

Aquaculture and Its Growing Importance

Ted Maney

Biology Department

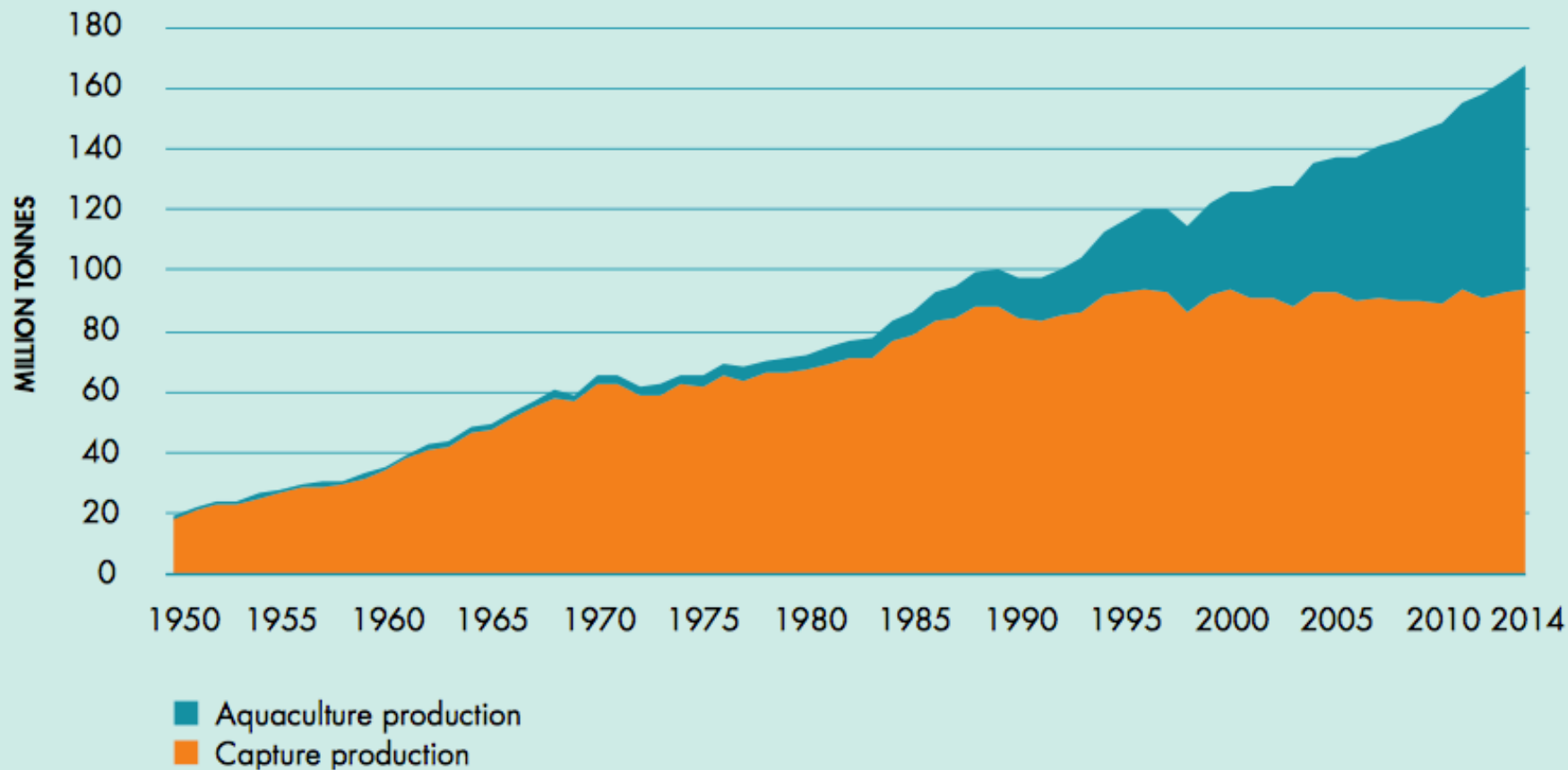
Cat Cove Marine Lab

North Eastern Massachusetts Aquaculture Center
(NEMAC)

Aquaculture Defined

- Aquaculture means the farming of aquatic marine organisms including, but not limited to fish, mollusks, crustaceans, echinoderms and plants.
- Farming implies some sort of intervention in the rearing process to enhance production including, but not limited to controlled propagation, feeding, protection from predators, etc.
- Although the U.S. is not a major aquaculture producer (ranking 17th worldwide), it is estimated that over half of the seafood that the U.S. imports comes from aquaculture.

