ENAO-Modeling to inform seaweed farm design for optimizing growth, production, and advancement of the U.S. marine aquaculture industry-MITSG

T. Angera, S. Redmond, J. Simpson,
M. Triantafyllao

Modeling to inform seaweed farm design for optimizing growth, production, and advancement of the U.S. marine aquaculture industry.

National Sea Grant Program funding opportunity, Exploring New Aquaculture Opportunities – 2019 (NOAA-OAR- SG-2019-2005960)

MIT Sea Grant and Springtide Seaweed, LLC

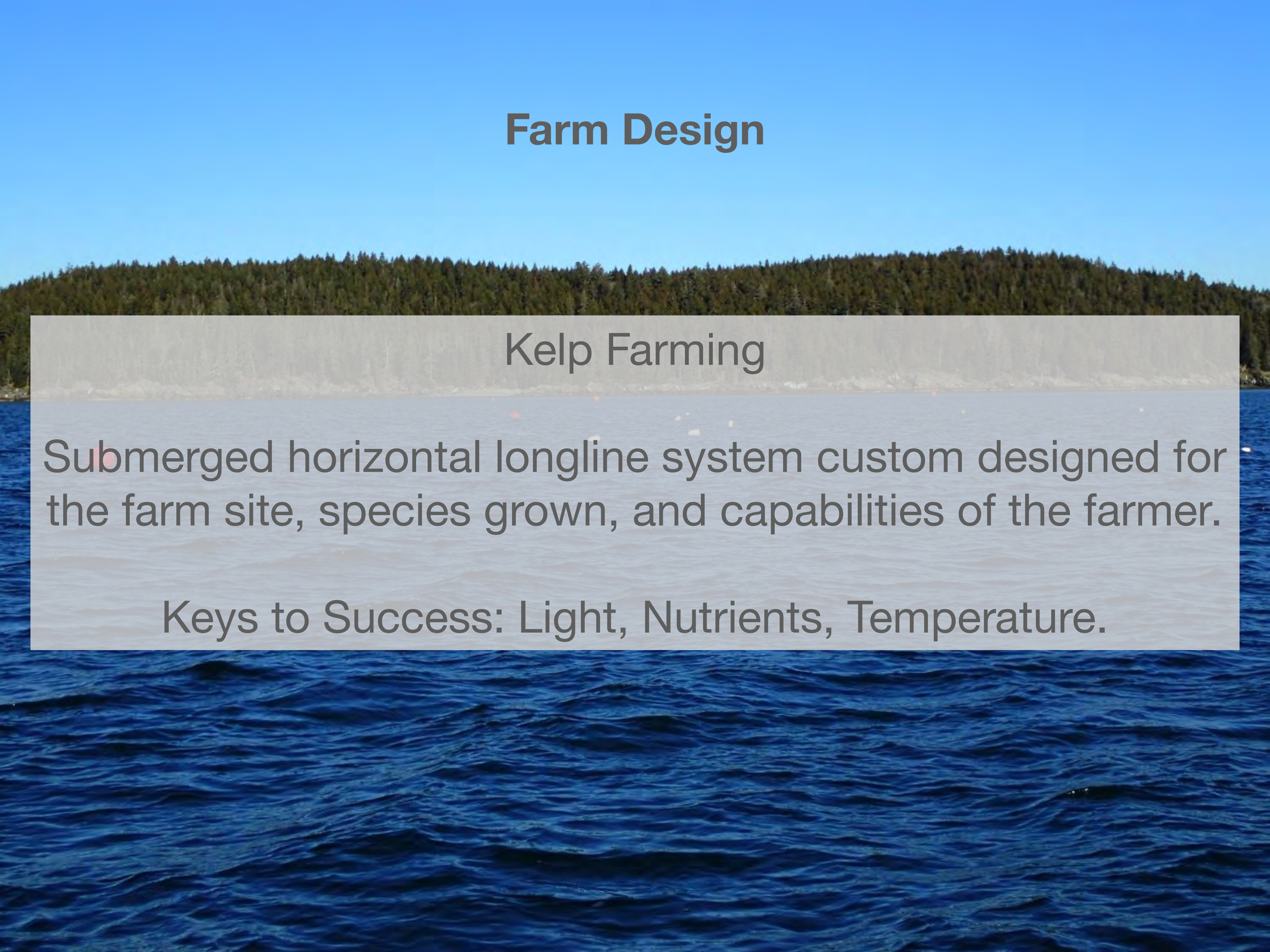
PIs: Andrea (Trey) Angera; Sarah Redmond; Prof. Michael Triantafyllau

MIT Faculty & Researchers:
Dr. Jiarui Lei, Dr. Dixia Fan, Dr. Yuming Liu, Prof. Heidi Nepf, Dr. Juliet Simpson

Drag force and reconfiguration of cultivated Saccharina latissima in current, Aquacultural Engineering 94 (2021) 102169

Jiarui Lei, Dixia Fan, Andrea Angera, Yuming Liu, Heidi Nepf; a Department of Civil and Environmental Engineering, MIT, Cambridge, MA 02138, United States b Department of Mechanical Engineering, MIT, Cambridge, MA, Springtide Seaweed, LLC, Gouldsboro, ME

Farm Design



Farm Design

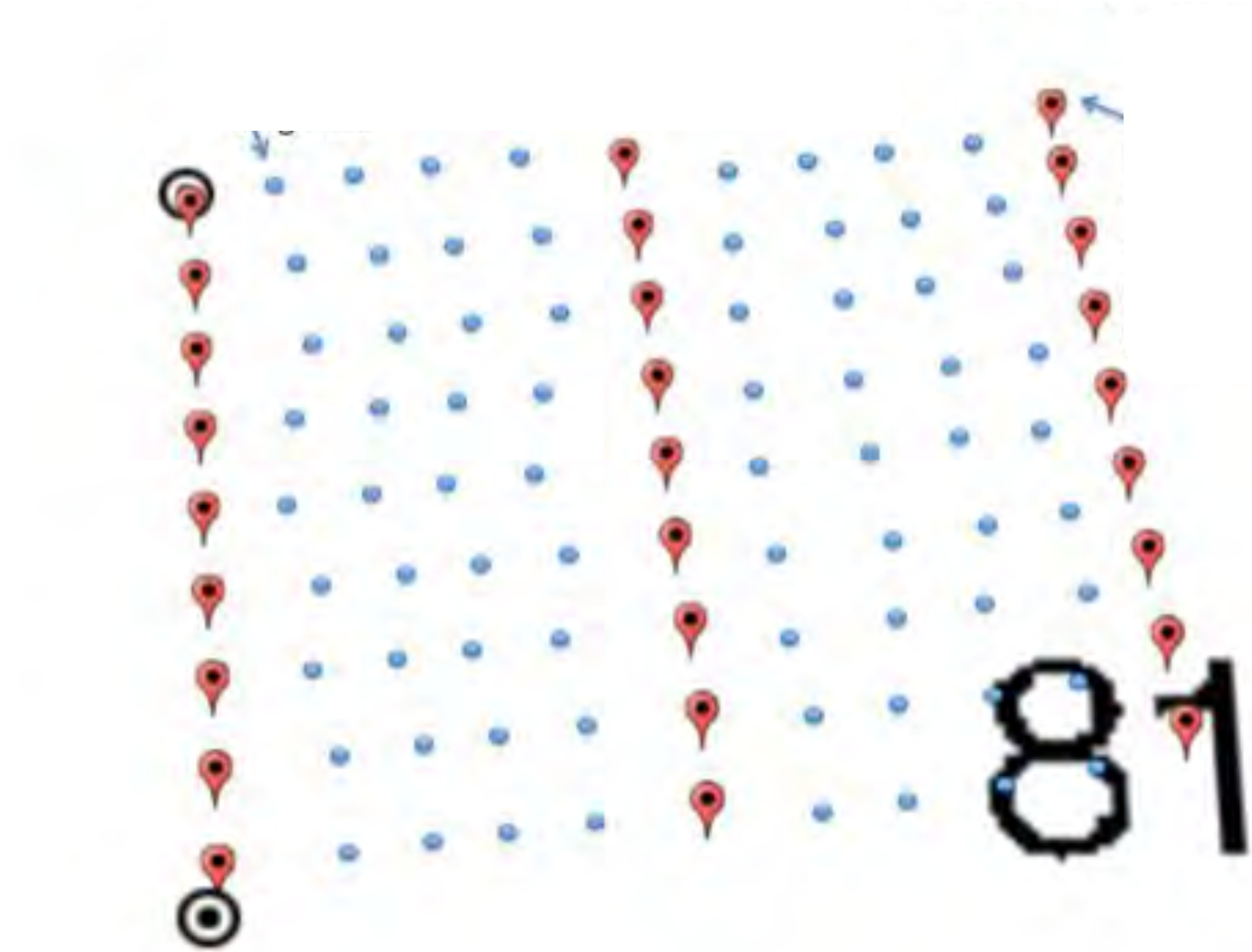
Kelp Farming

Submerged horizontal longline system custom designed for the farm site, species grown, and capabilities of the farmer.

Keys to Success: Light, Nutrients, Temperature.

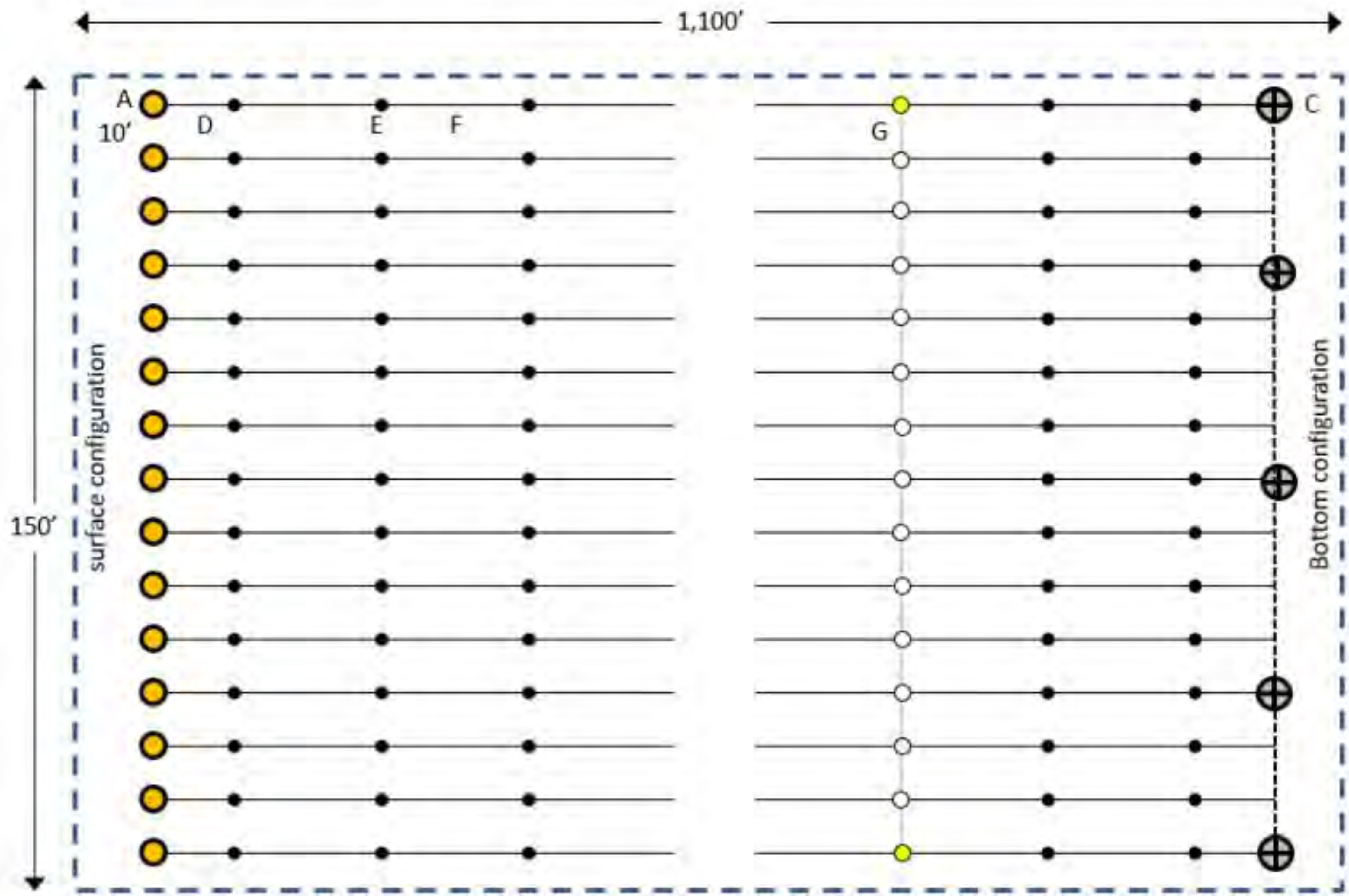
Typical Farm Layout

Mooring Grid Supporting Parallel Horizontal Submerged Long Lines



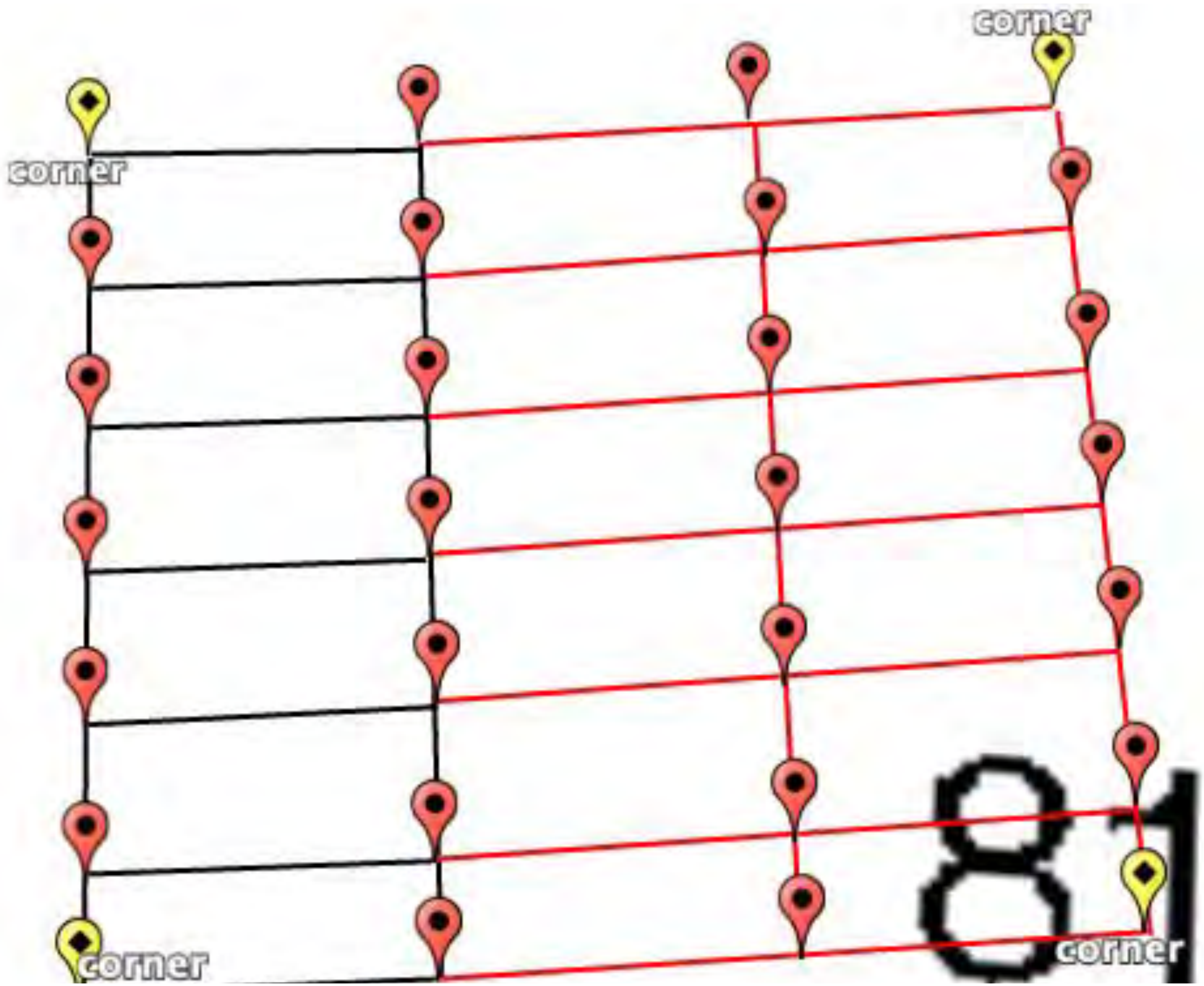
Intensive Designs
Lines Spaced 10-20' Apart

Crowding of lines can increase risk of tangling, and may have growth and yield impacts



Grid Format Design

Lower risk of loss from tangling, more opportunities for diversification in design
Potential improved growth and yields



Grid Format Design

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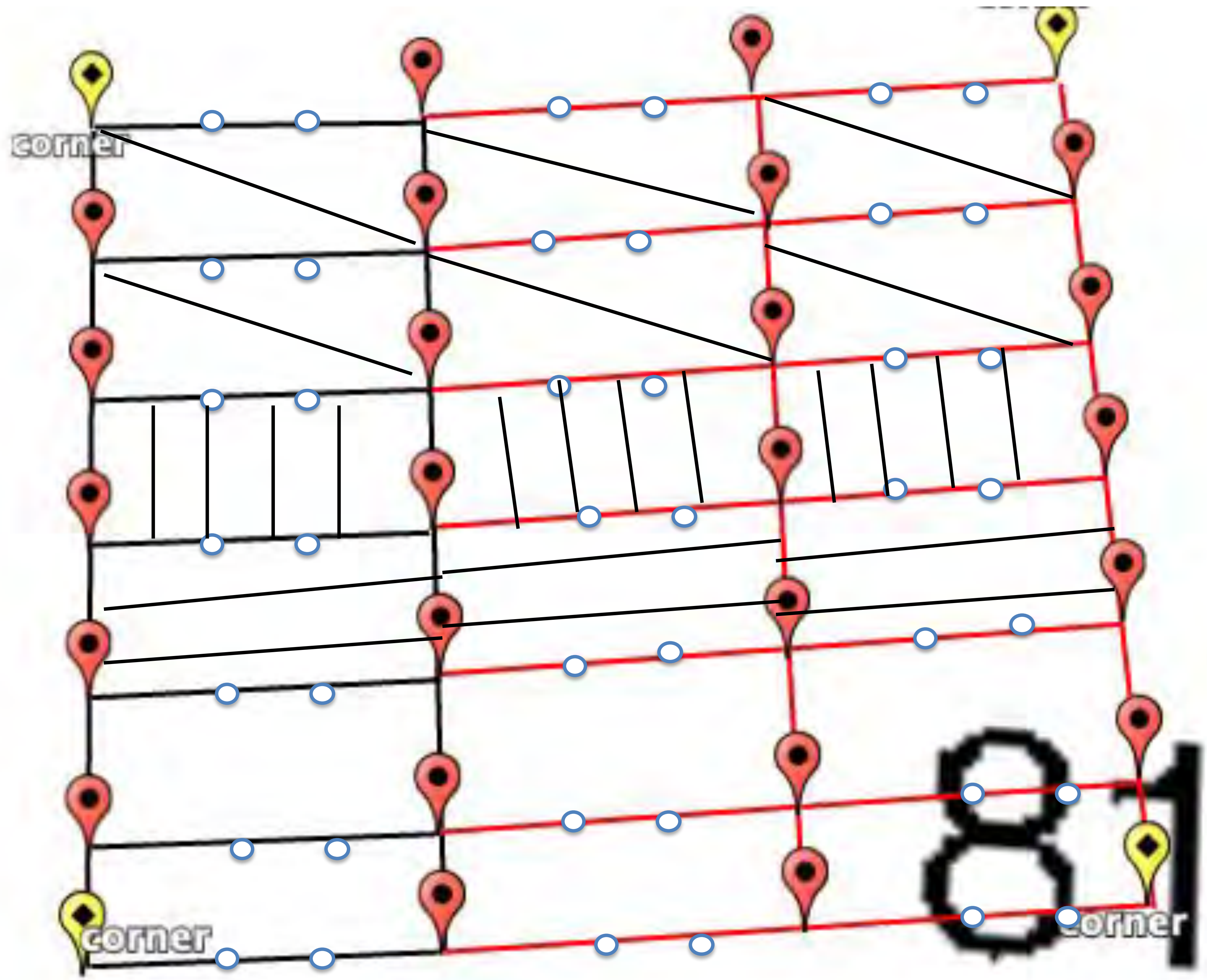


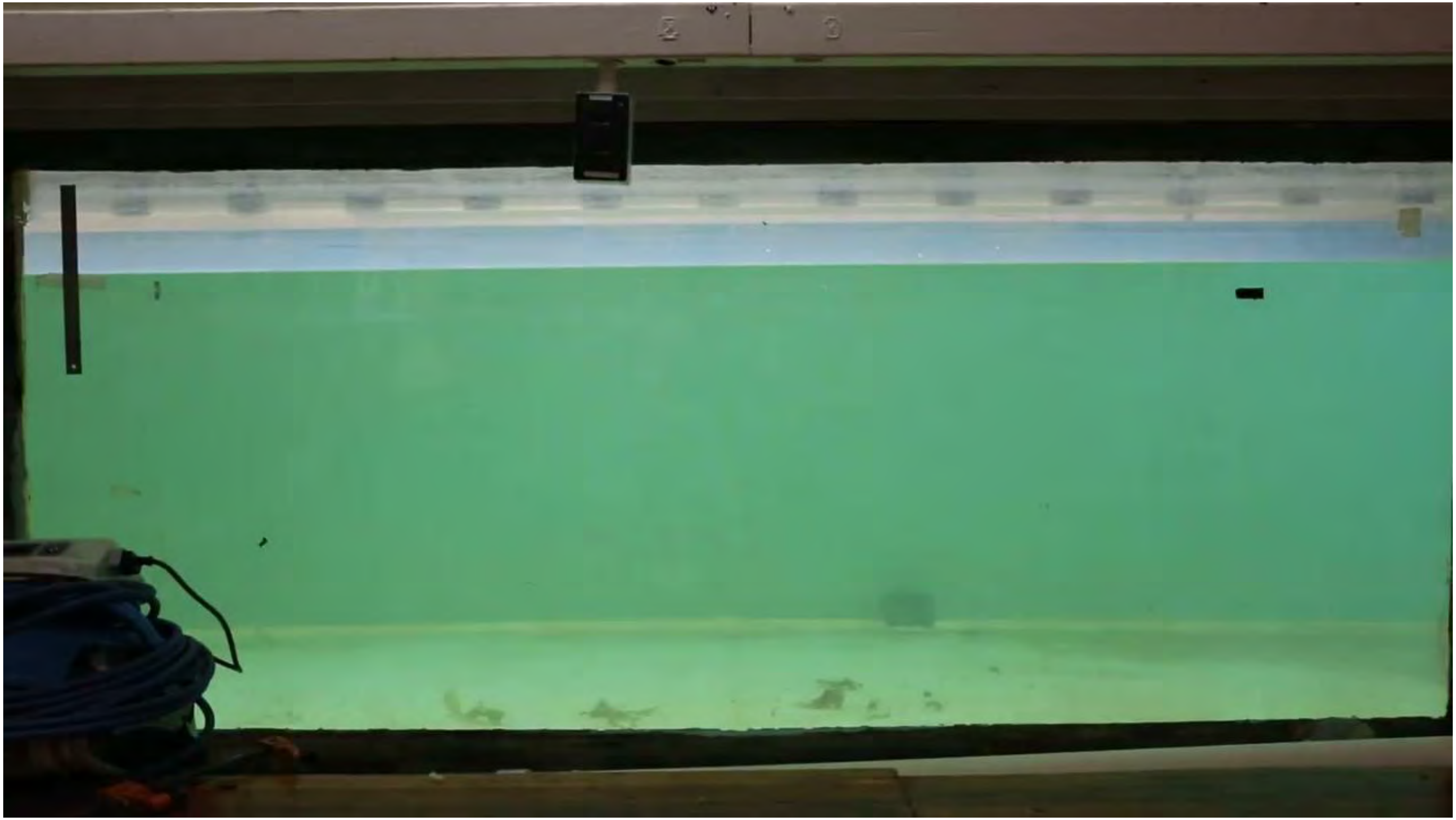
Modeling

The design of aquaculture systems requires an understanding of the drag forces on cultivated kelp. This study measured the drag on line segments of cultivated Saccharina latissima in a towing tank. The drag on segments of farm line with full kelp bundles and with stipes alone (fronds removed) was measured at tow speeds of 0.10 to 0.50 m/s. The drag on individual fronds cut from the line was also measured. Video images were collected to evaluate the plant reconfiguration.

Both kelp blades and stipes contributed to the total drag force on the line bundle. Within the velocity range of our experiments, the kelp blades were essentially horizontal. However, the pronation of kelp stipes increased as flow velocity increased. The reconfiguration of kelp stipes was observed to decrease the vertical extent of the kelp bundle. Due to this reconfiguration, the measured force, F, increased with velocity, U, at a rate slower than quadratic, and was consistent with scaling laws derived for reconfiguration. Specifically, $F \sim U\alpha$ with $\alpha = 1.35 \pm 0.17$.

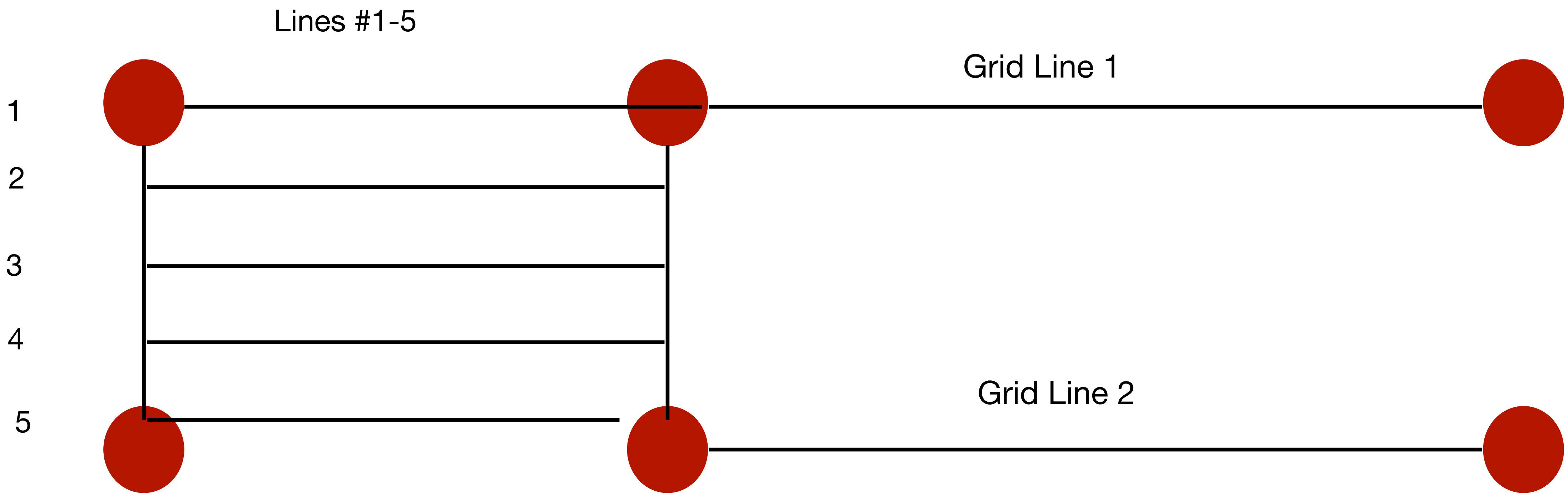
Modeling

Scaled physical model tests in the MIT towing tank at the Department of Mechanical Engineering, using a real seaweed line from the Springtide Seaweed farm to better understand hydrodynamic drag of seaweed



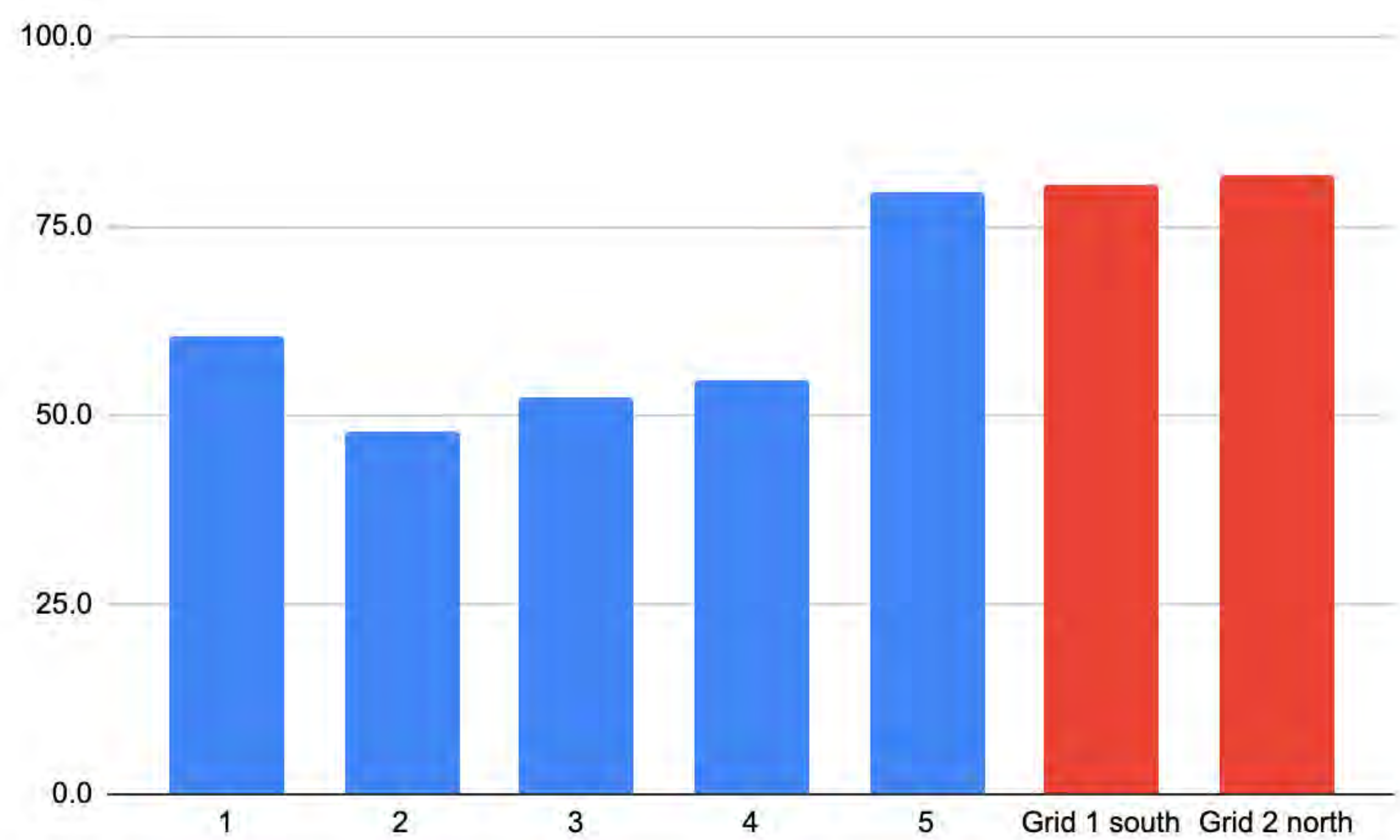
Farm Trial

Cultivate Sugar Kelp (*Saccharina latissima*) on the Springtide Seaweed farm in Maine within an intensive system, with parallel long lines approximately 20’ apart, and within the grid system, with lines approximately 80’ apart.



Farm Trial

Average Total Plant Length (cm) (n=3)



Line	Centimeters
1	60.5
2	47.9
3	52.6
4	54.7
5	79.5
Grid 1 south	80.5
Grid 2 north	81.7

South <<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>> North

Average Yield of 14.6 Pounds per linear foot.

Conclusions

Modeling: Moderate current drag forces around kelp lines with significant reconfiguration

Farm Trials: Depression of growth observed inside of farms with closely spaced long lines

Farm systems can be optimized for growth and yield by taking into account drag induced reconfiguration produced by kelp lines and designing for optimal growth and yields

www.SpringtideInnovations.com

SPRINGTIDE
SEAWEED

ENAO-Novel Mariculture of the Caribbean King Crab for Market and Coral Reef Restoration-VASG

M. Butler, A. Clark, A. Spadaro,T. Hartley

Novel Mariculture of the Caribbean King Crab for Market and Coral Reef Restoration

Mark Butler

Institute of Environment
Department of Biological Sciences
Florida International University
Miami, Florida



Project Overview

We envision the semi-wild mariculture of the herbivorous Caribbean King Crab (*Maguimithrax spinosissimus*) in Florida for:

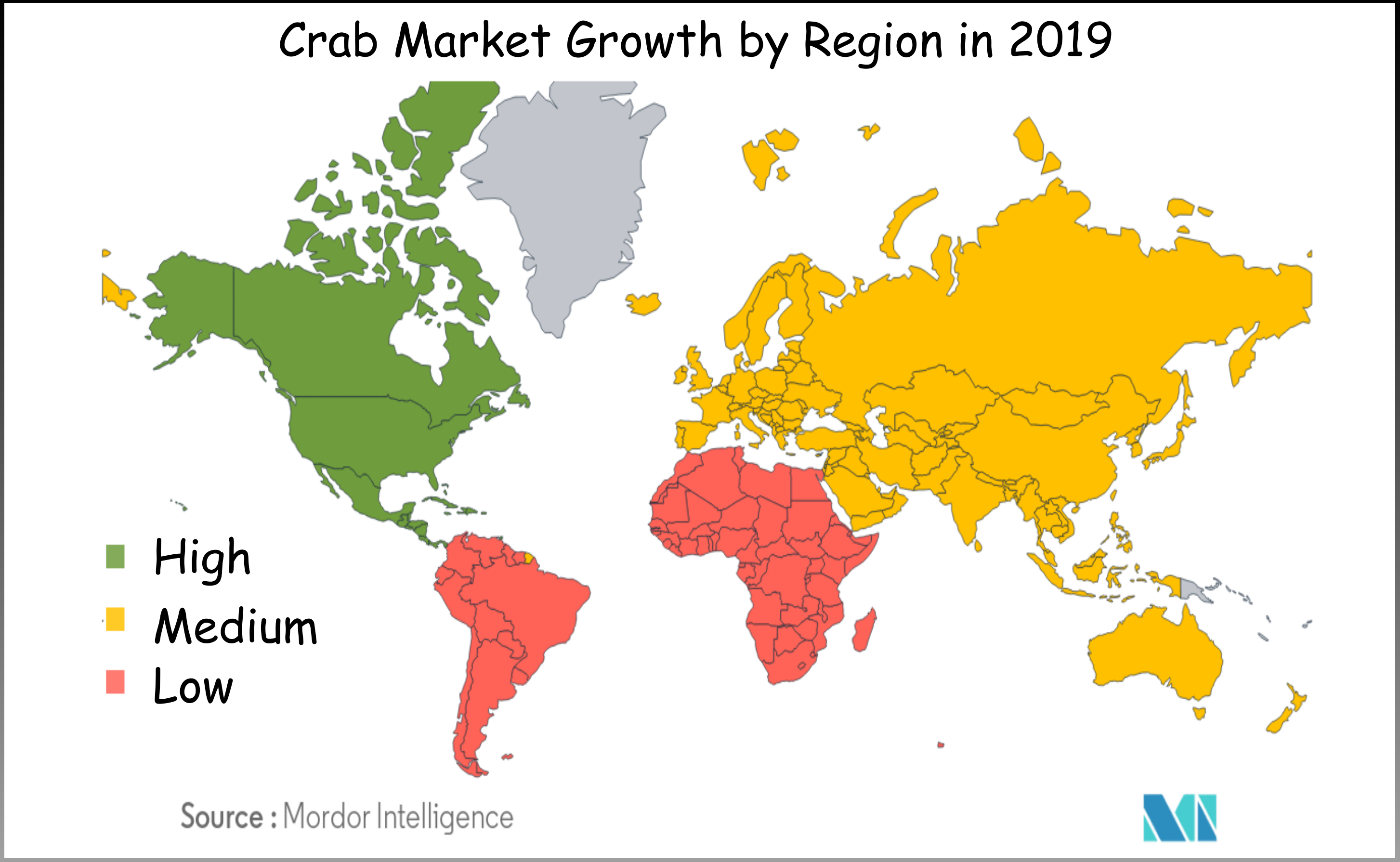
1. A new, potentially high-value seafood commodity.
2. Restoration of coral reefs overgrown by macroalgae.

