (SPMs)

- Least expensive option
- Applicable to any current
- Preferred by most other maritime sectors
- Lacks redundancy
- Minimizes benthic disturbance
Anchoring Options
Single Point Moorings (SPMs)

Minimum SPM spacing depends on the local reliability of currents
Mooring System Design

- Cage resistance
  - Towing experiment
  - Numerical modeling
- Current regime
  - Current meter deployment
  - Extrapolation from existing data
  - Numerical modeling
- Wave environment
  - Sensor deployment
  - Existing data
- Depths and bottom substrate
  - Site survey
Pacific Northwest Coastal Currents

http://bragg.oce.orst.edu/

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Caution

This data is surface currents only. Current at cage mid-depth is what matters.
Anchor Types

- Drag embedment anchor
- Deadweight anchor
- Penetrating
  - Pile
  - Screw-in
  - Toggle
- Combination
Anchor Types

Preferred for single-point moorings due to omni-directional holding and resistance to fouling.
Typical Pacific Northwest Coastline
Typical Pacific Northwest Coastline

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Pacific Northwest Coastline
Cape Flattery to San Francisco

You are here
200 mi.

Previous slide

U.S. EEZ

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99% of the West Coast EEZ is unsuitable for moored aquaculture operations.
Mobile Cage Operations

64,000 Cubic Meter Ocean Drifter

Manned or autonomous cages capable of low-speed self-propulsion operating in reciprocal or gyre currents.

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Rigid submersible cages do not require the outward tension of a mooring array to maintain shape and internal volume. Unmoored systems that “go with the flow” can be far more cost-effective than if they must stand and face weather extremes.
Mobile Cages

The feasibility of self-propelled cages was recently demonstrated by MIT at Snapperfarm in Culebra, P.R. using a 3,250 cu. m. Aquapod®.

Flygt S4420 thruster
Thruster Pair was retrofitted to stern of cage.
Each thruster is 8 feet in diameter and powered by a 6.2 hp motor.
Variable-frequency drives controlled speed and direction.

0.5 knots @ 10.4 kW
Whether anchored or mobile, there are numerous issues associated with conceptualizing, optimizing and implementing an offshore aquaculture operation:

Assembly & deployment
Transport from launch to site
System inspection and maintenance
Biofouling control
Stocking and harvest
Feeding
Underwater monitoring
Mortality removal
Containment integrity monitoring
Biomass assessment
Environmental monitoring
Automation
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- Automation
Automated feeding

Aquaculture Engineering Group, Hillsborough, NB
http://www.aeg-solutions.com/index.html

UNH Feed Buoy
http://ooa.unh.edu

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Automated Aquapod® Rotation

One of five rotation tanks, each providing 950 pounds of buoyancy.
Special-Purpose Mooring Hardware

The “Rotapent” by Ocean Farm Technologies

Custom-designed mooring hardware allows for cage rotation and one-stop diver inspection

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Ethernet-based Cage Automation

NOAA SBIR-funded project by OFT, MIT, and Marbotics

SBIR Phase II will commercialize the system and include wireless to shore.

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Summary

The Pacific Northwest presents a unique set of requirement that can be met with a unique combination of technologies. These technologies are available today but the operational paradigm needs to be developed and demonstrated.

Editorial

The informational and infrastructure requirements needed for a viable plan suggests fishermen should be leading the development rather than reacting to it.
Thank you, any questions?

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