WORLD CAPTURE FISHERIES AND AQUACULTURE PRODUCTION



Source: FAO The State of World Fisheries and Aquaculture 2016

TOP 25 PRODUCERS AND MAIN GROUPS OF FARMED SPECIES IN 2014

MAJOR PRODUCERS	FINFISH		MOLLUSCS	CRUSTACEANS	OTHER AQUATIC ANIMALS	TOTAL AQUATIC ANIMALS	AQUATIC PLANTS	TOTAL AQUACULTURE PRODUCTION
	INLAND AQUACULTURE	MARINE/ COASTAL AQUACULTURE						
<i>(Thousand tonnes)</i>								
China	26 029.7	1 189.7	13 418.7	3 993.5	839.5	45 469.0	13 326.3	58 795.3
Indonesia	2 857.6	782.3	44.4	613.9	0.1	4 253.9	10 077.0	14 330.9
India	4 391.1	90.0	14.2	385.7	...	4 881.0	3.0	4 884.0
Viet Nam	2 478.5	208.5	198.9	506.2	4.9	3 397.1	14.3	3 411.4
Philippines	299.3	373.0	41.1	74.6	...	788.0	1 549.6	2 337.6
Bangladesh	1 733.1	93.7	...	130.2	...	1 956.9	...	1 956.9
Republic of Korea	17.2	83.4	359.3	4.5	15.9	480.4	1 087.0	1 567.4
Norway	0.1	1 330.4	2.0	...	...	1 332.5	...	1 332.5
Chile	68.7	899.4	246.4	...	...	1 214.5	12.8	1 227.4
Egypt	1 129.9	...	...	7.2	...	1 137.1	...	1 137.1
Japan	33.8	238.7	376.8	1.6	6.1	657.0	363.4	1 020.4
Myanmar	901.9	1.8	...	42.8	15.6	962.2	2.1	964.3
Thailand	401.0	19.6	209.6	300.4	4.1	934.8	...	934.8
Brazil	474.3	...	22.1	65.1	0.3	561.8	0.7	562.5
Malaysia	106.3	64.3	42.6	61.9	0.6	275.7	245.3	521.0
Democratic People's Republic of Korea	3.8	0.1	60.2	...	0.1	64.2	444.3	508.5
United States of America	178.3	21.2	160.5	65.9	...	425.9	...	425.9
Ecuador	28.2	0.0	...	340.0	...	368.2	...	368.2
Taiwan Province of China	117.3	97.8	99.0	21.9	3.6	339.6	1.0	340.6
Iran (Islamic Republic of)	297.5	0.1	...	22.5	...	320.2	...	320.2
Nigeria	313.2	...	...	...	...	313.2	...	313.2
Spain	15.5	44.0	222.5	0.2	0.0	282.2	0.0	282.2
Turkey	108.2	126.1	...	...	0.1	234.3	...	234.3
United Kingdom	13.5	167.3	23.8	...	...	204.6	...	204.6
France	43.5	6.0	154.5	0.0	...	204.0	0.3	204.3
TOP 25 SUBTOTAL	42 041.2	5 837.5	15 696.7	6 638.3	890.9	71 058.2	27 127.2	98 185.4
WORLD	43 559.3	6 302.6	16 113.2	6 915.1	893.6	73 783.7	27 307.0	101 090.7
PERCENTAGE OF TOP 25 IN WORLD TOTAL	96.5	92.6	97.4	96.0	99.7	96.3	99.3	97.1

Note: ... = production data not available or production negligible.

ESTIMATED U.S. AQUACULTURE PRODUCTION, 2013 - 2014

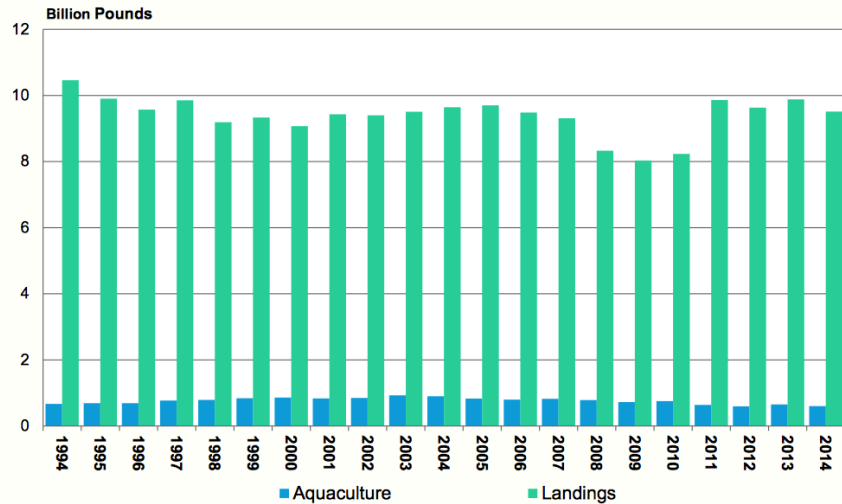
Species	2013			2014		
	Thousand pounds	Metric tons	Thousand dollars	Thousand pounds	Metric tons	Thousand dollars
Freshwater:						
Catfish	358,380	162,560	354,337	307,498	139,480	331,963
Striped bass	7,444	3,377	34,987	8,110	3,679	31,142
Tilapia	18,428	8,359	40,049	18,999	8,618	42,745
Trout	44,496	20,183	71,869	48,456	21,979	76,206
Crawfish	106,924	48,500	144,347	134,168	60,858	172,071
Total Freshwater	535,672	242,979	645,588	517,231	234,615	654,128
Marine:						
Salmon	41,593	18,866	104,709	41,268	18,719	76,186
Clams	9,533	4,324	122,150	10,405	4,720	120,727
Mussels	699	317	9,804	699	317	9,861
Oysters	35,243	15,986	157,272	33,323	15,115	168,991
Shrimp	3,355	1,522	7,108	4,870	2,209	10,316
Total Marine	90,422	41,015	401,043	90,565	41,080	386,081
Miscellaneous	-	-	289,181	-	-	291,717
Totals	626,094	283,994	1,335,812	607,796	275,695	1,331,926

Note: Table may not add due to rounding. Clams, oysters, and mussels are reported as meat weights (excludes shell), while all other species such as shrimp and finfishes are reported as whole (live) weights. Some clam and oyster production is reported with U.S. commercial landings. Weights and values represent the final sales of products to processors and dealers. The "Miscellaneous" category includes baitfish, ornamental/tropical fish, alligators, algae, aquatic plants, eels, scallops, crabs, and others. The production volume of "Miscellaneous" is not reported because production value, but not weight is reported for many species such as ornamental fishes.

