Bivalve Cultivation: Processes and business
A Maine Perspective

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• Why diversify into mariculture?
• Key factors contributing to success
• Examples from Maine Mariculture – oysters, mussels
• Mariculture research focused on industry development
• Choosing a site: emerging tools
Why diversify into mariculture?

1. Fishermen are **low cost producers** – they have the boats, trucks, distribution and marketing, marine skills, local knowledge
2. Mariculture provides **additional employment** working on the water (as opposed to carpentry, etc.)
3. It provides employment during times **when fishing is not possible** – weather days, closed seasons, market price, depleted resources
4. It produces consistent high **quality, stable price**, and stable market conditions
5. Virtually every world leader in mariculture also has or had a large fishing fleet
6. There is **rapid growth** in the industry
7. The U.S. imports over 90% of the seafood it consumes
Key Factors for Success

RIGHT SPECIES – native species, rapid growth rates (i.e. kelp, mussels, oysters, clams, scallops, other?)

RIGHT ENVIRONMENT – exposure to waves, temperature, salinity, phytoplankton, water quality, demonstrated growth on pilot project scale

RIGHT CULTURE TECHNOLOGY – proven techniques that will allow for efficient and profitable farming and processing

RIGHT MARKET PRICE – start with most valuable species with high market value, develop brand identity based on consistency and quality
Different mind-set

- **Be patient.** Choosing a farm site, getting permits, establishing gear, getting seed, growing a crop and harvesting can take several years before income is generated.
- **Start small** before you invest too much money.
- Don’t quit your day job when you are developing the new venture – **let the farm prove itself first**.
- Be ready to **innovate solutions** to challenges you might face.
- Keep on the lookout for **new technologies** that can make growing, harvesting and processing more efficient.
- Don’t be surprised if the **market will pay much** more for a consistent, high quality product available year round.
Maine Aquaculture

- Existing shellfish
  - Mussels
  - Oysters
  - Clams

- New shellfish
  - Flat oysters
  - Surf clams
  - Scallops

- Algae
  - Macroalgae
  - Microalgae

- Ornamental fish and invertebrates

- Other invertebrates
  - Sea cucumbers
  - Sea urchins
  - Polychaetes

- Baitfish
  - Halibut
  - Cod
  - Zebra fish

- Other finfish

Over 600 jobs
Estimated $100 million industry
Fastest growing sector worldwide in food production
MAINE AQUACULTURE Where are the farms?

South coast oysters inner bays, mussel and kelp outer bays

Down east finfish (high currents, no winterchill)

Mid coast oysters inner bays, mussels and kelp outer bays
Maine private aquaculture: expect growth in shellfish and seaweed sites
Lease criteria/know your site/start small

Stock enhancement
1. Collecting wild scallop seed
2. Enhancement of soft shell clam beds
3. Restocking freshwater fish
4. Restocking American shad
Oyster farming processes
site selection, hatchery, upwellers, nursery,
grow-out, processing, harvesting, sales.
Mussel farming processes: site selection, seed collection, grow-out, harvesting, processing, sales.
Aspects of Business plans i.e. **mussel example**

Maximize yield per rope, pounds sold annually related to investments (fixed costs). Labor costs highest expense in shellfish farming (variable cost: i.e. $.50 per pound harvested and sold).

Technology transfer and improvements in yield and culture technology have the best return on investment.

Maximize harvest per boat day to increase margin.

For both mussels and oysters: crop loss biggest risk

**Storms/predation/biofouling/disease/poaching/etc.**

2 years of investment required before achieving income.
What do we have going for us now?

