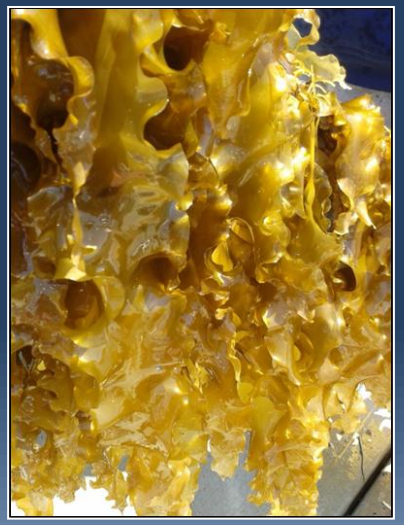
SMALL SCALE INTERGRATED MULTI-TROPHIC AQUACUTLURE OF STEELHEAD TROUT (*Oncorhynchus mykiss*), BLUE MUSSELS (*Edulis mytilus*) AND SUGAR KELP (*Laminaria saccharina*) FOR COASTAL FISHERS IN NEW HAMPSHIRE, USA.

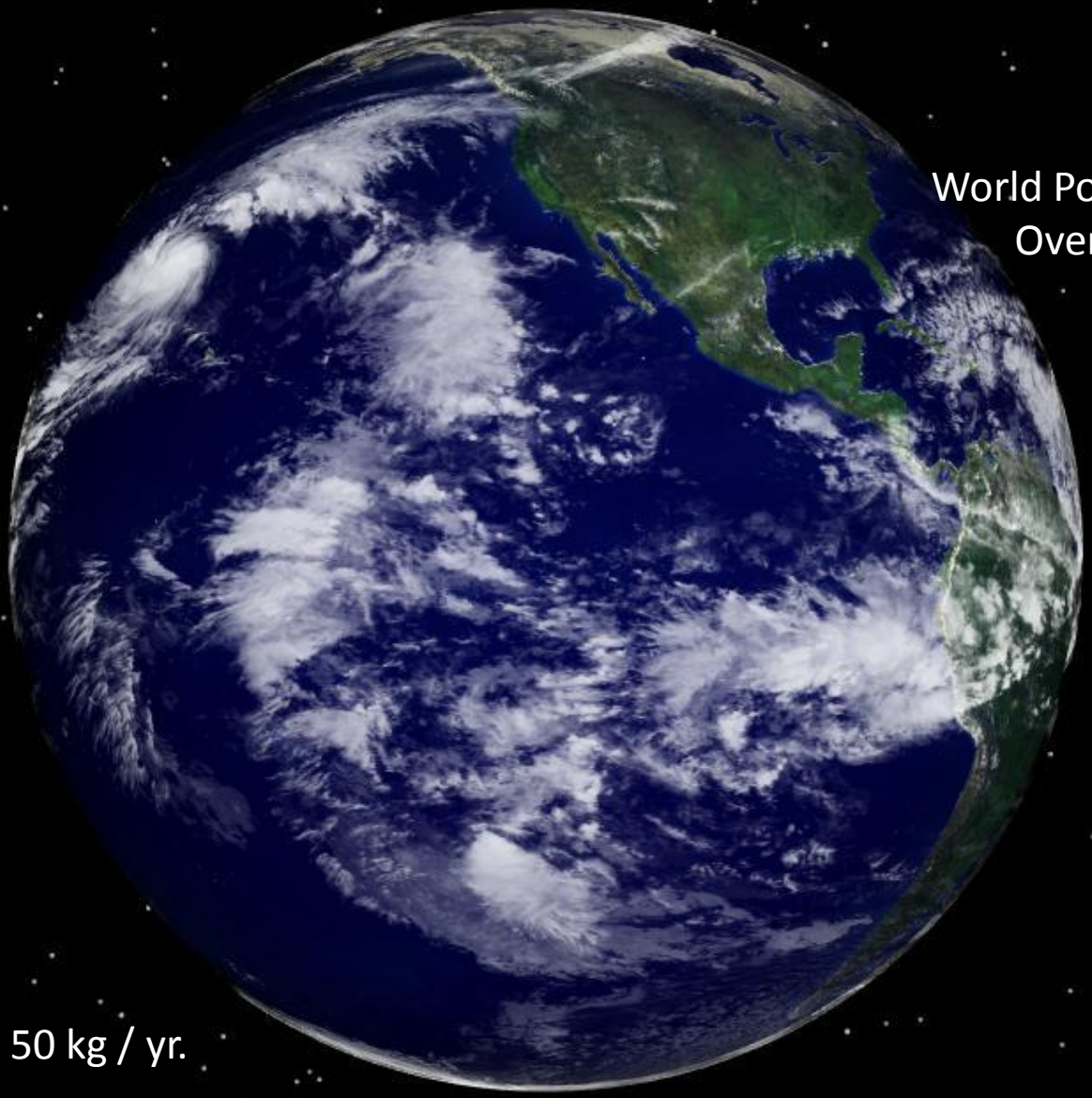


Michael Chambers and Hunt Howell, UNH and NH Sea Grant

Importance of Fisheries & Aquaculture

70% of the planet is ocean

Yet it produces only 2% of our food



World Population now Over 7 billion

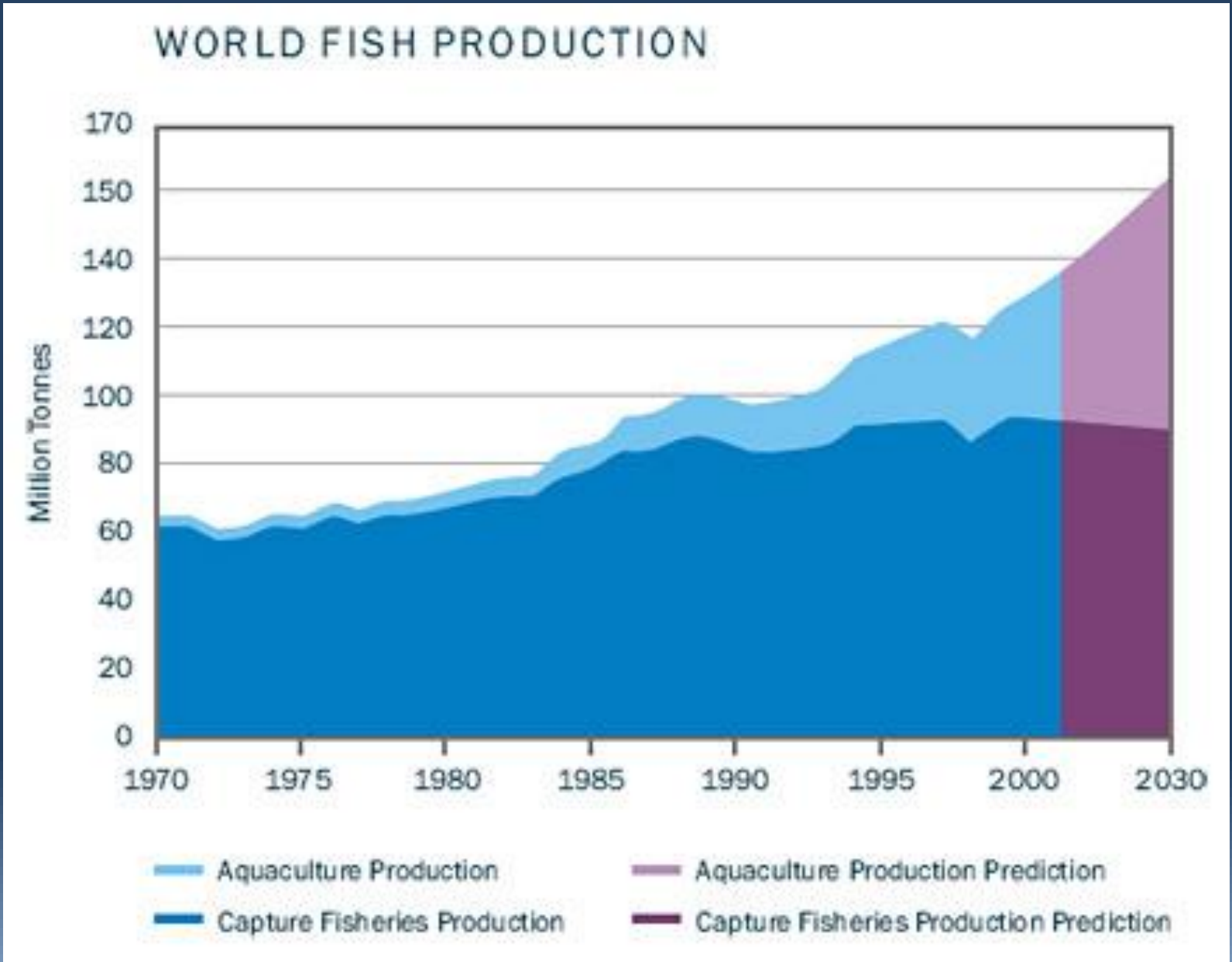
Japan consumes > 50 kg / yr.

US < 7 kg / yr.

US Exclusive Economic Zone

Commercial Fishing in the North Atlantic

- ✓ Fishing in New England has endured for hundreds of years.
- ✓ Early fishermen traveled across the Atlantic to catch cod in North America. Here, they were cut and dried before sailing back to Europe where they were sold.
- ✓ As a result, major cities developed around these fishing grounds.
- ✓ Historically, the Gulf of Maine has provided a livelihood for thousands of commercial fishermen and their families.
- ✓ More recently, these numbers have significantly decreased due to increased fishery management measures to help rebuild declining stocks.
- ✓ Currently in NH, the Portsmouth fishing community has engaged aquaculture as a means to diversify their catch and maintain their life style working on the ocean.


WORLD FISH PRODUCTION
Million Tonnes
170
150
140
120
100
80
60
40
20
0
1970
1975
1980
1985
1990
1995
2000
2030
Aquaculture Production
Aquaculture Production Prediction
Capture Fisheries Production
Capture Fisheries Production Prediction

Why Farm the Ocean?