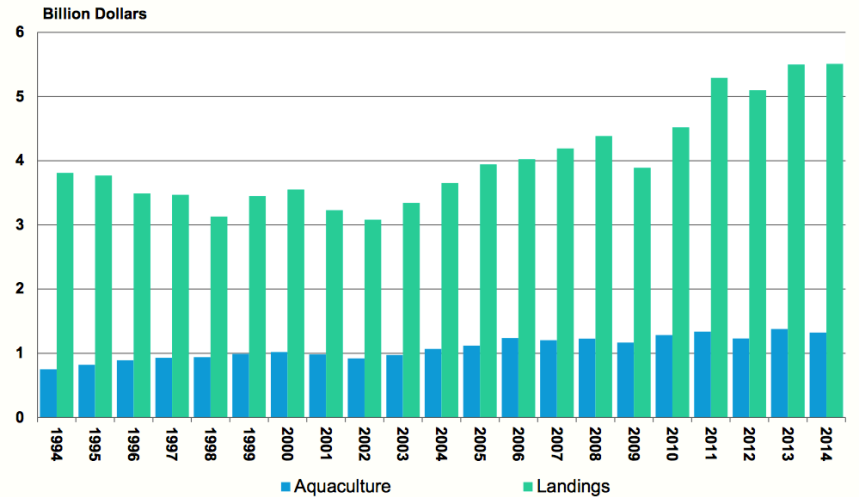
Source: Fisheries Statistics Division, F/ST1, State Data, NMFS and Census of Aquaculture, USDA

US Commercial Fishery Landings and Aquaculture Production

Volume of Domestic Commercial Landings and Aquaculture Production



Value of Domestic Commercial Landings and Aquaculture Production



Sustainable Shellfish Aquaculture



Soft Shell Clam *Mya arenaria*



American Oyster, *Crassostrea virginica*

Photos from East Dennis Oyster Farm (www.dennisoysters.com)

Quahogs, *Mercinaria mercinaria*

Bay Scallops, *Argopecten irradians*

Razor Clams, *Ensis directus*

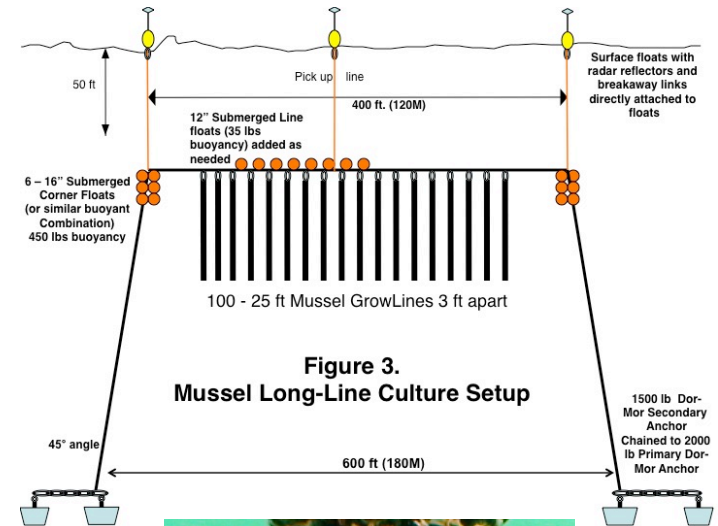


Figure 3.
Mussel Long-Line Culture Setup



Blue Mussel, *Mytilus edulis*

2014 Massachusetts Bivalve Landings

Species	Landings (whole pounds)	Value
Sea Scallop (offshore)	178,104,884	\$271,382,646
Surf Clam (offshore)	101,744,471	\$16,764,967
Eastern Oyster *	6,102,181	\$15,680,692
Ocean Quahog (offshore)	110,728,839	\$9,813,936
Softshell Clam *	1,924,619	\$3,686,808
Northern Quahog *	5,354,370	\$3,660,388
Bay Scallop	888,066	\$2,370,848
Razor Clam	277,460	\$2,347,954
Blue Mussel*	1,145,623	\$1,511,646

Source: Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse, as of April 22, 2015.

MA Shellfish Aquaculture

- The output of the shellfish aquaculture industry in Massachusetts was valued at approximately **\$25.4m** in 2013, which in turn generated approximately **\$45.5m** in the Massachusetts economy, or **1.79** times the activity.
- Shellfish farmers were responsible for approximately **909 jobs**.
- Shellfish farmers paid approximately **\$11.9m** in wages in 2013. Their economic activity generated additional labor income of **\$8.2m**, for a total of approximately **\$20.1m** in labor income in MA.
- Represents 5% of total agricultural production in MA

Bivalve Aquaculture

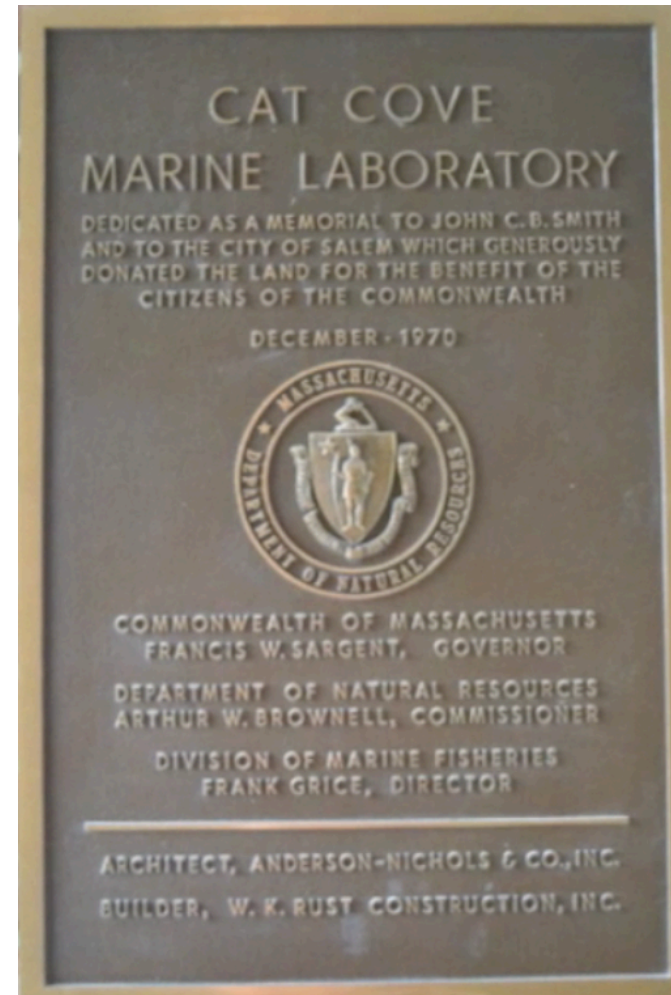
- Hatchery spawned
- Seed stock planted
 - Enhances natural sets
 - Enhanced survival
 - Restore traditional beds
- Wild Grow Out
- Harvest

Cat Cove Marine Laboratory

Northeastern Massachusetts Aquaculture Center (NEMAC)

The Cat Cove Marine Laboratory supports the aquaculture and marine biology programs at Salem State University and is also the home of the Northeastern Massachusetts Aquaculture Center (NEMAC).