Novel Attribute:

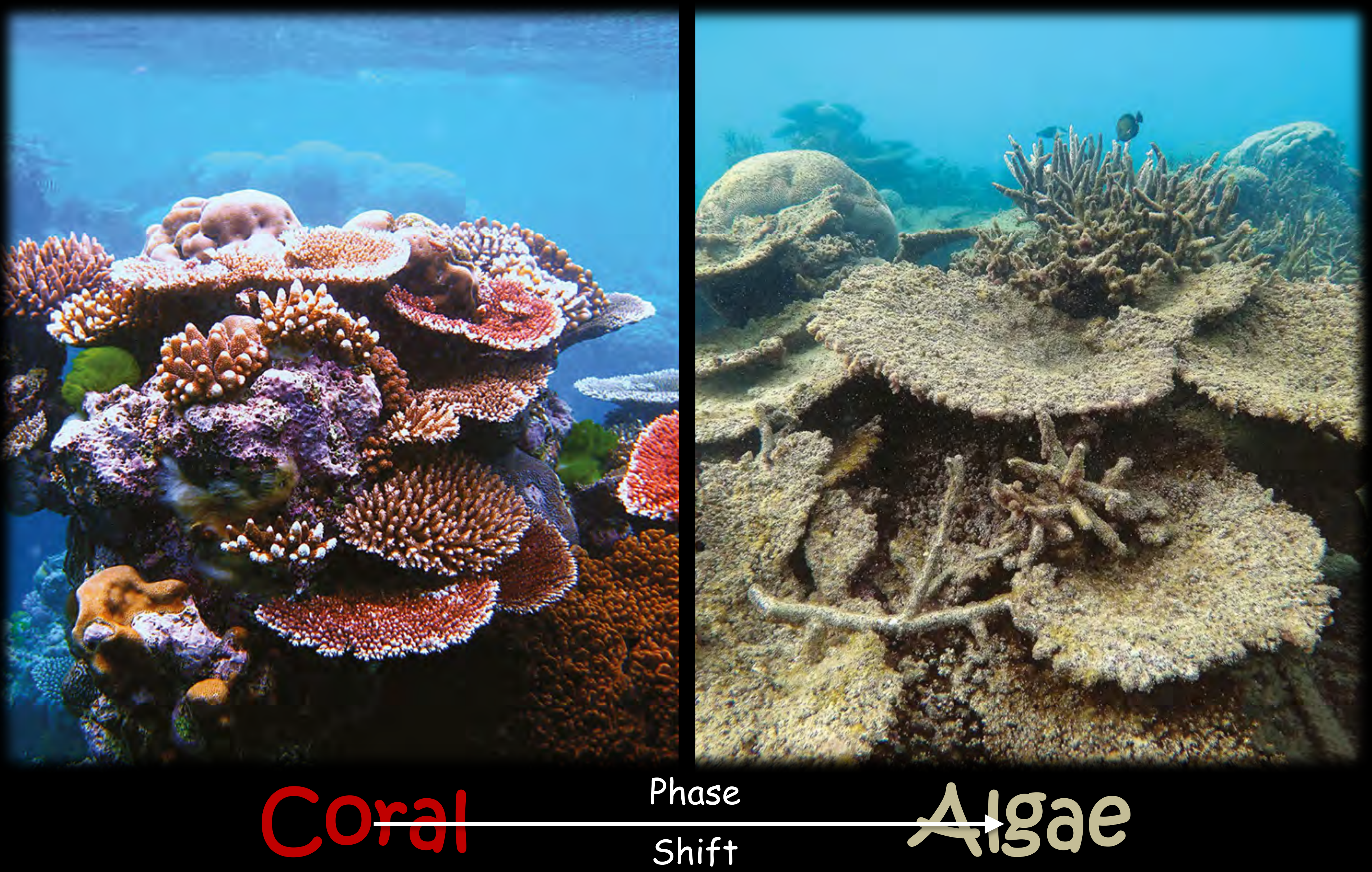
Capitalizes on the use of existing land-locked saltwater quarries in south Florida where *Maguimithrax* already occurs or can be introduced to develop a low-cost, sustainable stock source.

Global Market Overview for Crabs

- Asia-Pacific highest export market share; China = 44% exports.
- North America is fastest growing import market valued at $1.38B/yr
- Global market for crabs estimated to grow at 5.5% for 2020-2025



Coral reefs are in decline



Coral Reef Stressors

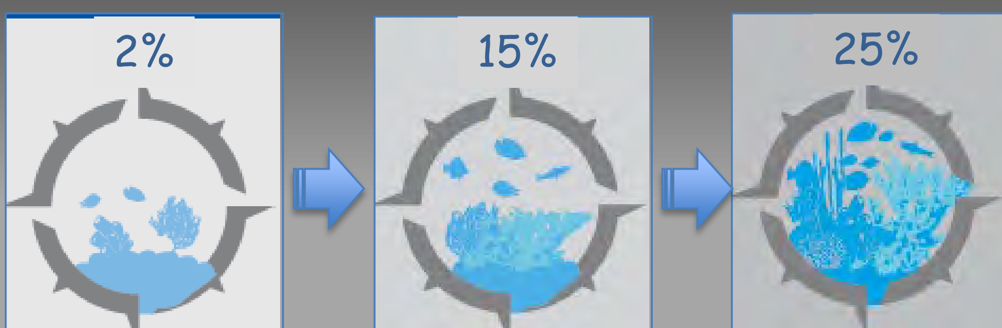
Eutrophication & Climate Change

Disease

Loss of Grazers

Photo Credit: A. Spadaro

- Historic coral cover: 30 – 40%
- Current coral cover: ~ 2%
- Reef Restoration Plan: increase corals



- Coral transplantation & stocking of grazers

CARIBBEAN KING CRAB

Maguimithax spinosissimus

Maguimithrax spinosissimus

The species possesses ideal biological attributes for culture:

- Non-feeding larval stage < 1 week
- Primarily herbivorous
- Rapid growth
- High fecundity
- Native species

Photo Credit: A. Baeza

Mar Biol (2012) 159:2697–2706
DOI 10.1007/s00227-012-2027-1

ORIGINAL PAPER

Herbivory by the Caribbean king crab on coral patch reefs

Mark J. Butler IV · Angela M. Mojica

Current Biology

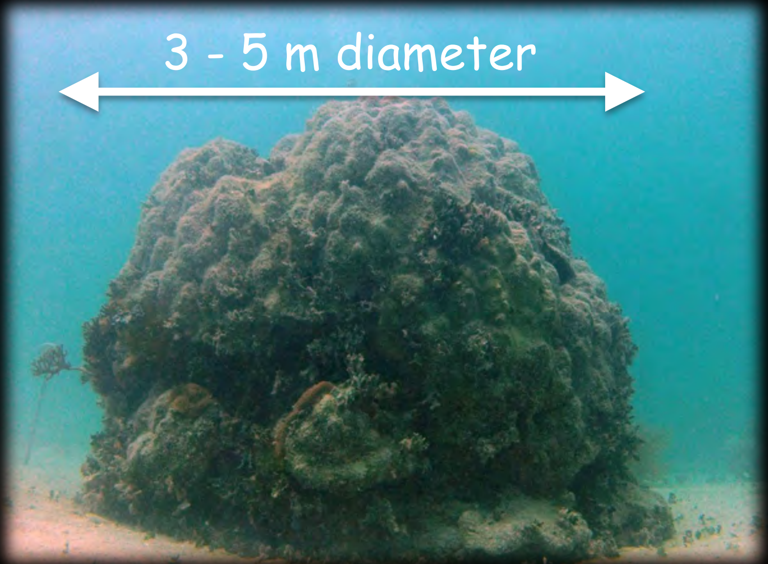
Report

Herbivorous Crabs Reverse the Seaweed Dilemma on Coral Reefs

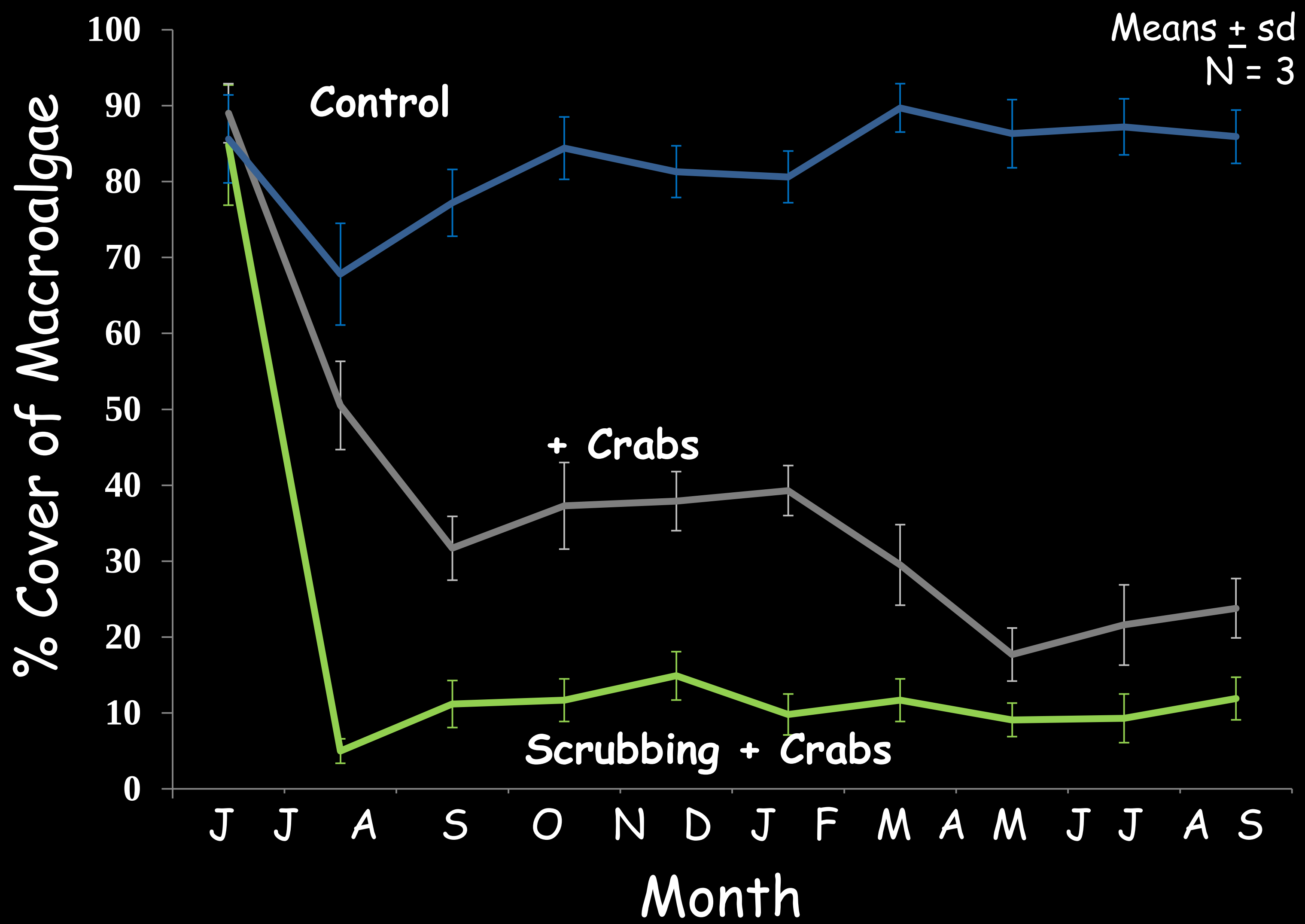
Angelo Jason Spadaro[1,*] and Mark J. Butler IV[2,3,*]

<u>Study Overview</u>

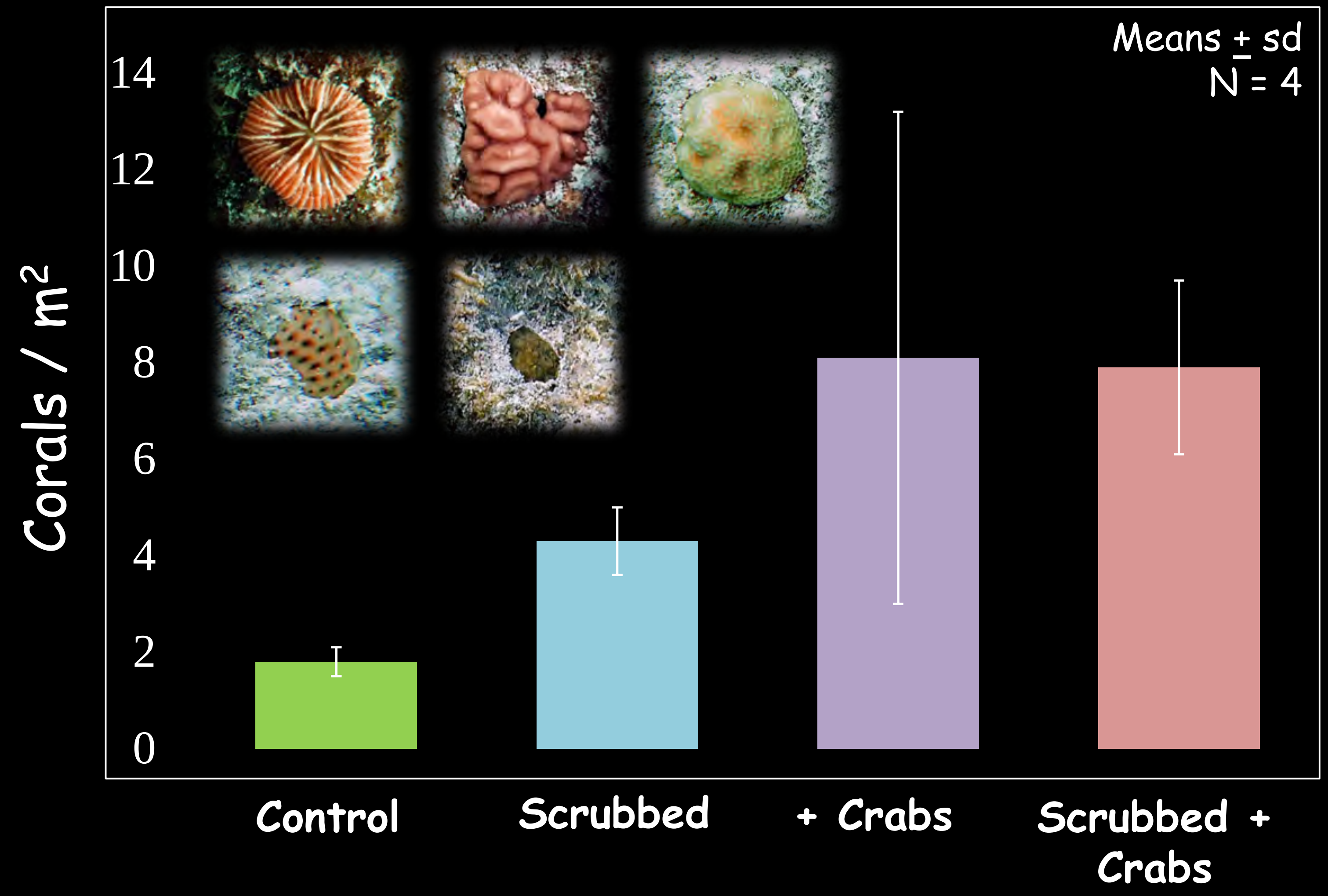
- stocked crabs, scrubbed reefs, scrubbed + crabs, & controls
- N = 3-4 reefs/treatment
- 1 yr long studies at 2 locations
- Monitored reef recovery
  - Algae cover
  - Coral recruitment
  - Fish recruitment



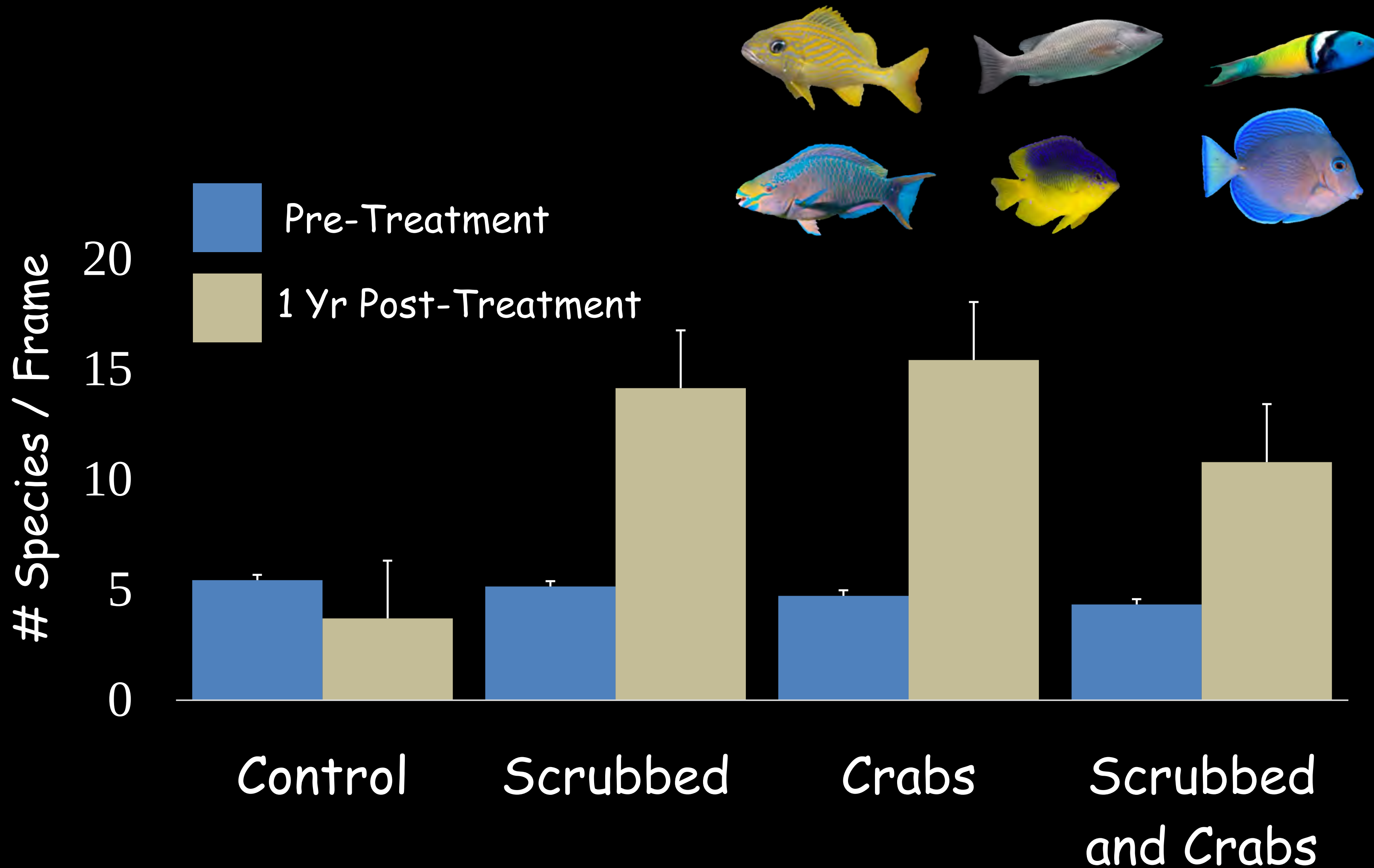
Change in Macroalgae Cover



Coral Recruitment



Species Richness of Fish



Objectives

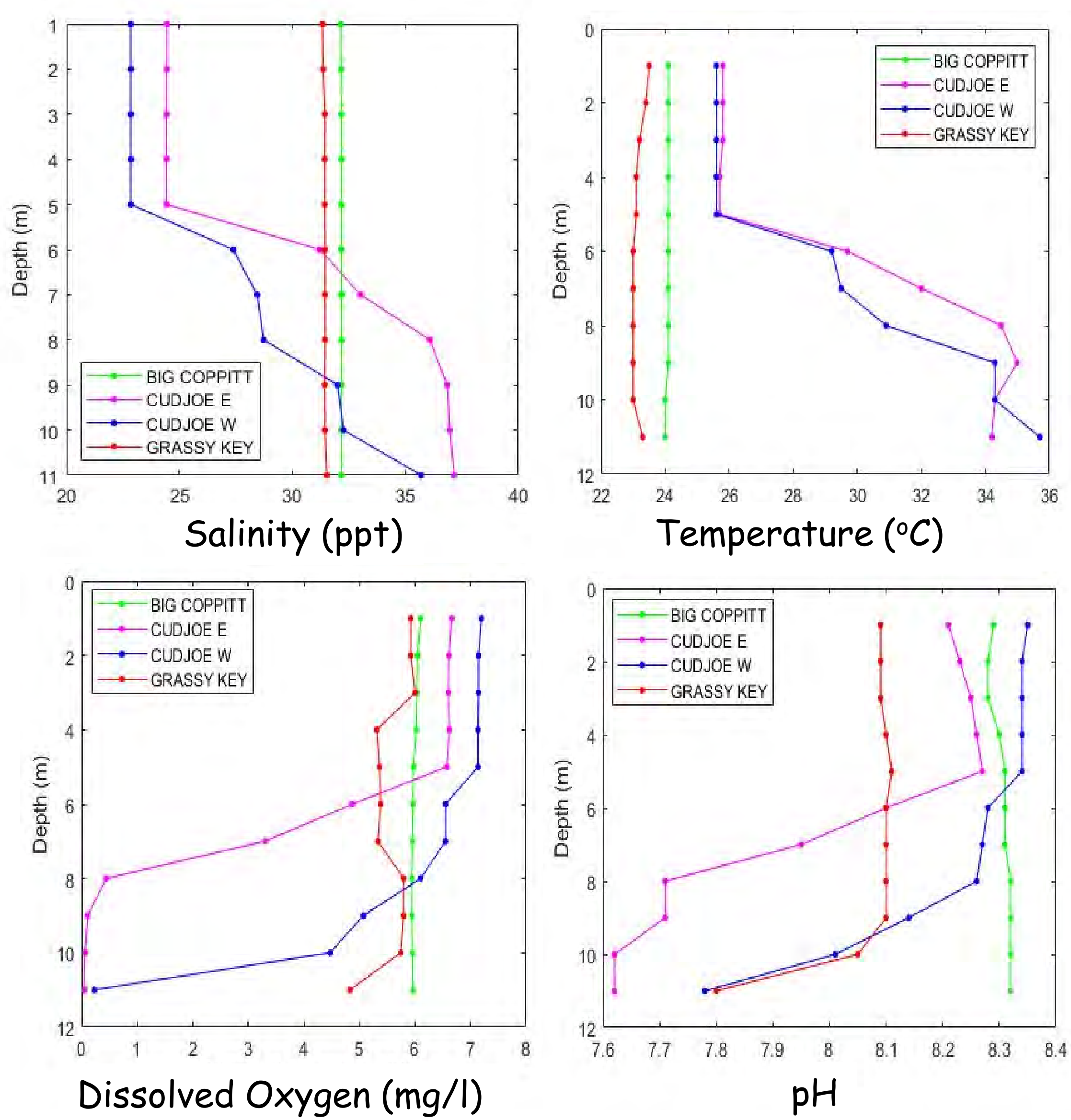
- **Suitability of quarries for mariculture of crabs**
  - Water quality
  - Habitat quality
  - Competitors & predators
- **Crab population structure and production in quarries vs. wild**
  - Population structure
  - Growth & nutritional condition
  - Fecundity
  - Predatory Mortality
- **Assessment of crab population genetics in quarries & wild**
  - Restriction site-associated DNA (2b-RAD) genotyping

Saltwater Quarries in Florida Keys

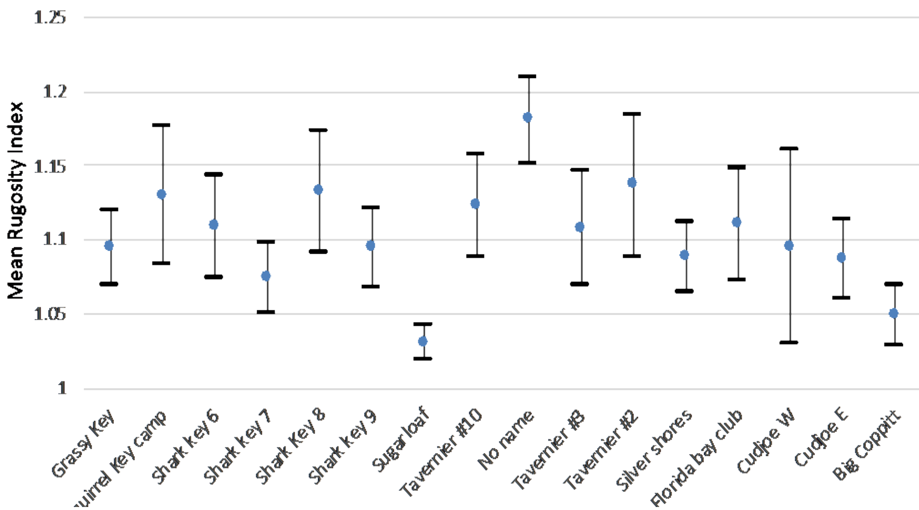
Water Quality in Quarries

Summary:

- 10 of 16 quarries have a reverse thermocline and are anoxic near bottom.
- Nitrate + Nitrite, Ammonia, SRP values are low above thermocline & often below detection limits
- Trace metals (n = 20) are also low and often below detection limits



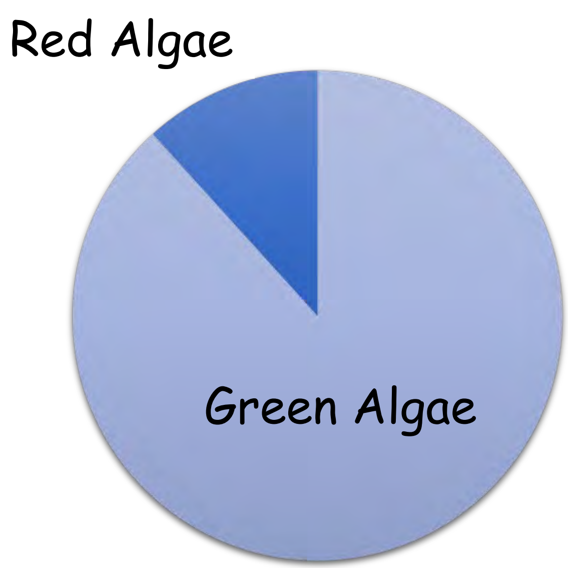
Habitat Quality: Rugosity & Algae



Rugosity

- Rugosity index (chain method)
- 1.0 = flat
- >1.0 = increasing roughness

- Quarry: 1.03 – 1.2
- Coral Reefs in FL: 1.4 – 2.5

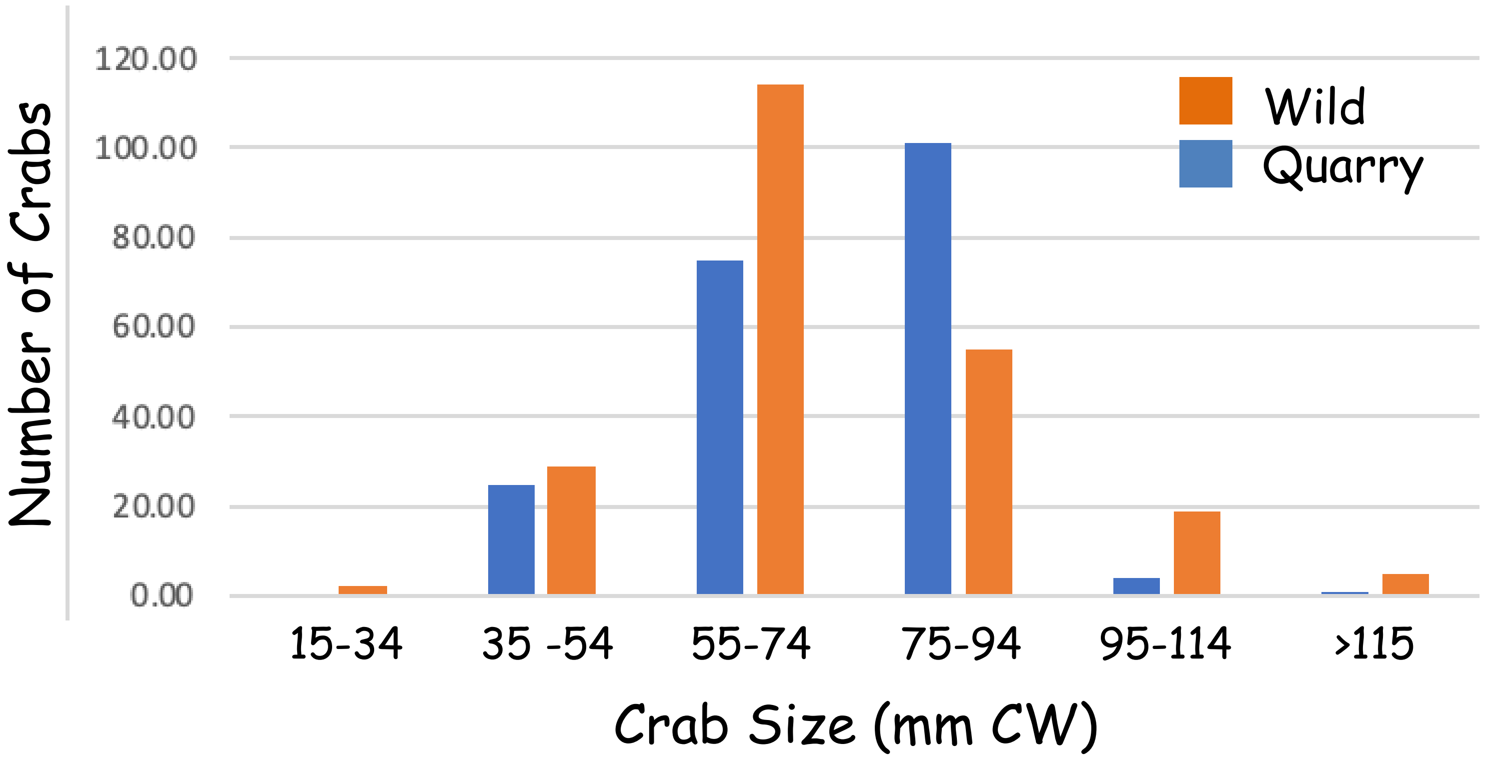


Algal Cover & Composition

- Quarry: 60 – 90%
- Coral Reef: 18 – 87%

- Quarries dominated by green filamentous and red algae
- Reefs dominated by calcareous green, red, and brown algae

Population Structure



Quarries

- Sex Ratio: 1.2/1 (F/M)
- Mean Size: 66 mm CW
- % Gravid: 42% summer
- 73% of crabs < 4m deep

Natural habitats

- Sex Ratio: 1.8/1 (F/M)
- Mean Size: 68 mm CW
- % Gravid: 52% summer

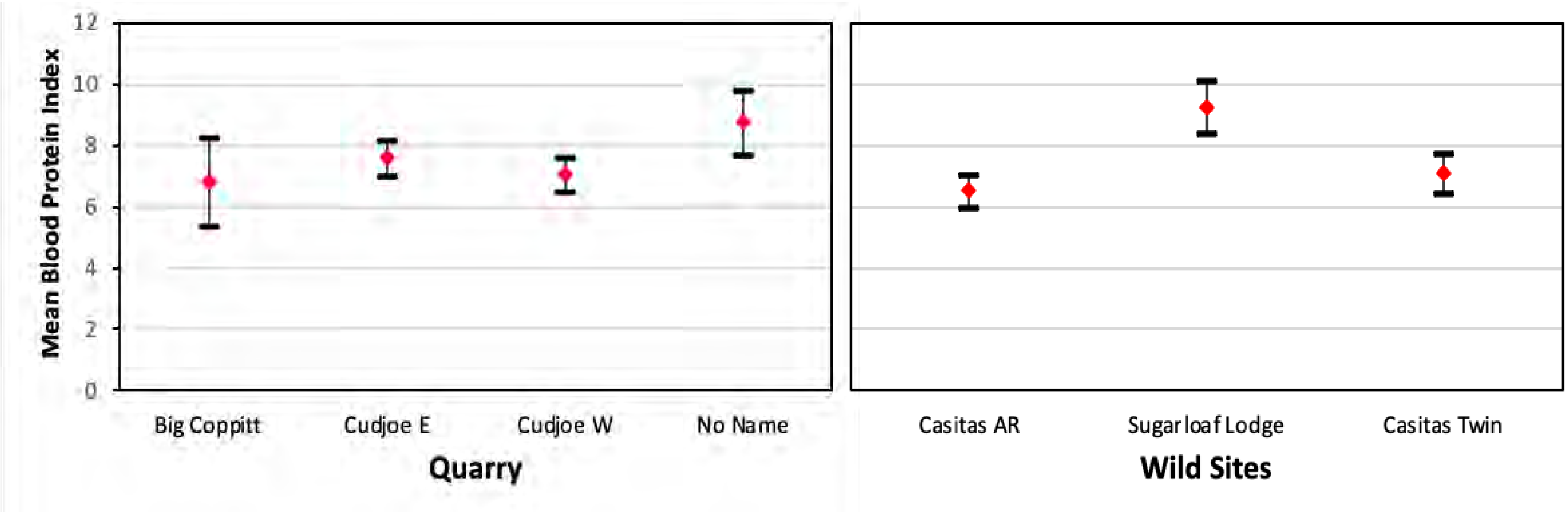
Growth & Nutritional Condition

1. **Relative Growth Rates (% of popl. in pre- or postmolt)**

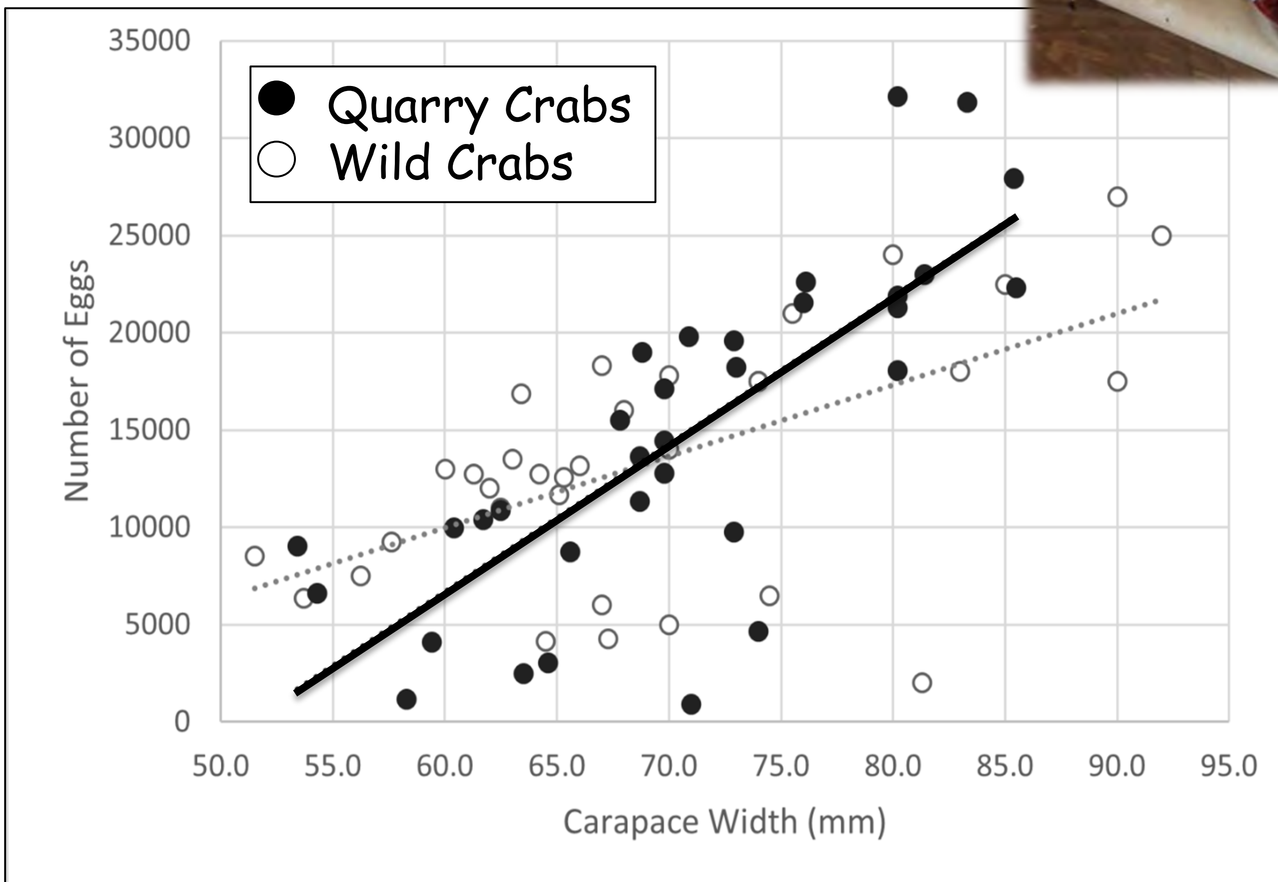
   Quarries: 18%

   Wild: 51%

2. **Relative Nutritional Condition (haemolymph protein)**

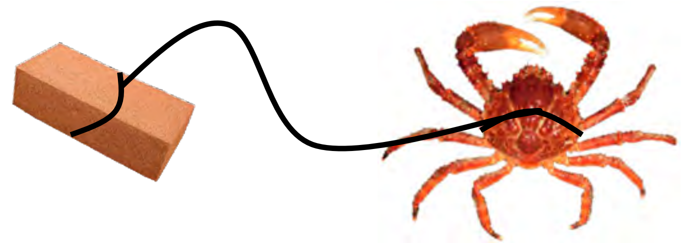


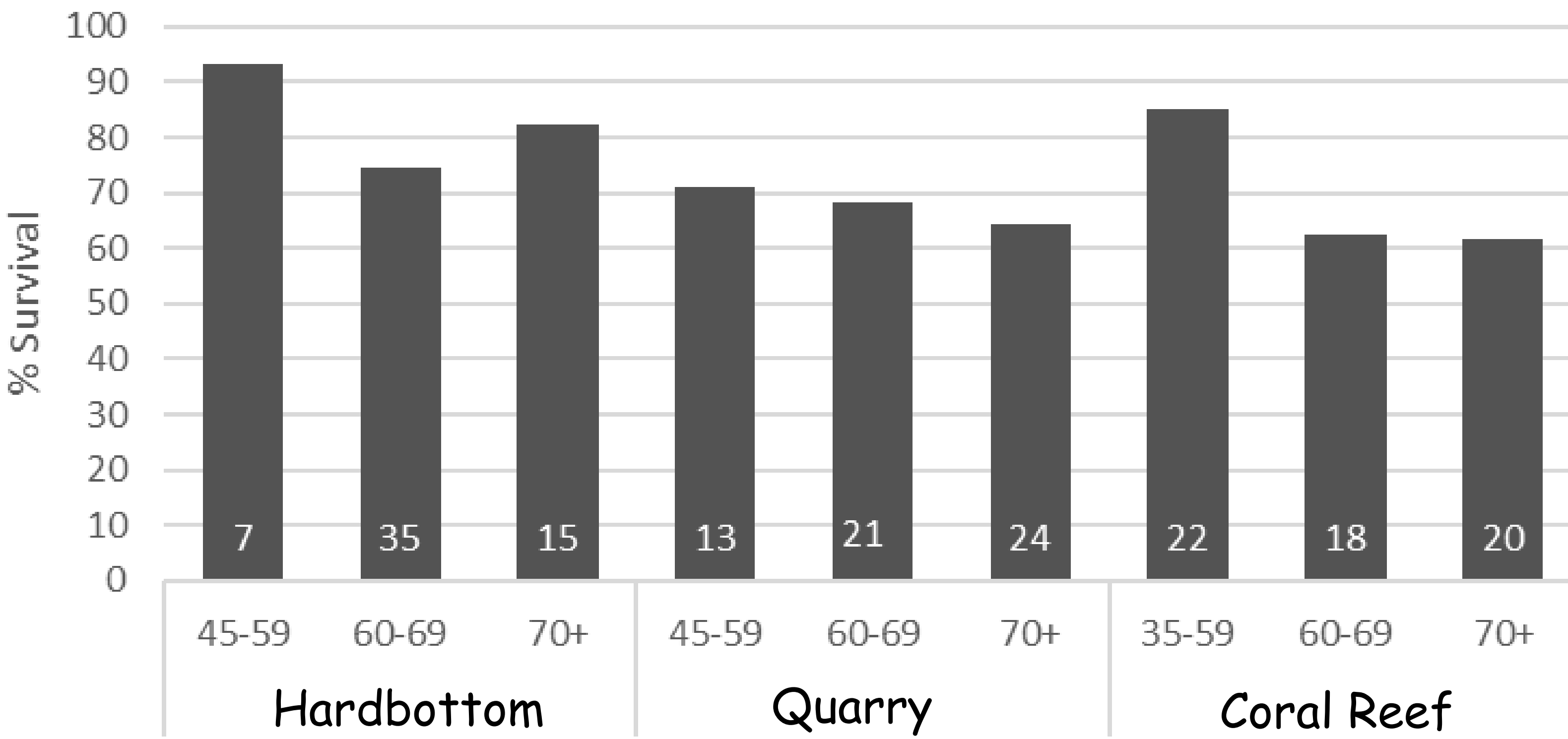
Fecundity



- Quarry crabs are significantly more fecund compared to wild crabs.