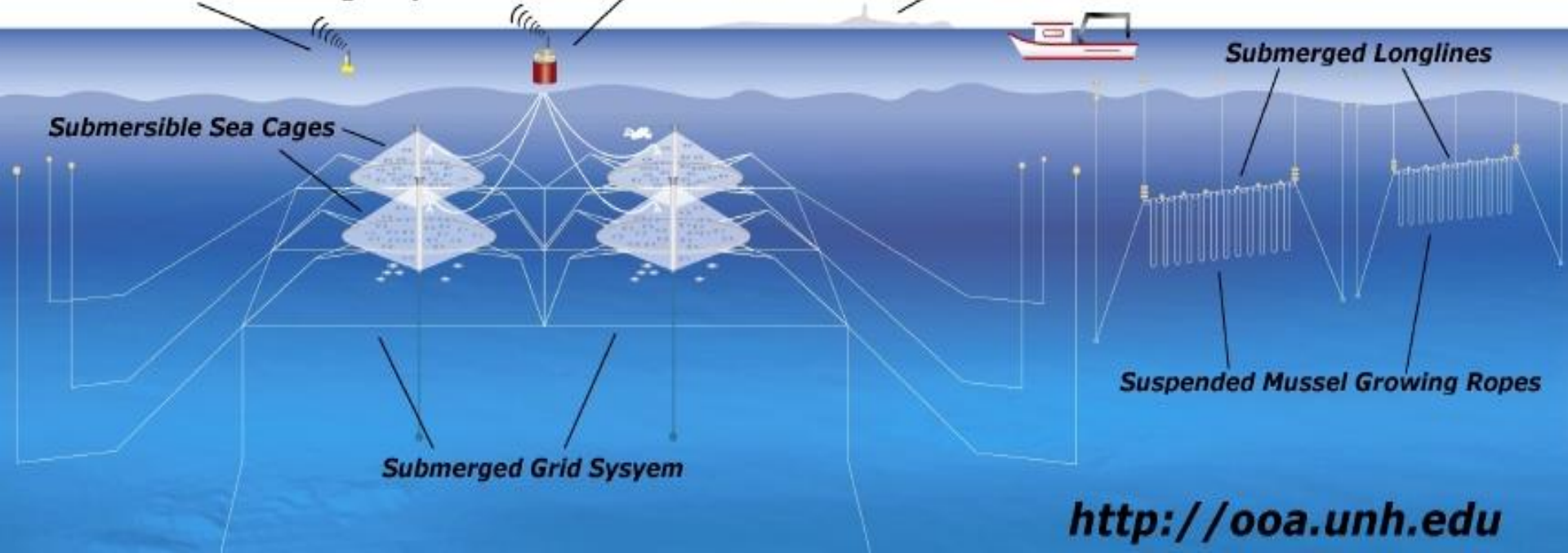
- ✓ Worldwide capture fisheries has plateaued around 100 mmt since the 1990's.
- ✓ Currently, the U.S. imports 90% of its seafood creating an annual deficit exceeding $10 billion.
- ✓ Over 50% of this seafood production comes from other countries as farmed raised product without the strict environmental regulations enforced in the U.S.
- ✓ The United Nation's Food and Agriculture Organization predicts a 40 million metric ton shortfall by 2030 which will have to be met through fish farming.
- ✓ Recent federal health guidelines call for Americans to double their seafood consumption.
- ✓ If more seafood is cultured in the US, it will create jobs, reduce the carbon foot print on foreign imports, provide fresh product and will increase seafood security.
- ✓ FCR, growth efficiencies in aquatic environments and fresh water conservation.
- ✓ As the population grows and the demand for seafood increases, aquaculture will play an increasingly important role in domestic and global seafood production.