The mission of the Cat Cove Marine Laboratory is to develop research and technologies in aquaculture as well as increasing the understanding of marine organisms and ecosystems, through research, education, and outreach.





Cat Cove Marine Lab and Smith Pool

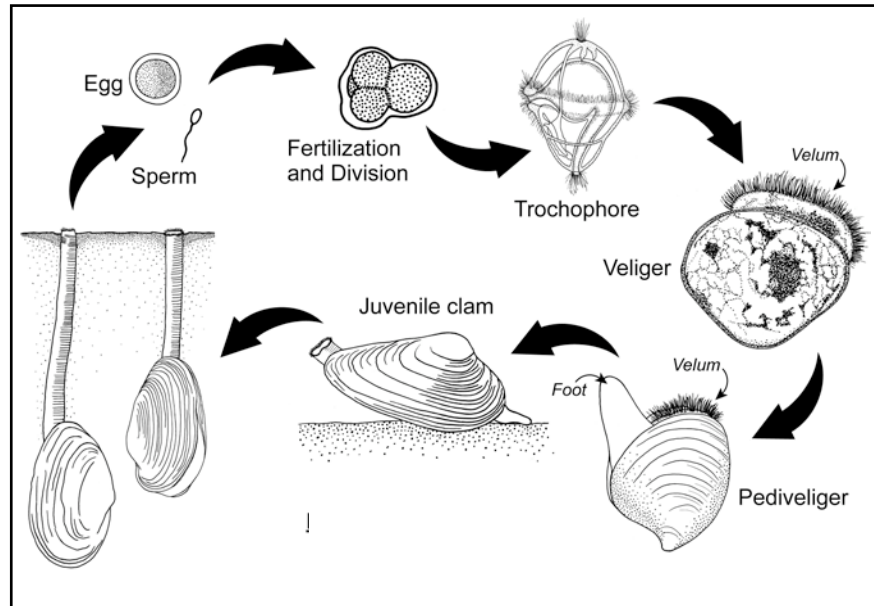




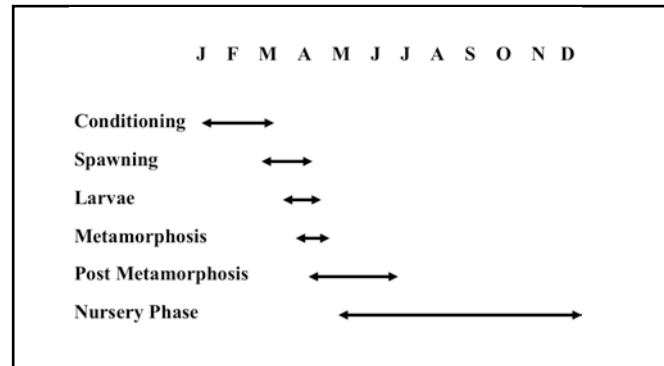
Cat Cove Marine Lab and Smith Pool – 8 Acre Tidal Pond



