Open ocean aquaculture:

Economics (and policy)

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Outline

• Global trends in aquaculture
• Economic drivers of profitability
• Potential for robotics
World Population: 1950-2050

- 1950: 3 Billion
- 1960: 4 Billion
- 1970: 5 Billion
- 1980: 6 Billion
- 1990: 7 Billion
- 2000: 8 Billion
- 2050: 9 Billion

Source: U.S. Census Bureau, International Data Base, J
World Demand is Growing Rapidly

Source: FAO
US Seafood Supply, 2012

80% + of US consumption is imported
50% + of that is farmed
Future Seafood Demand

US population:
- 2015: 322 million
- 2050: 440 million

Seafood consumption:
- 12 kg/year live weight; trend?
  (US gov’t recommends 25% more)

World population:
- 2015: 7.3 billion
- 2050: 9.4 billion

Seafood consumption:
- 19.5 kg/year live weight & rising

We’ll need another 1-2 million tons/year by 2050 in the USA, and 40 million tons/year by 2050 globally...at least.
Aquaculture...but what kind?

Global trends that will shape food production:

• Concern over C emissions, ecological efficiency of food production
• Constraints on fresh water and arable land
• Trend toward locally produced food, shorter and simpler supply chains

Source: Pelletier and Tyedmers (2007)
Aquaculture...but what kind?

- Historically dominated by freshwater finfish
- Recent growth: shellfish
- Future:
  - Marine
  - Open ocean
  - Recirculating
# Near-Shore vs. Open-Ocean

<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>
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<tr>
<td>Site rotation for fallowing</td>
<td>Little or no bottom impact</td>
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<tr>
<td>Rely on human intervention</td>
<td>Mechanization where possible</td>
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- Conventional technologies are suitable only a narrow band of sheltered waters.

Source: Cliff Goudey
Near-shore Technology

Salmon pens, Maine and Washington
OceanGlobe
Byks AS, Norway

• 40,000 m³ design

Source: Byks AS, Norway
Ocean Drifter
Conceptual design by Cliff Goudey

- 64,000 m³ design
- Manned or autonomous
- Low-speed self-propulsion (gyres/reciprocating currents)

Source: Cliff Goudey
Pros and cons of open ocean

• Cons:
  – Exposure (structures, vessels)
  – Logistics (transport costs)
  – Water depth (mooring system)
  – Working conditions
  – Industry economies of scale
  – Operating and regulatory experience

• Pros:
  – Water quality
  – Availability of sites
  – Use conflicts
  – Farm economies of scale
  – Distance from markets

Knapp (2008)
Some basic economics of aquaculture, courtesy of Gunnar Knapp

Higher production costs at open water sites limit competitiveness with low-cost near-shore sites

Figure 2.2. Hypothetical U.S. marine aquaculture supply curve.

Knapp (2008)
What could make open water aquaculture more competitive?

Demand growth

Supply constraints on near-shore sites

Stricter regulation on near-shore sites

Technological change

Knapp (2008)
The role of local production

Open-ocean technology could enable greater US production, even if near shore sites are limited

US-produced open ocean seafood might command a price premium

Knapp (2008)
What affects economic viability?

- Capital investment
- Operating cost
- Production density
- Juvenile survival rate
- Feed conversion ratio
- Market price
- Cost of capital

Knapp (2008)
Production cost: Near-shore vs. Open Ocean

- Increased capital and operating cost of cages, feed system, mooring: 2-3 X near-shore costs
- Increased cost of logistics due to greater distance from port
Cost Effect of Distance from Shore

The graph shows the NPV at a 5% discount rate ($m) for different distances from the shore base (km) for cod, salmon, and flounder. The NPV is represented for 3 RTs/day, 2 RTs/day, and 1 RT/day. As the distance from the shore base increases, the NPV decreases for all species.
Major Cost Components

Feed: 40%
Facilities: 20%
Stocking: 10-15%
Operations: 15%
   labor: 7-10%

Knapp (2008)

Kite-Powell et al. (2003)
Summary

• Global aquaculture output will have to grow significantly
• Marine, open water production will be needed
• Key challenges in open water aquaculture: efficient facilities, and operations/logistics
• Robotics/automation can directly address about 15% of cost of current operational model
• Robotics/automation that enables very large autonomous systems can open new possibilities in scale economies