New Hampshire Open Ocean Aquaculture Demonstration Site

NH Mainland Shore - 10 km

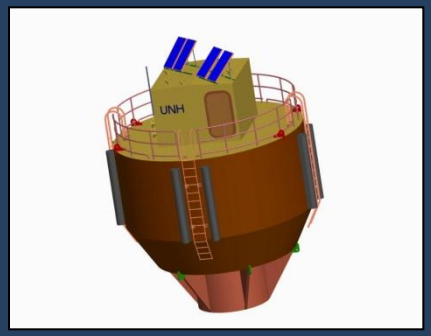
Remotely Controlled Automated Feed Buoy

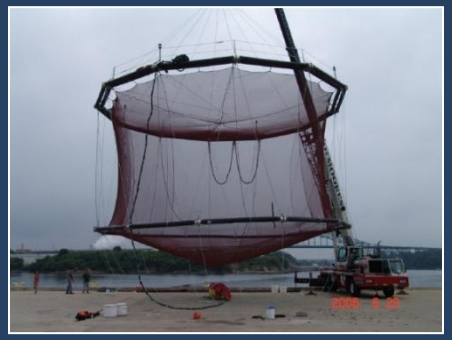
Isles of Shoals- 2 km north

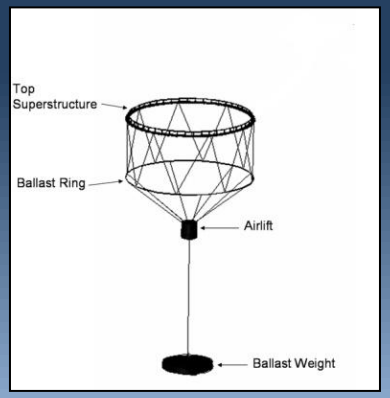


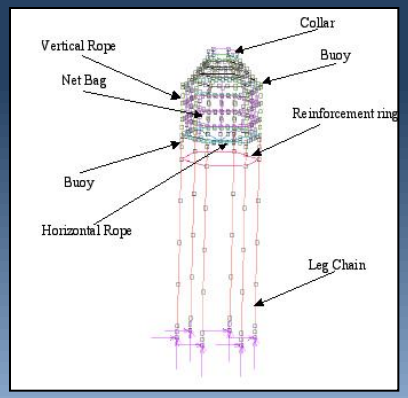
http://ooa.unh.edu

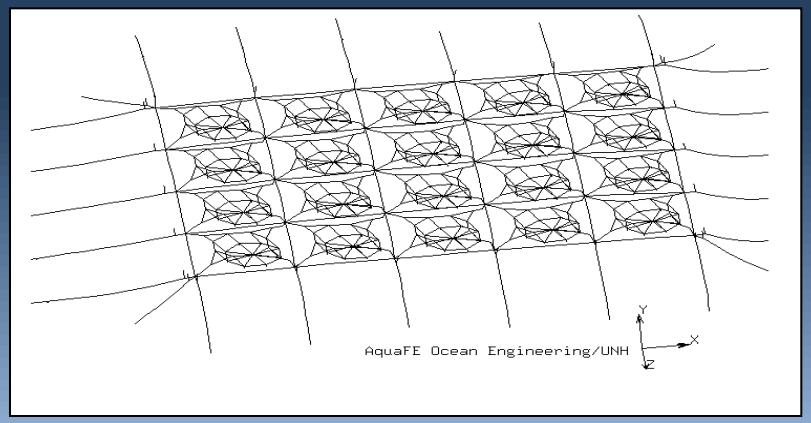
Ocean Systems Evaluated at UNH











Marine Organisms Cultured Offshore NH

Hippoglossus hippoglossus

Mytilis edulis

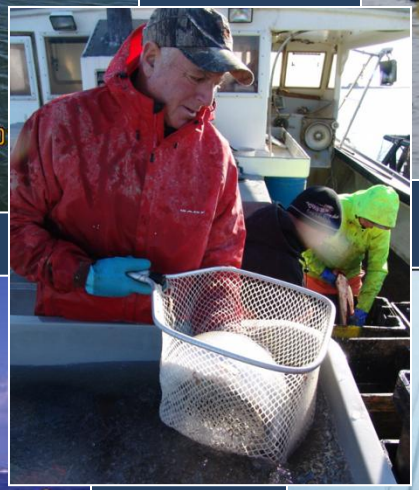
Gadus morhua

Melanogrammus aeglefinus

Placopecten magellanicus

Oncorhynchus mykiss

Involvement with Fishing Community



What were the Lessons Learned?

OOA in the North Atlantic

Risky

Expensive

Challenging

Difficult to Maintain Systems

Economically not Viable with Slow Growing Species

UNH Explored Alternative Aquaculture Methods that:

- ✓ Utilized smaller scale aquaculture systems, closer to shore.
- ✓ Fishermen could adopt with their vessels and infrastructure.
- ✓ Considered faster growing species with high market value and demand.
- ✓ Have seasonal growout periods.
- ✓ Considered culture sites located in between fishing grounds.
- ✓ Could provide a new, local seafood product.
- ✓ Fishermen could conduct part time to subsidize their wild catch.
- ✓ Could produce 5-10 ton/year.

Extension Program Developed

- UNH and NH Sea Grant engaged fishermen on small scale aquaculture.
- Meetings were held to gather interest amongst fishermen who wanted to invest their time and vessel.
- Hands on training helped fishermen diversify and learn a new skill set to supplement their income.

First Step - Site Selection and Sampling

Information for application

1. Site coordinates (GPS)
2. Water quality (dissolved oxygen, pH, temperature and salinity)
3. Bottom substrate
4. Wave and current climatology
5. Proximity to historical sites
6. Critical habitat for marine organisms
7. Proximity to commercial traffic
8. Potential user conflict by fishermen and recreational boaters
9. Product to be raised
10. Planned annual production

Aquaculture Permitting in NH

State and Federal agencies involved with the permitting process:

1. NH Fish & Game (Aquaculture permit - 1 yr.)
2. NH Department of Environmental Services (Wetlands permit -5 yr.)
3. NH Port Authority mooring permit (1 yr.)
4. Army Corp of Engineers (Mooring permit - 5 yr.)
5. US Coast Guard (Aids to Navigation - 5 yr.)
6. NH Department of Health and Human Services (Sale of Shellfish)
7. National Marine Fisheries Services (review and comments)
8. Environmental Protection Agency (review and comments)

After aquaculture application has been filed:

- ✓ Review and comment period
- ✓ NH Fish & Game divers conduct survey of each site
- ✓ Public Hearing
- ✓ At the public hearing, EPA expressed concern of additional nitrogen to an already nitrogen impaired river.