Soft Shelled Clam Culture



Connecticut Sea Grant/UCConn



Clam Hatchery Timeline

Soft Shelled Clam Culture







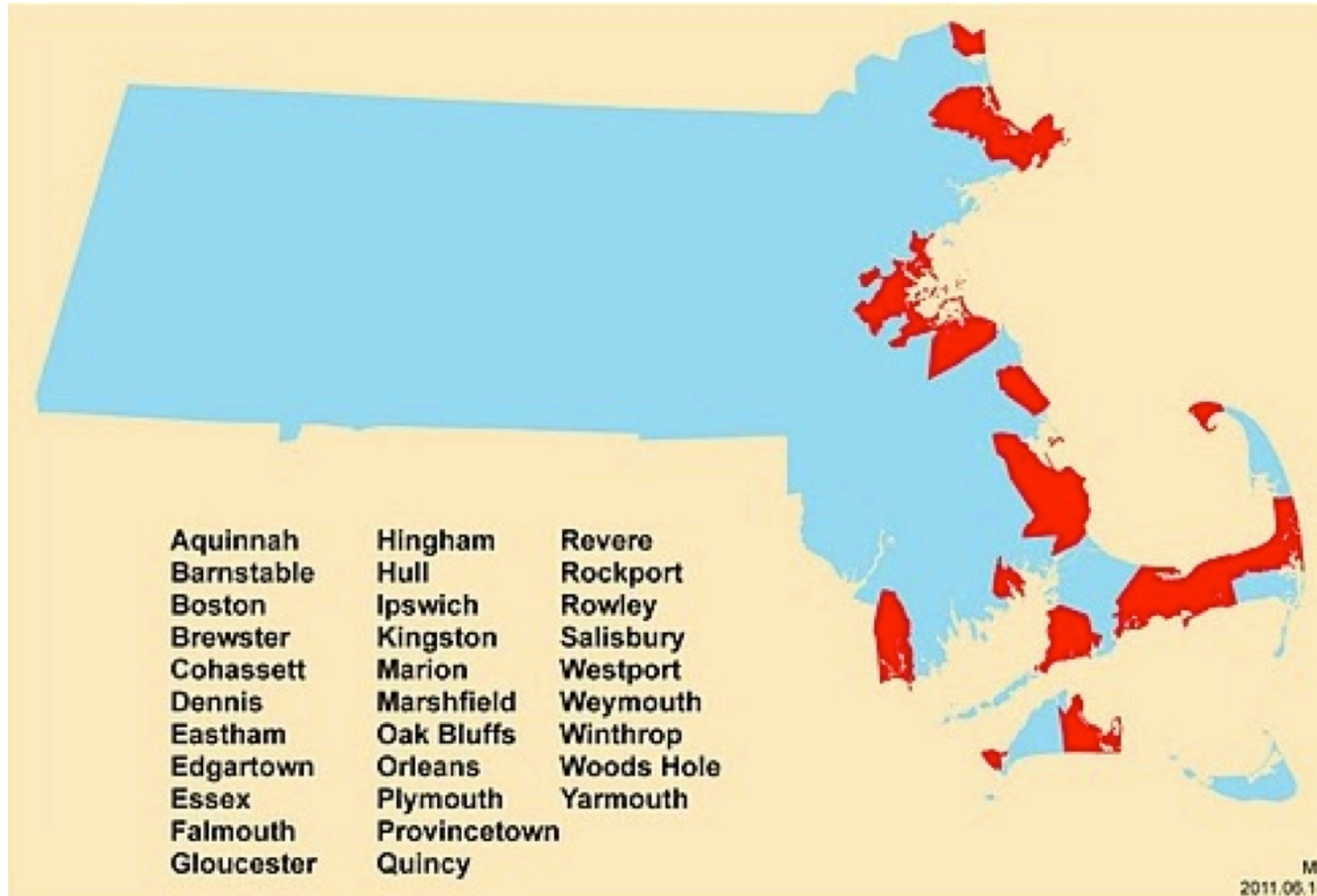








Communities Receiving Clam Seed Stock from NEMAC



Oyster Farming



Near Shore – tidal range



Offshore Longlines - Salt Water Farms, Kingston RI

Longline Mussel Farming

Experimental mussel lines at Sandy Bay, Rockport and Hodgkins Cove, Gloucester





OFFSHORE SHELLFISH AQUACULTURE IN FEDERAL WATERS

Ted Maney, Mark Fregeau

Northeastern Massachusetts Aquaculture Center
(NEMAC)

Cat Cove Marine Laboratory, Department of Biology
Salem State University

Captain Bill Lee, FV Ocean Reporter, Rockport, MA



Background

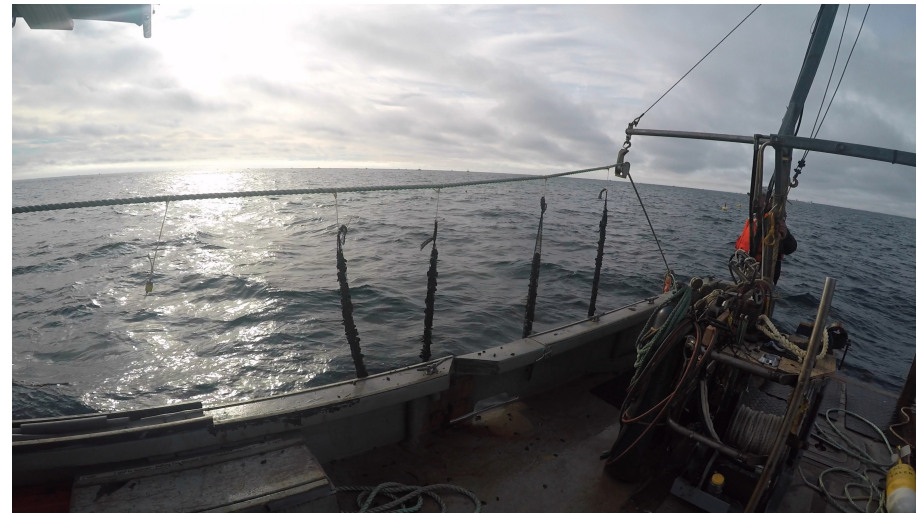
- **2015:** obtained an Army Corps of Engineers (ACOE) permit pursuant to Section 10 of the Rivers and Harbors Act of 1899 to establish a commercial scale (33 acre) offshore mussel farm 7 nautical miles off the coast of Cape Ann Massachusetts (NAE-2012-1598 NEMAC Aquaculture).
- **Conditions** of permit allow the establishment of up to 3-longlines as a pilot study to determine feasibility and any possible habitat or protected species interactions.