Predatory Mortality





- No effect of habitat, size, or gender on crab survival

Conclusions

1. Suitability of quarries for crab mariculture
   - All quarries had suitable water quality to depths of at least 4m.
   - Macroalgal food is abundant and diverse in quarries
   - Predators and competitors are few in most quarries
   - Rugosity is lower in quarries than on reefs; shelter limited?

2. Crab population structure and production in quarries vs. wild
   - Population structure is similar in quarries and the wild
   - Nutritional condition is similar in quarries and the wild
   - Growth is higher in wild
   - Fecundity is higher in quarries
   - Predatory mortality is similar in quarries and in the wild

3. Assessment of crab population genetics in quarries & wild
   - In Progress

Acknowledgements

- Samantha Glover (M.S. Thesis)
- Dr. Heather Bracken-Grissom (genomics)
- <u>Field Team:</u> Leah Cifers, Nick Evans, Jeanette Fantone, Adrian Marchi, Mary Williams

Sea Grant

NOAA – Sea Grant National
Virginia Sea Grant

"Exploring New Aquaculture Opportunities Program"

Award #: NA18OAR4170083

ENAO-Walleye Aquaculture Working Group: Developing walleye aquaculture in Illinois and Indiana-ILINSG

S. Carlton, K. Quagrainie, R. Rode,
J. Balagtas, T. Hook

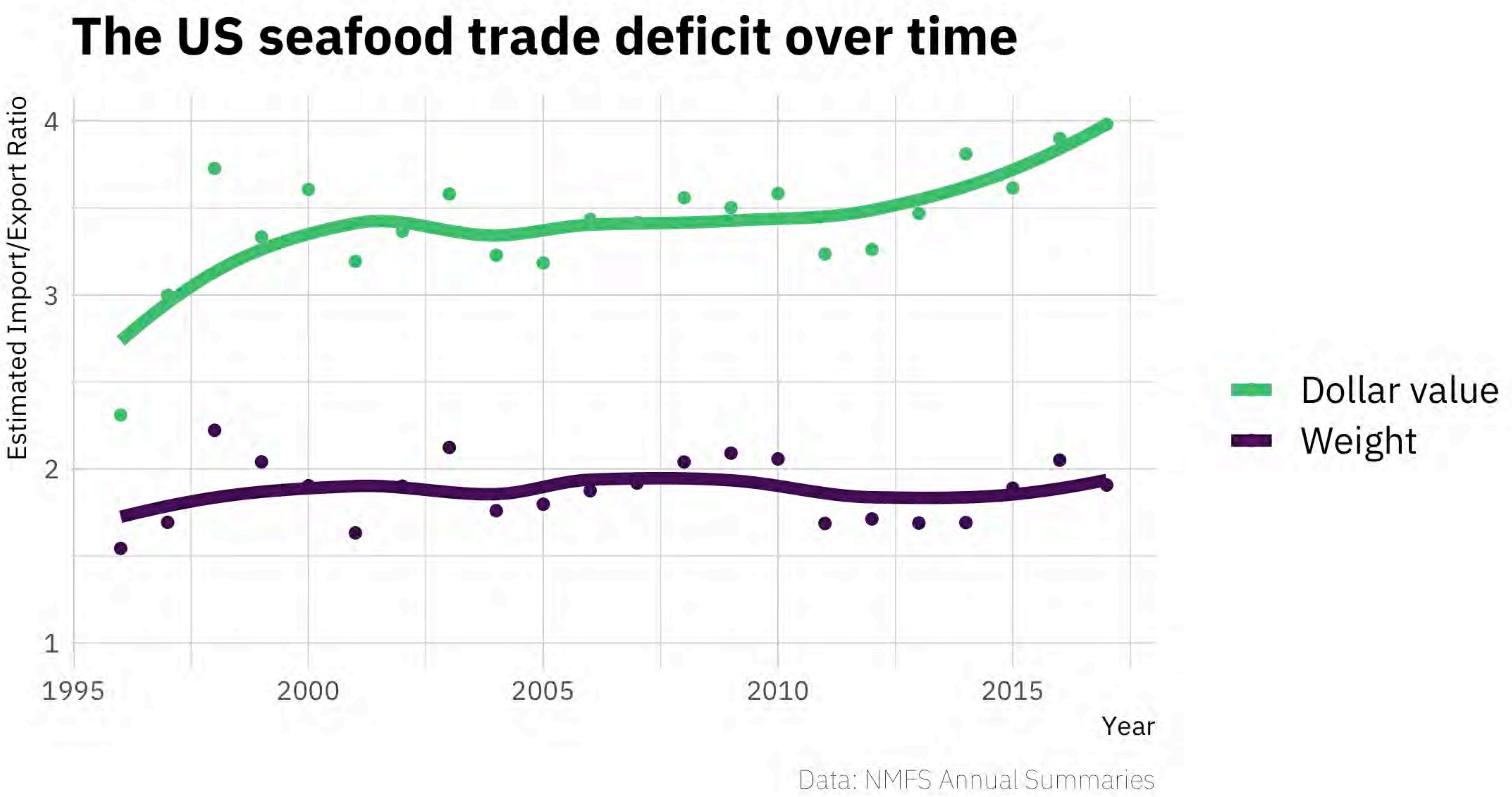
Walleye Aquaculture Working Group

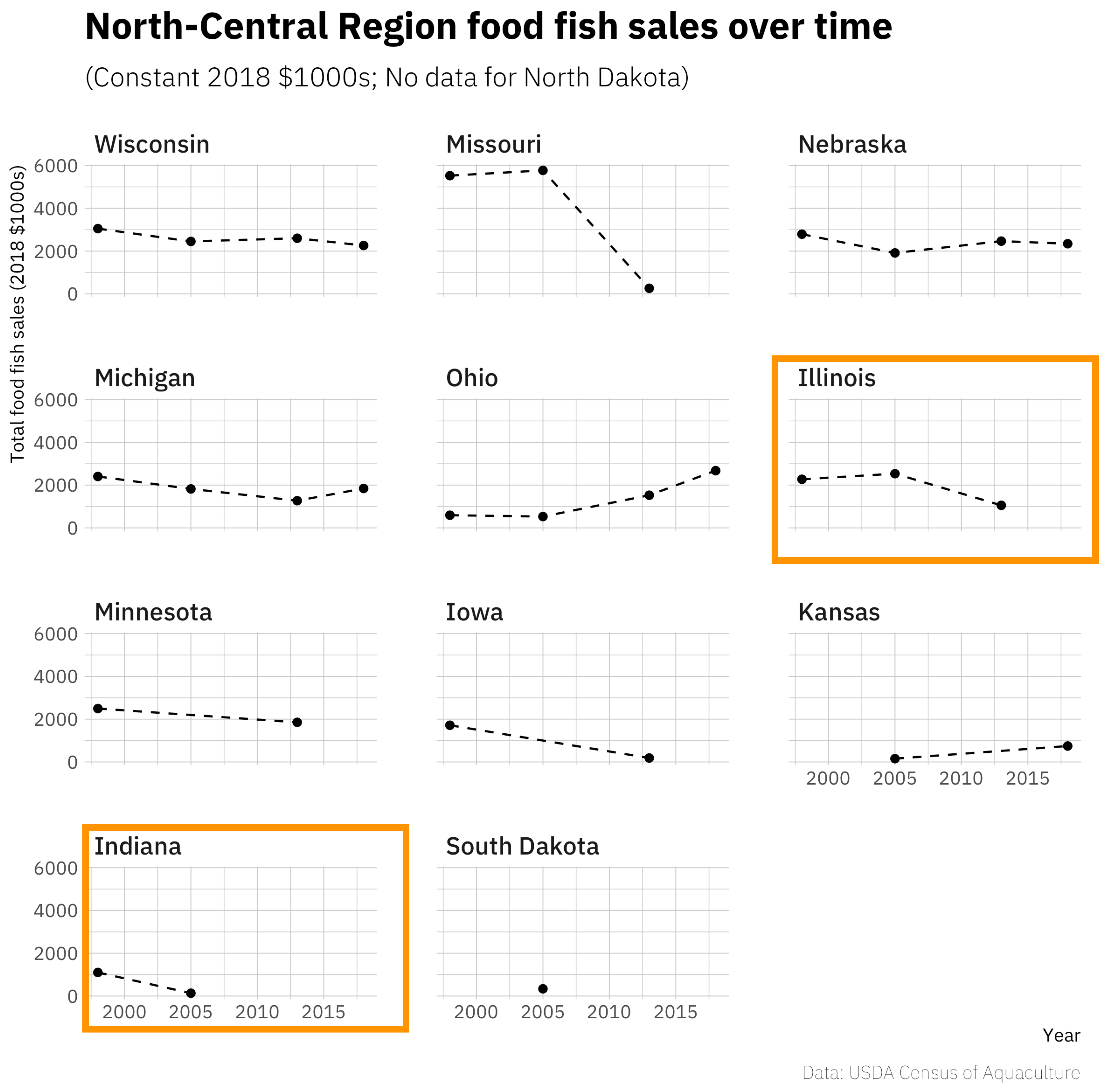
Developing walleye aquaculture in Illinois and Indiana

J. Stuart Carlton Joseph Balagtas Tomas O. Höök
Kwamena K. Quagrainie Robert Rode

WALLEYE AQUACULTURE WORKING GROUP

Background

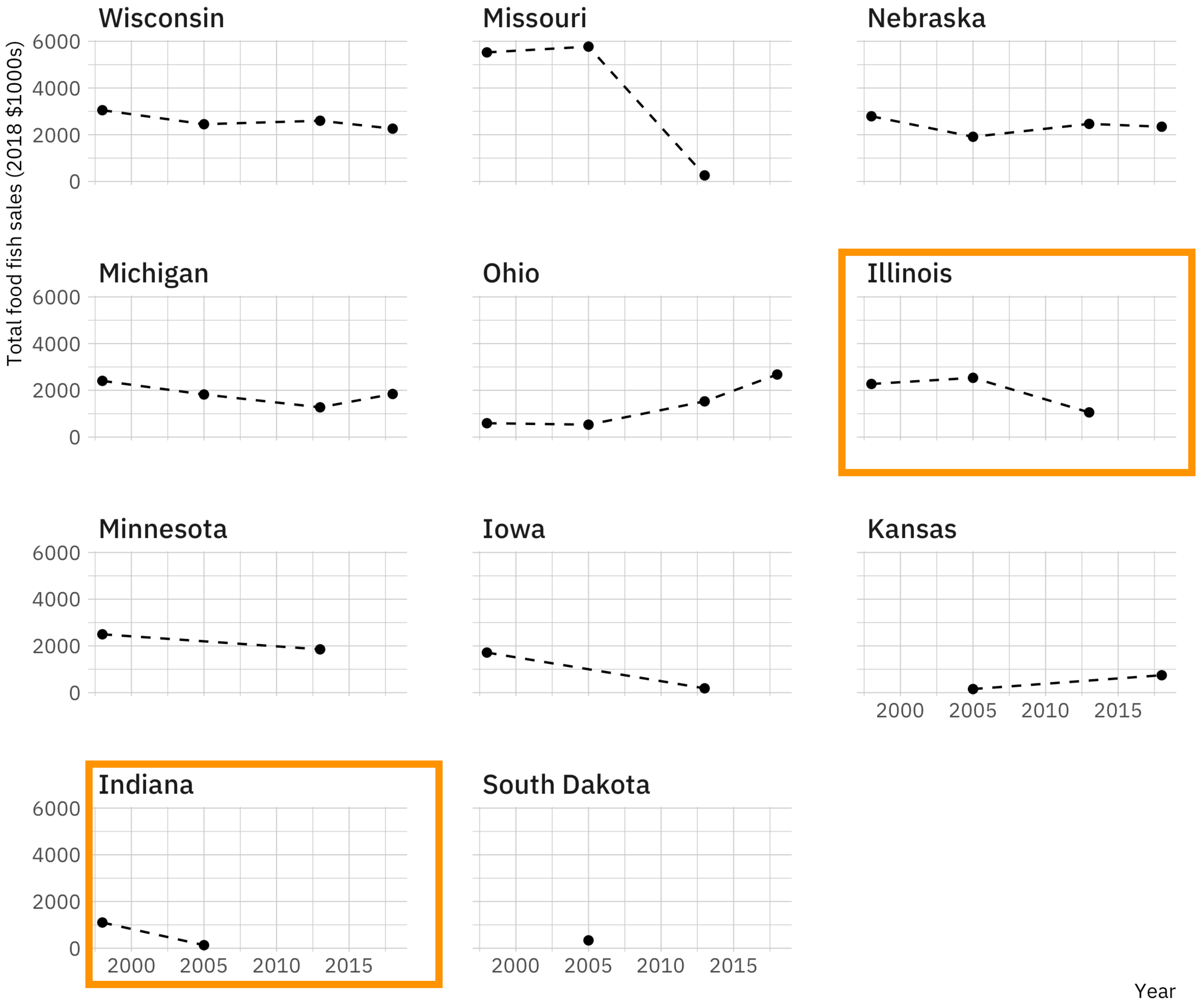

The US seafood trade deficit over time
Estimated Import/Export Ratio
4
3
2
1
1995
2000
2005
2010
2015
Year
Dollar value
Weight
Data: NMFS Annual Summaries



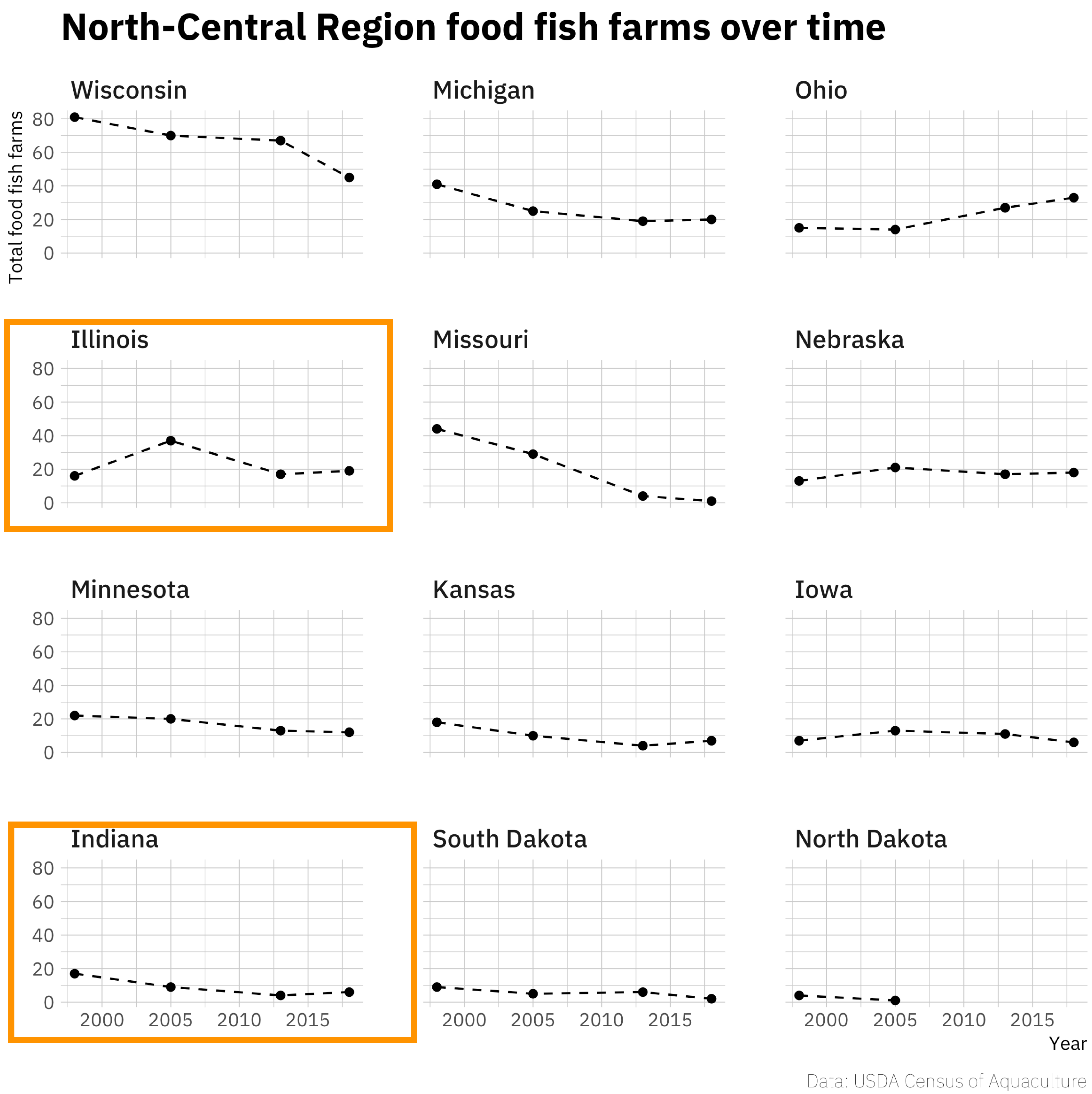
North-Central Region food fish sales over time
(Constant 2018 $1000s; No data for North Dakota)
Wisconsin
Missouri
Nebraska
Michigan
Ohio
Illinois
Minnesota
Iowa
Kansas
Indiana
South Dakota
Total food fish sales (2018 $1000s)
6000
4000
2000
0
2000
2005
2010
2015
Year
Data: USDA Census of Aquaculture

North-Central Region food fish sales over time

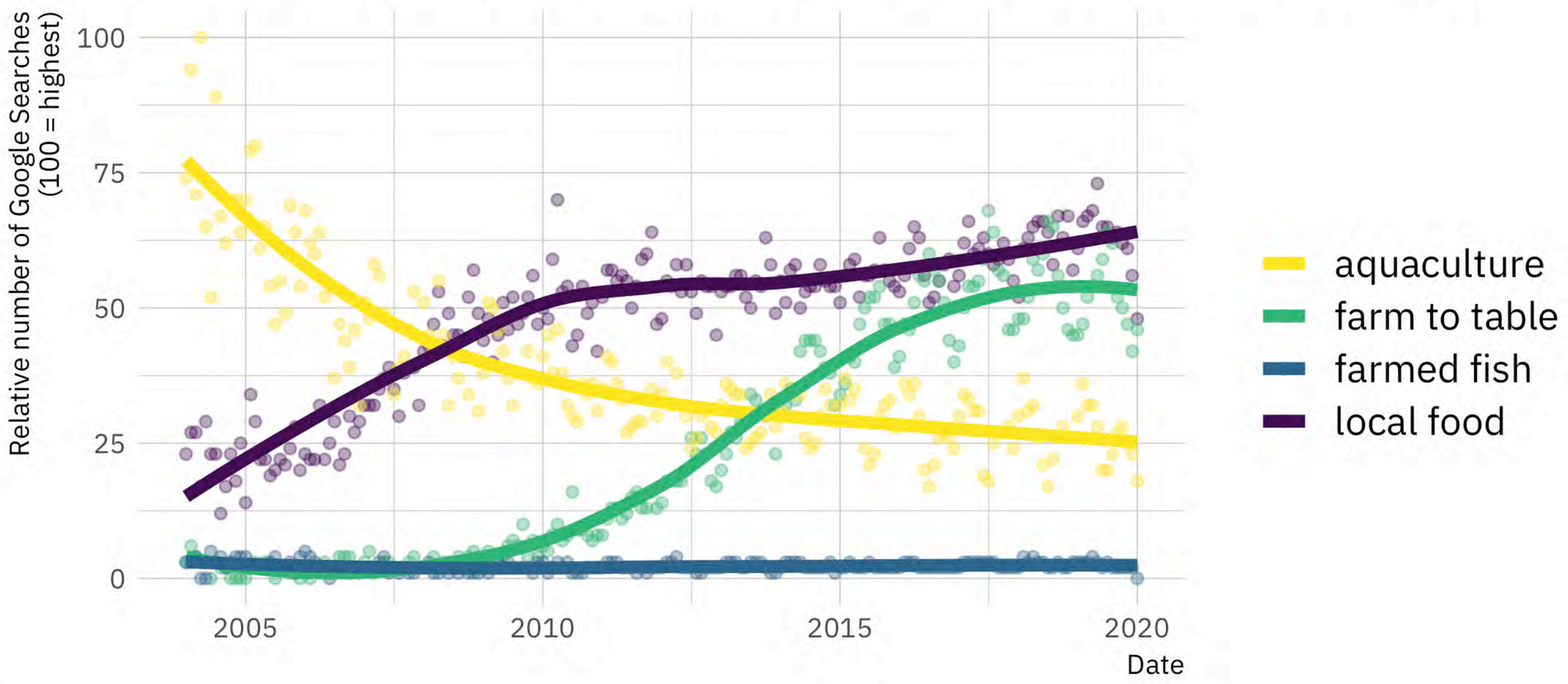
(Constant 2018 $1000s; No data for North Dakota)



Data: USDA Census of Aquaculture


North-Central Region food fish farms over time
Wisconsin
Michigan
Ohio
Illinois
Missouri
Nebraska
Minnesota
Kansas
Iowa
Indiana
South Dakota
North Dakota
Total food fish farms
0
20
40
60
80
2000
2005
2010
2015
Year
Data: USDA Census of Aquaculture

Google Trends Data for Searches About Local Foods



Data: Google Trends. Numbers indexed so that 100 is the highest number of searches over the time period

WALLEYE AQUACULTURE WORKING GROUP

Is there a way to connect these two ideas?

WALLEYE AQUACULTURE WORKING GROUP

A multi-stakeholder, interdisciplinary team to address the potential for this market

PURDUE UNIVERSITY | Forestry and Natural Resources

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Sea Grant ILLINOIS-INDIANA

IISG20-SAQ-BRC-005

(Illinois-Indiana Sea Grant Photo/Hope Charters)

AUTHORS
Stuart Carlton
Amy Shambach
Carolyn Foley

Walleye Aquaculture Working Group Workshop: Identifying Walleye Marketing and Production Barriers

Introduction[1]

Illinois-Indiana Sea Grant (IISG) is working to support the development of a sustainable regional aquaculture market through various research, outreach, and education activities. These efforts focus on fish species that are currently produced in the bi-state region, many of which are non-native and don't have a strong association with the Midwest. Research and anecdotal evidence suggest that farmed fish with a stronger local identity may be more successful in the marketplace because it is more familiar to Midwesterners as a local, native fish as opposed to the exotic species that are currently the focus of regional aquaculture.[2]

Walleye is one such fish: it has a strong association with the Midwest, is available in restaurants as a commercially caught species, and may be suitable for aquaculture. However, there is currently minimal walleye aquaculture in Illinois or Indiana.

The business and real-world production barriers to developing walleye aquaculture are not fully understood, but they include technical barriers to raising the fish in an economically sustainable manner, challenges inherent in developing new markets, policy barriers, and more. Simply put, there is reason to believe that walleye aquaculture could be successful, but there is a lot of background work that needs to be done to see if it is even feasible.

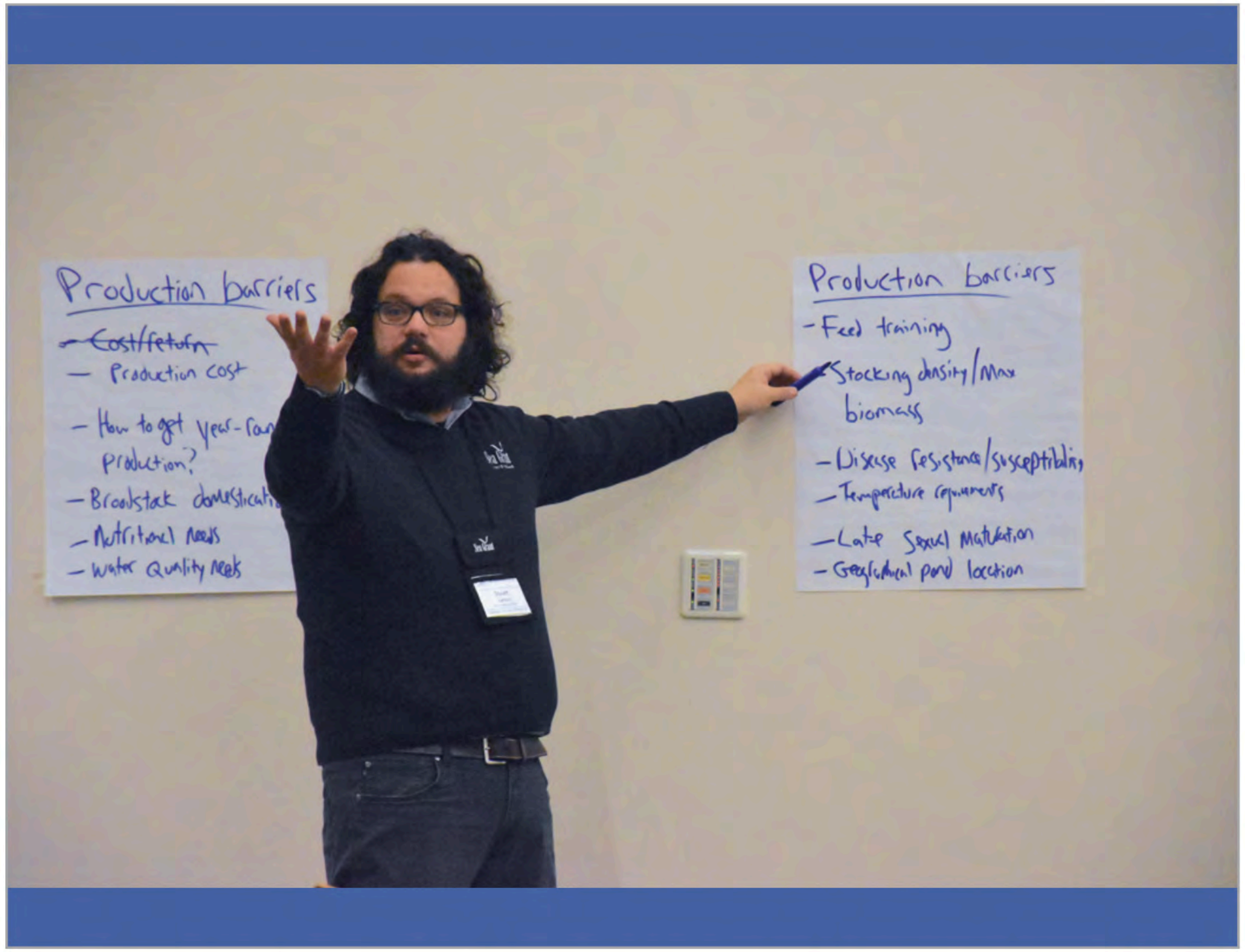


Figure 2. Dr. Stuart Carlton solicits questions about stocking density as a potential barrier to walleye production. (Illinois-Indiana Sea Grant Photo/Hope Charters)

Production Barriers

Item	Total votes
Fingerling supply	12
Broodstock domestication	11
Production cost	8
Egg supply	7
Year-round production	6
Feed training	6
Growth rates compared to existing species	5
Disease resistance/susceptibility	4
System types (Pond/RAS/Cage)	3
Water quality needs	2
Market-size of the fish	2
Saugeye vs walleye tradeoffs	2
Nutritional needs	1
Light levels	1
Late sexual maturation	1
Dress-out percentage	0
Knowledge barriers	0
Stocking density/biomass	0
Temperature requirements	0
Geographic farm location	0

Market Barriers

Item	Total votes
Processing	9
Competing with wild market for demand	9
What size fish?	8
Market price	5
Necessary price?	4
Will buyers pay more?	3
No established market for farmed fish food (food walleye)	3
Market size and location	3
Consumer perception	3
Sensory tests	1
Mislabeling	1
Fingerling supply...who does this?	1
Farmed vs wild	1
Does seasonality kill marketability?	1
Biochemically	1

Research period (eventually)

IS WALLEYE FARMING ECONOMICALLY FEASIBLE?

- The market test: will consumers pay a price that can support commercial production?
- Novelty of farmed walleye means lack of market data.
- Choice experiments allow us to illicit consumer preferences for "nonmarket" goods
    - Experiments where people make hypothetical shopping choices over products and attributes of interest
    - Yields estimates of consumers' Willingness to Pay (WTP) for a set of attributes (frozen walleye fillets farmed in the North Central Region)

MSU CHOICE EXPERIMENT FOR FRESHWATER FISH

- April Athnos and Simone Valle de Souza (Michigan State) conducted a choice experiment aimed at exploring consumer demand for freshwater fish

- 3 species: walleye, trout, yellow perch
- 2 production technologies: wild-caught, farmed
- 2 geographic production regions: North Central Region, other
- 2 product forms: fresh fillets, frozen fillets
- 2 consumer groups: US, North Central Region

BASELINE WTP FOR FROZEN FARMED FILETS

	U.S. Consumers			NCR Consumers		
	Mean	95%CI L.B.	95%CI U.B.	**Mean**	95%CI L.B.	95%CI U.B.
Walleye	**17.05**	15.01	19.08	**20.45**	16.10	24.80
Yellow Perch	**14.67**	11.68	17.67	**19.11**	13.24	24.98
Trout	**18.62**	16.78	20.46	**21.95**	17.00	26.91

CONSUMER WTP FOR WALLEYE ATTRIBUTES US SAMPLE (N = 1151)

CONSUMER WTP FOR WALLEYE ATTRIBUTES US SAMPLE (N = 1151)

CONSUMER WTP FOR WALLEYE ATTRIBUTES US SAMPLE (N = 1151)

CONSUMER WTP FOR WALLEYE ATTRIBUTES NCR SAMPLE (N = 249)

SUMMARY OF KEY PRELIMINARY RESULTS

- WTP for farmed, frozen walleye fillets is $17.05/lb in the US, $20.45/lb in the NCR
  - Higher than yellow perch, lower than trout
- The premium for live-caught walleye (or discount for farmed walleye) is $2.05/lb, and $0.67/lb in the NCR
- Consumers are also willing to pay for fish produced in the NCR, and for fresh fillets.

REMAINING QUESTIONS

- Will walleye producers/supply chain be able to get fish to market for $17/lb, or $2 under live-caught price?

- Are these preliminary WTP estimates robust to:
  - Scale
  - Consumer familiarity with farmed walleye
  - Consumer understanding of environmental benefits
  - Seasonality

In Person Survey of Producers

Public and Private Production

- Two Research Institutions
- Four Private Farms
- Three Pond Based Producers
- Three Indoor Producers
- Techniques/ Markets (Supply)

Production Techniques

Pond Producers

- Variations on Techniques from State and Federal Hatcheries

- Hand Stripping Gametes
- Indoor incubation with Temperature Control
- Fertilized(Fertile) Ponds Stocking
- Supplement with Forage Fish
- Harvest in the Fall of First Year

- Walleye Manual – NCRAC Website

Production Techniques

Indoor Production

- Techniques Developed at Iowa State U./DNR

- Strip Spawning
- Indoor Incubation
- Larval Rearing through Fingerling in Tanks
- First Feeding with Processed Feeds

- Video Tutorial Available from UWSP.

Impressions

Pond Producers

- Low Cost Production
- No Feed Training
- Supply Does Not Meet Demand

Impressions

Indoor Production

- High Capital Costs
- Better Survival
- Better Growth
- More Consistent????
- Feed Trained Fingerlings!!!

Conclusions

Food Fish Producers/ Industry

- Little to No Feed Trained Fingerlings Available
- Probably will need to Vertically Integrate Fingerling Production with Food Fish
- Availability and Condition of Broodstock

THANK YOU

Bob Rode
rrode@purdue.edu

ENAO-Seaweed lines of change: Laying the groundwork to advance the practice of sustainable seaweed farming in the Pacific Northwest-WASG

M. Chadsey, T. King, B. Peabody, J. Davis,
J. Toft, R. Callender

Seaweed Lines of Change

Laying the groundwork to advance sustainable seaweed farming in the Pacific Northwest

Meg Chadsey, WSG

Sea Grant Aquaculture Research Symposium

October 26, 2021

Co-PIs: Teri King, WSG
Betsy Peabody, Puget Sound Restoration Fund
Jodie Toft, Puget Sound Restoration Fund
Joth Davis, Hood Canal Mariculture
Russell Callender, WSG Director

Sea Grant Washington

Teri King

Washington Sea Grant

Betsy Peabody & Jodie Toft

Puget Sound Restoration Fund

Nicole Naar

Joth Davis

Hood Canal Mariculture

SUMMARY OF FINDINGS

INVESTIGATING SEAWEED CULTIVATION AS A STRATEGY FOR MITIGATING OCEAN ACIDIFICATION IN HOOD CANAL, WA

FOR ACTIVITIES PERFORMED MAY 2015 – DECEMBER 2019

FUNDED BY THE PAUL G. ALLEN FAMILY FOUNDATION AND US NAVY

PUGET SOUND RESTORATION FUND · Hood Canal Mariculture · APL University of Washington · PMEL · SCCWRP · Aqua Model · EASy · Sea Grant Washington · Washington Department of Natural Resources

CBS News 60 Minutes *Seaweed Farming and its Surprising Benefits* (aired 04/29/2018)

Project Objectives

1. Develop and deliver an effective training program for potential seaweed farmers in Washington State.

2. Identify stakeholder needs for growth of seaweed aquaculture in Washington State.

Approach: Two-part program. Initial large introductory workshop followed by smaller intensive multi-day training.