Concern of Nitrogen from Farming Fish

- With this concern, integrated multi-trophic aquaculture (IMTA) was investigated as a means to extract nutrients from farming inputs.
- A model was developed with steelhead trout, blue mussels and sugar kelp.
- Nitrogen produced from fish production would be removed by lower trophic shellfish and seaweed species.
- Strict environmental monitoring program was initiated.
- The demonstration project collected biological and environmental data for state and federal regulatory authorities.

Species of Choice

Steelhead Trout

Sugar Kelp

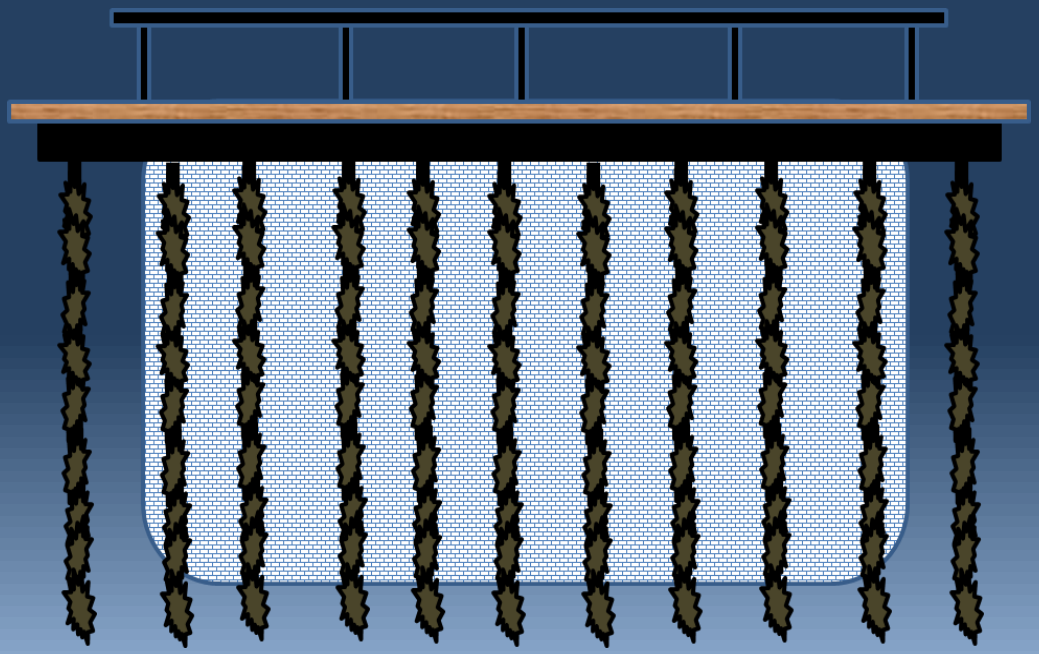
Blue Mussels

Why Steelhead Trout (*Oncorhynchus mykiss*)

- Readily available in NH from local hatchery's.
- Diploid – all female eggs from Trout Lodge.
- Can be transferred directly from FW to SW.
- Robust fish for handling and cage culture.
- Exceptional growth rates from May – November obtaining 1-2 kg weight gain in 8 months period.
- High market value.
- Unique, fresh, local product for New England.

Bio-filtration of N through Integrated Multi-trophic Aquaculture

- Inorganic (kelp) and organic (mussels) uptake of nutrients from the farm and river.
- Secondary products can be sold for additional income.
- Ecosystem services.
- At harvest, N is removed from the ecosystem.



Nitrogen Input of Feed

(45% protein, 22% lipid)

Excretion 50%

Retention 40%

(Hardy, 2012)

Loss: 5%

Feces: 10%

Environmental Monitoring Protocol

1. Sampling of the farm site three times throughout the trout production cycle (8 months).
2. Sampling occurred before fish transfer, mid point of production cycle and at harvest of fish.
3. Water quality :

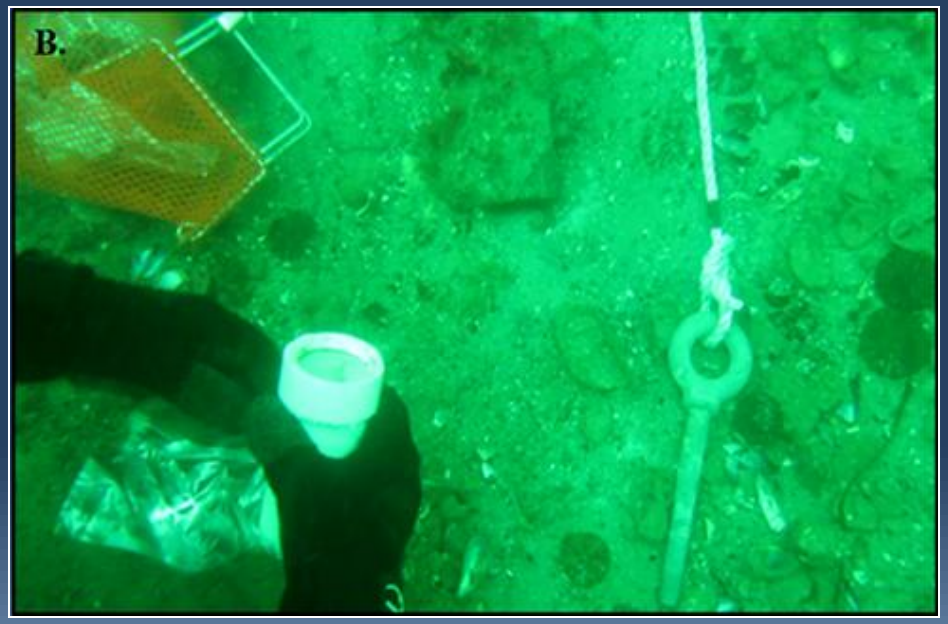
   - Temperature
   - DO
   - pH
   - Current speed
   - Salinity
   - Ammonia
   - Nitrite
   - Nitrate
   - Current direction