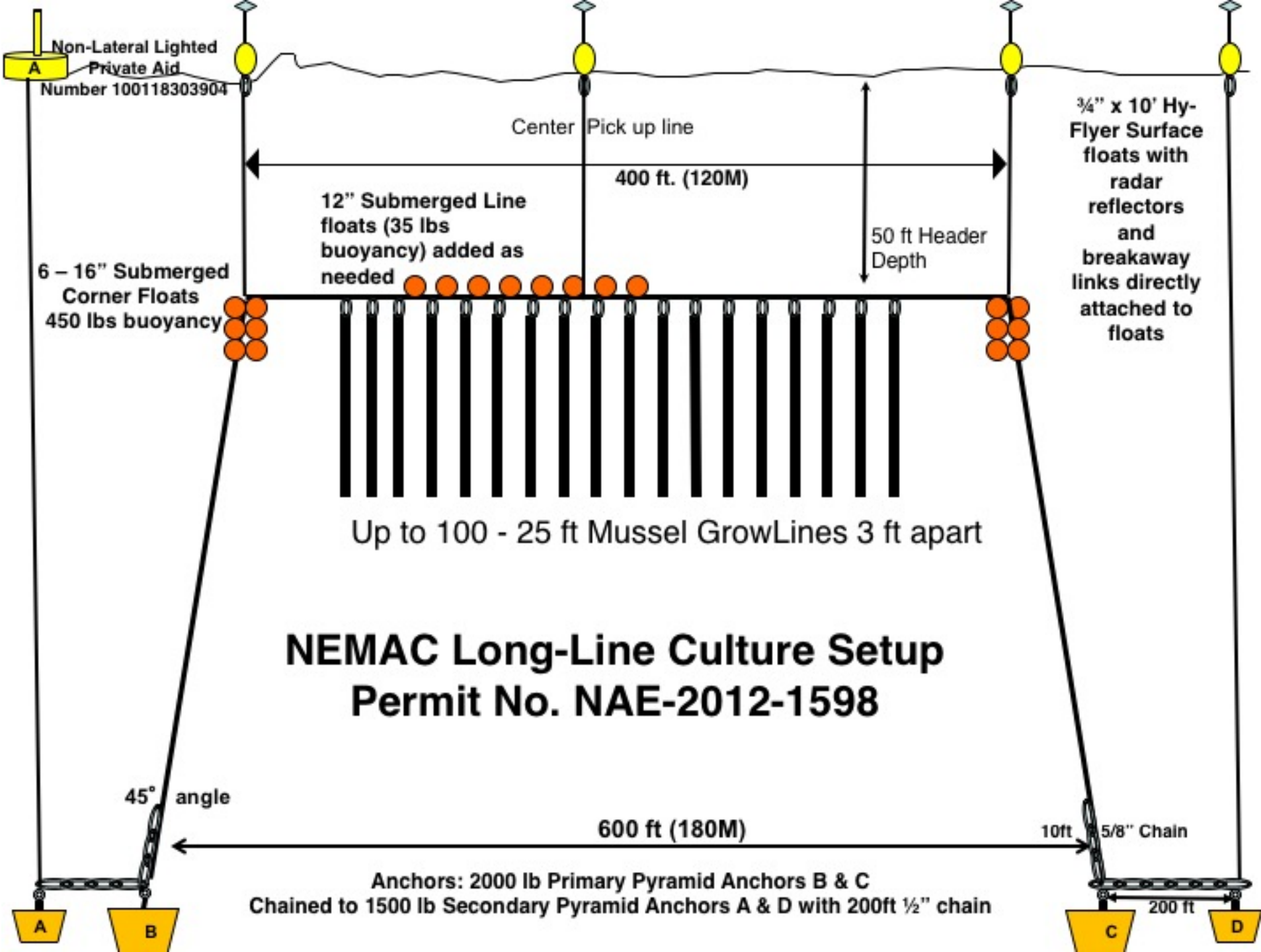
Project Goals

- Secure Funding and Establish pilot study of 3-longlines.
 - Demonstrate feasibility
 - Confirm “Not Likely to Adversely Affect any Endangered or Protected Species”
- Submit for Permit Modification for site commercial buildout of 32 longlines.
- Expand to develop “incubator farm” to encourage and train potential farmers in offshore shellfish aquaculture.
- Rationale: NOAA Marine Aquaculture Strategic Plan 2016 - 2020

Establishing the First Shellfish Aquaculture Farm in Federal Waters on the Atlantic Coast

- **27 July 2016** (Week 30/16)
Posted Coast Guard Local Notice to Mariners with PATON Listing NEMAC/Salem State University Aquaculture Lighted Buoy A (Aid Number **100118303904**)
Required 30 days prior to the installation of gear.
- **September 2016** Began setting up longline
- **8 October 2016** Set out 3 – 15 ft. growlines with 1 – 3ft measured sock







NEMAC Mussel Farm Set Up





5 December 2016
Mussels are
growing fine!

Growth Measurements



28 Sept 2016

Mean Shell Height
34.6mm

2 January 2017

Mean Shell Height
43.1mm

Industry Partner



If it isn't fresh, it isn't Legal! ®

Acknowledgements

- Captain Bill Lee, FV Ocean Reporter, Rockport MA
- Alli Matzelle, PhD. Student in Helmuth Lab at Northeastern University Marine Science Center
 - Measure physical parameters of food availability: Chlorophyll a (fluorometry), Temperature, Salinity, pH, dissolved oxygen, and dissolved organic matter
 - Monitor mussel growth parameters; growth rates, meat:shell ratio, byssal thread strength, seed socking densities, grow line spacing.
- Curtis Fahey and Conor Donovan
 - SSU Students



If it isn't fresh, it isn't Legal!®

Seaweed Aquaculture



A few types of edible seaweed

Larry Crowe / AP

Kelp Is the New Kale

The global seaweed harvest is worth more than all the world's lemons and limes.

NICOLA TWILLEY AND CYNTHIA GRABER | SEP 13, 2016



Finfish Aquaculture

The Commonwealth's finfish growers produce a variety of species of finfish including:

- barramundi
- tilapia
- largemouth bass
- black sea bass
- brown bullhead
- several species of trout
- several species of baitfish
- ornamentals

Zebra Fish Aquaculture For Medical Research

- BCH (Boston Children's Hospital)
- DFCI (Dana Farber Cancer Institute)
- BIDC (Beth Israel Deaconess Medical Center)
- Harvard Medical School
- Harvard Main Campus
- Brigham and Women's Hospital
- MIT
- Boston Medical School
- UMass Boston
- Northeastern University
- Others



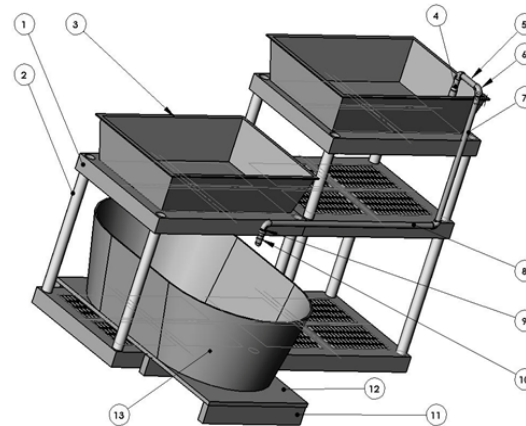
Aquaponics: Small Scale for Classroom and Personal Use