NOAA WDVA Veterans Conservation Corps Internship Program

John Floberg
NOAA Restoration Center

Veteran intern Barney Boyer and NOAA staff on a boat conducting field research.

Photo: NOAA Fisheries

Aquaculture
Boating
Fisheries
Hazards, Resilience and Climate Change
Environmental Threats
Marine and Coastal Planning
Safe, Sustainable Seafood
Shoreline Living and Restoration
Volunteer Opportunities

Seaweed Farming Introductory Workshop

Wednesday, November 20, 2019 8:30 a.m. – 4:00 p.m.

This free online workshop provided participants with an overview of seaweed farming in Washington State.

Hosted by Washington Sea Grant, in partnership with the Puget Sound Restoration Fund, Hood Canal Mariculture and the NOAA WDVA Veterans Conservation Corps Internship Program.

Topics included:

- Suitable species for cultivation in Washington waters
- Factors to consider
- Operating a seaweed farm in Washington State
- A survey of potential markets

Washington kelp farmer Joth Davis (photo: Puget Sound Restoration Fund)

View the agenda and download PDFs of the presentation slides.

The entire webinar broadcast was recorded. Close-captioned video presentations will be freely available on this page by mid-December, 2019.

This webinar-based workshop was broadcast live from Pacific Lutheran University. Veterans and active-duty military personnel were invited to attend in person and learn about additional seaweed farming programming and benefits offered through the Washington State Department of Veterans Affairs.

Topics introduced at this workshop will be covered in depth at a multi-day, Seattle-based training in early 2020 (dates and location TBA). *Only individuals who attend the November workshop (or the archived recording) will be eligible to apply for the multi-day training.*

Funding for this workshop is provided by the National Sea Grant College Program, with additional support from the NOAA WDVA Veterans Conservation Corps Internship Program. Also sponsored by the Pacific Lutheran University Center for Military Support.

Sea Grant Washington | NOAA | Washington State Department of Veterans Affairs "Serving Those Who Served" | Veterans Conservation Corps | Pacific Lutheran University

Meg Chadsey

206.616.1538
WSGseaweed@uw.edu

November 2019 Introductory Workshop

- Hybrid in-person/webinar
- >200 participants (18 veterans)
- Audience included:
  - Prospective seaweed farmers
  - Shellfish growers
  - Tribes
  - Regulators
  - Policymakers
  - Researchers
  - Conservation organizations
  - Media

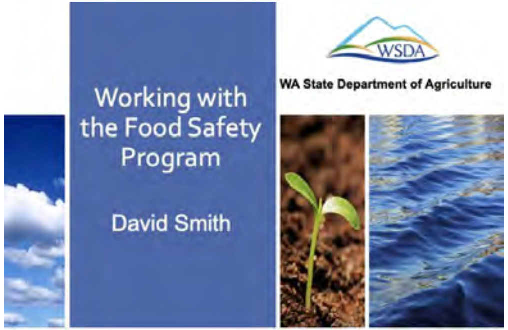
Your Facilitator:

Meg Chadsey
Washington Sea Grant

Welcoming Remarks

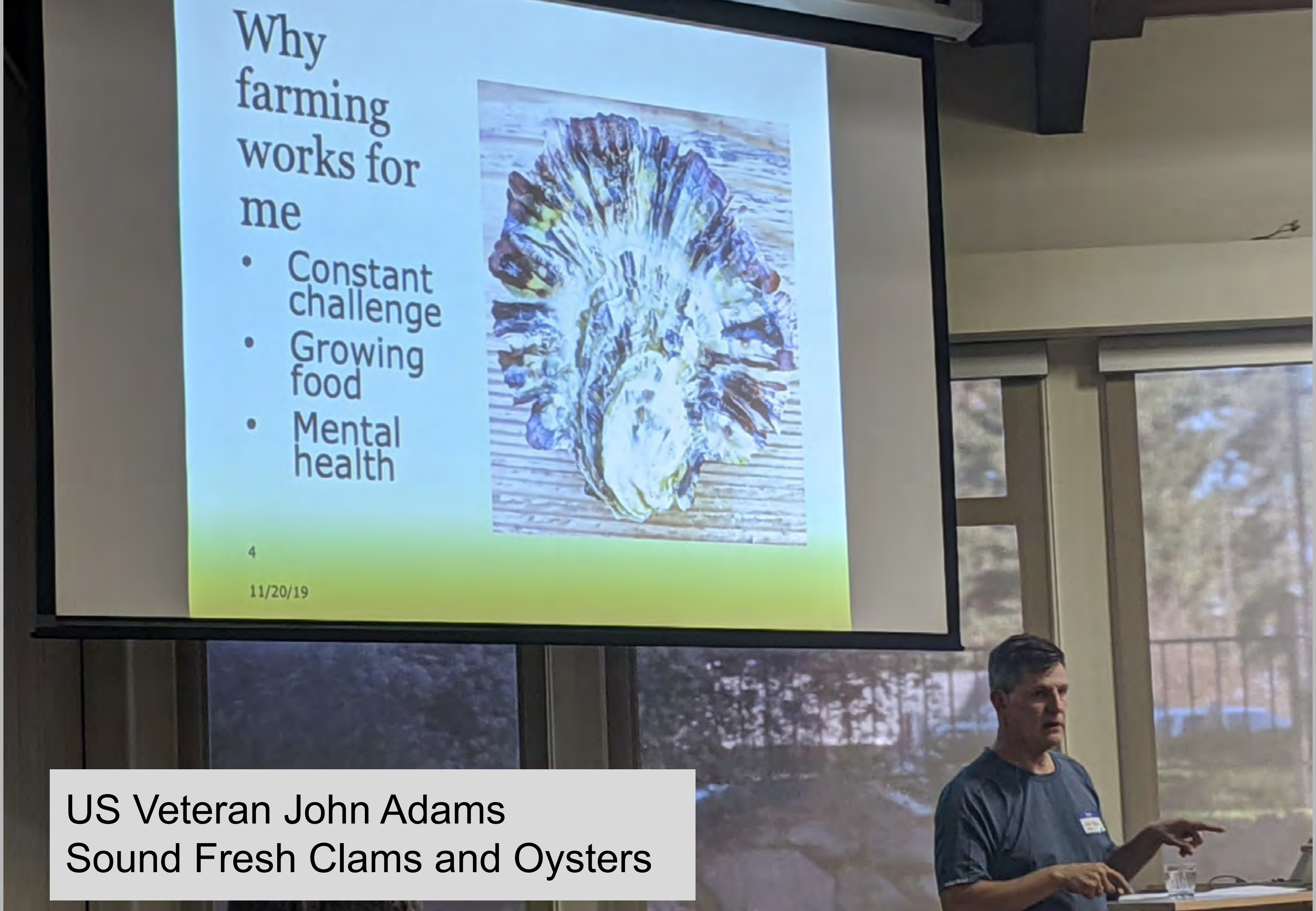
Dr. Peter Schmidt
Director of Counseling & Wellness Programs for the Washington Department of Veterans Affairs (WDVA).

Megan Callahan-Grant
NOAA NW Northwest Regional Supervisor for Nat'l Marine Fisheries Service Restoration Center



Case Study 2: From Shellfish to Seaweed

Farmer Veterans John Adams and Dan Barth



US Veteran John Adams
Sound Fresh Clams and Oysters

Could seaweed be Washington's next cash crop?

With Washington's natural kelp beds declining, some scientists think seaweed aquaculture could fill an ecological niche and serve an emergent market. But the barriers to entry remain high.

by Hannah Weinberger / December 4, 2019 / Updated at 9:45 a.m. on Dec. 4, 2019

February 2020 Intensive Training

- Three *jam-packed* days, in three locations around Puget Sound
- Combination of lectures, tutorials and facility tours (Hood Canal Mariculture, Kenneth K. Chew Center for Shellfish Research and Restoration (PSRF), and SolSea Ltd.
- Guest experts:
  - *Washington Sea Grant*
  - *NOAA Fisheries*
  - *WA Dept of Veterans Affairs*
  - *Academia* Univ. of WA, Western WA Univ., WA State Univ., Dr. Tom Mumford
  - *State agencies* Depts of Ecology, Agriculture, Health, Fish & Wildlife, and Natural Resources
  - *Federal agencies* US Army Corps
  - *Business planning & finance* Enterprise For Equity
  - *Seaweed growers* Hood Canal Mariculture, Sol Sea Ltd., Puget Sound Restoration Fund
  - *Value-added processors* Salish Sea Greens, Barnacle Foods, Food Scientist Travis Bettinson
  - *Market research* Maine Island Institute





EXIT

Thank you!

Sea Grant
Washington

ENAO-Exploring the Potential for Sustainable Capture-Based Aquaculture of Spiny Lobster (Panulirus spp.) in Pohnpei, Federated States of Micronesia-HISG

S. Ellis, D. Lerner, D. Okimoto

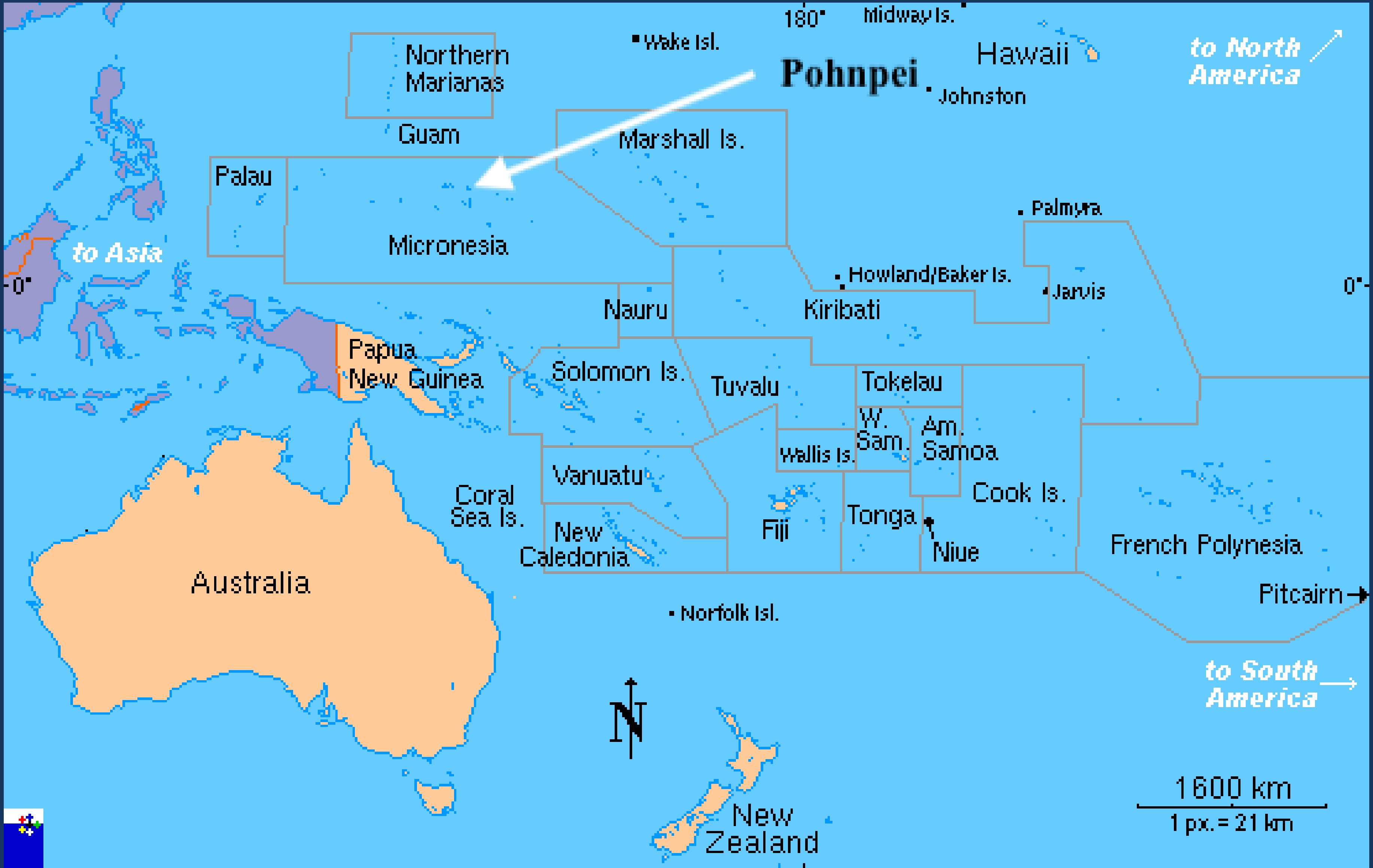
Exploring the Potential for Sustainable Capture-Based Aquaculture of Spiny Lobster (Panulirus spp.) in Pohnpei, Federated States of Micronesia-HISG

Simon Ellis, Darren Lerner, Darren Okimoto

Hawaii Sea Grant, UH Hilo and MERIP

Marine and Environmental Research Institute of Pohnpei, Micronesia (MERIP)

Where are we?



180°
Midway Is.
Wake Isl.
Northern Marianas
Guam
Pohnpei
Hawaii
Johnston
to North America
Marshall Is.
Palau
Micronesia
to Asia
0°
Palmyra
Howland/Baker Is.
Jarvis
Nauru
Kiribati
0°
Papua New Guinea
Solomon Is.
Tuvalu
Tokelau
W. Sam.
Am. Samoa
Wallis Is.
Vanuatu
Coral Sea Is.
Fiji
Tonga
Cook Is.
New Caledonia
Niue
French Polynesia
Australia
Pitcairn
Norfolk Isl.
to South America
N
New Zealand
1600 km
1 px. = 21 km

Project Background

- 3 species of spiny lobster with commercial value: *Panulirus penicillatus*; *P. versicolor*; and *P. ornatus.*
- Large clean, sheltered lagoon for puerullus collection
- Sufficient air freight infrastructure to meet Asian market demand for live lobsters or puerulli (pre-pandemic)
- Looking to replicate successful capture-based efforts in Vietnam and Indonesia.

Project Objectives

- a. Technology transfer of lobster pueruli collection methods through a study tour of facilities in Vietnam and Indonesia.
- b. Determine the best type of collector for use in Pohnpei waters by testing different collectors at different depths.
- c. Determine seasonality, if any, of settlement
- d. Test simple grow-out technology with any juvenile lobsters collected.
- e. Outreach and training

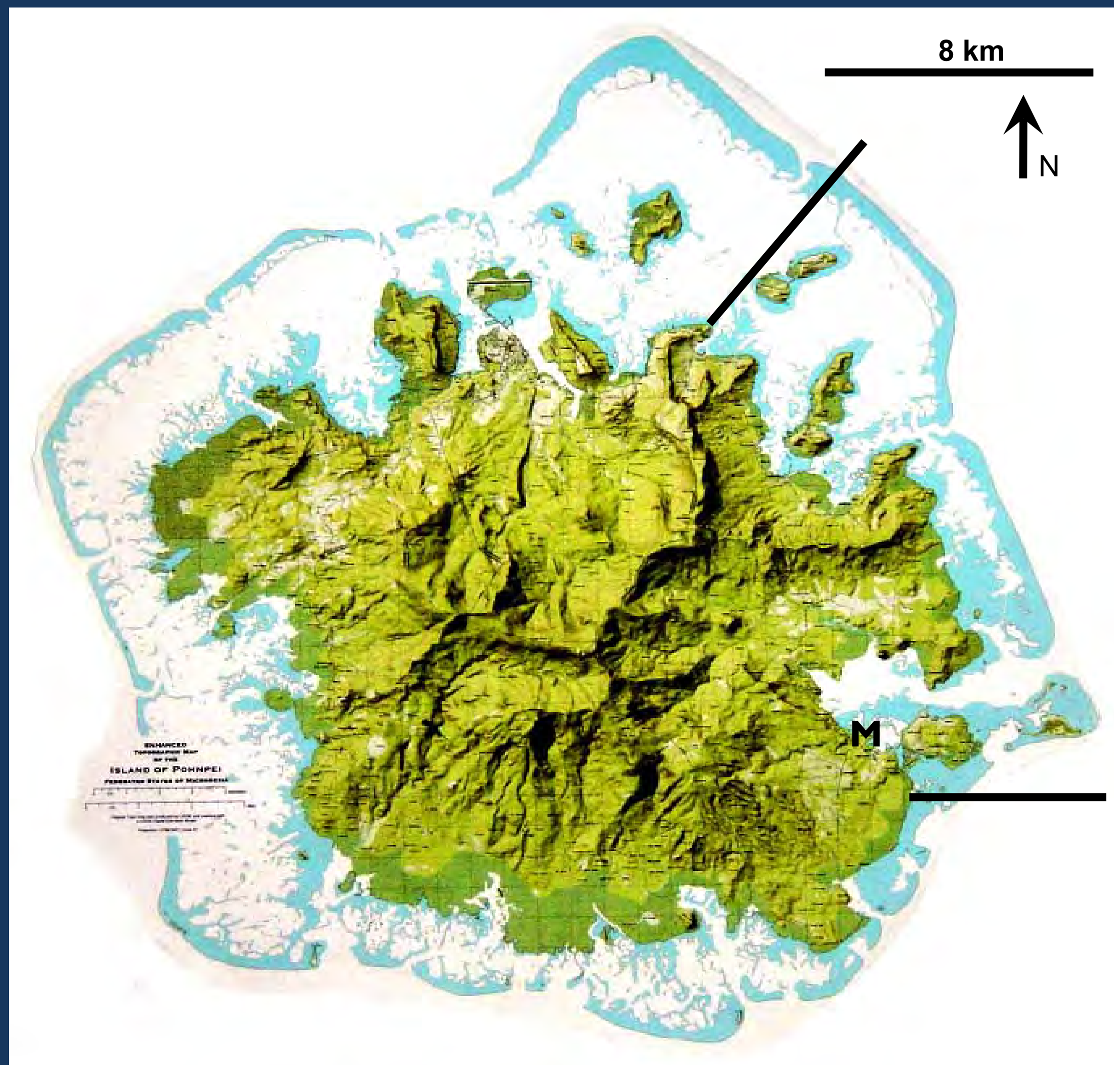
Objective 1. Study tour Vietnam and Indonesia (Lombok)

- Due to COVID-19 pandemic there has been no travel to Indoneisa and Vietnam.
- Both countries have highly restricted entry requirements
- This was a key learning aspect of the project.
- Restricted to literature searches and limited correspondence

Objective b and c. Best collector type and seasonality of settlement

- Five types of collectors tested
- Different depths and locations in lagoon
- Collection has occurred over 18 months and will continue

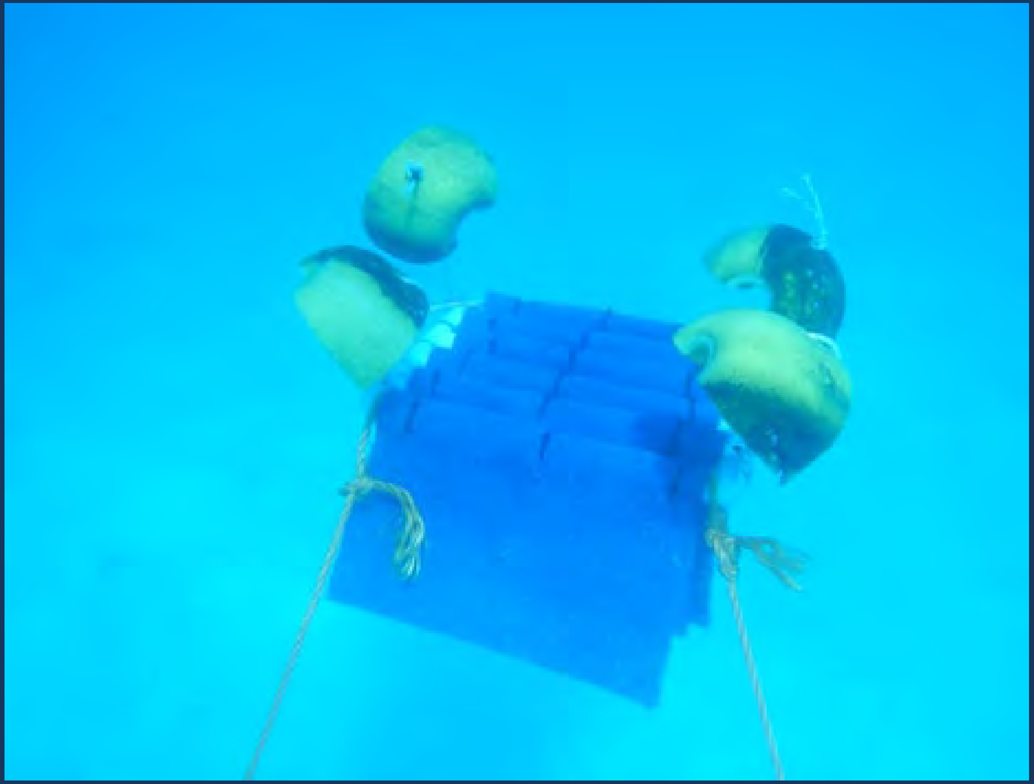
Project Area – NE Pohnpei



Types of Collectors Tested

- Witham Collectors
- Indonesian folded paper - Bowtie
- Burlap
- Woven polyethylene – shade cloth
- Woven polypropylene – rice bags

Witham Collectors



Accordian Kraft Paper

Polypropylene, Polyethylene and Burlap

Results - Collectors

- Witham collectors are attracting lobsters and many other species of crustaceans
- The other collectors have had poor results.
- Best depth so far seems just under the surface. Collectors on the surface get broken quickly.
- Collectors closest to the reef edge perform best
- No seasonality trends due to low catch rates






Typical successful collector sites

Grow-out

- Only a few lobsters caught to date
- Lobsters are fed fish and kept in aquaria

Summary

- Project is only 25%-30% complete
- Lobsters are being collected but in low numbers
- Best collection sites and depths partially understood
- Best collector type still not fully determined and is likely to be something large with a lot of shelter
- Hope to complete the study tour in 2022

ENAO-The Perfect Storm: Establishing a Pilot Seaweed Farm in the Alaska Peninsula-AKSG

M. Good, C. Levy, G. Eckert

ENAO: The Perfect Storm - Establishing a Seaweed Pilot Farm on the Alaska Peninsula

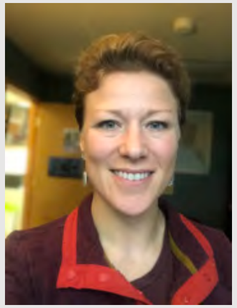
Melissa Good* - Mariculture Specialist

Charlotte Levy - Natural Resources Assistant Director, Aleutians East Borough

Alaska Sea Grant Marine Advisory Program

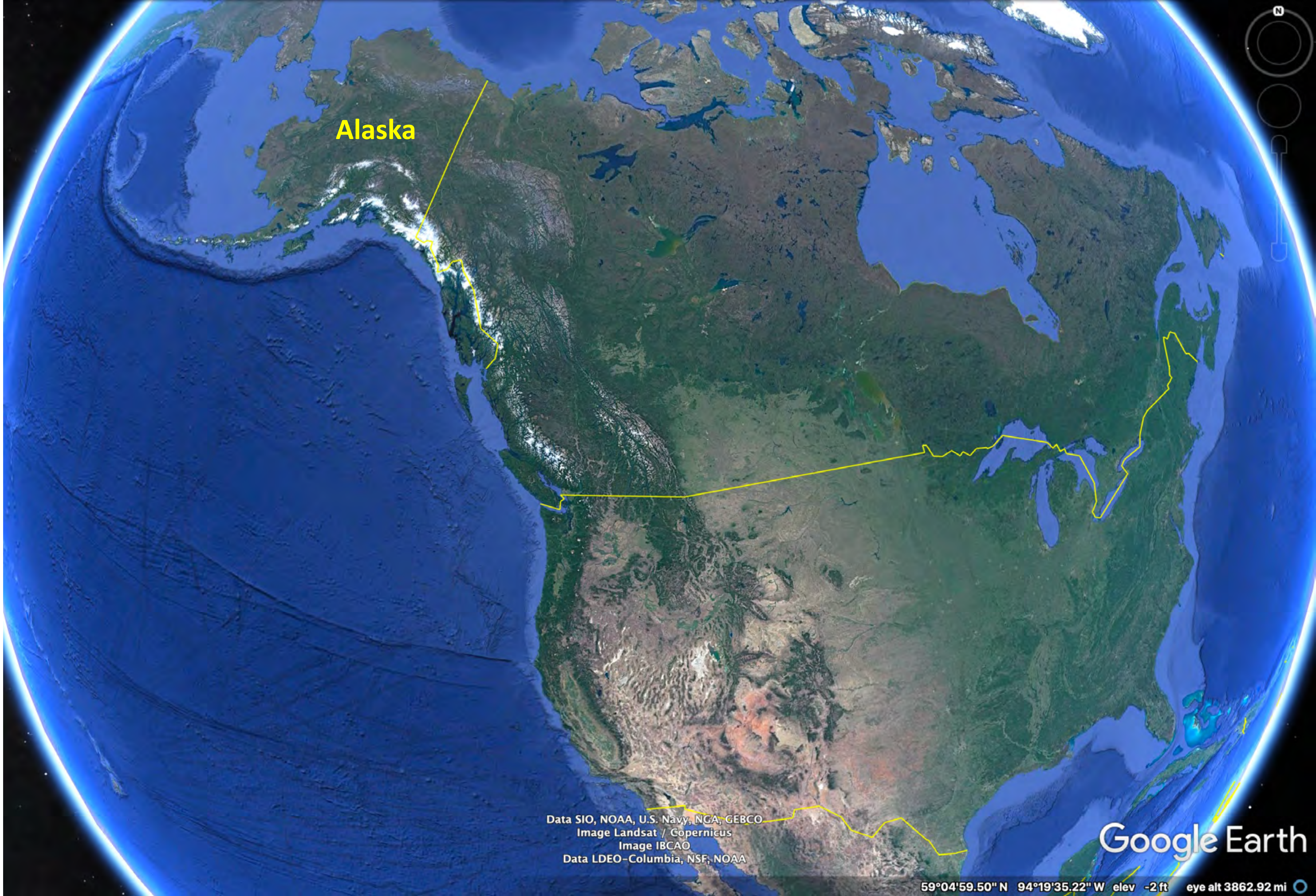
melissa.good@alaska.edu 907-486-1517

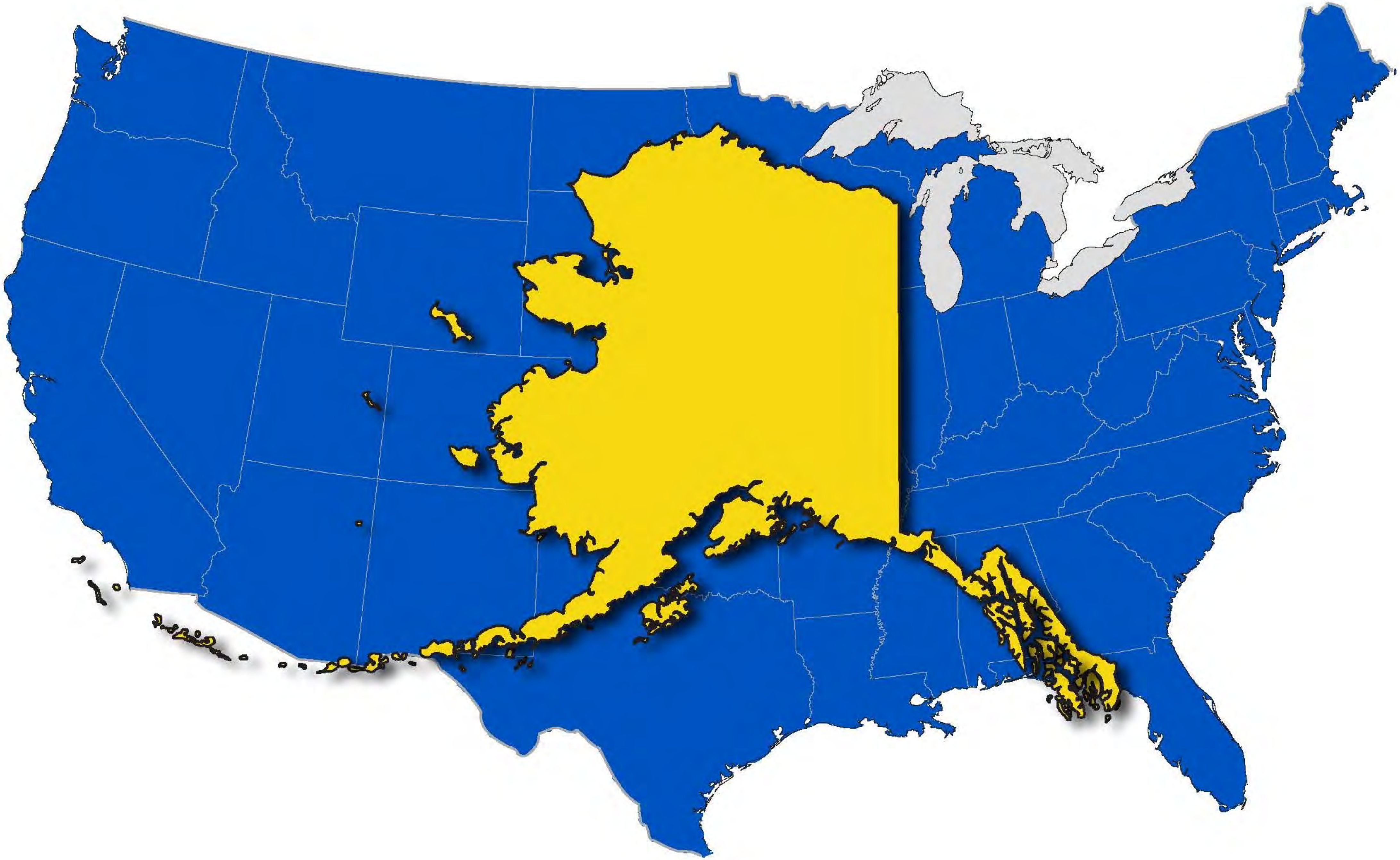
October 26, 2021



Agenda

- Setting the stage - Alaska
- Background – Aleutians East Borough
- Project Start
- Project Hurdles
- Continuing Forward





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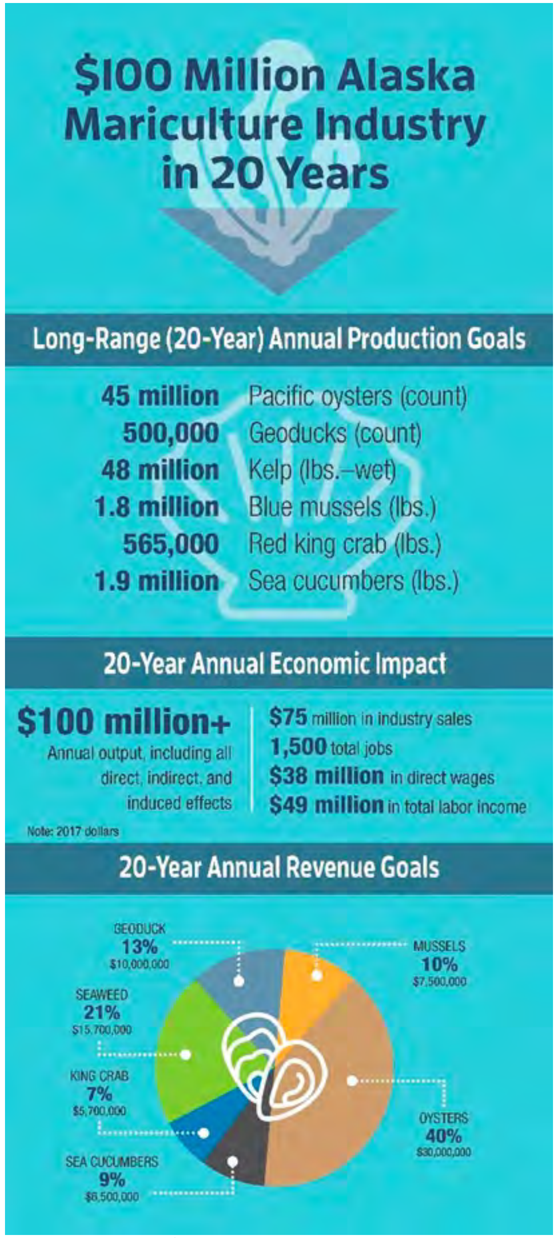

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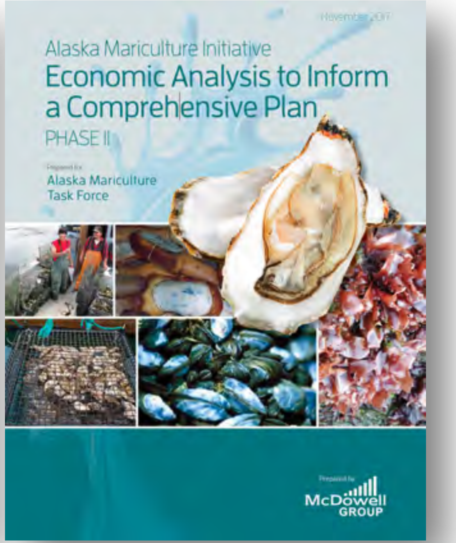
Available at: www.afdf.org

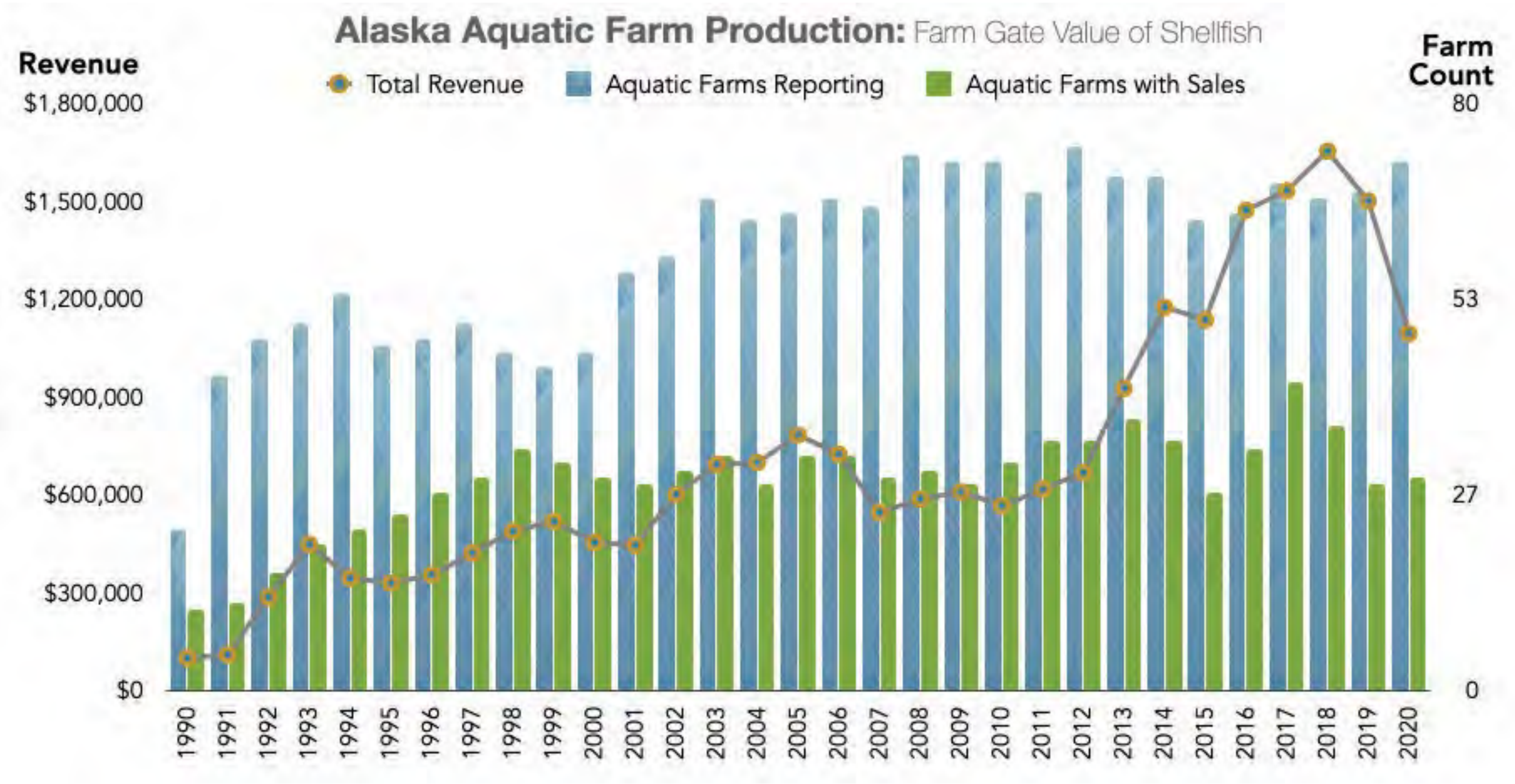
Goal: Grow a $100 million mariculture industry in 20 years.