4. Benthic sampling
5. Video sampling
6. Annual reporting to EPA, NH Fish & Game, NH Dept. of Environmental Services.

Video and Benthic Sampling

Diver with a Go Pro™ underwater camera

- 30 m bottom transect
- Video taken along the entire transect
- Sediment samples taken:
  - underneath the cage
  - 15 m up current
  - 15 m down current

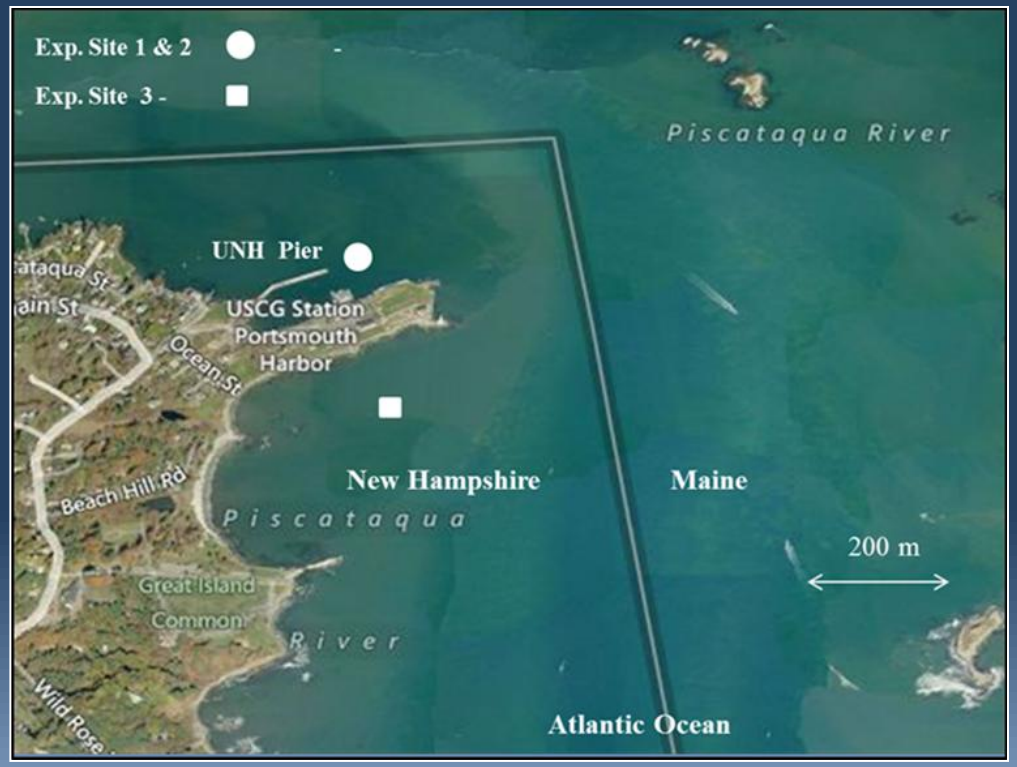


Sediment sampling with a PVC pipe and cap (5 cm x 10 cm)