- A strong and growing market approaching $50 million USD.
- Improved technology for seeding, harvesting, processing, packing
- Improved site selection techniques
- Successful involvement of commercial fishermen
Emerging trends: sustainability, local food movement, polyculture

- Mussels have 1/10 carbon footprint rel. to chicken and 1/30 relative to beef
- Artificial reef, ecosystem engineers
- Maine mussel and kelp polyculture
EARLY EXAMPLE: LEARNING HOW TO FARM THE BOTTOM

Mud Cove, Maine, approx. 15 hectares, farmed since 1982, over 5000 tons production and lots of happy Eider ducks
WE FIGURED OUT THAT PLANTING DENSITY ON THE FARM HAS A HUGE EFFECT ON THE GROWTH RATES AND YIELD

Figure 2. Final model MUSMOD®.(3) Food is supplied to the mussels from the surface layer and both food components (phytoplankton cells (C) and detritus (D)) are mixed to the bottom, resuspended or ingested by the mussels (M). For a given density N (300 m²), current speed (V) and food supply, mussels will grow as a percentage of the food available at the edge of the lease site.
PLANTING AT HIGH OR LOW DENSITIES CAN REDUCE THE GROWTH BY OVER 50% BECAUSE THE MUSSELS COMPETE FOR FOOD

Scope for growth as a function of particle depletion at Mud Cove during 1990
Mussel Bottom Culture: Carlingford Lough Example (N. Ireland)

Recommended Seeding Densities
Mussel Bottom Culture: Carlingford Lough
MUSMOD simulation: LESS IS MORE!
HOW WE DO IT: MUSSEL RAFTS
Seed Collection

- Right density on rope – 2-5,000 per foot of collector
- Right timing of rope deployment: late June
- Right temperature and food for growth to seed size: ½ inch to 1 inch long.
- MAIC study: not all sites are good for seed collection. Starfish also a big factor. Coiled ropes collect more seed.
- Can collect it from predator nets and harvest lines.
- Seed attached to lines using biodegradable cotton
Floating and new submersible rafts
Harvesting and processing at sea: declumping, debyssing, grading, purging, bagging, seed recovery
Site Hydrodynamics
Currents can`t be too high or too low
Raft hydrodynamics

- Friction on rafts decrease flow by about 80%
- Water velocity at the site should be about 25 to 30 cm per second to get good growth
- Growth is faster with more food (phytoplanton) at a site
- Optimum density on a mussel rope is about 200 per foot yielding 35 tons in a 16 month grow out cycle
This model demonstrates that you need 15 cm per second currents going into your raft or the mussels will starve.

Scale is chl a ug l$^{-1}$

Model simulation for 15 cm s$^{-1}$ approach velocity and 30 cm diameter ropes

### 30 cm diameter ropes modeled food (chl a)

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HOW YOU MOOR THE RAFTS EFFECTS MUSSEL GROWTH

What-if Scenarios: Totten Inlet Mussel Rafts (existing and potential if orientation to flow was modified)

Calculated Food Availability
(colored by concentration, red – 18.0 μg/l, arrows show direction of approach flow - 15 cm/s)
DEVELOPMENT OF SUBMERSIBLE RAFT TO REDUCE RISK AND INCREASE YIELD
Prototype testing, design, scale model testing and beta testing for novel Pemaquid™ Submersible Mussel Raft (patent pending).
Aqua finite element model (University of New Hampshire) shows in a simulated storm that the submersible raft provides a stable calm rope surface for the mussels to attach to
Value Added Processing can increase margins
Mussel MAP doubles demand and improves quality

- USDA Phase II Mussel modified atmosphere package botulism challenge studies for FDA approval
- Great Eastern Mussel Farms 2004
- Partners: University of Georgia Department of Food Safety

- Project aided by MTI seed grant
- Opportunities for value added products
Remote sensing (Landsat satellites) – PROSPECTING*

*Aquaculture Site Prospecting: Developing Remote Sensing Capabilities for the Aquaculture Community of Maine, National Sea Grant Extension 2016-2018, U Maine SMS, Brady, Boss, Thomas, Newell and Morse.

Chl a mid-coast Maine August

Water temperature
Penobscot Bay Maine August
Putting it all together

**SHELLGIS** (shellgis.com). We have developed a software that provides, on a 50 m grid, a prediction of how fast your oysters will grow depending on type of culture (surface or bottom), time of year planted, seed size, and density in the culture unit.
Site selection and farm management: SHELLGIS
Shellfish growth model based on site specific environmental growth drivers reduces risk and trial and error

Using SHELLSIM to model growth

$\text{NEB} = \text{C} - (\text{F} + \text{R} + \text{E})$

Using Mike 21 to model water flow (50 m grid)

Using Flow-3D to model effects of cultures on flow and food
Choose species

Whilst ShellGIS has been calibrated for 14 commonly-cultured species to date, those species including the mussels Mytilus edulis, Mytilus galloprovincialis, Perna canaliculus and Modiolus modiolus; oysters Crassostrea gigas, Crassostrea virginica, Crassostrea plicatula and Ostrea edulis; clams Ruditapes philippinarum, Ruditapes decussatus, Tegillarca (= Anadara) granosa and Sinonovacula constricta; and scallops Chlamys farreri and Pecten maximus; current options may be limited to species that are relevant to the domain for which the present version of ShellGIS has been prepared.