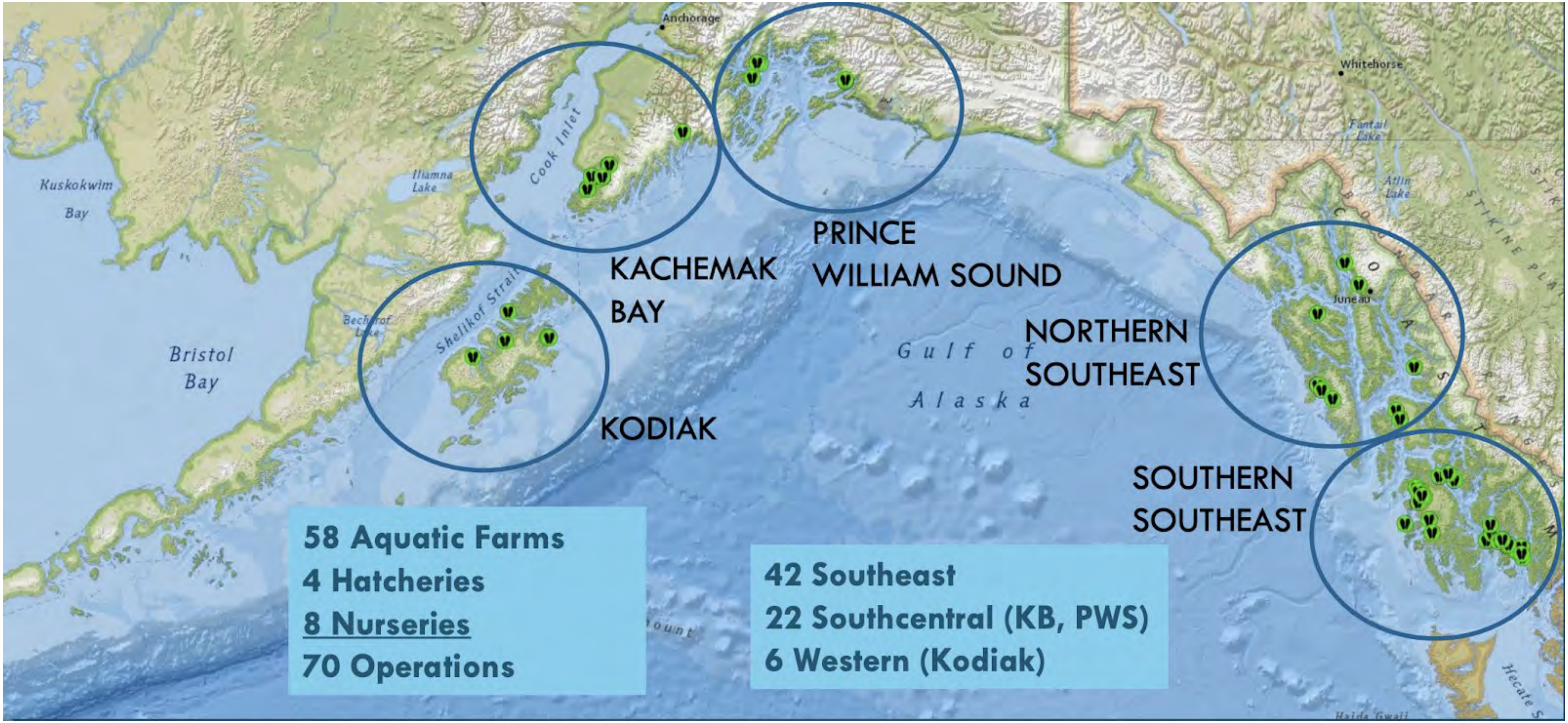
alaskaseagrant.org

Alaska Department of
Fish and Game

- 2020 Sales
  - 615,000 oysters (down from 1.3 million in 2019)
  - **225,000 lbs of seaweed** (up from 112,000 in 2020)
  - smaller amounts of other shellfish species
- Active permits of February 2021
  - 67 aquatic farms
  - 4 hatcheries
  - 6 nurseries
    - Pacific oysters, geoduck clams, bull kelp, ribbon kelp and sugar kelp
- New applications under review
  - 32 primarily seaweed and oysters



Currently permitted mariculture sites



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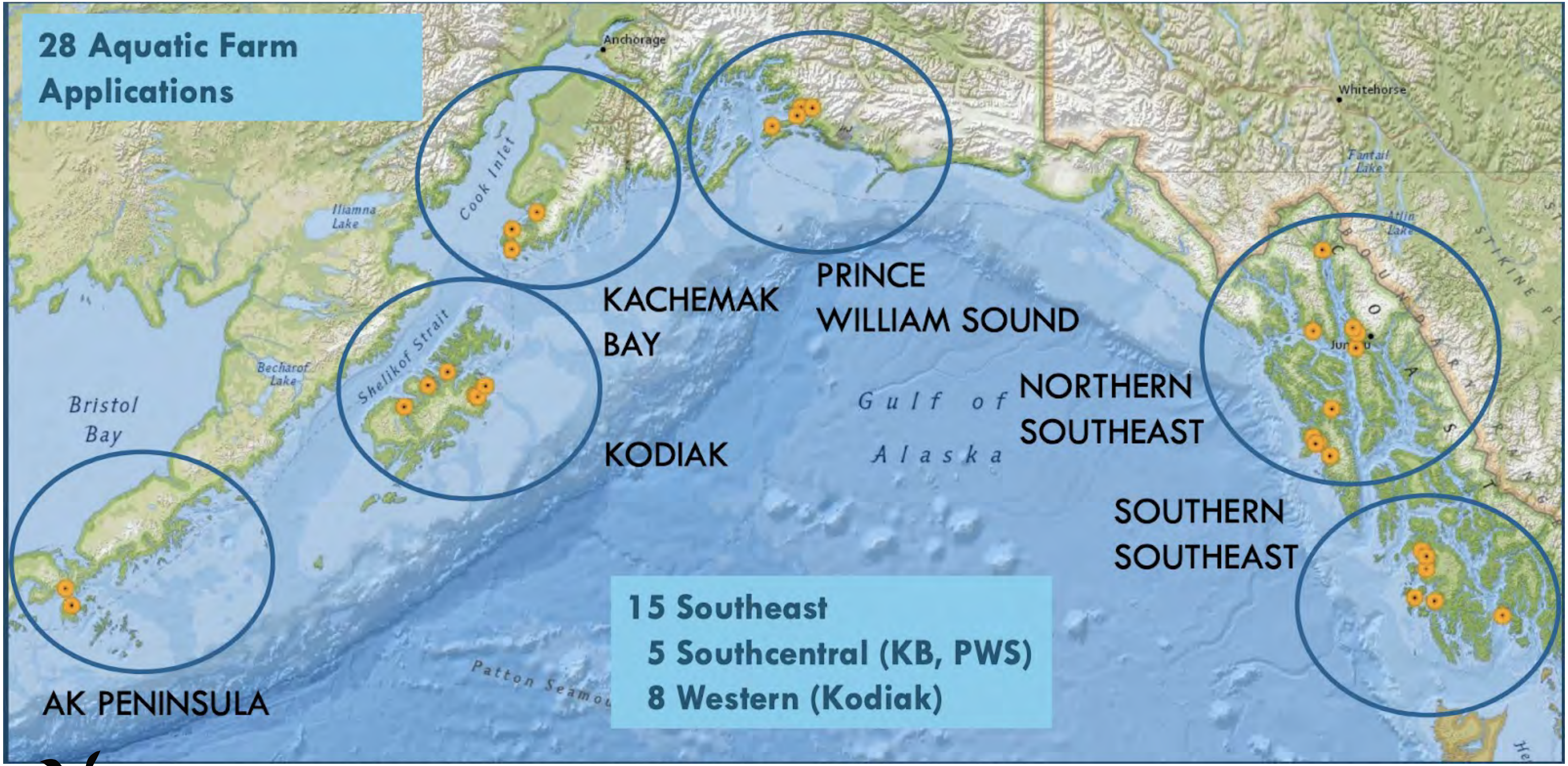
https://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/2020_af_permitted_op_status_report.pdf

Farm applications in review



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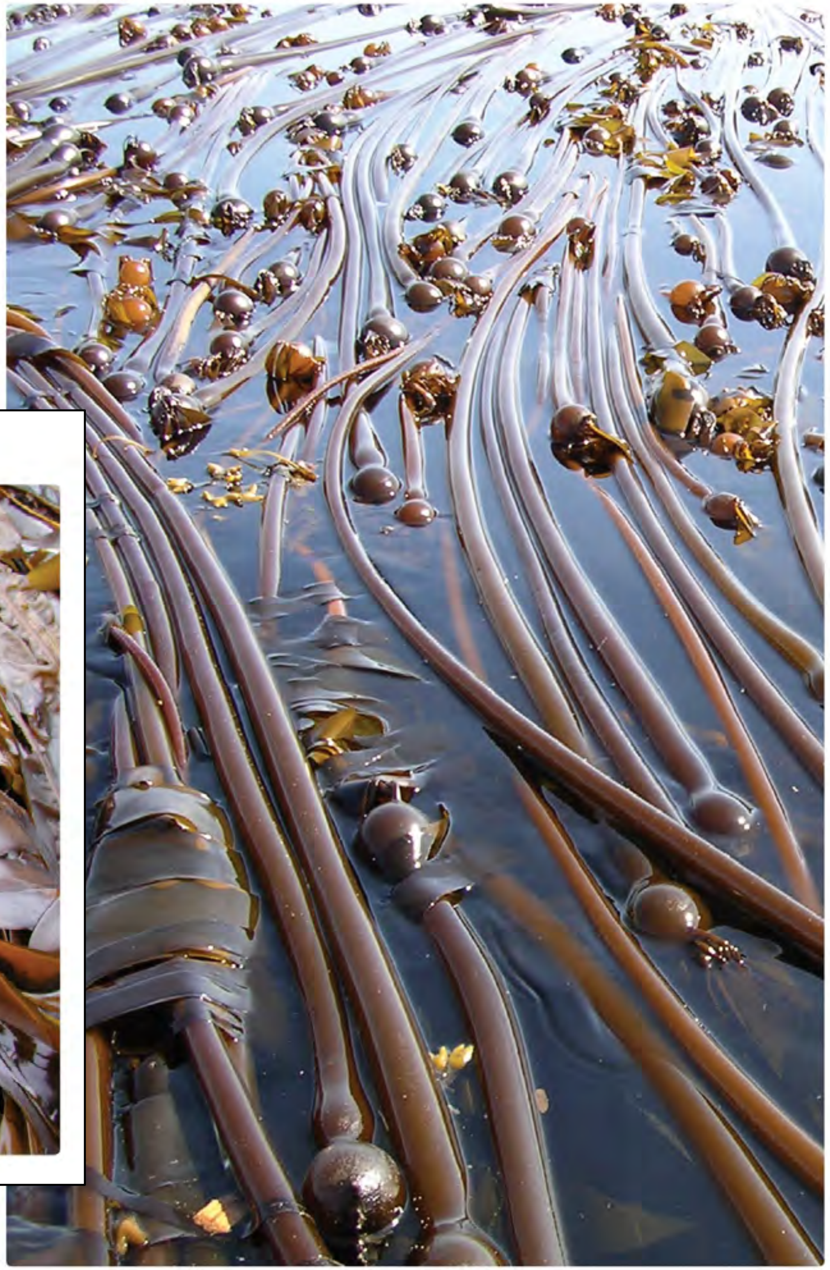
https://www.adfg.alaska.gov/static/fishing/PDFs/aquaticfarming/2020_af_permitted_op_status_report.pdf

Farmed Seaweeds in Alaska

Sugar kelp *Saccharina latissima*

Ribbon kelp *Alaria marginata*

Bull kelp *Nereocystis luetkeana*



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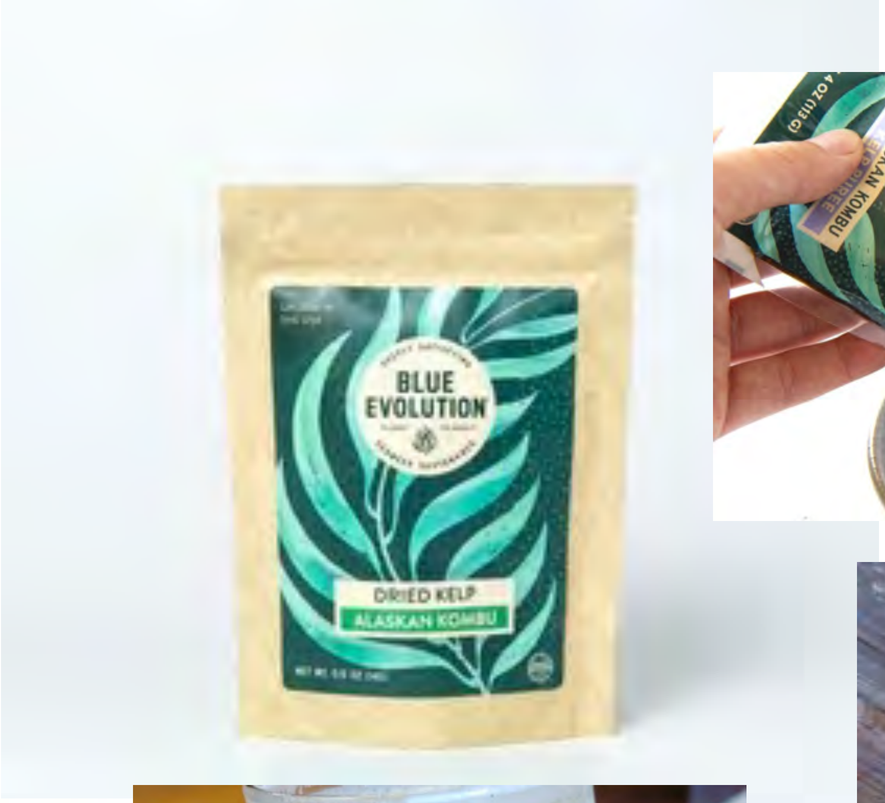
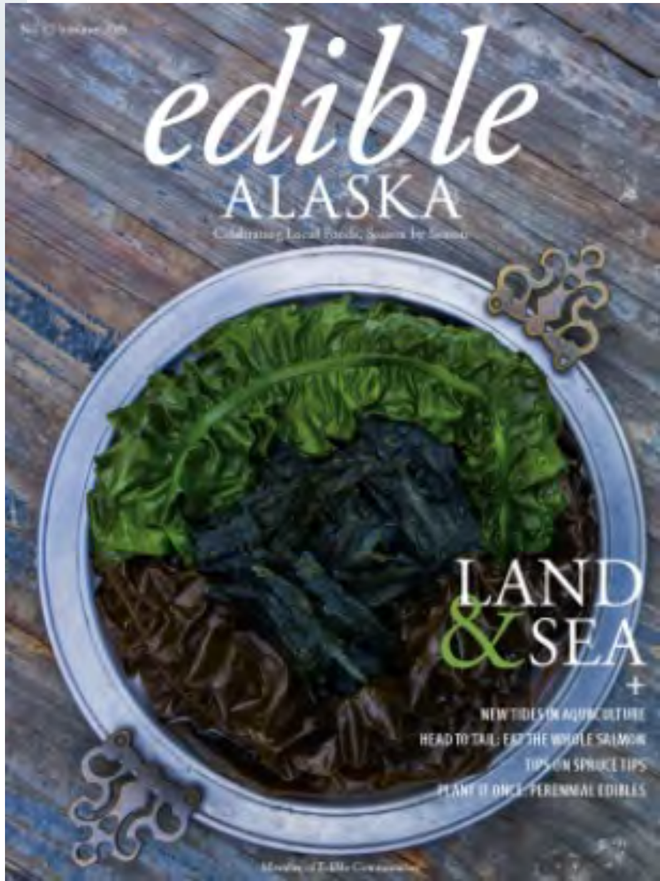
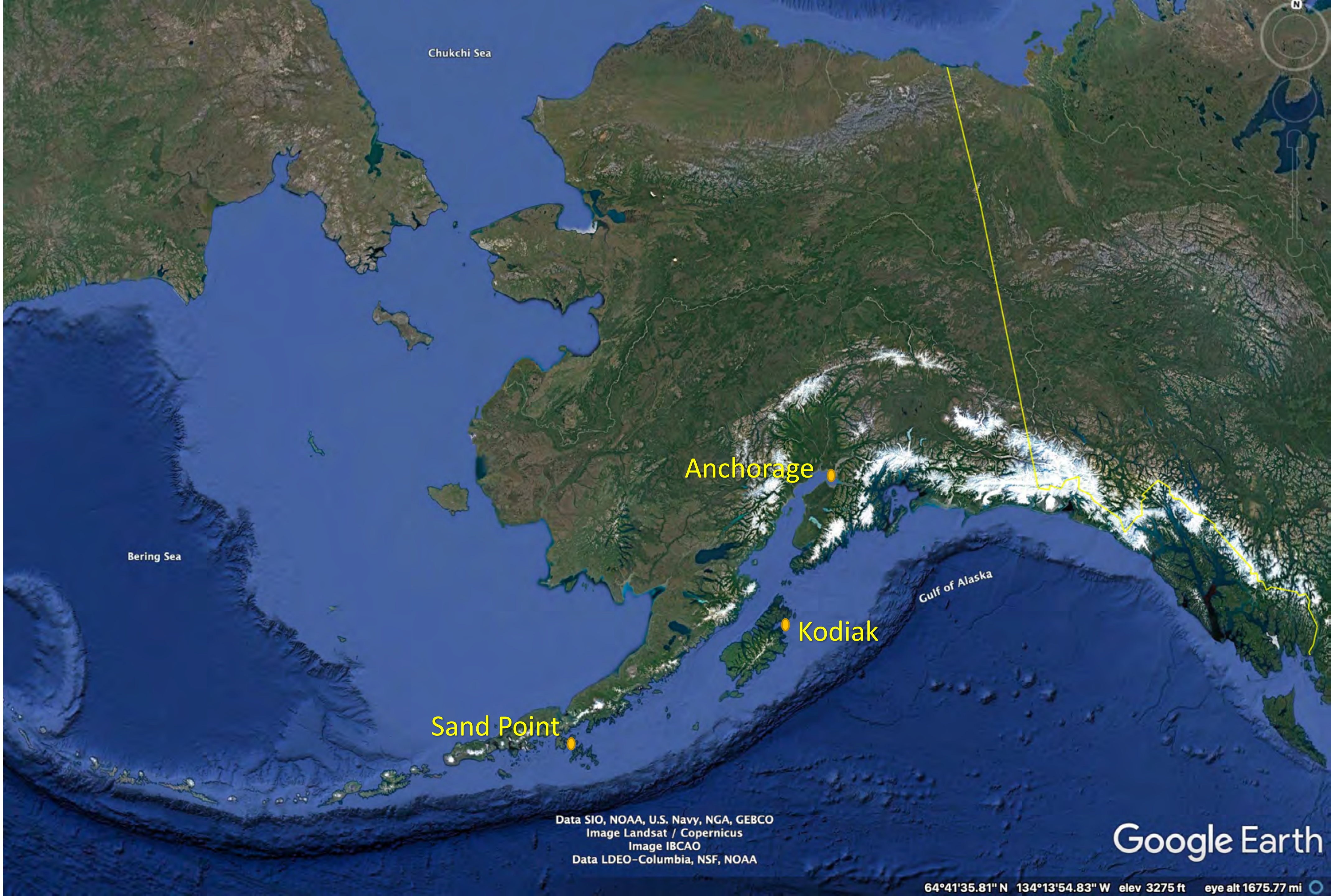




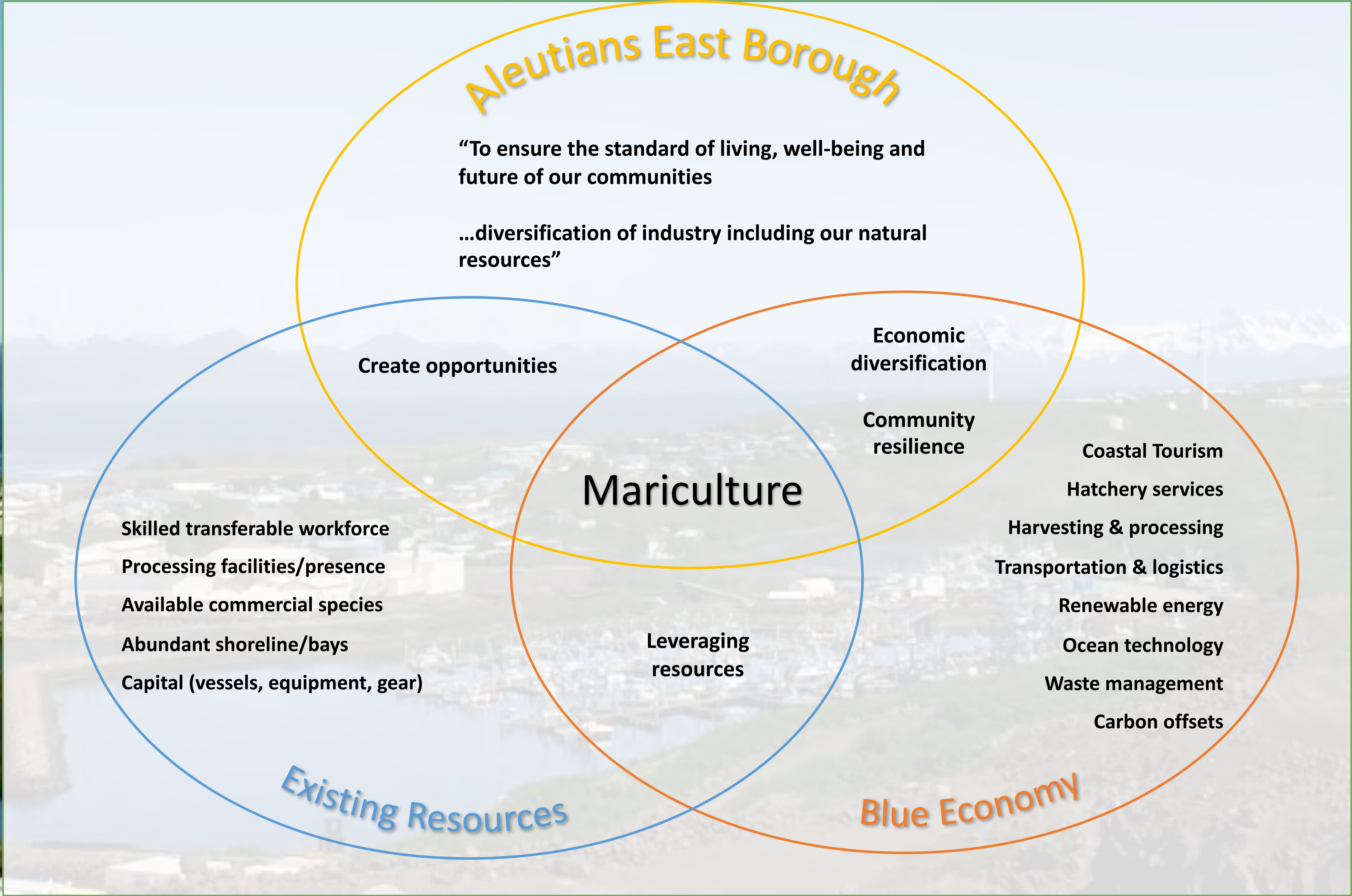
Sea Grant
Alaska

Aleutians East Borough (AEB)

- 560 miles from Anchorage
- 340 miles from closest established farm
- Extreme weather
  - 132 mph last week!
- Largest fishing port in the nation



Why?



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What is the Community-Based Model?



Feasibility

- Will it work in our region?
- Are other best practices transferable?
- If not, what do we need?

Building Capacity

- R & D
- Infrastructure
- Training

Collaboration

- Stakeholders
- Aleutians East Borough
- Regulatory agencies
- Processors

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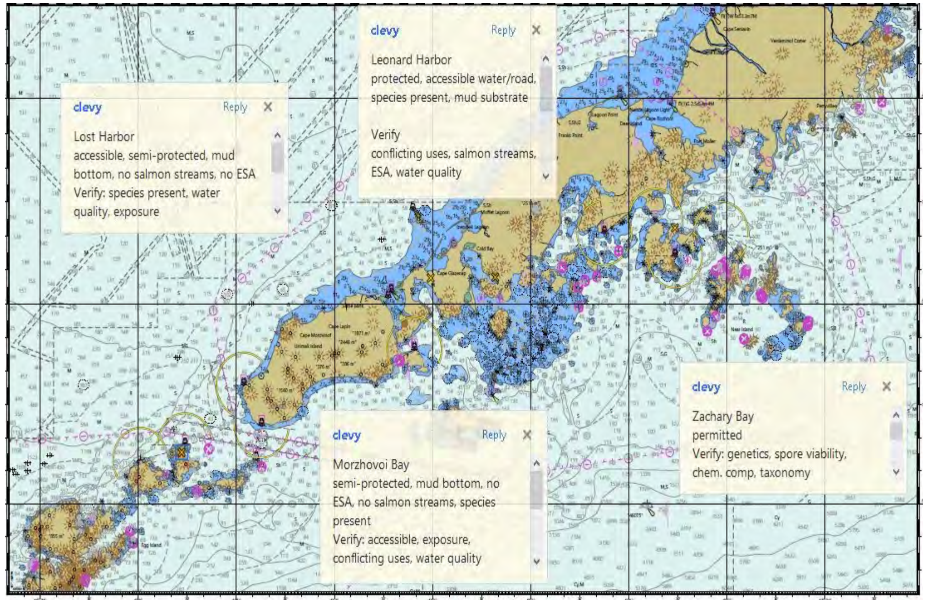
How: AEB Mariculture Projects

NFWF Project, Phase 1: Siting, permitting, planning



1. **Site suitability assessment in the AEB region**
   - e.g. biological, environmental, social, logistical
2. **Seed development**
   - What species are available? What species currently have a market and can be cultured? Is the local broodstock viable?
3. **Advance concepts > commercial operations**
   - Permitting = farm design, gear lists, operation plans
4. **Research cruise = baseline data**
   - Boat travel is more efficient than air travel
   - Short hold samples: In-field sampling using multiparameter meter
   - Variability: genetics, spore viability, chemical composition, taxonomy

Lessons Learned: Be flexible, be resourceful

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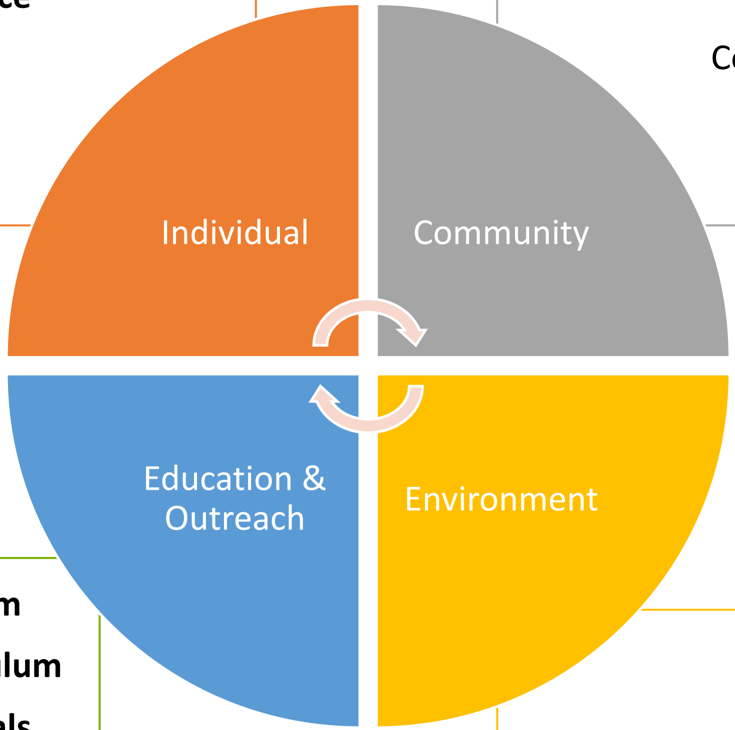
Overarching Goals

Access to regional data/guidance
Entrepreneurial opportunities
Job creation
Portfolio effect

Increased tax revenue
Community stability and resiliency
Keep people in community
Repurpose old unused gear



Hands-on demo/training farm
Student engagement/curriculum
Training and support materials
R&D

Carbon sequestration
Improved water quality
Create habitat

The Perfect Storm: Establishing a Pilot Farm in the Alaska Peninsula

Exploring New Aquaculture Opportunities - 2019, NOAA-OAR-SG-2019-2005960

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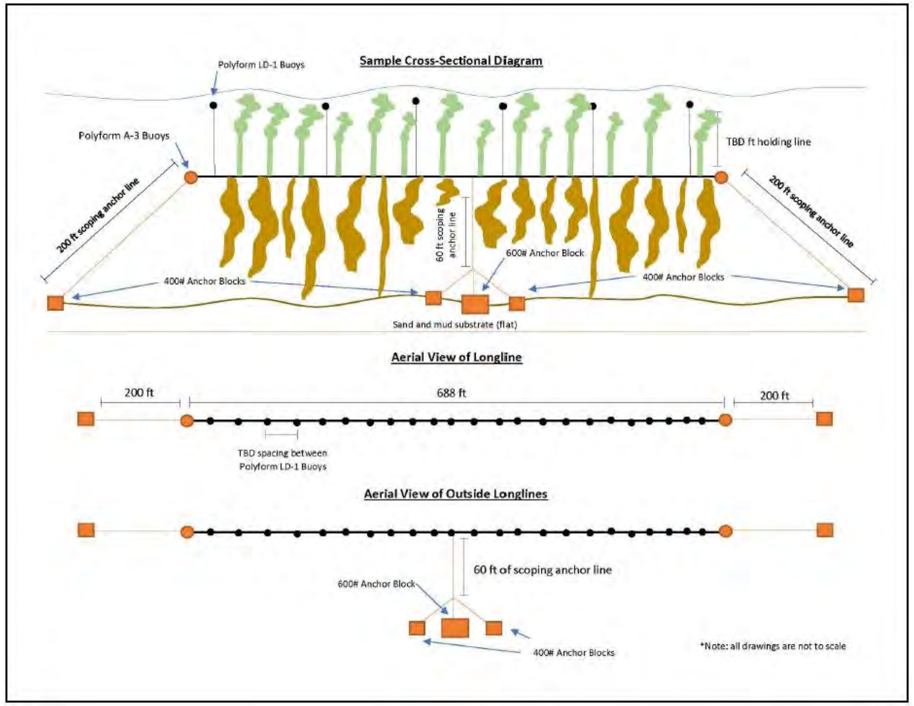
AEB Mariculture Projects

Alaska Sea Grant Project, Phase 2: Pilot Farm in Sand Point

1. **Construct/operate a pilot farm near Sand Point**
   - Gear list
   - Farm design
   - Monitoring protocols
2. **Training and outreach**
   - Hands on training
   - Student curriculum
   - Community presentations
3. **Research**
   - Monitor environmental conditions (e.g. nutrients, temp, salinity, pH)
   - Monitor production parameters (e.g. yield, growth rate, survival)
   - Test multispecies farm configuration



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1. Develop standardized monitoring protocols tool (Yr 1)

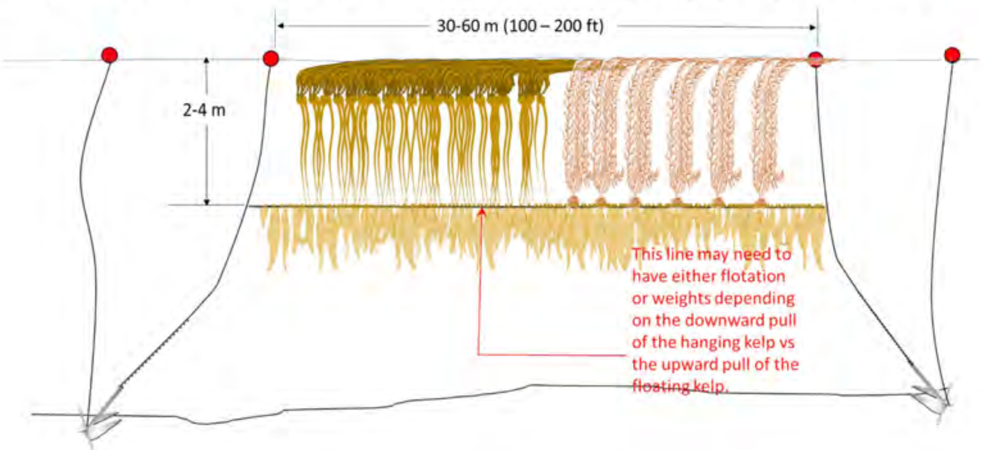
- Develop standardized monitoring protocols: monitoring metrics

Purpose	Metric
To monitor and assess environmental conditions, compare to other sites	pH Temperature Salinity Nutrients (N+P) CO_2 Dissolved Oxygen
To monitor production parameters that contributes to improved economic planning	Yield/ft Survival Growth (biomass, length)

Longline Diagram and Sample Protocol for Sand Point Kelp Project

Submitted by Mike Stekoll
May 18, 2020

Diagram of a combined longline with floating and non-floating (hanging) kelps on the same line:



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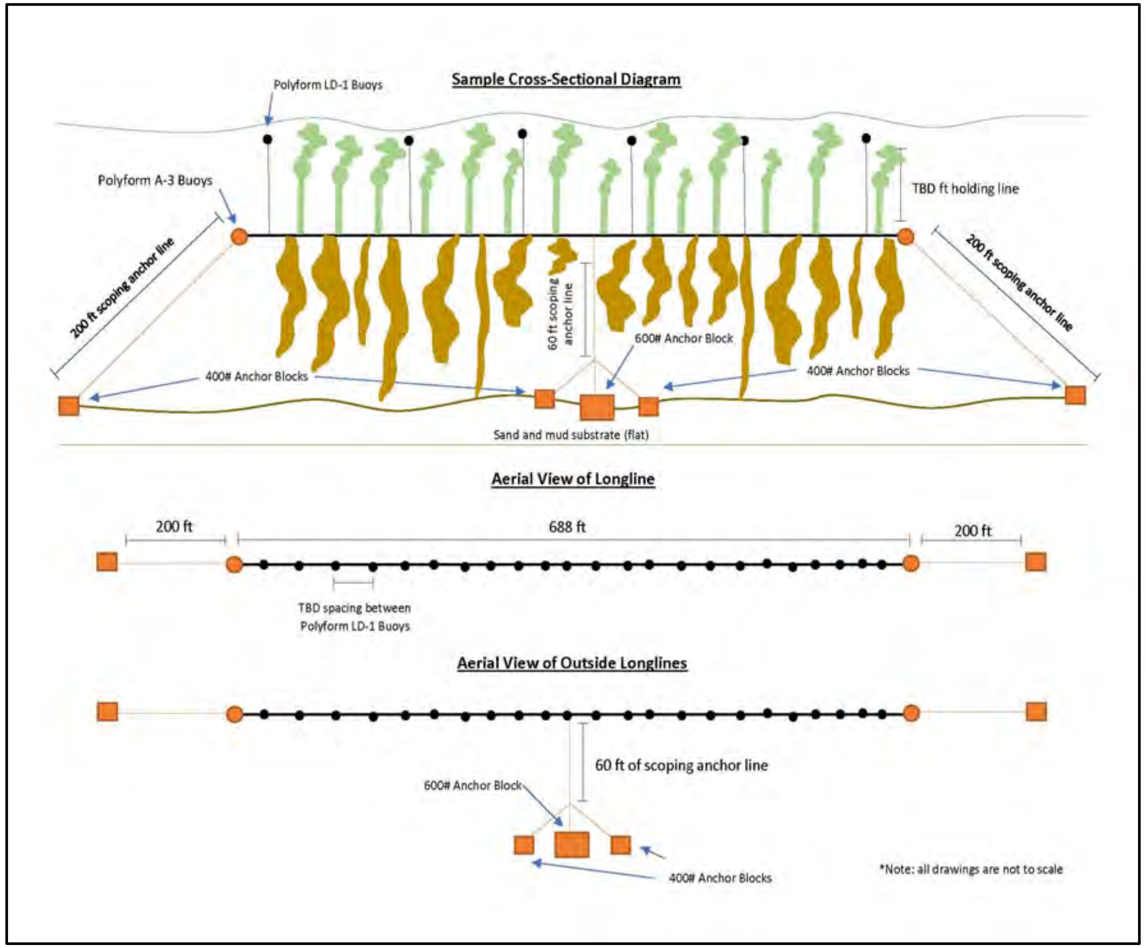
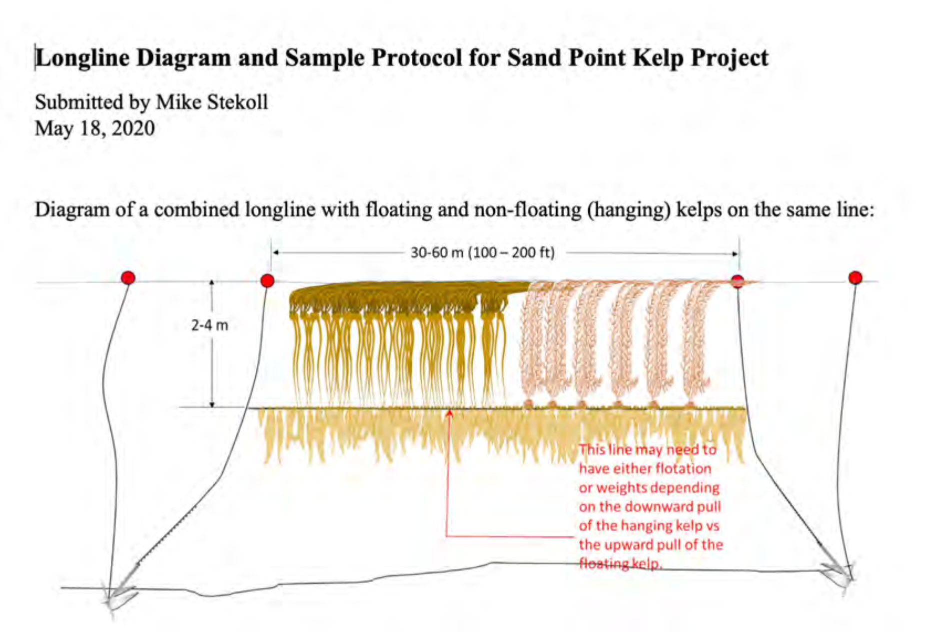
1. Design and assess an innovative multi-species farm configuration (Yr 1&2)