Mouth of the Piscataqua River, NH

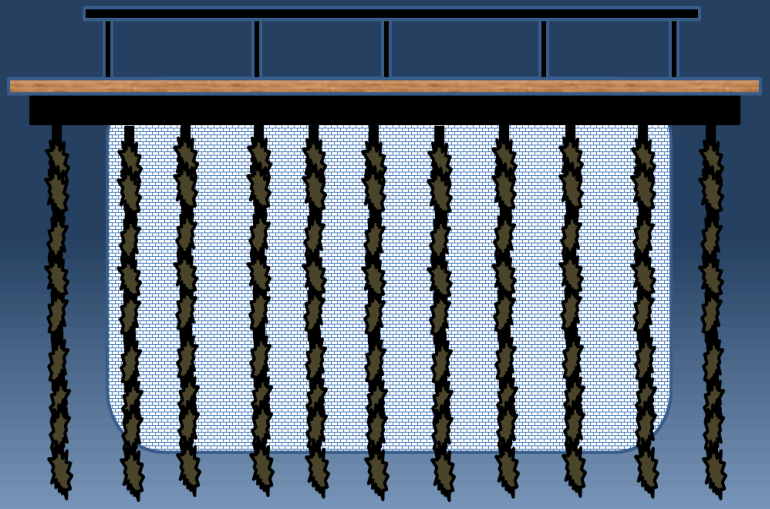
Culture Location

- In between vessel dockage and commercial fishing grounds

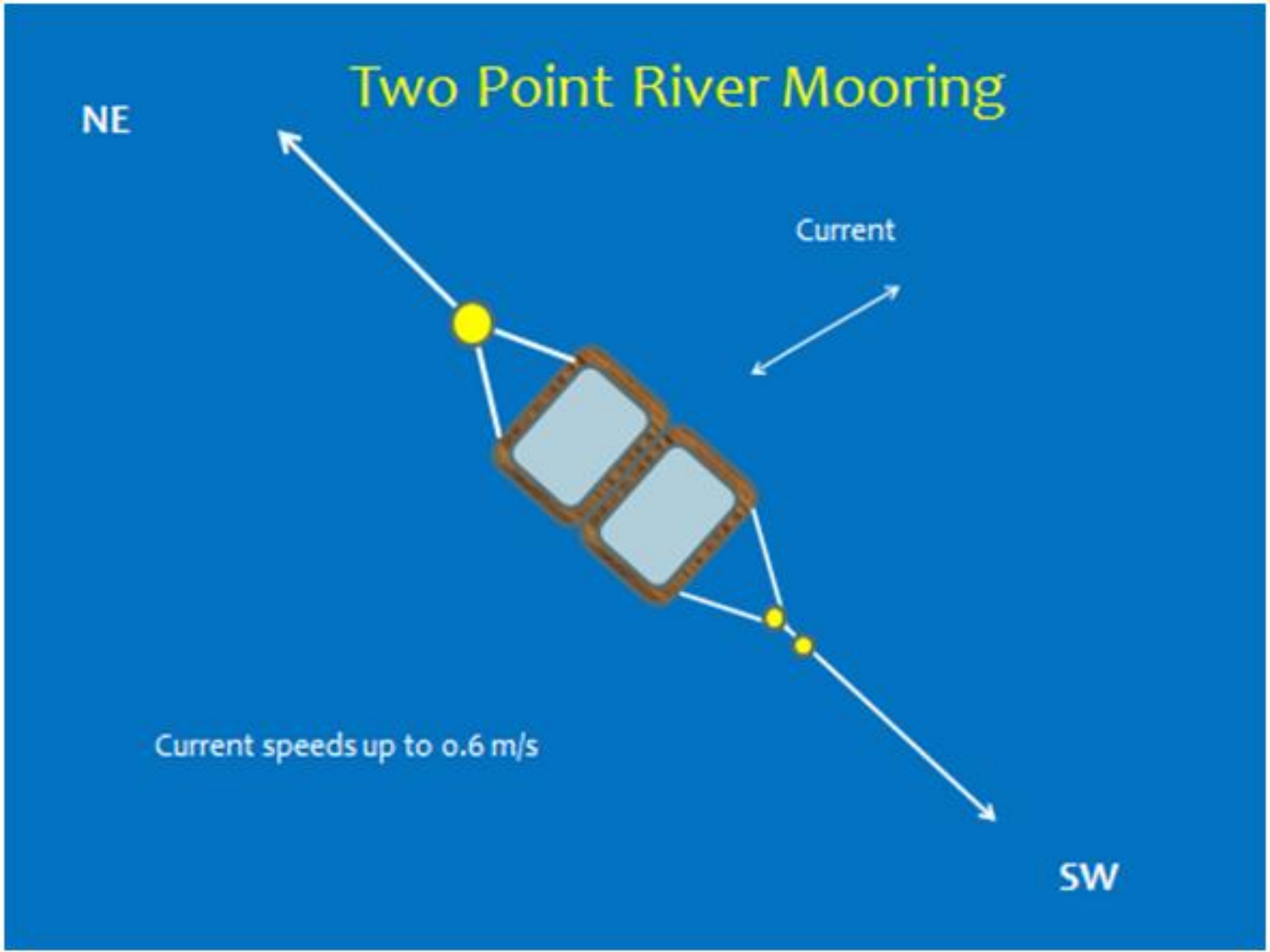


Trout Cages with Mussel Droppers

- Cage frame 20’ x 16’ per cage
- Water depth 30’
- Mussels lines suspended from cage
- 2 spawns per years in GOM



Two Point River Mooring



Initial Training of Fishermen on IMTA

Portsmouth Commercial Fishermen's Association

Second year training

Trout Transfer to Sea Cages

- From Sumner Brook Trout Farms, Ossipee, NH.
- In 0.5 m^3 insulated boxes with aeration.
- Stocked in mid-May
- Direct from FW to SW 28 ppt at 8°C.
- (+/- SD) weight and length were 571.7+/-170.8 g and 35.6+/-2.8 cm, respectfully.
- The initial stocking density was 2.28 kg / m^3.