Floating raft



Total system



System
diagrammatic

Demonstration in Beverly, MA



Solar Powered



System Works



Largemouth Bass



Luscious growth in December 2015



Peppers and basil in summer

Water Gardens

Ornamental Fish Ponds



Country Gardens of Rowley

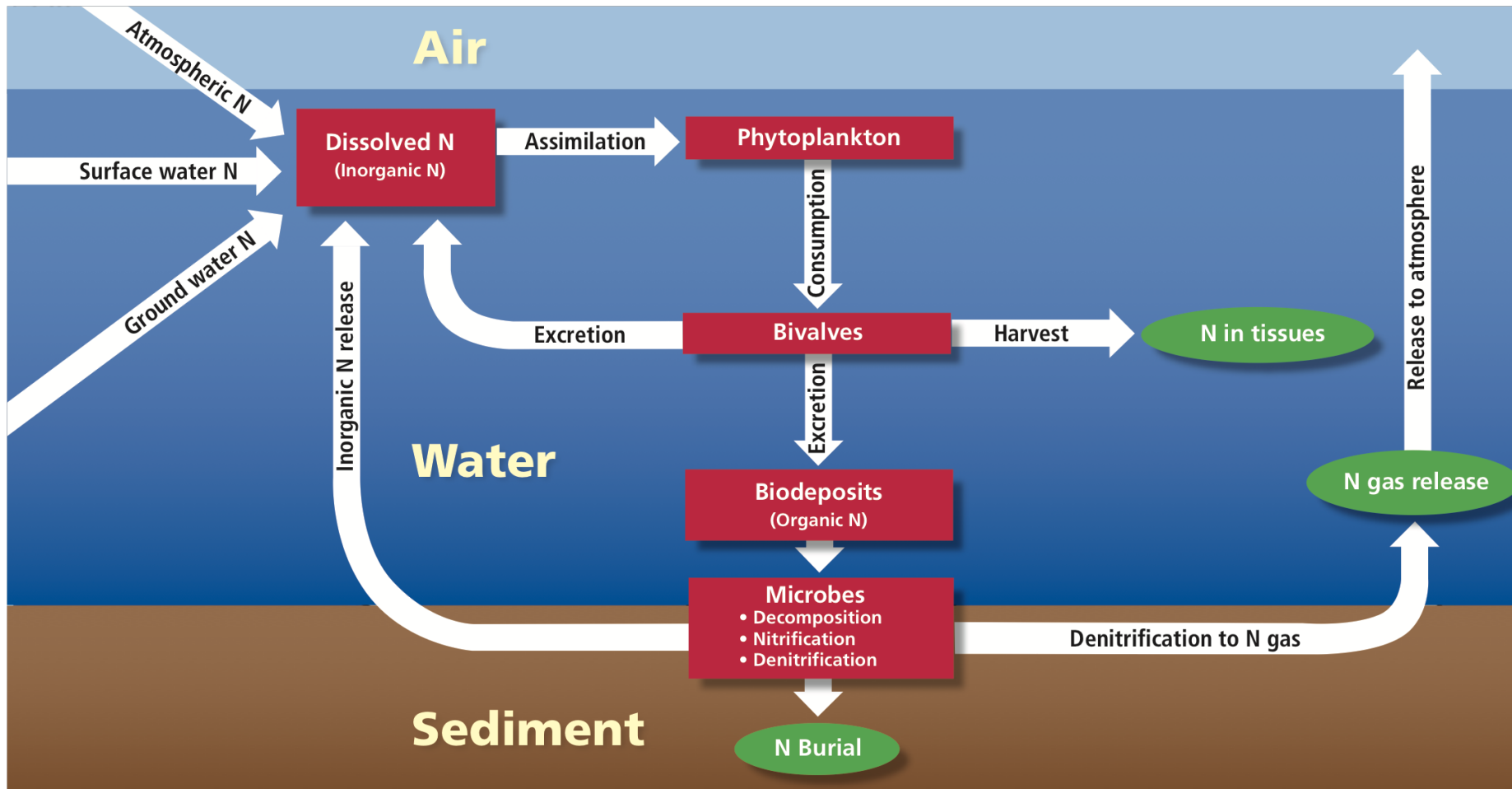
Ecological Services of Shellfish Farming

- Shellfish clean the water by filter feeding.
 - Improves water quality by reducing turbidity, improving light penetration and reducing anoxia (low oxygen). Estimated that the oysters and mussels growing at Salt Water Farms, RI clear 25 million gallons of bay water each day.
- Shellfish convert nitrogen into edible animal protein. When harvested the nitrogen is permanently removed from the ecosystem. Excess nitrogen in coastal waters contributes to anoxia and kills fish.
- Shellfish farms provide essential habitat for a wide variety of marine plants and animals.
- Shellfish farms provide traditional marine related jobs in the local community.
- Shellfish farms provide wholesome and tasty farmed goods to the restaurants that feature local foods.

Because of the environmental benefits of shellfish farming, shellfish are listed as "green" on the seafood consumer's guide of many environmental organizations.