- Design and implement multi-species farm configuration study





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2. Develop workforce through training and student outreach (Yr 1, 2)

- Community Outreach Presentations
- Develop Student Curriculum
- Seaweed Farm Training Workshop

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2. Develop workforce through training and student outreach (Yr 1)

- 2019: Community Outreach Presentations
  - Crash causes nearly all commercial flights to the Alaska Peninsula and Aleutian Islands for 1.5 years.
  - Virtual Presentations: 50 people reached


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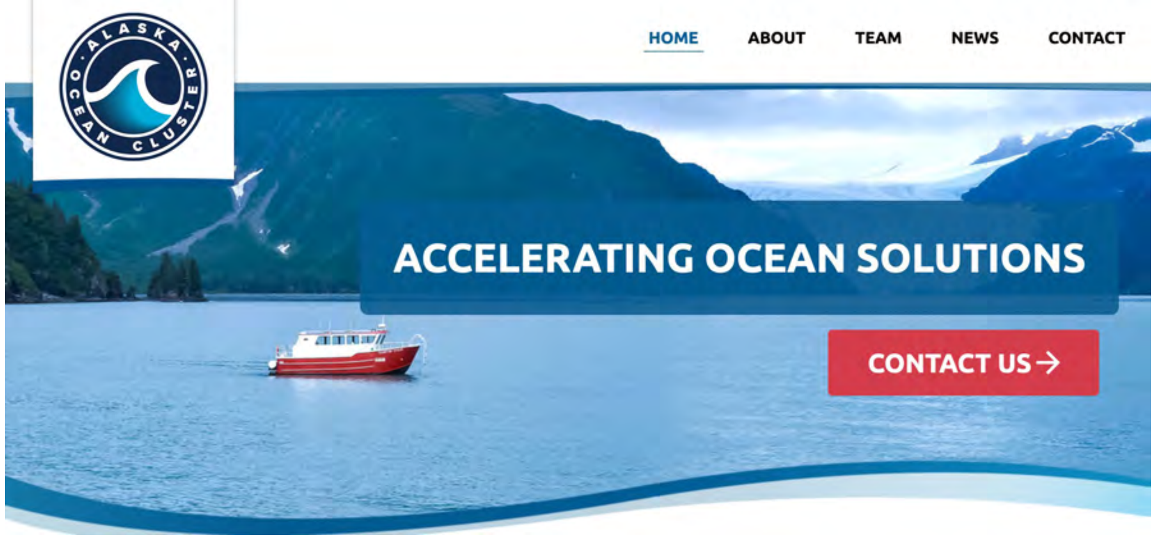
NTSB investigation into fatal Unalaska plane crash reveals mechanical problem

By Zoë Sobel, Alaska's Energy Desk - Unalaska - December 18, 2020

A crane hoists a PenAir Saab 2000 airplane on Oct. 18, 2019. One person was killed and multiple peo… the plane went off the runway while attempting to land the evening before. (Laura Kraegel/KUCB)



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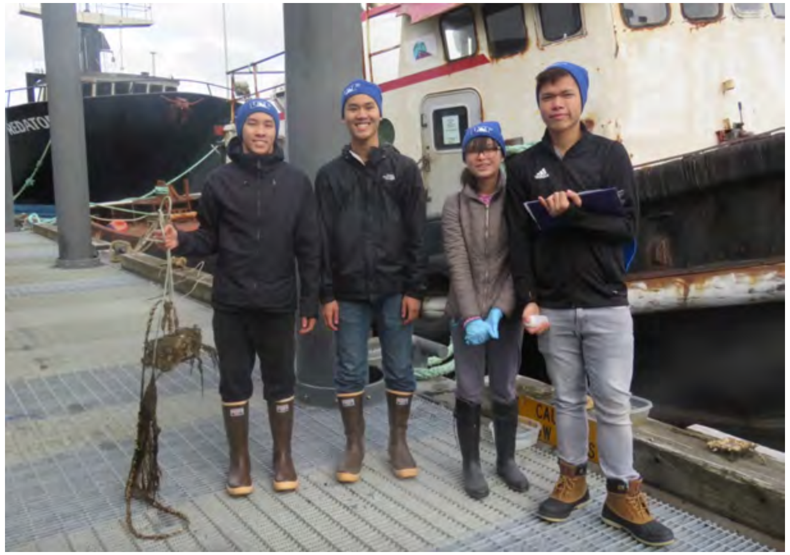
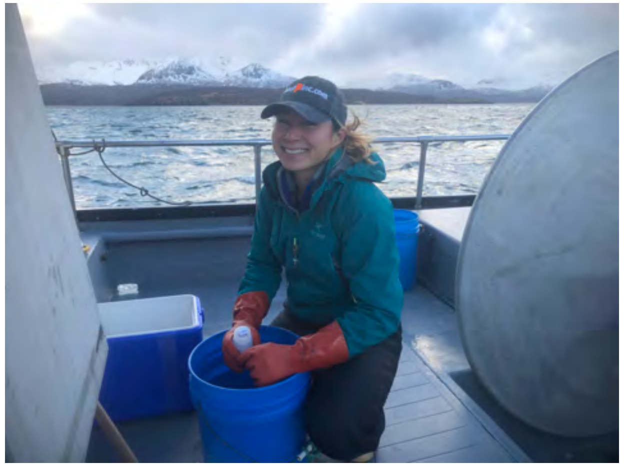
2. Develop workforce through training and student outreach (Yr 1)

- Develop student curriculum
  - Started with some hands on activities and compiling ideas.
- ON HOLD DUE TO COVID-19





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2. Develop workforce through training and student outreach (Yr 1)

- **Seaweed Farm Training**
  - Introductory Training Webinar
    - Yr 1: 48 attendees (statewide)
    - Yr 2: 300 attendees (statewide)
  - Hands-on Workshops
    - Yr 1: 16 per workshop in Ketchikan, Sitka & Kodiak
    - Yr 2: 150 statewide due to COVID-19 (virtual)
      - ~~Training in Sand Point~~
- ***Topics covered:*** *identification of seaweed species, lifecycles of seaweed, the hatchery process, site selection, use of the Mariculture Map, farm gear and equipment, business plan development, farm loans available, state lease application process, gear deployment, seeding and harvesting techniques, quality handling, and safety considerations.*

Alaska Longline Fishermen's Association

OceansAlaska Marine Science Center & Shellfish Hatchery

Blue Evolution

Sea Grant Alaska

GreenWave

AFDF Alaska Fisheries Development Foundation, Inc.

Akutan • Cold Bay • Nelson Lagoon Aleutians East Borough False Pass • King Cove • Sand Point

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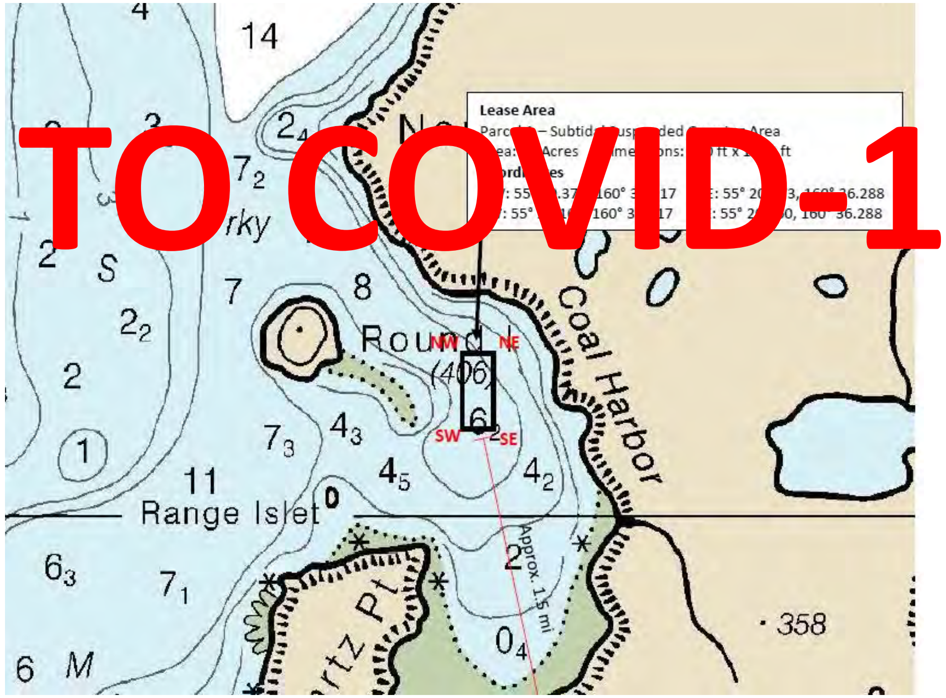
3. Construct and assess multi-species farm configuration (Yr 1&2)

- Construct and Operate a Pilot Seaweed Farm
- Environmental Monitoring
- Production/Yield Assessment

DELAYED DUE TO COVID-19



Species Intended

- Sugar Kelp (*Saccharina latissima*)
- Bull Kelp (*Nereocystis luetkeana*)
- Winged Kelp (*Alaria marginata*)
- Giant Kelp (*Macrocystis sp.*)

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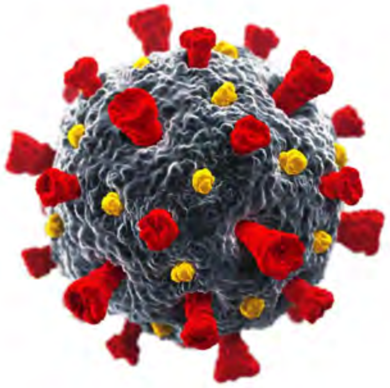
Timeline of farm implementation and trial.

What is on hold:

- Farm site construction
- Sand Point Training
- Curriculum Development
- Regional Data
- Harvested seaweed offered to local community members and regional processing plants for product development.



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What is the plan?

- Community, community, community
- Work closely with school to finalize curriculum development
- Travel to Sand Point
  - In-school teacher training and curriculum implementation
  - Hands-on training for Sand Point residents
- No cost extension ☹
  - Build farm fall 2022
  - 2022-2023 implement monitoring plan
- Training farm and regionally specific farm site data available ☺

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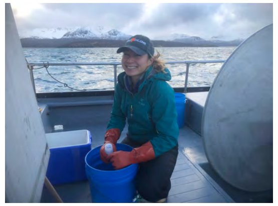
Questions?



Contact: Melissa Good
Alaska Sea Grant Marine Advisory Program
melissa.good@alaska.edu
907-486-1517

ENAO-Nanobubble oxygenation of recirculating aquaculture systems to increase fish production-WISG

C. Hartleb, S. Israni, G. Fischer,
E. Wiermaa, A. Cheng, J. Hurley

Nanobubble Oxygenation of Recirculating Aquaculture Systems to Increase Fish Production

Chris Hartleb, Greg Fischer, Kendall Holmes, Emma Wiermaa
University of Wisconsin-Stevens Point
Northern Aquaculture Demonstration Facility

Sameer Israni, Alan Cheng
Praxair Inc, part of the Linde Group

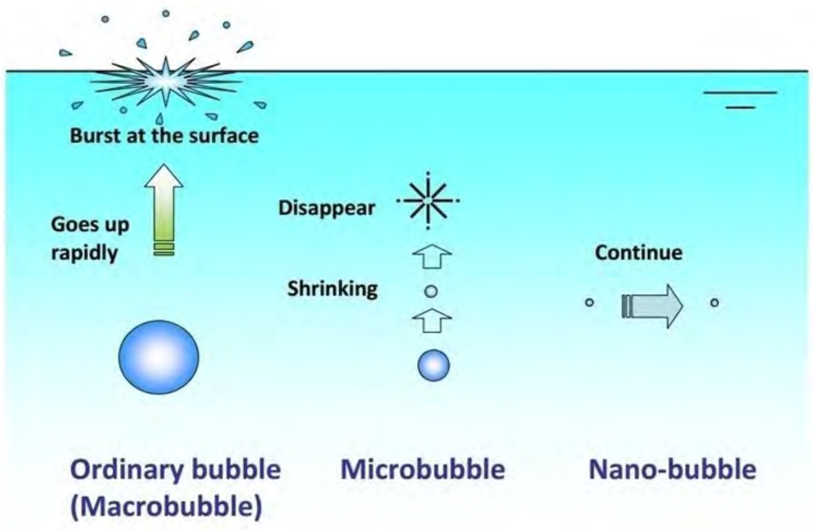
Source: https://www.walpa.org/waterline/december-2020/small-bubbles-big-impact-nanobubbles-for-effective-deep-water-oxygenation-and-algae-control/

Nanobubbles

- Dissolved oxygen is the most critical factor determining stocking density and production yield of fish in RAS.
- Traditional aeration (diffusers) are limited by temperature, salinity, and altitude on oxygen solubility.
- Devices created to overcome limitations include U-tubes, packed columns, low-head oxygenators and Speece cones plus other gas transfer devices; including pure oxygen.
  - Still have a ceiling as to how high they can go.

Nanobubble Characteristics

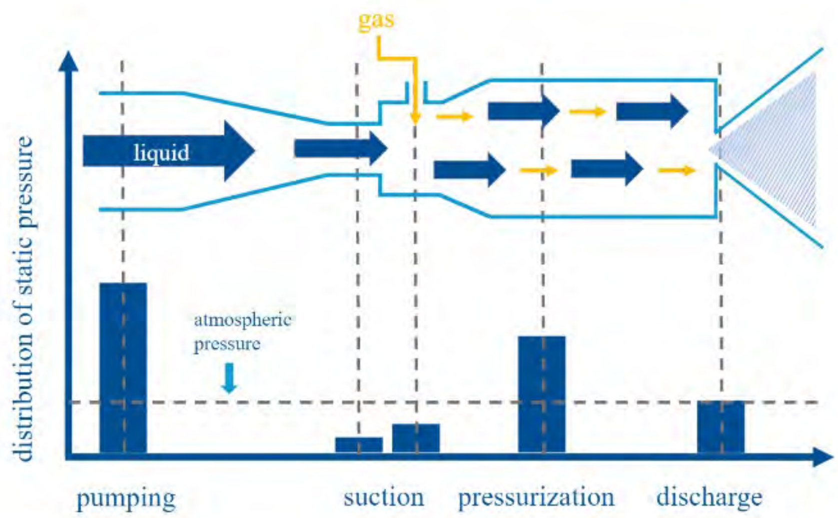
- Nanobubbles are stable for a long time.
- Shrink and disappear due to dissolution of gasses.
- Follow Brownian motion (zig-zag)
  - Homogenous distribution in tank
- Neutral buoyancy and negative surface charge keeps them in suspension at saturation.
  - Oxygen reserve
- When nanobubbles collapse, free radicals are generated, improving collusion efficiency.



Source: https://www.azonano.com/article.aspx?ArticleID=4444

Nanobubble Generator

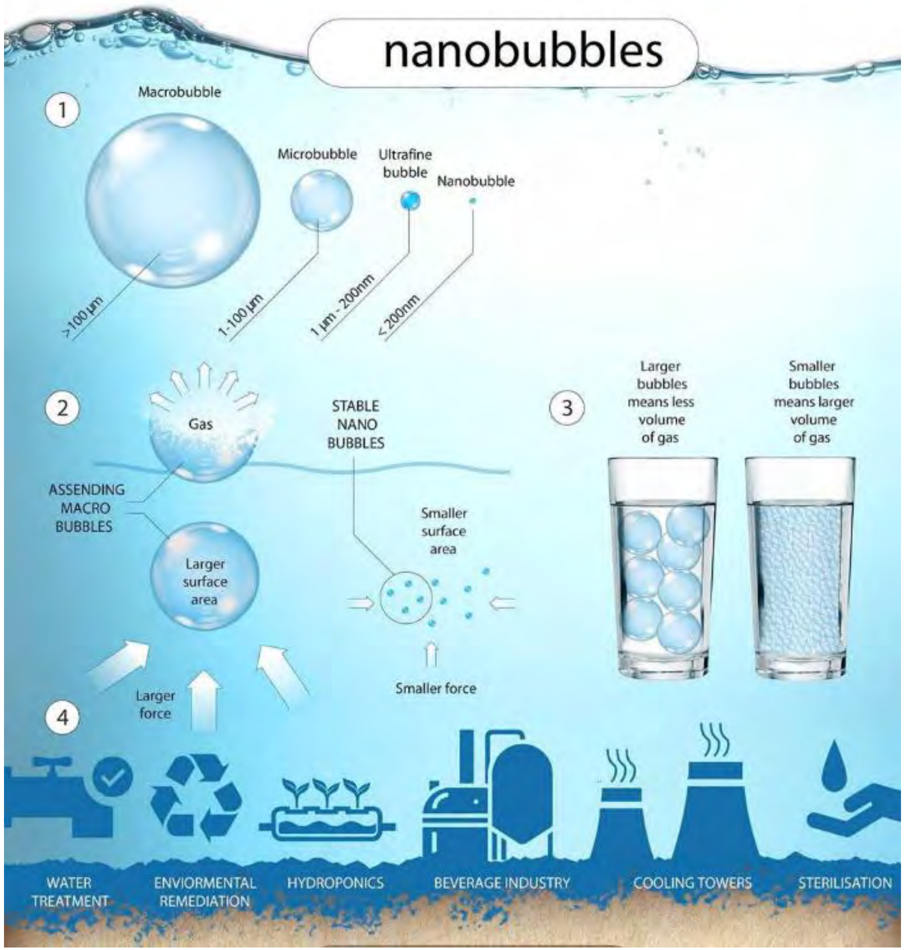
- Gas injection with turbulent static mixing to create bubbles <200 nm
- Produces hydroxyl radicals that can:
  - Destroy pathogens
  - Eliminate algae
  - Reduce off-flavor
  - Degrade water contaminants
- Adhere to colloidal particles making filtration more effective



Source: https://www.acniti.com/technology/ultrafine-bubble-generation/

Nanobubble Application

- Oxygen bubbles are unstable.
- Large force (surface tension) on larger bubble = burst
- Smaller the bubble the greater the solubility of gas (Laplace pressure) & the larger the volume of oxygen.
  - Fish are calm
  - Improved feed conversion
  - Faster growth rate potential
  - Lower mortality potential

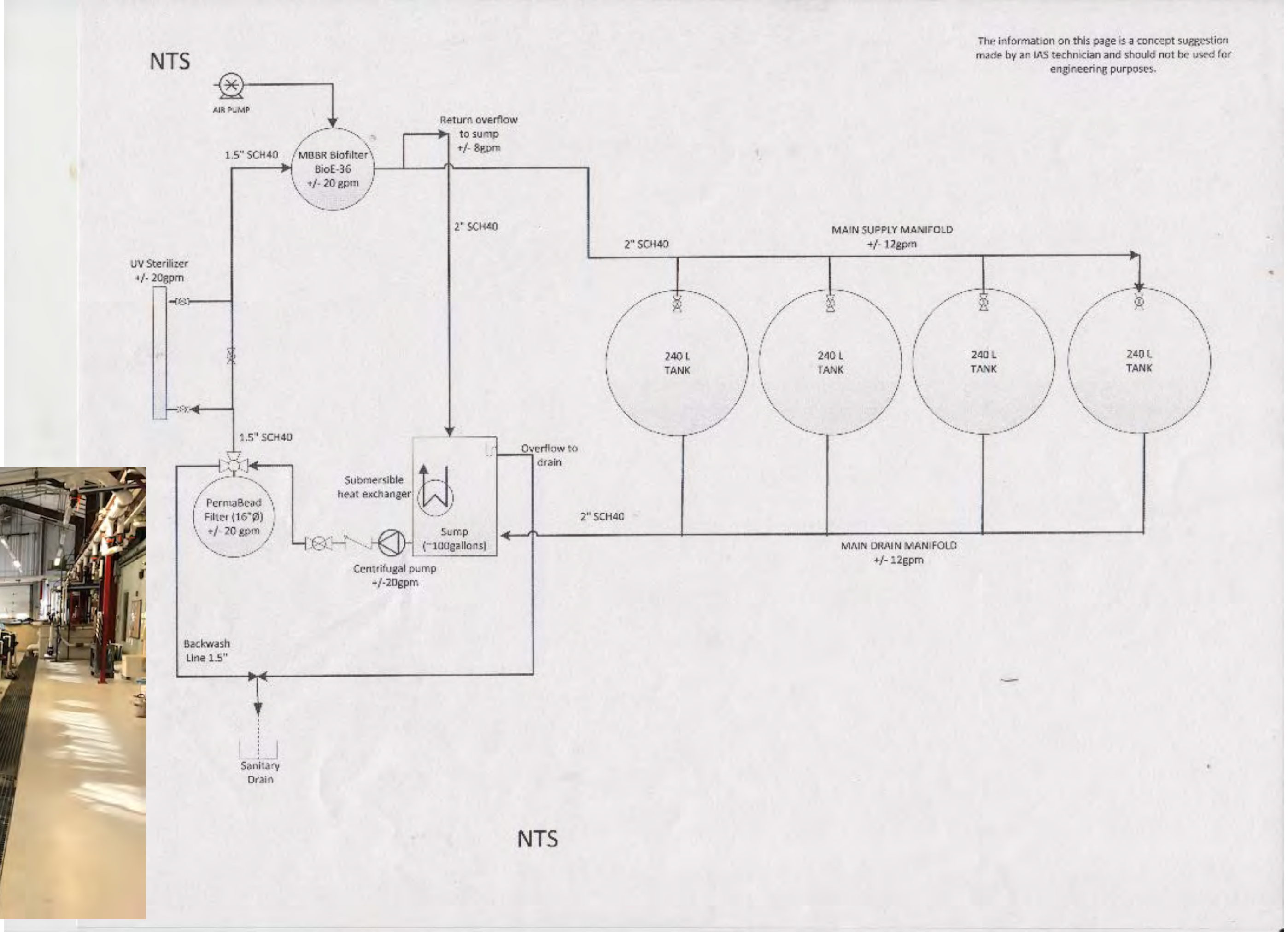


Source: https://phys.org/news/2020-04-method-nanobubbles.html

Objectives

- Compare traditional oxygen delivery using diffusers and Speece cones with nanobubble delivery.
  - Comparisons at same DO in each system to separate DO effect from nanobubble effect
- Document differences in amount of oxygen required and overall power required to maintain same DO level.
- Characterize nanobubbles to better understand their chemistry.
- Determine cost-benefit.

RAS Schematic



Atlantic Salmon
Salmo salar

- Coldwater fish
  - Optimum 12-13°C
  - pH = 7.6
  - CO_2 under 12 mg/L
  - 24-hour lighting (50-200 lux); seasonal daylength
  - DO range 9-11 mg/L; held constant
  - Flow rate: 3 water exchanges per hour (R)
  - TDG <103%
  - Alkalinity 80-100 mg/L
  - Ammonia <2.0 mg/L, nitrite <1.0 mg/L

Walleye
Sander vitreus

- Coolwater fish
  - Optimum 22-23°C
  - pH = 7.6
  - CO_2 under 12 mg/L
  - 24-hour, in-tank, dim lighting (<10 lux); seasonal daylength
  - DO range 9-11 mg/L
  - Flow rate 3 water exchanges per hour (R)
  - TDG <102%
  - Alkalinity 80-100 mg/L
  - Ammonia <1.0 mg/L, nitrite <1.0 mg/L

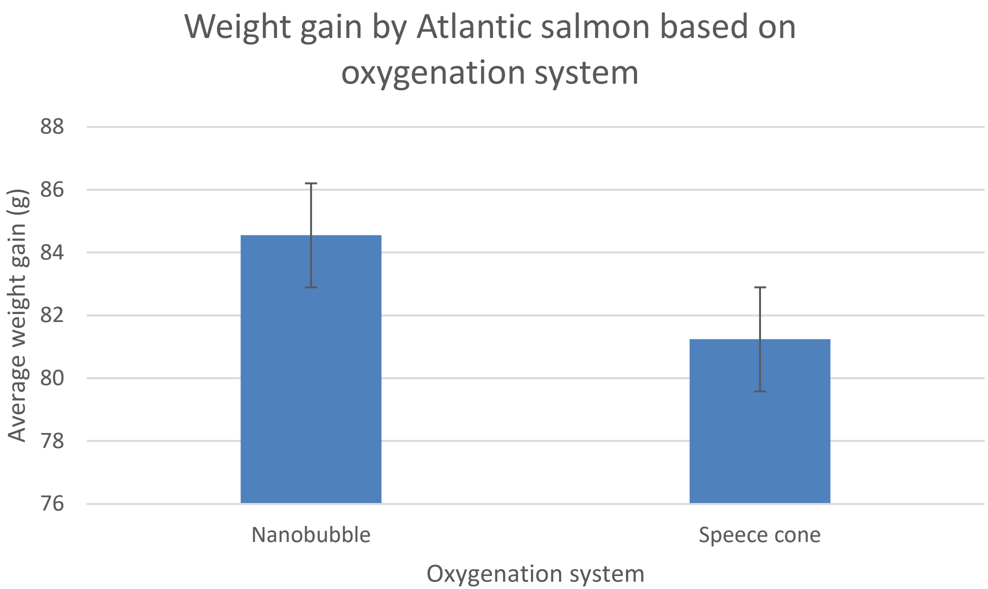
Variables

- Oxygen transfer efficiency
- Equipment characterization
- Stocking density (20 kg/m^3; 50 fish per 240 L tank)
- 100-day grow out
- Feeding frequency 3x daily, to satiation (BioOregon Biovita)
- Presence, size distribution, and concentration of nanobubbles
- Water temperature
- Length & Weight
- Mortality (two systems lost most fish to base jumping)
- Health index
- Cost to add/operate nanobubbles

SOLVOX® F cabinet for the operation of two SOLVOX® C cones

Results

- Slightly greater average weight gain but not statistically significantly greater for nanobubble compared to Speece cone ($p=0.26$).
- No difference in length gain.
- No mortalities
- Health index



Results

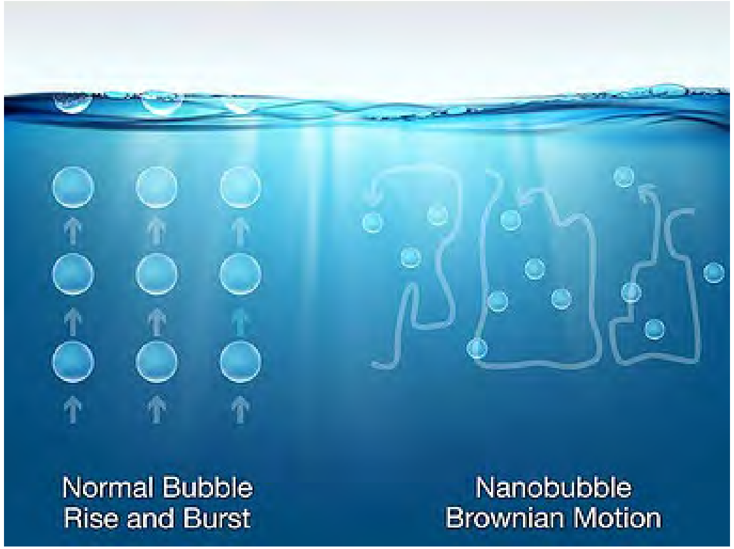
	Nanobubble	Speece cone	*p*
Duration (s)	396 ± 15	397 ± 38	*0.982*
Interval (s)	3236 ± 84	4879 ± 231	*0.021*

- When DO delivery was turned on, time to oxygenate nanobubble and Speece cone systems to set level of 9-11 mg/L did not differ significantly.
- Once DO delivery was off, time for each system to drop below lowest set level did differ significantly.

Results?

Yet to Come

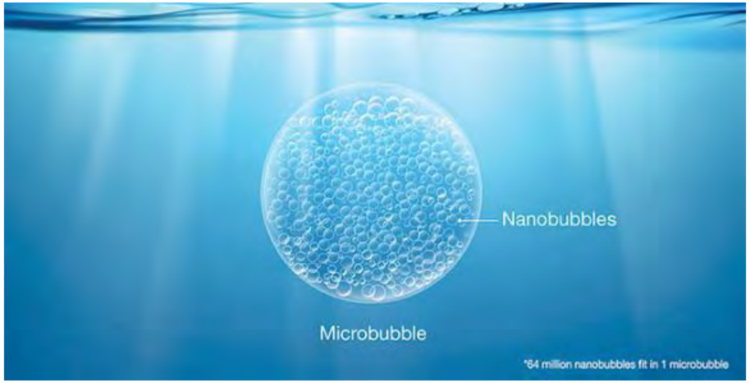
- No aeration to biofilter
  - Initial observation of CO_2 buildup
- Reduce turbulence throughout system
- Run walleye trials (Coolwater)
- Run diffuser trials
- Set DO level at 'skies the limit'
  - Gas bubble disease
  - Actual optimum setting may be somewhere in between.



Source: https://www.nanobubblesystems.com/nanobubbles

Conclusions & Questions

- Nanobubble systems had greater water surface area exposed to atmosphere.
  - Head tank
- Turbulence in nanobubble system.
  - Pump, sand filter, aerated biofilter (CO_2 off-gas)
  - May need RAS designed for nanobubbles
- Nanobubble characterization
- Cost-benefit analysis



Source: https://www.hatcheryinternational.com/new-study-reinforces-efficacy-of-nanobubble-technology/

ENAO-Culture of Native Bivalve Species to Expand Mariculture Opportunities and Improve Coastal Environments-HISG

M. Haws, D. Lerner, R. Chander-`Iao,
K. Warfield, T. Grabowski, D. Okimoto

Culture of Native Bivalve Species to Expand Mariculture Opportunities and Improve Coastal Environments

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Waiwai Ola Waterkeepers Hawaiian Islands

Shadd Keahi Warfield
Revealing Individual Strenghts for Excellence (RISE)

Tim Grabowski
USGS Fisheries Cooperative Studies Unit

Darren Lerner & Darren Okimoto
University of Hawaiʻi Sea Grant Program

Background & Rationale

Availability of native, high-value bivalve species supports:

- New opportunities for Hawai‘i’s aquafarmers
- Diversification
- Restorative aquaculture
- Species restoration
- Cultural aspects
- Community engagement
- Education (all levels)

Hualalai Four Season Resort Oyster Farm   Source: West Hawaii Today

Shellfish are Important!

- Shellfish farming started in 2010 after a lengthy campaign to overcome legal obstacles
- Bivalves account for 16% of the ~1,000 marine molluscan species- many species now rare
- Few ecological studies for native species
- High potential due to:
  - Clean water
  - Large bivalve hatcheries (4)
  - High local demand
  - 69 million visitor days/year
- New opportunities arise from mainland problems and local needs


He`eia oysters

Shellfish Farming Started in 2010 in Hawaiian Fishponds (impeded by water quality)

Keawanui, Molokai

He‘eia, O‘ahu

Thanks to support from UH Sea Grant Program, CTSA and commercial producers

Current status of bivalve culture in Hawai‘i

5 shellfish hatcheries on Hawai‘i Island
-These hatcheries provide ~50-80% of the shellfish seed used on the West Coast

4 commerical producers (2 more in process)

6 Hawaiian fishponds groups with experience

7 restorative aquaculture sites

Pacific Oysters (*Crassostrea gigas*) are the main commercial species

Hawaiian Oysters (*Dendostrea sandvicensis*) mostly for restorative aquaculture but have commercial potential

Pacific Aquaculture and Coastal Resources Center (PACRC)
University of Hawaiʻi Hilo

UHH offers the only 4-year academic aquaculture program (specilization) in Hawaiʻi

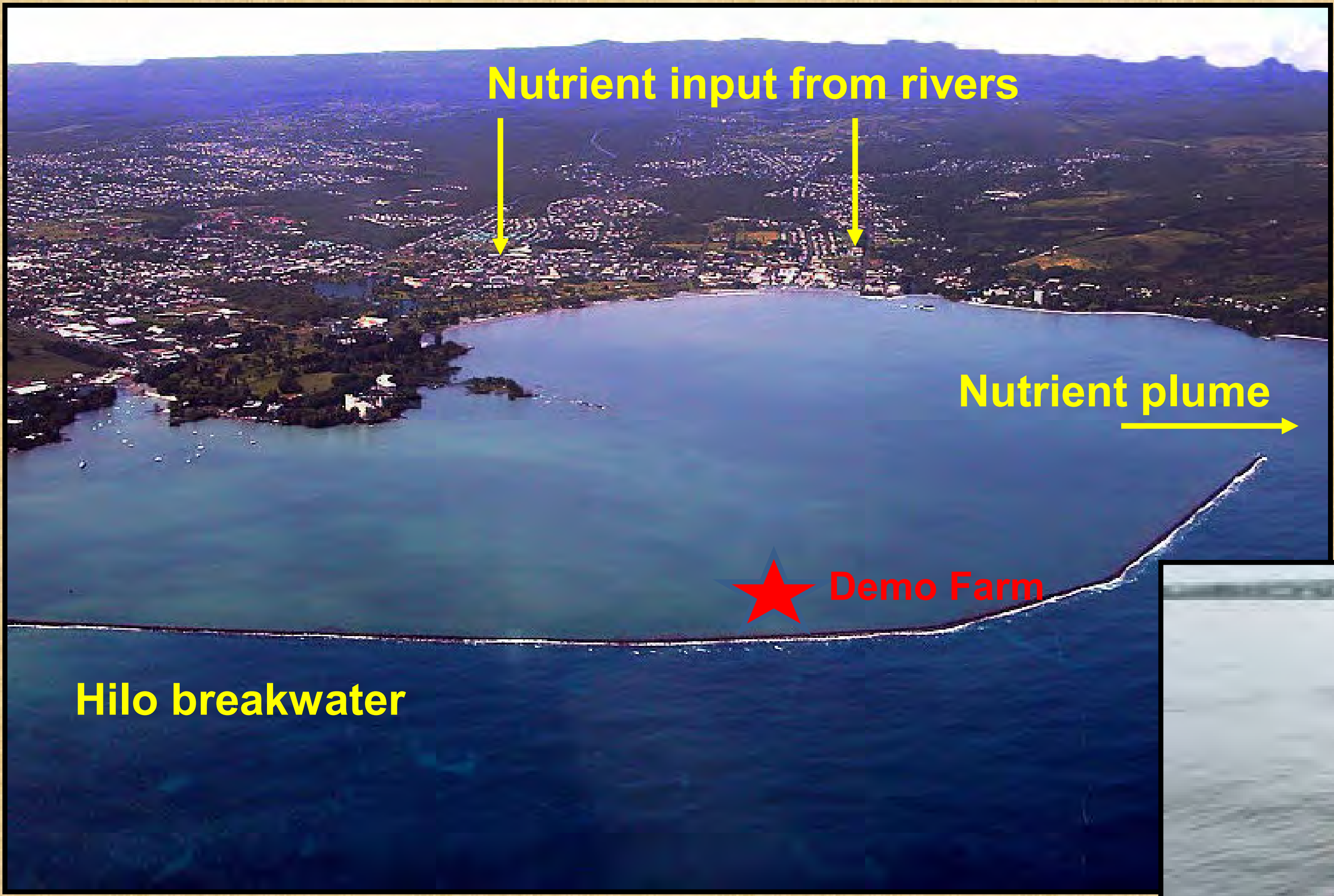
2 marine fish hatcheries
2 invertebrate hatcheries
Macroalgae & microalgae

Extension program
Community education center
Classrooms

Freshwater fish
Labs

Shellfish and Macroalgae Demonstration “Farm”
Hilo Bay (since 2013)

First trials with oysters for water quality improvement in HI



PACRC Shellfish Program

- Student education and training
- Student-operated hatchery and nursery
- R&D to support aquaculture development
- Extension and training
- Development of native species
- Hilo Aquaculture Cooperative
- Use of shellfish for water quality improvement and conservation

PACRC Shellfish Hatchery

Aquaculture Student Workforce Training Program

Celebrating 15 Years of Applied Learning

- **Over 375 students employed**
- **1 billion larvae/year**
- **~8 million spat/year**
- **Other research and training projects, e.g. fish and *limu***

Project Goals

- **Develop mariculture methods** for two native species of bivalves for the dual purposes of:
  - remediation of water pollution
  - economic development resulting in benefits for coastal communities and fishers
- **Student training**-supplements academic classes and as workforce training
- **Raise awareness** of potential for shellfish farming and water quality issues

Objectives

A. Develop hatchery and nursery methods for ***Black-lip pearl oysters*** and ***Pen shells*** for farming and use as benthic dwelling bivalves for aquaculture, restoration and water quality mitigation projects.