Select a species

Crassostrea virginica (Eastern Oyster)

Crassostrea virginica Gmelin, 1791 [Ostreidae]

Common names: En - American cupped oyster, Fr - Huitre creuse américaine, Es - Ostión virginico, Ch - 美国牡蛎

American cupped oysters are the most economically important group of molluscs in U.S. capture fisheries, with more than 100,000 tonnes harvested per annum worldwide.
Type of culture

Seeding date and model run

Step 2: Shellfish Growth
Select Culture Type

ShellGIS has been developed to account for interactive effects of seed density and current flow on food supply during either bottom or suspended culture, as influenced by boundary layer physics and aquaculture structure porosity, respectively. Consequences of those interactive effects on food supply are computed for population dynamics, accounting for mortality. During bottom culture, present outputs are computed using a resolution of 1 metre within 1 hectare patch, the User being able to seed between 50 and 1000 individuals m⁻². During surface culture, outputs are computed for the OysterGro™ floating tray system, assuming 10 strings each with 50 cages, strings separated by 7.6 metres and with cages separated by 3.9 metres along each string, 6 bags.

Action

- Bottom
- Surface

Bottom Density: 50
Relative Angle Of Flow (deg):
Oyster Size: Small (25mm)

Species: Crassostrea virginica (Eastern Oyster)
1200 Oysters Per

Back Next

Step 3: Shellfish Growth
Specify a start date and period to run the prediction model

The calculations run for a number of days. You can specify the start date and the number of days that the prediction model should run for. The start or seeding date should specify when you plan to seed your farm. The number of days may indicate when you plan to harvest or you may decide to run the model for a longer timeframe to investigate what happens beyond the planned harvest date.

Seeding date
Period to run (days)

01/05/2011
180

Species: Crassostrea virginica (Eastern Oyster)
Culture Type: Bottom

Back Next
Seed size (length or weight)

Location within the GIS system

Step 4: Shellfish Growth

Specify the seeding size

Seed Size upon seeding may be defined either as

i) Initial Shell Length (cm), or

ii) Initial Live Weight or Total Fresh Weight (g; the mass of whole live shellfish, including water remaining in the shell cavity).

Enter the value you want to use in either text box and then leave the other text box blank or with a value of zero.

Shell Length (cm)
0

Live Weight (g)
24

Step 5: Shellfish Growth

Location of site

This defines the location at which you would like to run the prediction model. Click on the 'Click on map' button to do this interactively in the map viewer (a simple left-click on the map selects the location and returns you to this interface) or type in the co-ordinates if you know them.

X Co-ordinate
456389

OR

Click On Map

Y Co-ordinate
4873000

Back

Next
At this site oysters planted at over 400 m$^{-2}$ grow significantly slower than at lower densities.

At this site the amount of food in the oyster tray longline is greatly improved if the lines are angled a little relative to flow direction.
Percent reduction in growth vs density in a 1 acre bed of oysters

You can plot in an estuary what growth you could expect at a given planting density.

Blue = <10% reduction  Red = over 50% reduction

100 per square meter  500 per square meter
Simulated growth at 300 m\(^2\) on a hot year (green) or cold year (blue) (+/- 3 C)
The information needed to drive the growth models is collected by automated buoys.
Future Directions:
Where do we go from here?

• Reduce risk with **improved technology and site selection** (submersible rafts for semi-exposed sites, ShellGIS, brush declumpers, mooring systems, seed collection)

• Developing low cost COB ($2,000) automated data buoys for mariculture GIS

• **Technology transfer, extension**

• **Business planning and marketing**
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