Eutrophication

Excess Nitrogen and Phosphorous – Algal Blooms

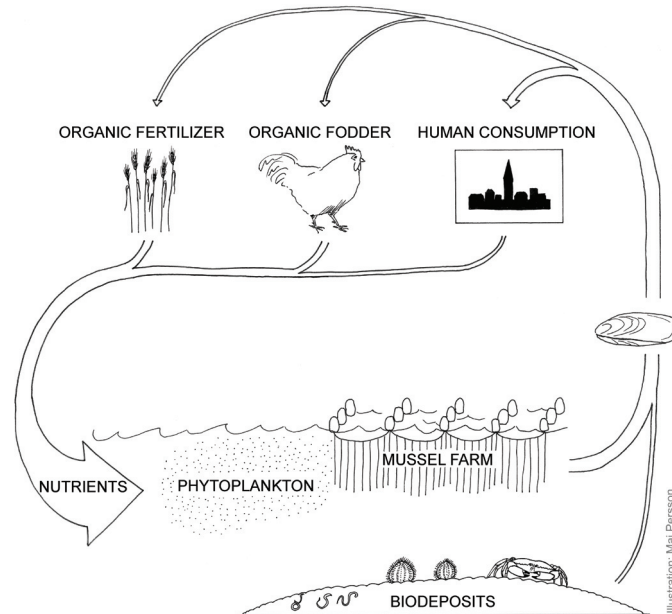


Overview of how bivalves interact with the marine nitrogen cycle, and potential ways in which nitrogen may be removed in green.

Adapted from Newell et al. 2002 and <http://oyster.agecon.vt.edu>

Reducing Eutrophication

- Restoring Oyster Reefs
- Longline mussel farms/Oyster farms



The Agro-Aqua recycling system of nutrients from sea to land.

From: Lindahl, O. et al 2005. Improving Marine Water Quality by Mussel Farming: A Profitable Solution for Swedish Society. *Ambio* Vol. 34, No. 2.

Oyster Reef Restoration in Great Bay NH



Carbon Sequestration

- Shellfish production sequesters carbon in 3 ways:
 - In the shells harvested and distributed for sale;
 - In the shells that are dead on thinning/grading or harvesting;
 - In the shells that die at sea, detach and sink to the bottom.
- The carbon sequestered in the shells harvested
 - 218 kg CO²-eq per tonne of mussels harvested
 - 441 kg CO²-eq per tonne of oysters harvested.
- The carbon sequestered in mussels that die at sea
 - 12 kg CO²- eq per tonne of mussels harvested.
 - Assuming of a drop off rate of 1% per month and a linear growth rate

Source: Carbon Footprint of Scottish Suspended Mussels and Intertidal Oysters

ISBN: 978-1-907266-44-7

First published: January 2012

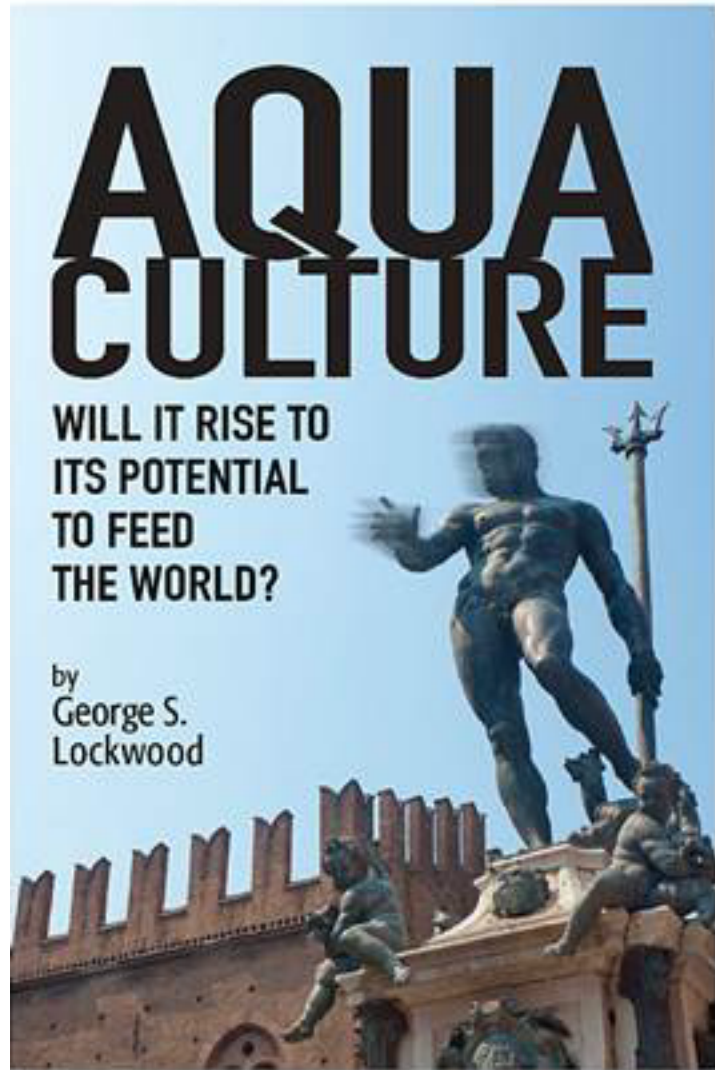
Published by the: Scottish Aquaculture Research Forum (SARF)

This report is available at: <http://www.sarf.org.uk>

Aquaculture Pros and Cons

- Sustainability
- Locally produced
- Revitalizing working waterfronts
- Lowest feed/meat conversion efficiency
 - Finfish < 2:1
 - Shellfish near 1:1
- Bioremediation
- Culturing Non-natives
- Culturing hybrids/GMOs
- Habitat modification
- Protected species interactions
- Potential conflicts with other uses

More Information



World Premiere

Free Event

OCEAN FRONTIERS III

Leaders in Ocean Stewardship & the New Blue Economy

Wed. February 8 • Virginia Aquarium

Reception 6:30pm • Film 7pm • Panel/Q&A 8pm

Shaping the future of our ocean amidst a modern wave of big ships, energy industries and a changing climate.



Viewing at SSU on April 11th

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- MARINE SCIENCE & CONSERVATION
PUBLIC FORUM

For more information on Tickets, Speakers,
Workshops, Exhibitors, Location and more:

BostonSeaRovers.com

2-DAY EVENT

MARCH
11 & 12, 2017

DoubleTree by Hilton Hotel
Boston North Shore
50 Ferncroft Road
Danvers, Massachusetts



photo: © Becky Kagan Schott

Questions?