B. **Train students** in the PACRC Aquaculture Student Workforce Training Program and the One Youth Keaukaha/RISE program in the methods developed in Objectives 1 and 2, as well as water quality issues

C. **Increase public awareness of water quality issues** in Hawai‘i, and the environmental uses of aquaculture

Target Species

Black-lip pearl oyster
(*Pinctada margaritifera*)

Pen shells (*Atrina* spp.,
Streptopinna spp., *Pinna* spp.)

Why These Native Species?

- Many native bivalves are now extremely rare
  - If efforts are not made to assist populations, they may disappear
- Native species more suited to oligotrophic waters
- Bivalve diversity provides new opportunities for aquafarmers and restorative aquaculture
- Filtration and assimilation rates vary by species
- These are larger species, with higher filtration capacity

Shellfish culture complicated by poor water quality in many of the best areas

Wide spread and chronic water pollution

Inorganic nutrients

Sediment

Fecal bacteria

Photo credit: PacIOOS

Scallop equivalents?

Since Hawai‘i does not have “conditional” areas in its Shellfish Sanitation Rules, bivalves with large adductor muscles may allow for production in areas which can‘t meet the “Approved” status for growing areas.

“Callo de hacha” ceviche-México
Collaborative Research Support Program/USAID

Accomplishments

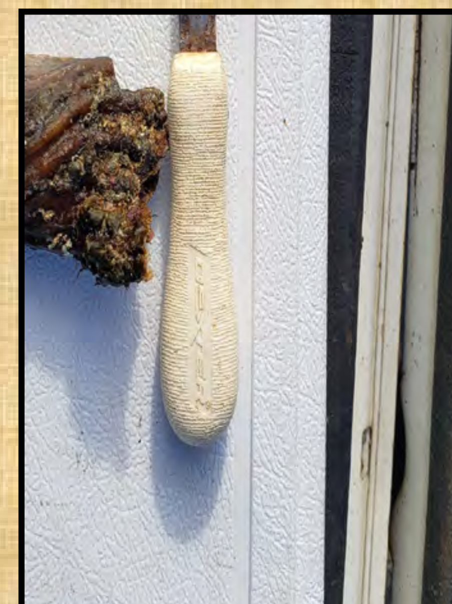
(despite pandemic and permitting delays)

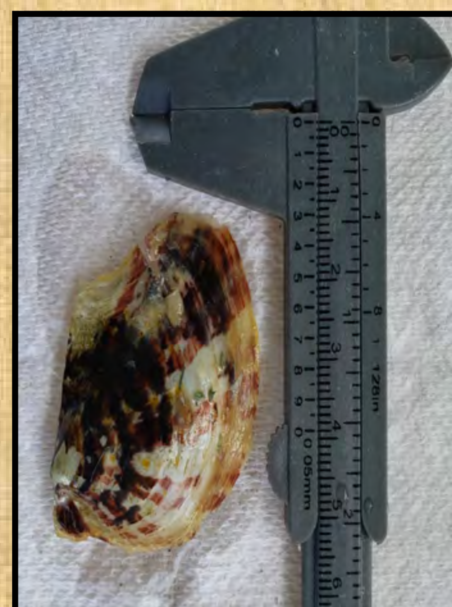
- New “native species” bivalve hatchery operating
- Over 300 students and volunteers trained
- Collection permit obtained (after lengthy wait)
- Collection of broodstock begun
- Pearl oysters now being conditioned
- Online training materials nearing completion
- Waterkeepers collaboration for outreach and education about water quality

Preparing for spawning trials

PACRC's native species hatchery

Baggy pen shell
Streptopinna saccata



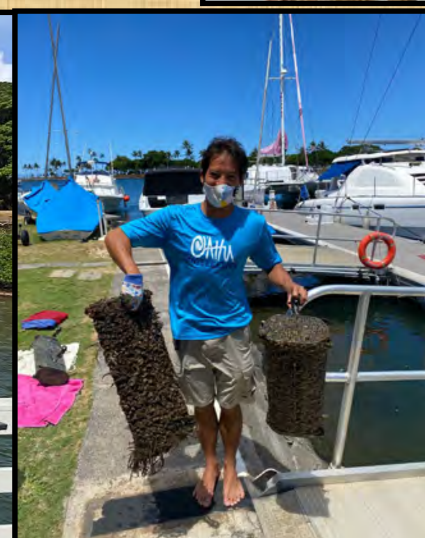


Rayed pearl oyster (?)
Pinctada radiata

Waterkeepers & PACRC Trials

Hawaiian Oyster, *Dendostrea sandvicensis*

- **Hilo Bay**
- **Ala Wai Boat Harbor (2 sites)**
- **Kaneohe Marine Corps Base**
- **Joint Base Pearl Harbor**
- **Marine Education & Training Center, Sand Island**
- **Nomilo fishpond (Kauai)**



Outreach & Education

Oysters are making a difference in our communities.

(>80 major water bodies are impaired)

Oyster restoration raises awareness about water quality challenges. This leads to cleanup events and storm drain stenciling projects that allow community members to actively participate in improving water quality.

Next steps

- Continue collection of pearl oysters and pen shells
- Continue collecting samples for DNA fingerprinting (need collaborator)
- Spawning trials to begin in November
- Continue student training & outreach and extension

Acknowledgements

- Our 100's of students!
- Waiwai Ola Waterkeepers Hawaiian Islands
- University of Hawaii Sea Grant College Program
- National Sea Grant Program & NOAA
- Center for Tropical and Subtropical Aquaculture
- DAR, HDOA, DOH
- Hawaii Community Foundation
- Western Sustainable Agriculture and Extension (WSARE)
- Center for Tropical and Subtropical Aquaculture
- Hilo Fish Company
- Goosepoint Oyster & Hawaiian Shellfish LLC

High School Students
Keawanui, Moloka`i

ENAO-Developing eDNA tool for early detection of two main fouling organisms of oyster aquaculture farms-VASG

K. Hudson, B. Fisher, J. McDowell, T. Hartley

Developing eDNA tool for early detection of common fouling organisms on oyster farms

VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

Sea Grant Virginia

Market quality – aesthetics and shuckability


Karen Hudson

Shellfish Aquaculture Specialist

Bob Fisher

Commercial Fisheries Specialist

Jan McDowell

Research Associate Professor

Ellen Biesack

Senior Lab & Research Specialist

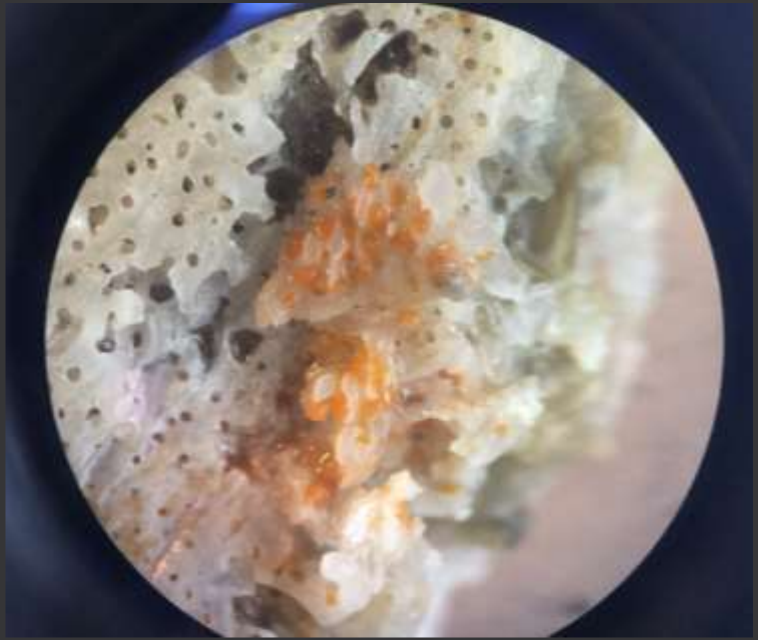
VIMS | William & Mary
Virginia Institute of Marine Science

Sea Grant Virginia

Objectives

1. Develop quantitative PCR assays specific to P. websteri and Cliona spp.

2. Field test the assays to ensure specificity and compare eDNA presence and prevalence with visual observation of farmed oysters



Year 1

Optimize lab methods, collect tissue samples of sponge and worm, develop species specific primers

- Sample water at oyster cages in York River Aug - Oct 2019

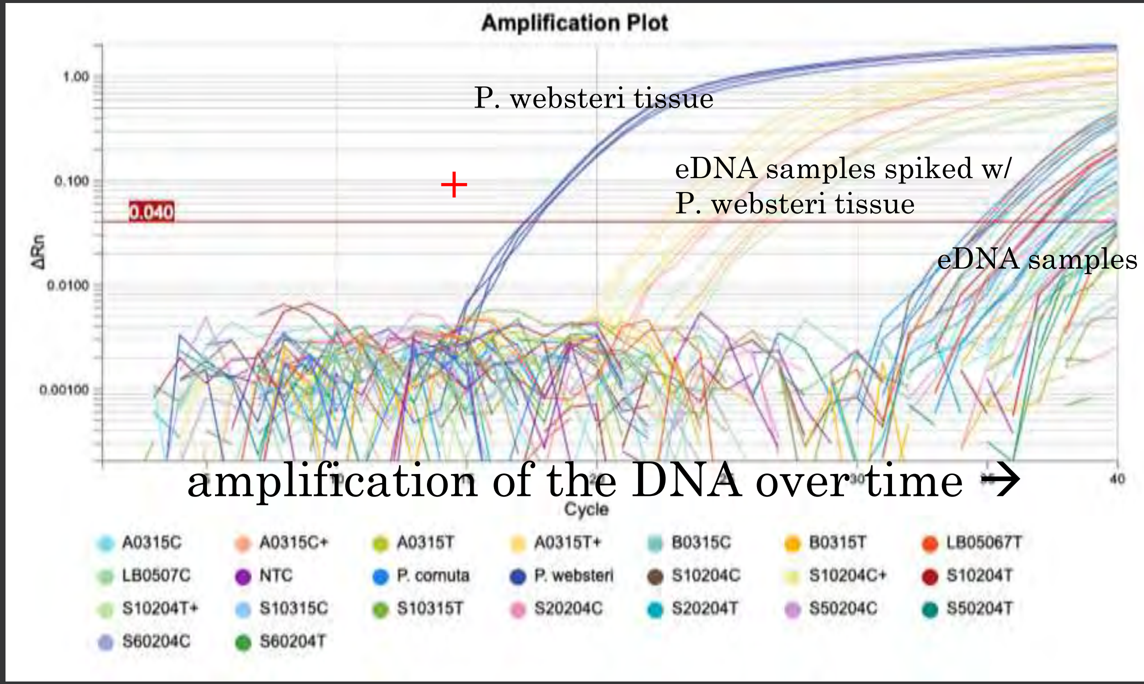
  Test DNA quality & quantity:
    - filtration methods (cup vs Sterivex capsule)
    - storage (frozen dry, ethanol, Longmire's buffer)
    - sample depth (top of cage vs bottom)

- Collection of worm assemblages from field oysters - surface, shell matrix and inside shell burrows
  *used preserved cliona samples from ESL

Year 2

- qPCR primers developed – P. websteri and Cliona spp.
- Covid delays –spring 2020
- Include P. cornuta in assay development to figure out the mixed assemblages on shell exterior.
- Spring 2021 – field observational component as scheduled

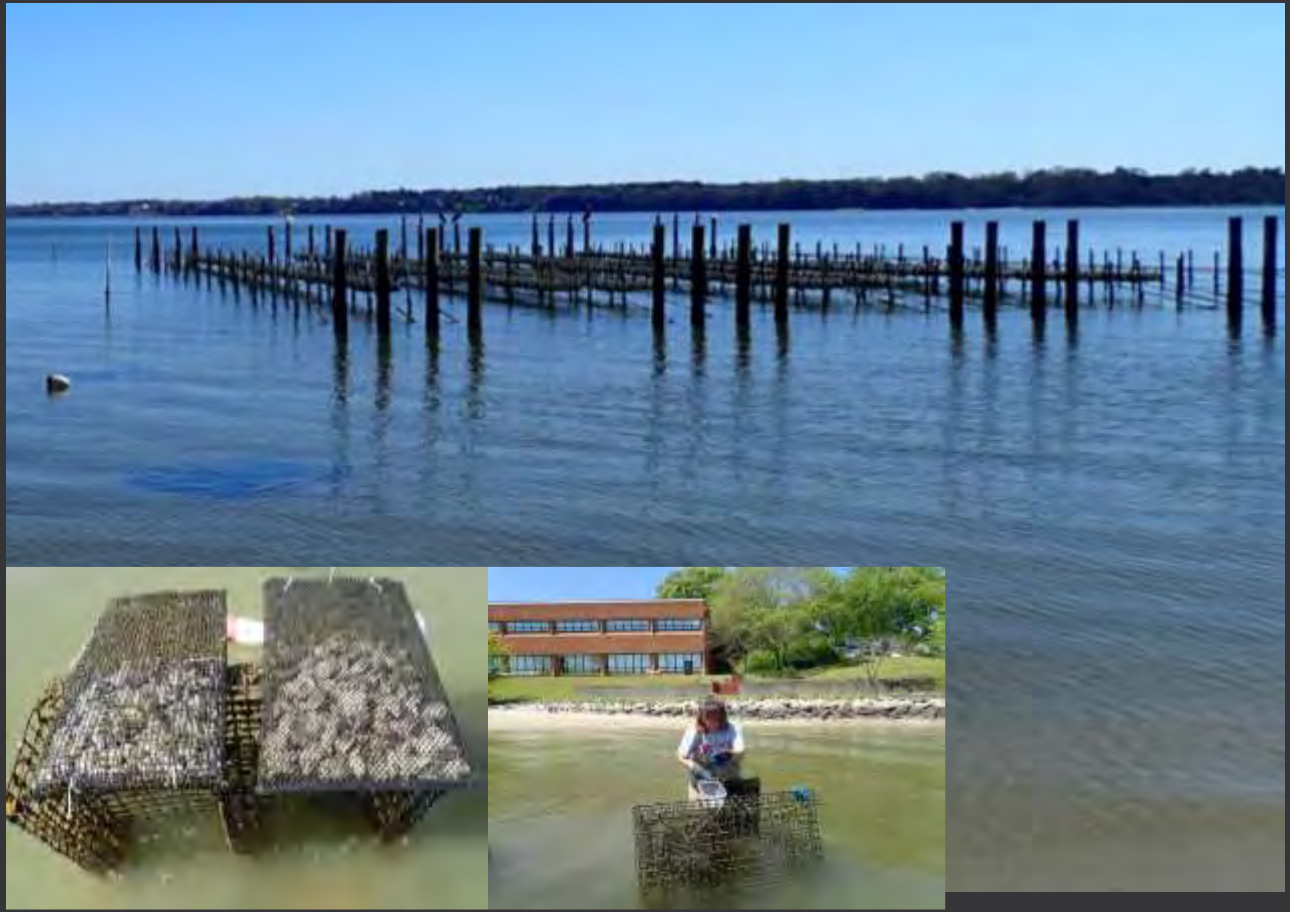
Preliminary P. websteri-specific qPCR assay



2021 field deployment

York River - farm site (w/oysters) @ control site (no oyster farm)

March (50 C) sample for 8 weeks



2021 field component





Water samples from control and farm site (triplicate) → filtered and frozen
9 oysters sampled each week

- rinsed w/ sterile SW (500 mls) → filtered and frozen
- exterior rinse evaluated / sampled for polydora
- interior shells evaluated for blisters (% coverage), location (peripheral, aductor scar)
- worms sampled from exterior (rinse water) and extracted from interior shell blisters

Exterior observations

April

June

July

Interior observations

April

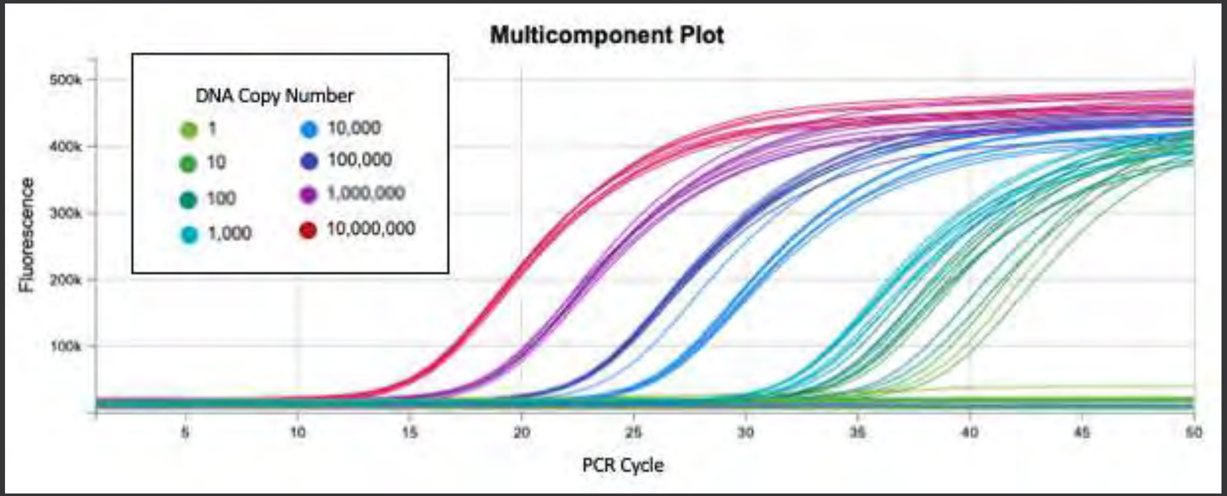
May

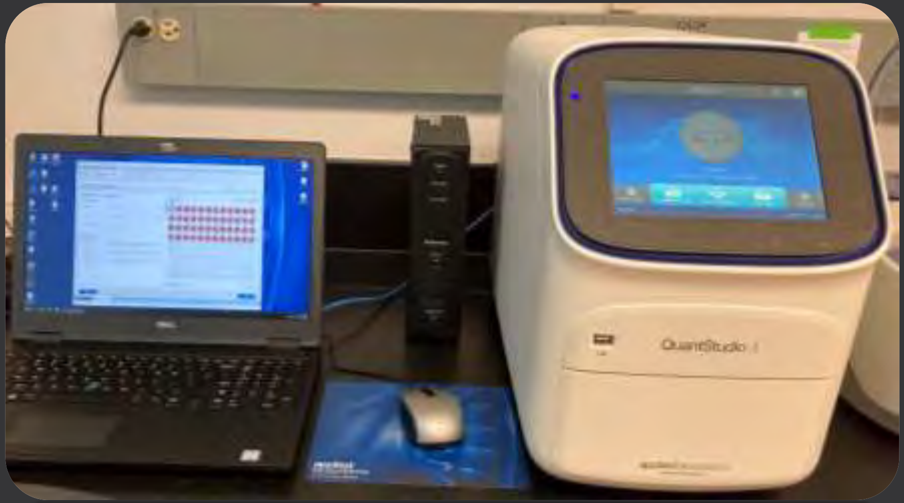
June

July

2021 eDNA assay (P. websteri example)

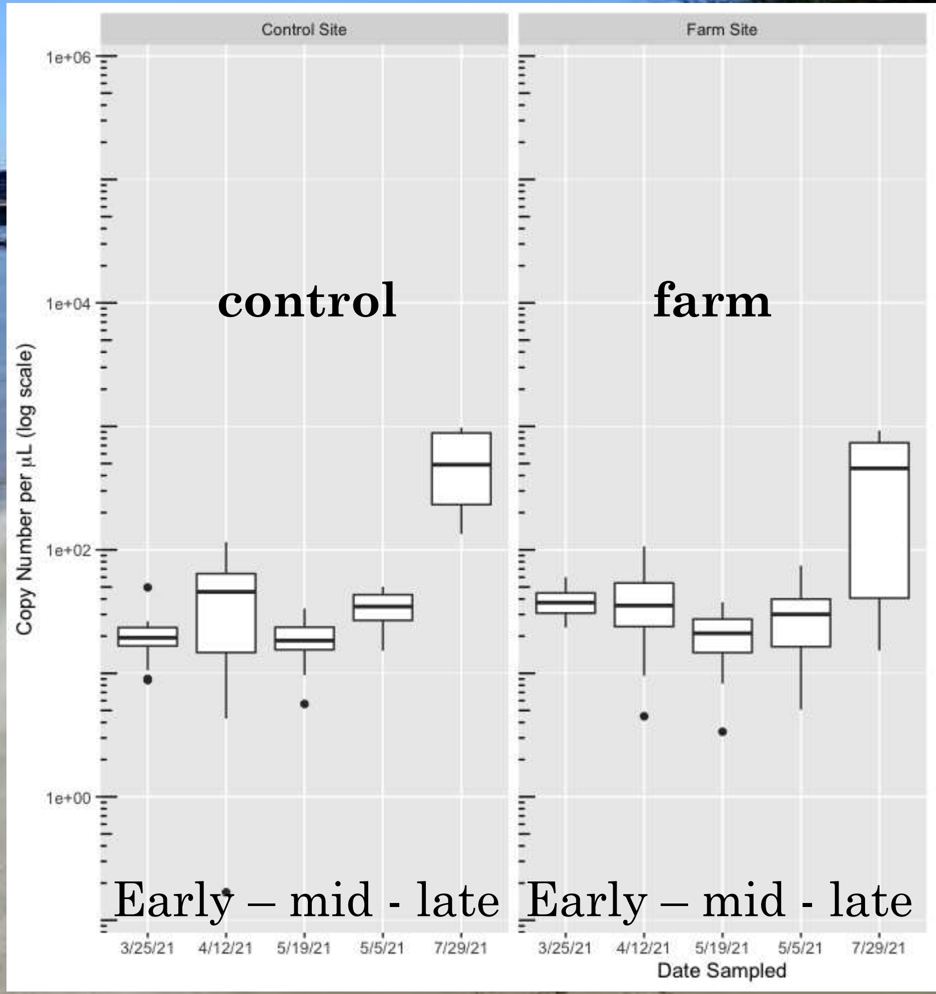
- Species specific
- Sensitive



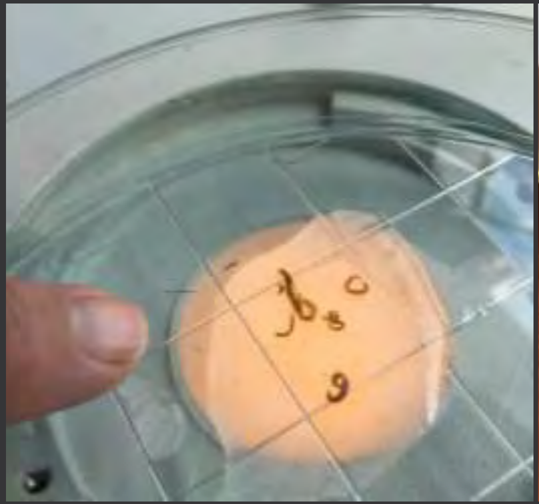


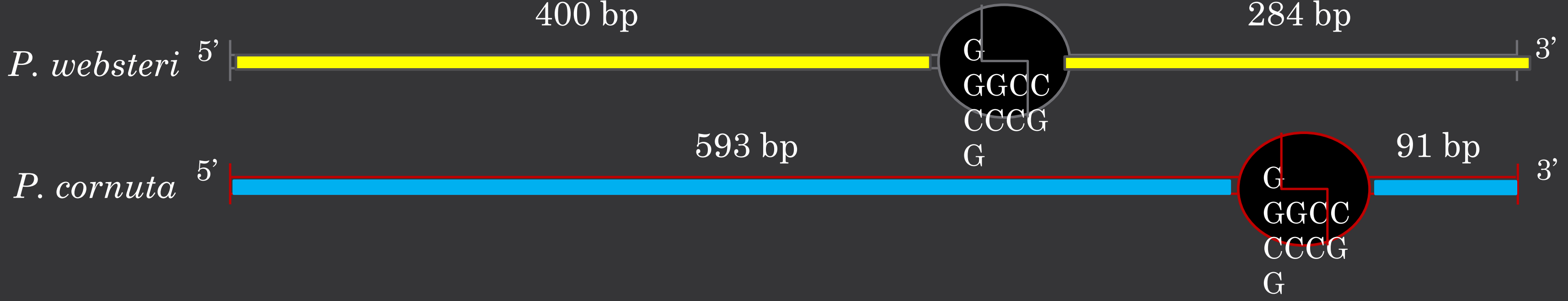
1/8 PCR replicates could detect a single copy of the target amplicon
4/8 PCR replicates could detect when there were 10 copies
8/8 PCR replicates could detect 100+ copies (standards go up to 10 million copies per microliter of DNA)

2021 eDNA assay (P. websteri)

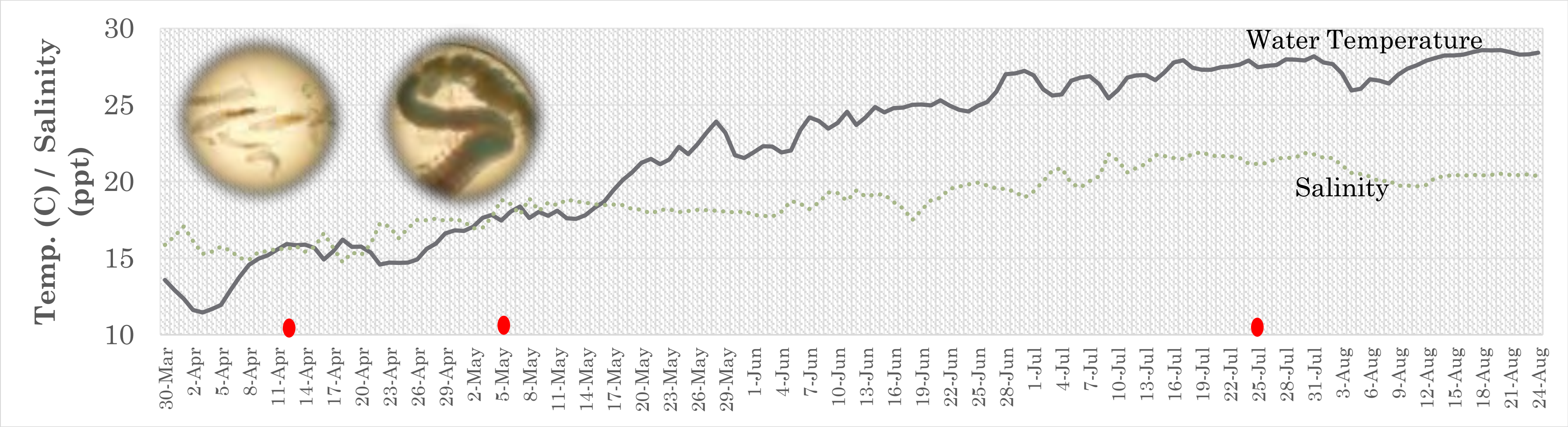


2021 Worm assays





Ongoing work….



- Multiplex P. websteri and cornuta assays
- Finish running eDNA assays on water samples across the season
- Finish worm identification
- Pull all the results together

Thank You

khudson@vims.edu

VIMS | William & Mary
Virginia Institute of Marine Science

Sea Grant Virginia

ENAO-Innovative restoration aquaculture of freshwater mussels in the tidal freshwater zone of the Delaware Estuary Watershed for water quality improvement-NJSG

P. Rowe, D. Kreeger, R. Thomas

Restoration Aquaculture of Freshwater Mussels in the Delaware Estuary Watershed for Water Quality

Danielle A. Kreeger[1,2], Kurt M. Cheng[1], Roger L. Thomas[2], Peter Rowe[3]

[1]Partnership for the Delaware Estuary
[2]The Academy of Natural Sciences of Drexel University
[3]New Jersey Sea Grant Consortium

October 26, 2021

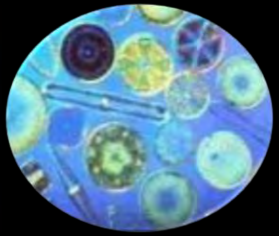
Blue Collar Bivalves

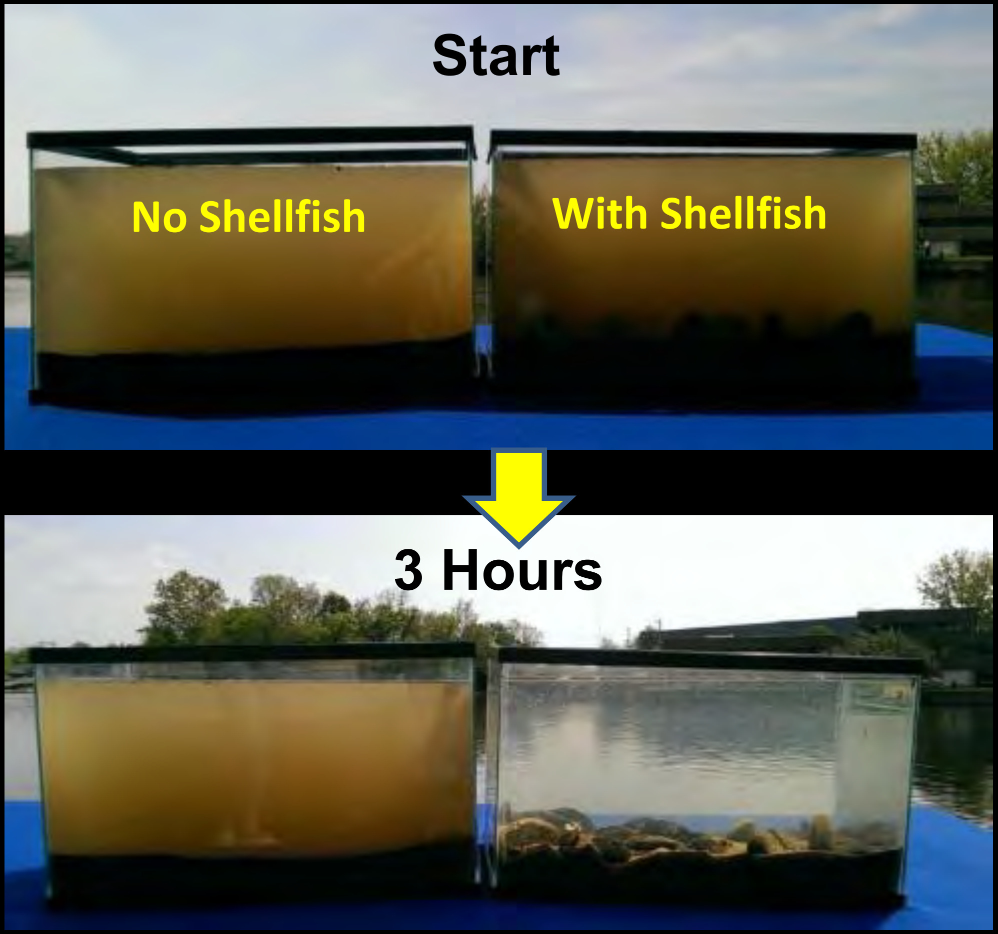
Ecosystem Engineers

Blue Collar Bivalves

Biofiltration

Each adult filters
> 10 gallons of water
per day





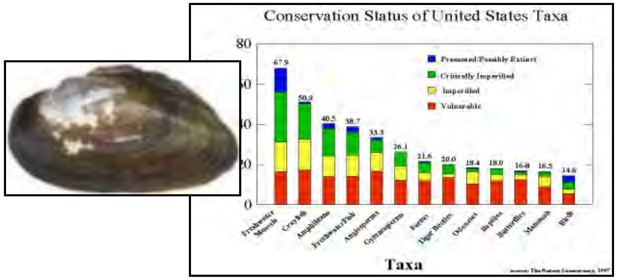
Blue Collar Bivalves

Photo Credits:
Resilience and Water Quality:
Partnership for the Delaware Estuary
Aquaculture: Brian Donohue. NJ
Advance Media for NJ.com

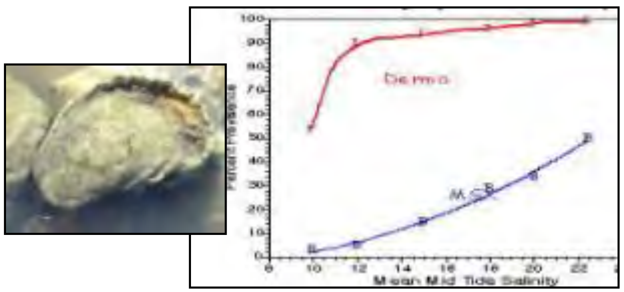
Why Important?