Fishermen took turns Feeding by Hand

1. Transfer Diet - 2 weeks prior to transfer
2. Bio Oregon 6 mm pellet from Skretting (45% protein, 24% fat)
3. Fed 1-2 times daily
4. A hungry fish is a healthy fish
5. Feed costs represent 50% of farm budget
6. Feed lost to environment:
    1. Throwing $$$ away
    2. Excess nutrients to the environment
7. Best time to feed is slack current
8. With current, feed through PVC pipe

Steelhead Trout Production

1. Trout were made available to the Portsmouth Fishermen's Cooperative after the SK research.
2. Fishermen took turns feeding daily and conducting cage and net maintenance weekly.
3. They produced and sold 415.61 kg of fish (mean wt. of 1127.7 ± 96.4 g) with a SGR 1.24 % and survival of 98 %.

Harvest and Final Fillet on Display

Sanders Fish Market Portsmouth, NH

Blue Mussel Mitigation, Ecosystem Services

- *Mytilus edulis* spawn twice /year
- Seed naturally settles onto substrate - dropper lines suspended around the cage platform.
- Transferred to a growout raft at JGP so the trout farm could lay fallow for the winter.
- Estimated > 12 million 10-15mm seed collected.

Mussel Relay Offshore in Lobster Pots

- ✓ 35 lobster pots were modified and stocked with mussels.
- ✓ Over 2050 kg of mussels taken to open waters.
- ✓ Will be harvested and sold in the spring of 2014
- ✓ A mussel reef was created with 1000 kg and will be inspected by divers for survival and predation.

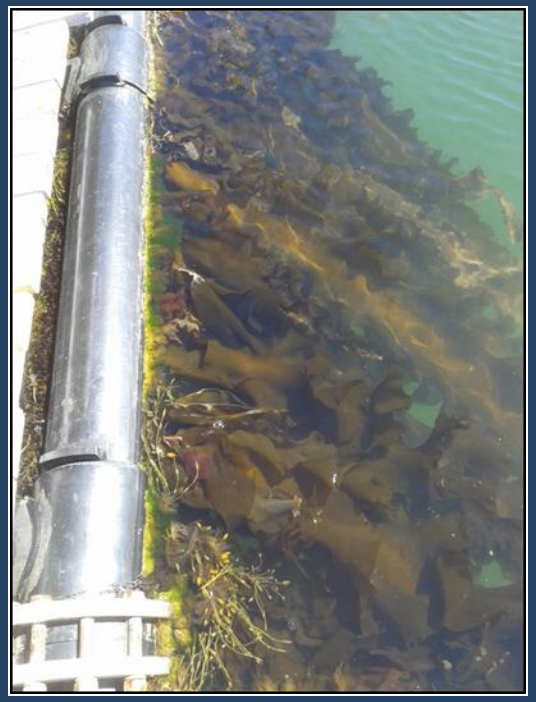
Sugar Kelp Culture during Winter Months

ME Sea Grant

Ocean Approved

Sugar Kelp Production

- ✓ *Saccharina latissima*
- ✓ 55 m of seeded line
- ✓ 6000 spores / m
- ✓ 638 kg of kelp by June
- ✓ @ 2.4% N content, 15.31 kg N extracted
- ✓ Test Marketed at the Black Trumpet in Portsmouth, NH



Mature kelp on cages

Spore line

3 months later

Fate of Nitrogen

Table 1.

Nitrogen inputs and outputs from integrated multi-trophic aquaculture

A. Nitrogen input from feed

Date	Total N input (kg)	Total N retained in trout (kg)	Total N loss to environment
Dec. 2012	37.10	14.0	23.1 kg

B. Nitrogen extraction by mussels (weight/m = 25.6 kg)

Date	Total line (m)	Total weight (kg)	Total N extracted (@ 2.0%)
October 2013	120	3072	61.44 kg

C. Nitrogen extraction by sugar kelp (weigh t /m = 11.6 kg)

Date	Total line (m)	Total weight (kg)	Total N extracted (@ 2.4%)
June 2013	55	638	15.31 kg

Total N input from trout production	23.1 kg
Total N extraction from mussels and kelp	76.75 kg
Net N extracted from the river	53.65 kg

In Summary

- Initial technology transfer of small scale aquaculture was passed onto NH fishermen.
- Nitrogen extraction by the mussels and kelp was demonstrated and exceeded the nitrogen input from trout production and thus had a positive ecosystem effect.
- Trout were sold to local markets at a high price with demand for more.
- Markets are being developed for the mussels and kelp.
- The training program provided the fishermen with a new skill set, that they could adopt either part time or full time, to provide additional income.
- Fishermen are eager to continue with IMTA this spring.
- This training program can serve as a model for other fishing communities in the NE and the US.

Next Steps for NH Fishermen

- Move further offshore into deeper waters to increase production.
- Form a cooperative to share risk and investment.
- Locate funding to support a commercial scale demonstration project.
- Develop an ocean ready, polyculture platform.
- Expand local and domestic markets for trout, mussel and kelp.
- NOAA Aquaculture office conducted a short video on the project at: http://www.nmfs.noaa.gov/aquaculture/

Questions??

NH Steelhead Trout Farmers