Millennium Ecosystem Assessment Categories	Specific Services/Values	Oysters	Marsh Mussels	FW Mussels
		Relative Importance Scores		
Provisioning: Food & Fiber	*Dockside Product*	✓✓✓		✓
Regulating	*Shoreline & Bottom Protection*	✓✓		
	Shoreline Stabilization	✓✓	✓✓✓	✓✓
Supporting	*Structural Habitat*	✓✓✓	✓✓	✓✓
	Biodiversity: Imperiled Species			✓✓✓
	Bio-filtration	✓✓✓	✓✓✓	✓✓✓
	Biogeochemistry	✓✓	✓✓	✓✓
	Prey	✓	✓✓	✓
Cultural/ Spiritual/ Historical/ Human Well Being	*Waterman Lifestyle, Ecotourism*	✓✓		
	Native American	✓✓		✓✓✓
	Watershed Indicator	✓✓✓	✓✓	✓✓✓
	Bio-Assessment	✓✓✓	✓✓	✓✓✓

Shellfish Declines



Freshwater Mussels - imperiled



Oysters - prone to disease, salinity

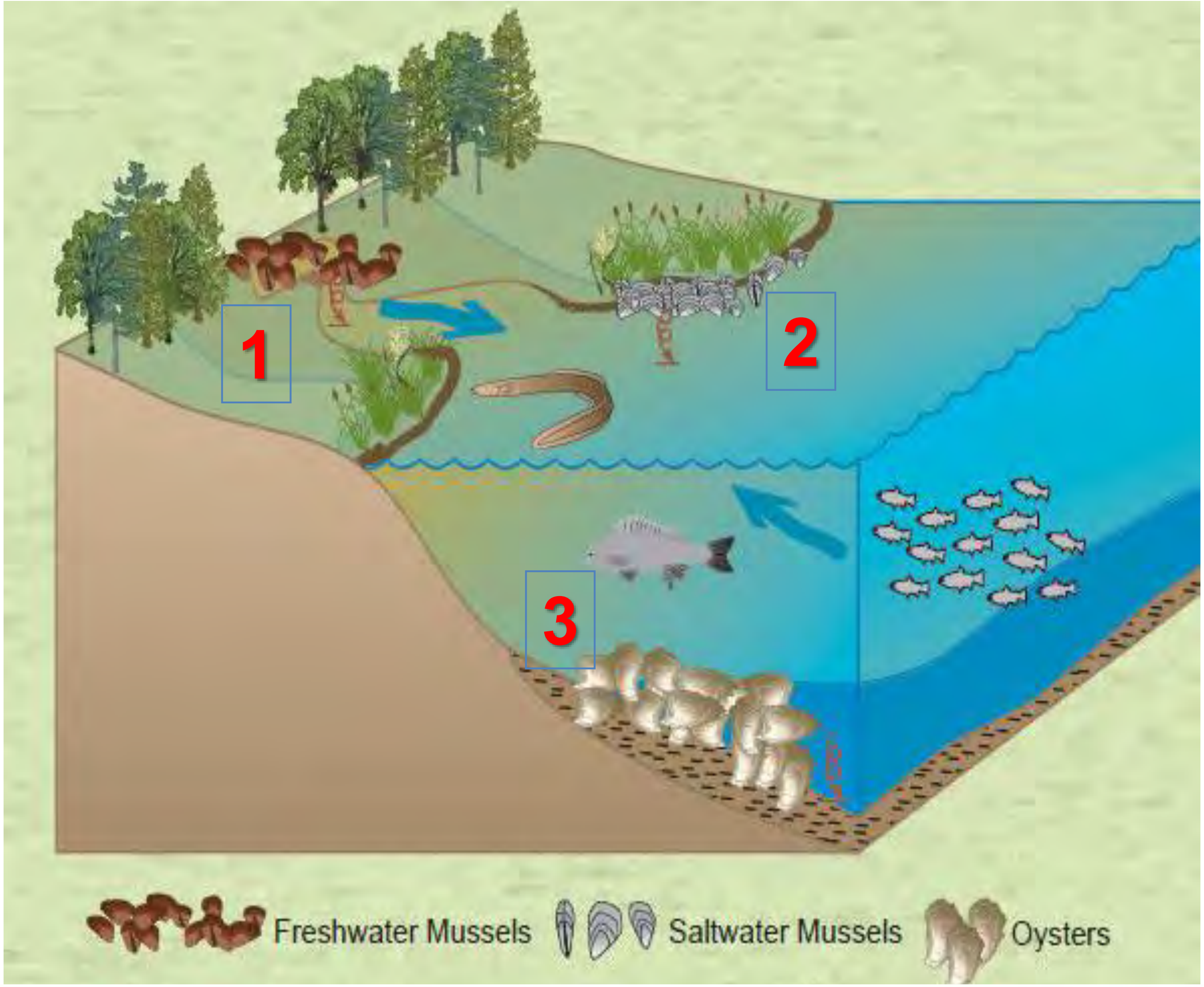
Ribbed Mussels - losing marsh

Shellfish Restoration Strategy

Headwaters to Ocean Shellfish Restoration

1. Non-tidal
2. Intertidal
3. Subtidal

Tidal / Non-Tidal Synergisms



Freshwater Mussel Recovery Program

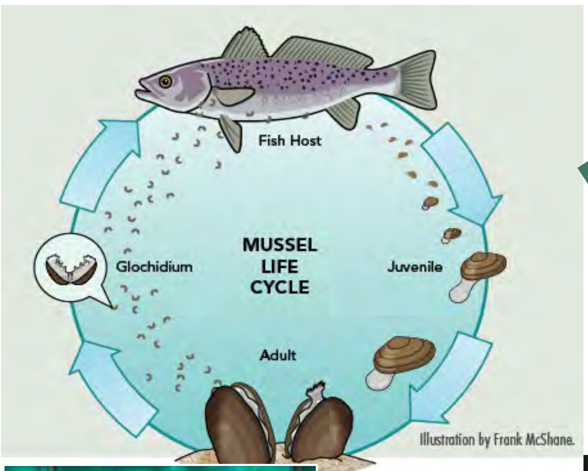
Restoration Aquaculture of Freshwater Mussels

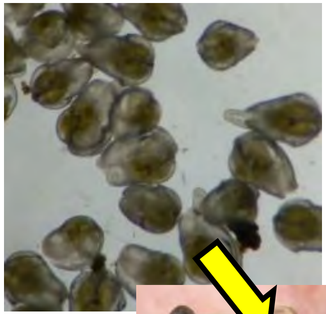
Goal: Address Supply Bottleneck

Study Focus: Increase Production

Other Projects:

> Propagation





This Project:

> Rearing

- **Methods?**
- **Gear?**
- **Location?**

Freshwater Mussels

- Filter-feeding bivalves

- Freshwater subtidal

- Aquaculture initially reactionary response for conservation

- Gear Updates
  - Tethering
  - Substrate
  - Oyster gear

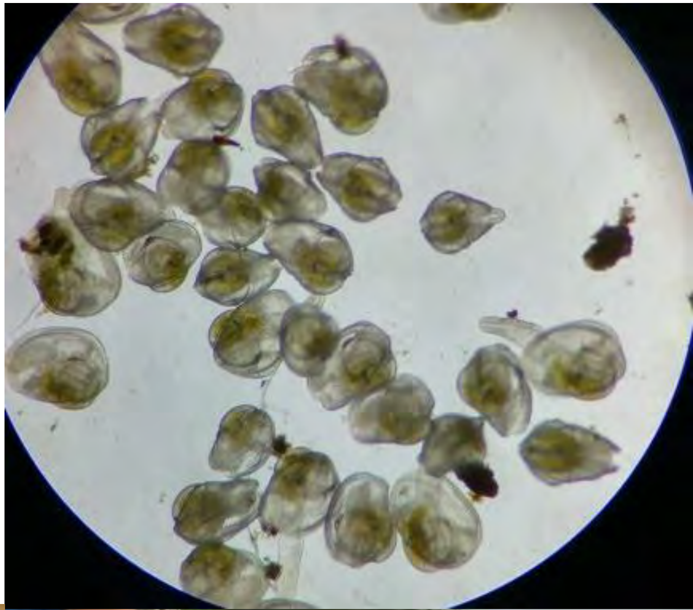
- Site comparisons
  - Reference Pond
  - Aquaponics Pond
  - Reservoir (Roger)

Eastern Pondmussel (Sagittunio nasutus)

Alewife Floater (Utterbackiana implicata)

Freshwater Mussel Grow-Out

- Very Small Seed
- Infaunal
- Limited existing techniques



Aquaculture Operation Scale

Scale of maintenance becomes an issue

Floating Baskets

Original	Initial Updates	New Update
• Baskets + Lids	• Can Floats	• Tether System
• Pool Noodles	• Central Anchor	• Substrate Type


Sand
Chicken Grit

Oyster Aquaculture Gear

Floating Cage (6 bays)

Floating Single Cage

- Carrying Capacity
- Maintenance
- Scale up operations

Small Pond Sites

<u>Winterthur</u>

Proven success

Access to shallow areas

Operations streamlined

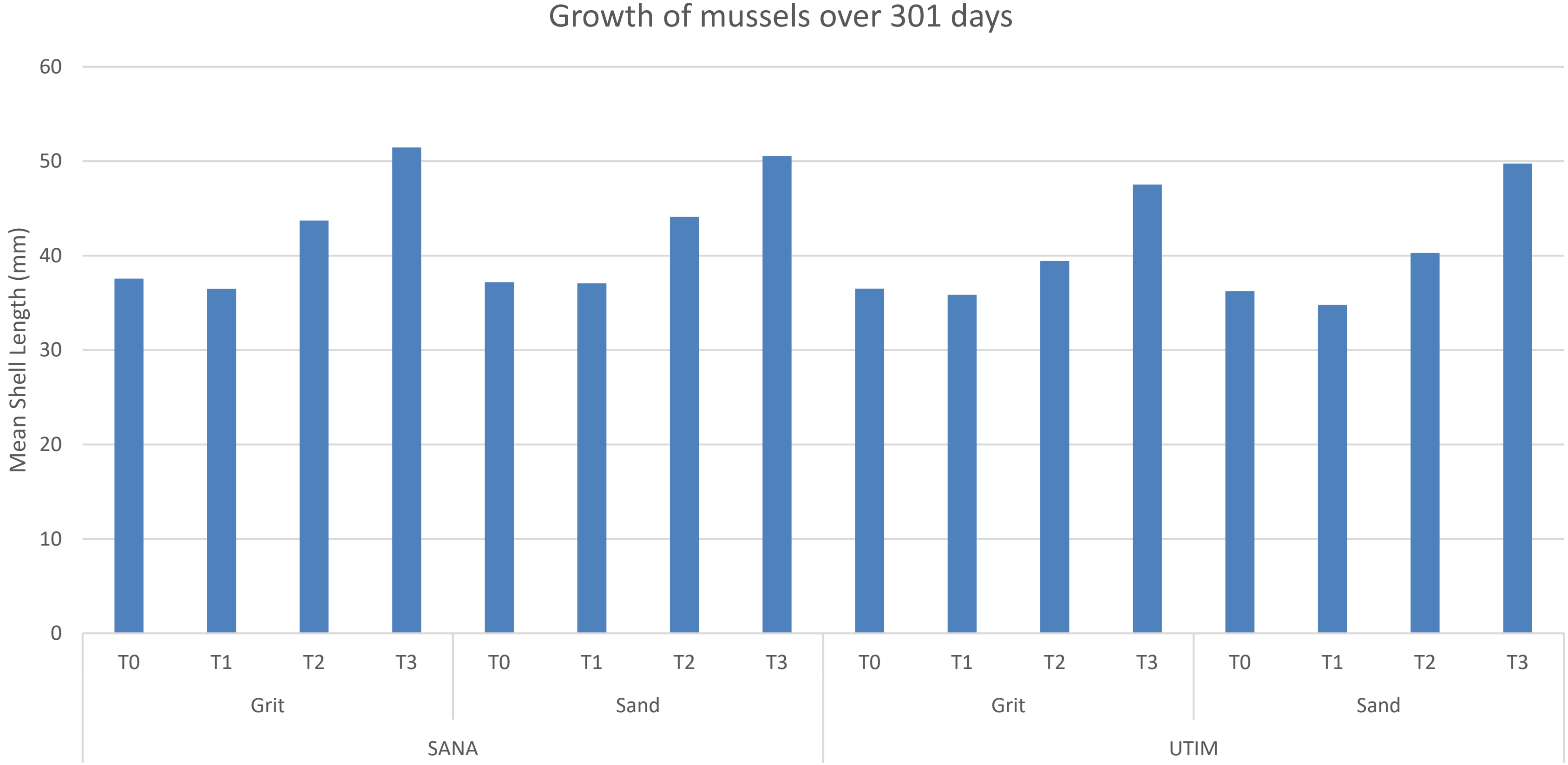
<u>Aquaponics Farm</u>

Brand New Ponds

Effluent/Volume/Age

Needs more refinement

Small Pond: Sand vs. Grit

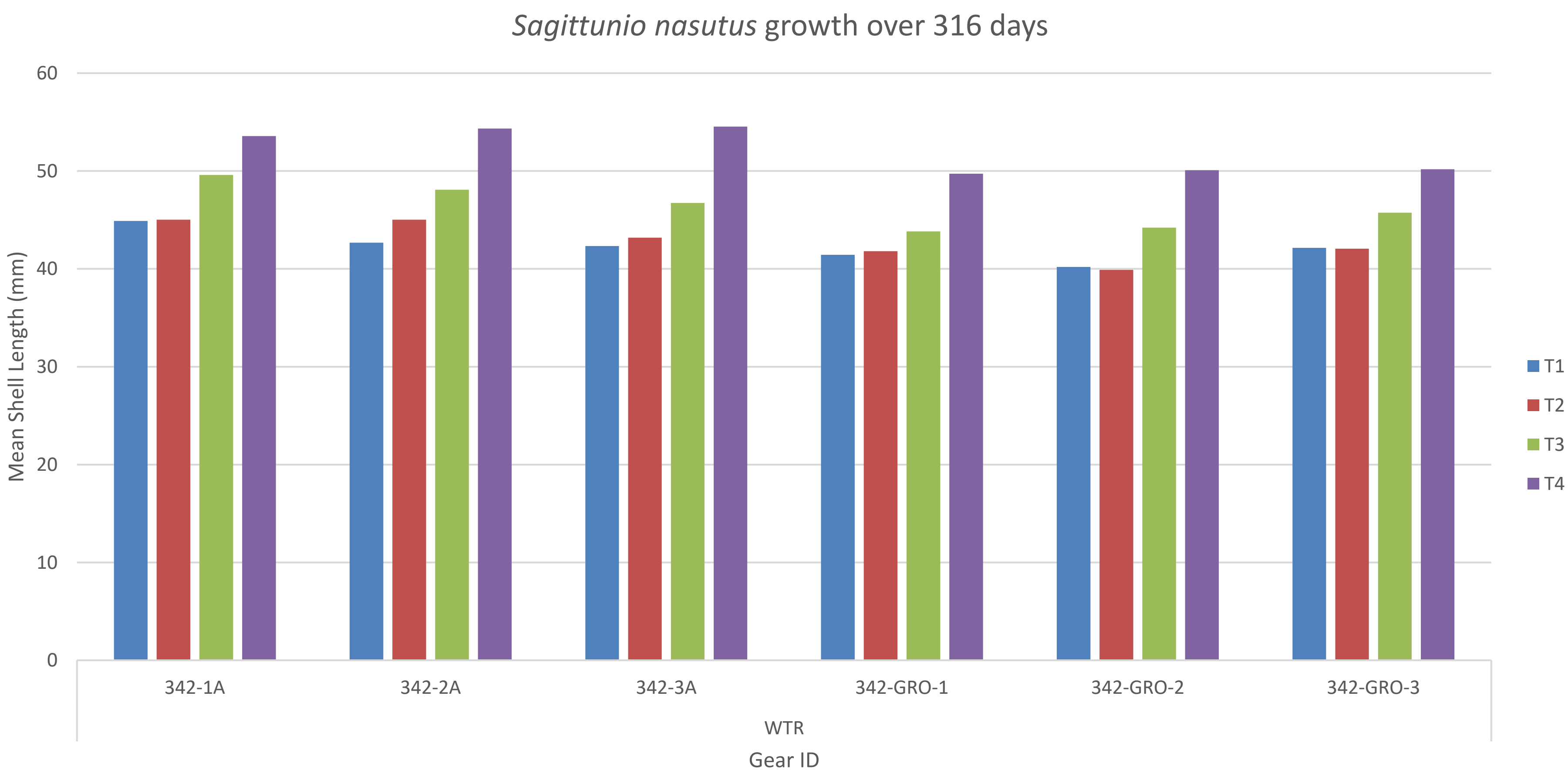


Species	Substrate	Stocked	Mortality
Sagittunio nasutus	Grit	300	3
	Sand	300	10
Utterbackiana implicata	Grit	300	62
	Sand	300	87

Small Pond: Oyster Gear

Gear Type	Stocking Density
Floating Basket	50
Oyster bag in cage	100

Insignificant mortality for all gear



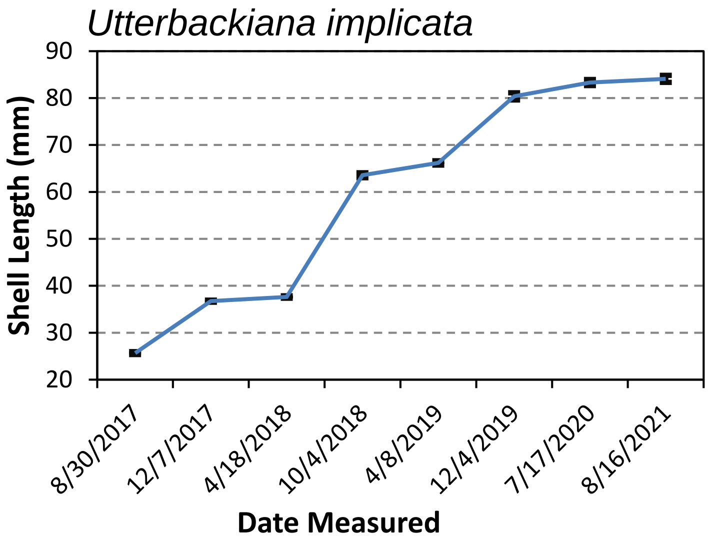
Green Lane Reservoir Program

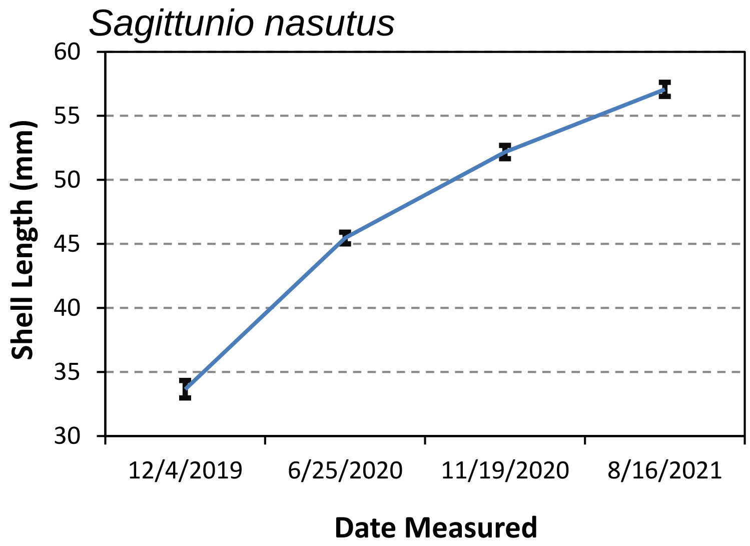
- Multi-year 12-month deployment and retrieval of numerous baskets containing several species of freshwater mussels.
  - Use of grappling techniques and GPS to recover overwintering mussel baskets and platforms after ice cover melts
  - >95% installation recovery

- Successful adaptation of oyster mariculture techniques (Flow N Grow floating oyster platforms)
  - Increased numbers of mussels that can be deployed and greater food availability compared to baskets
  - Less on-site maintenance and servicing time

- Basic water quality and food availability/quality more than adequate for long-term freshwater mussel propagation

Green Lane Reservoir Draft Data





Average Survivorship: >70% per basket or platform

Growth Rates: Varies by species but among the highest compared to other propagation sites

Next Steps at Green Lane Reservoir

- Expand the numbers of baskets and Flow N Grow platforms installed within the reservoir

- Potential Use of Surplus Concrete Tank at Upper Montgomery Joint Authority
  - Positive evaluation by Aqua PA staff
  - Increase numbers of mussels that could be propagated
  - More easily accessible
    - Year round
    - No need for boats
  - Easier to control temperature
  - Year-round feeding
  - Community outreach and environmental education
  - Conduct more extensive mussel propagation research

Operations Improvement Summary

Successes	Lessons	Future Growth
Chicken Grit	Pond Volume	Stocking Densities
Oyster Gear	Dynamic inputs to aquaponics system	Unique Facilities
Field Efficiencies & Overwintering	Advanced Water Chemistry	Pulley System?

Outreach Strategies

- Digital (PDE and NJSGC websites)
  - Articles
  - Videos
- Social Media
- Demonstrations (PDE has started)
  - Training
  - Small Scale (Backyard)
- Local Buy-in
  - Community Watershed Restoration

Moving Forward

- Progress through Covid Delays
  – PDE and ANSDU did great job
    - Adaptable
- NCE (1^{st} 9/30/2022; 2^{nd} ???)
- Future Funding
  – Education
  – Training
  – Restoration

Summary

- Freshwater mussels furnish diverse ecosystem services
- Mussel restoration is constrained by animal supply
- Shellfish aquaculture gear and practices can be adapted
- Mussel farms can be developed to supply animals and supply ecosystem services

Thank You

- New Jersey Sea Grant Consortium
  Project # 6317-0000; NA19OAR4170297

- Philadelphia Water Department

- Harrison Lake National Fish Hatchery

- Winterthur Garden Museum and Library

- Upper Montgomery Joint Authority

- Montgomery County Parks, Trails, and Historic Sites

- Aqua America

- Beni Hana Nishikigoi LLC

- All project staff and volunteers that supported this work

Questions?

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Roger Thomas - RLT47@drexel.edu

Peter Rowe - Prowe@njseagrant.org

Partnership for the DELAWARE ESTUARY

THE ACADEMY OF NATURAL SCIENCES of DREXEL UNIVERSITY

NOAA

Sea Grant NJ Sea Grant Consortium

ENAO-Developing a Framework to Expand Comprehensive Training Opportunities for Prospective Shellfish Growers in North Carolina, South Carolina, and Georgia-NCSG

F. Lopez, B. Snyder, D. Cerino, T. Bliss, S. Lovelace, S. Pedigo, G. Gaines, E. Herbst, S. White

Developing a Framework to Expand Comprehensive Training Opportunities for Prospective Shellfish Growers in North Carolina, South Carolina, and Georgia

Project Team:

- Eric Herbst, Frank Lopez;
  NC Sea Grant
- David Cerino, Bryan Snyder;
  Carteret (NC) Comm. College
- Graham Gaines, Matt Gorstein, Susan Lovelace, Sarah Pedigo;
  SC Sea Grant Consortium
- Tom Bliss; **GA Sea Grant**

Photo by Baxter Miller

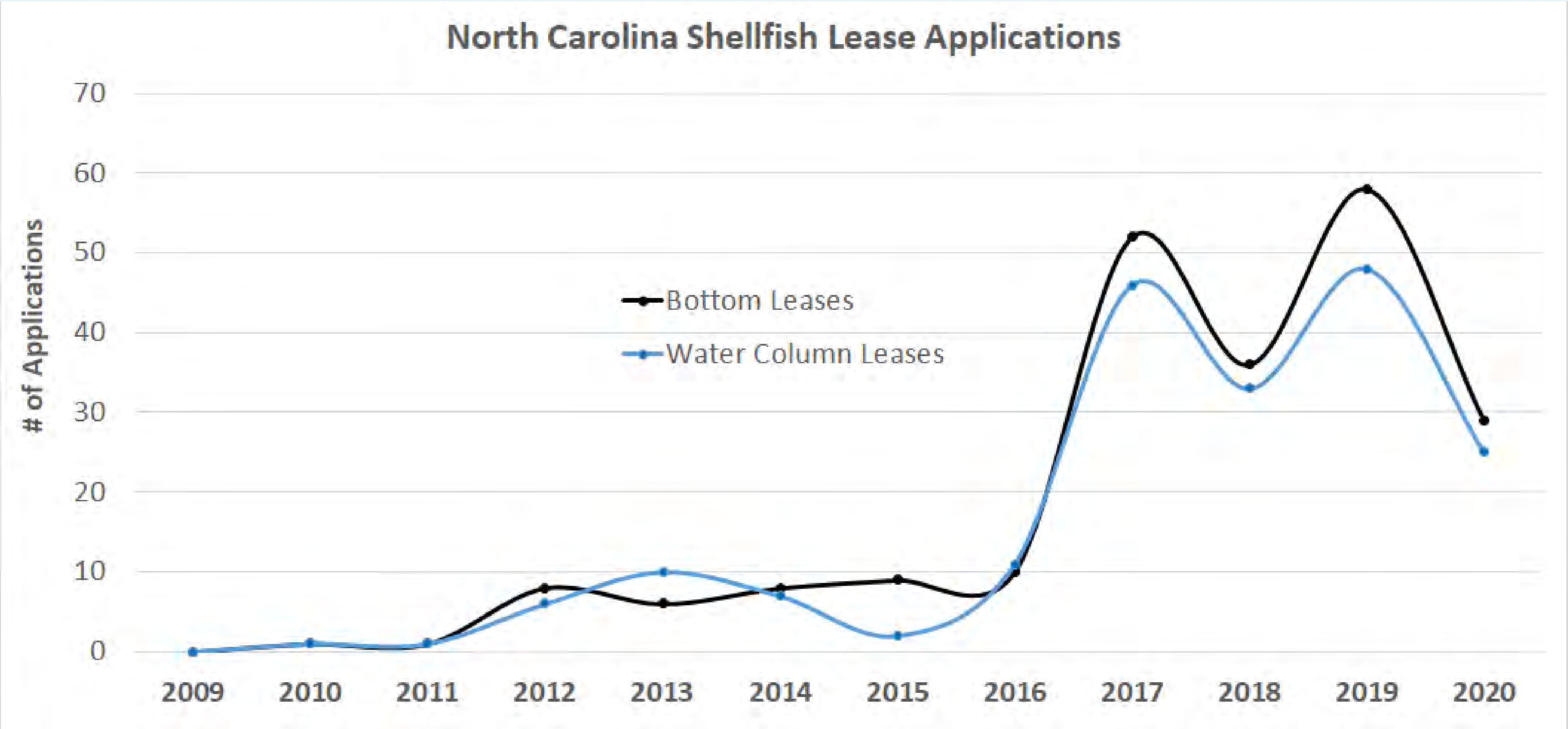
Framework for prospective shellfish grower training in North Carolina, South Carolina, and Georgia

- *Outline*
  - **How it started**
    - North Carolina
    - South Carolina
    - Georgia
  - **What we did about it**
    - Project objectives
  - **How it's going**
    - North Carolina Shellfish Farmers Academy
    - South Carolina
    - Georgia
    - Final thoughts

Photo by Baxter Miller

How it started

- *North Carolina*
  - Restaurant oyster half shell market drives demand
  - Tremendous growth potential for oyster aquaculture & diversification into other crop lines



How it started-North Carolina

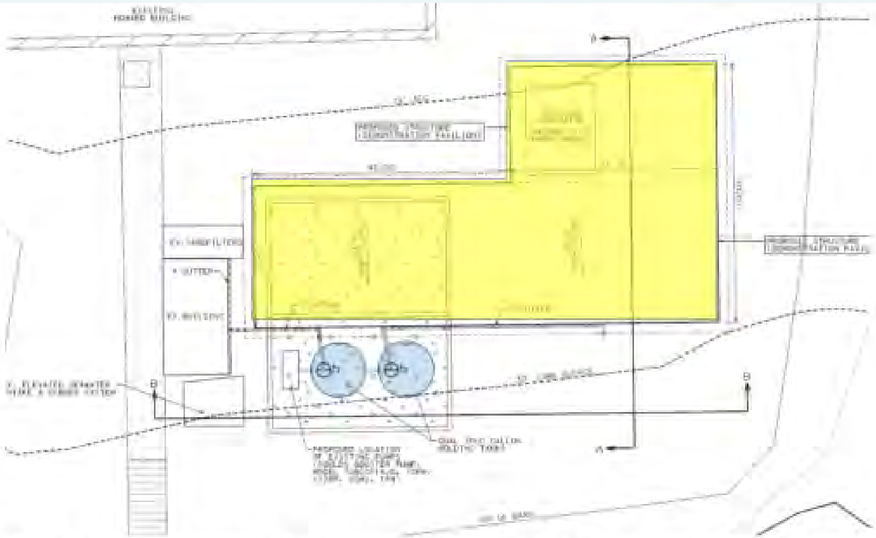


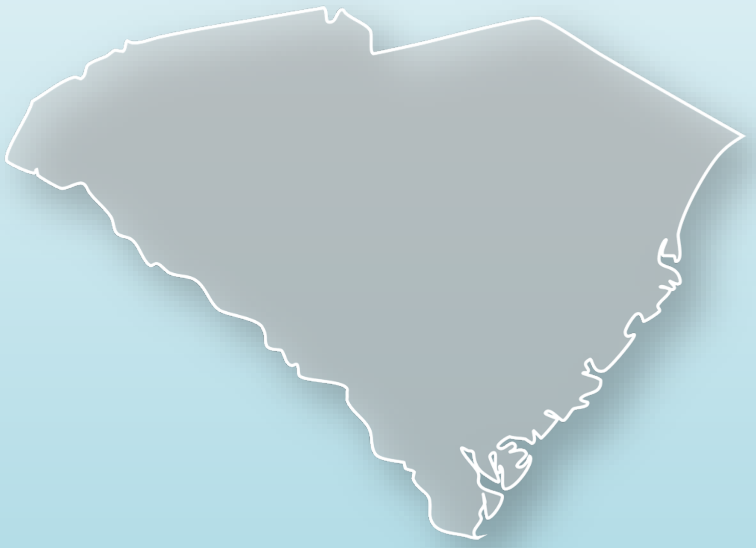
Figure 14b: Inset of 14a Location of Demonstration Pavilion (Yellow) and rainwater storage tanks (blue) that will be used for stormwater management


CARTERET
Sea Grant
North Carolina
NC STATE UNIVERSITY
CMAST
Shellfish Mariculture
Demonstration Center
Sea Grant
Funded in part by the 2015 NOAA National Sea Grant
Aquaculture Extension and Technology Transfer Program


CMAST
CCC
Aquaculture
Facility
pavilion
Legend
Bottom culture (predator netting)
Floating/suspended gear main line
Screw anchor or PVC pipe
Bottom Cage
Rack and Bag
Floating Upweller
Dock and Gangway
Submerged Aquatic Vegetation Area
Designated walkway

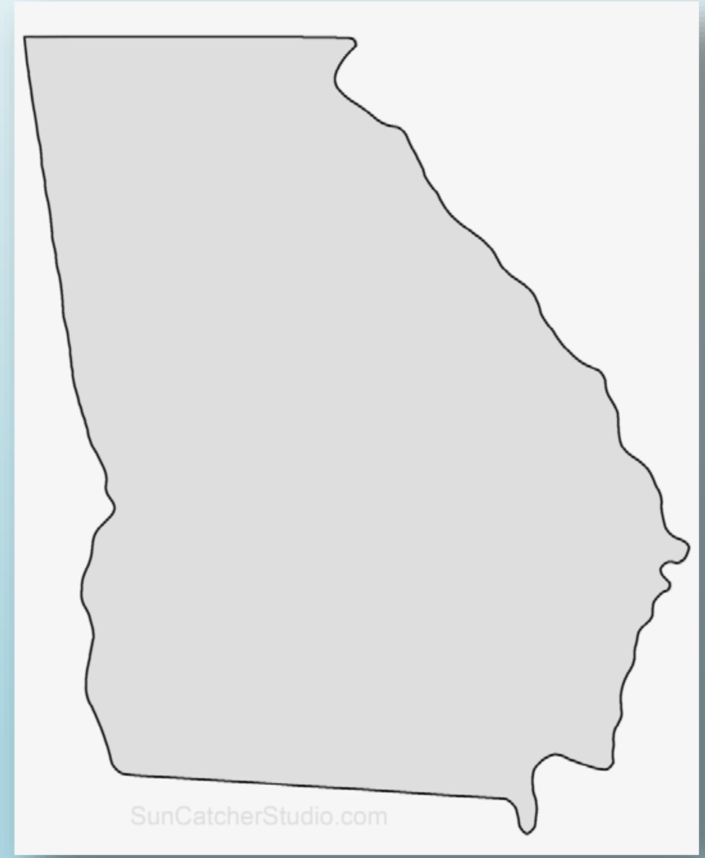
How it started

- *South Carolina*
  - Off bottom harvest techniques caused number of growers to increase from three to 16 (2014-2018) and revenues to increase substantially
  - SCSGC evaluating capacity for research and training within its member institutions



How it started

- *Georgia*
  - Restrictions on out-of-state seed sources and gear types
  - GA SG established hatchery in 2014 to provide in-state seed and conducted off bottom gear research



How it started

- *Barrier*
  - Lack of training opportunities for prospective and new shellfish growers in the three states.

Photo by Robert Hickerson

What we did about it

- Objective 1: Recruit & hire NC Sea Grant extension associate

Sea Grant
North Carolina

Bryan Snyder,
Carteret Community College

What we did about it

- Objective 2: Gather information from established training programs re: curriculum

Image by Shutterstock

What we did about it

- Objective 3: Develop curricula for shellfish training program

Sea Grant North Carolina

1. Introduction
2. Bivalve biology
3. Hatchery techniques
4. Nursery design/strategies
5. Hard clam grow out
6. Oyster grow out
7. Risks to crops
8. Farm management/BMPs
9. Regulations
10. Proper siting & lease applications

What we did about it

- Objective 4: Deliver an initial shellfish aquaculture training program in North Carolina

Sea Grant
North Carolina

- North Carolina Shellfish Farming Academy
  - Classroom instruction and accompanying field sessions
  - Offered through the Carteret Community College Continuing Education program

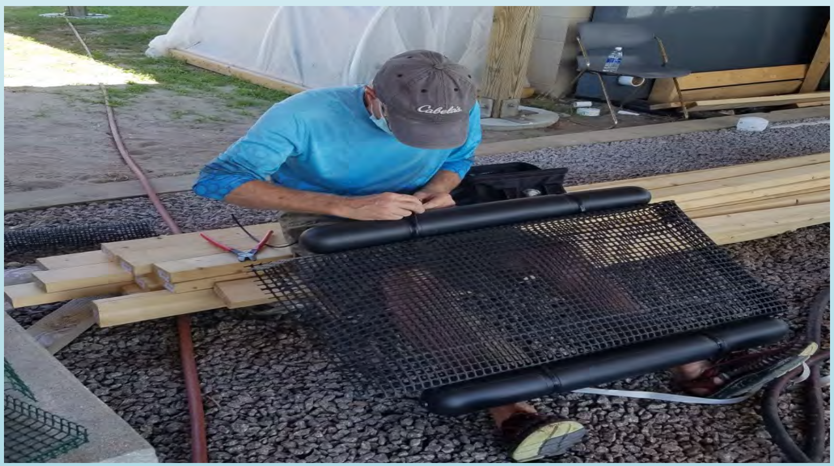
NC Shellfish Farming Academy

Nursery operations and maintenance

NC Shellfish Farming Academy

Preparing and planting seed

NC Shellfish Farming Academy



Constructing grow-out gear

NC Shellfish Farming Academy

Tumbling and grading oysters

NC Shellfish Farming Academy

Bio-fouling control

Hard clam planting

What we did about it

- Objective 5: Conduct post-training program assessment and workshop to share best practices

How it’s going - NC

Measures:

- Total courses to date: 5
- Total enrollment: 65
- NC Shellfish Farming Academy Graduates: 55
- # of students who have started farming: 3
- # of students with current pending leases with DMF: 7
- Established relationships with new and prospective growers

Photo by Baxter Miller

How it's going - SC

Outcomes:

- Direct participation in summer Academy
- Shared materials
- Potential partner engagement with USC Baruch Marine Field Lab
- Small demonstration site (OysterGro cages, FLUPSY)
- Feasibility study: Commercial fishing and aquaculture training programs

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Coastal Science Serving South Carolina

How it’s going - GA

Outcomes:

- Regulations changed to allow for intensive gear for aquaculture
- GA SG is in the final steps of permitting a research and training site adjacent to the Shellfish Research Laboratory (SRL) and plans two Shellfish Farming courses in 2022

Final thoughts

- Regional Sea Grant programs are better positioned to support shellfish aquaculture workforce development
- Expansion considerations:
  - Accessibility
  - Capacity
  - Policy changes (NC education requirements)

Framework for prospective shellfish grower training in North Carolina, South Carolina, and Georgia

- *Funding provided by:*
  - Sea Grant Aquaculture Program 2019-NOAA-OAR-SG-2019-2005960-Enabling New Aquaculture Opportunities/Social, Behavioral, and Economic Needs in Aquaculture

Photo by Baxter Miller

Framework for prospective shellfish grower training in North Carolina, South Carolina, and Georgia

Thanks to our partners!

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1785
Marine Extension and
Georgia Sea Grant
UNIVERSITY OF GEORGIA
Sea Grant

CARTERET
COMMUNITY COLLEGE

Questions?

Photo by Baxter Miller

ENAO-Investigating the viability of quahog and oyster polyculture in Maine-MESG

M. McMahan, E. Wilkerson, C. Cleaver,
J. Kramer, G. Zydlewski

Investigating the viability of quahog and oyster polyculture in Maine

Marissa McMahan, PhD

Manomet

Caitlin Cleaver

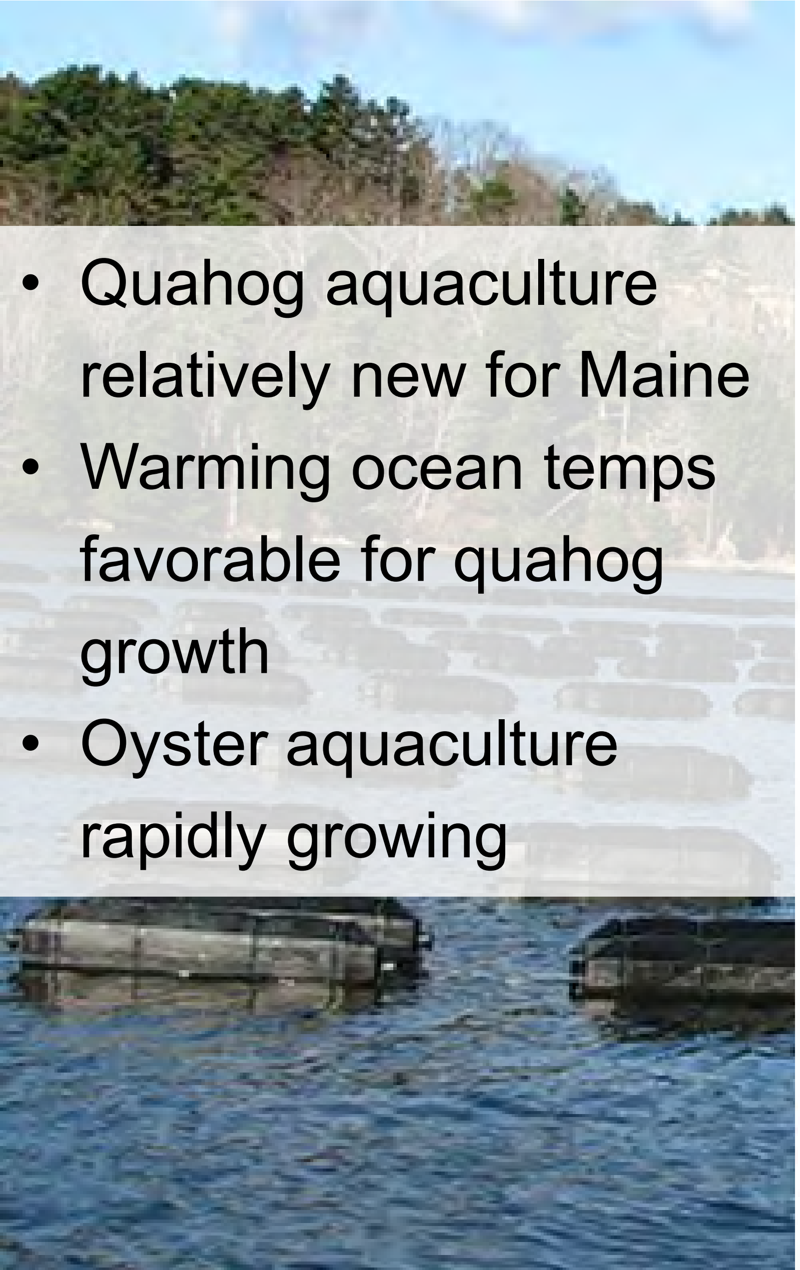
Bates College

Jordan Kramer

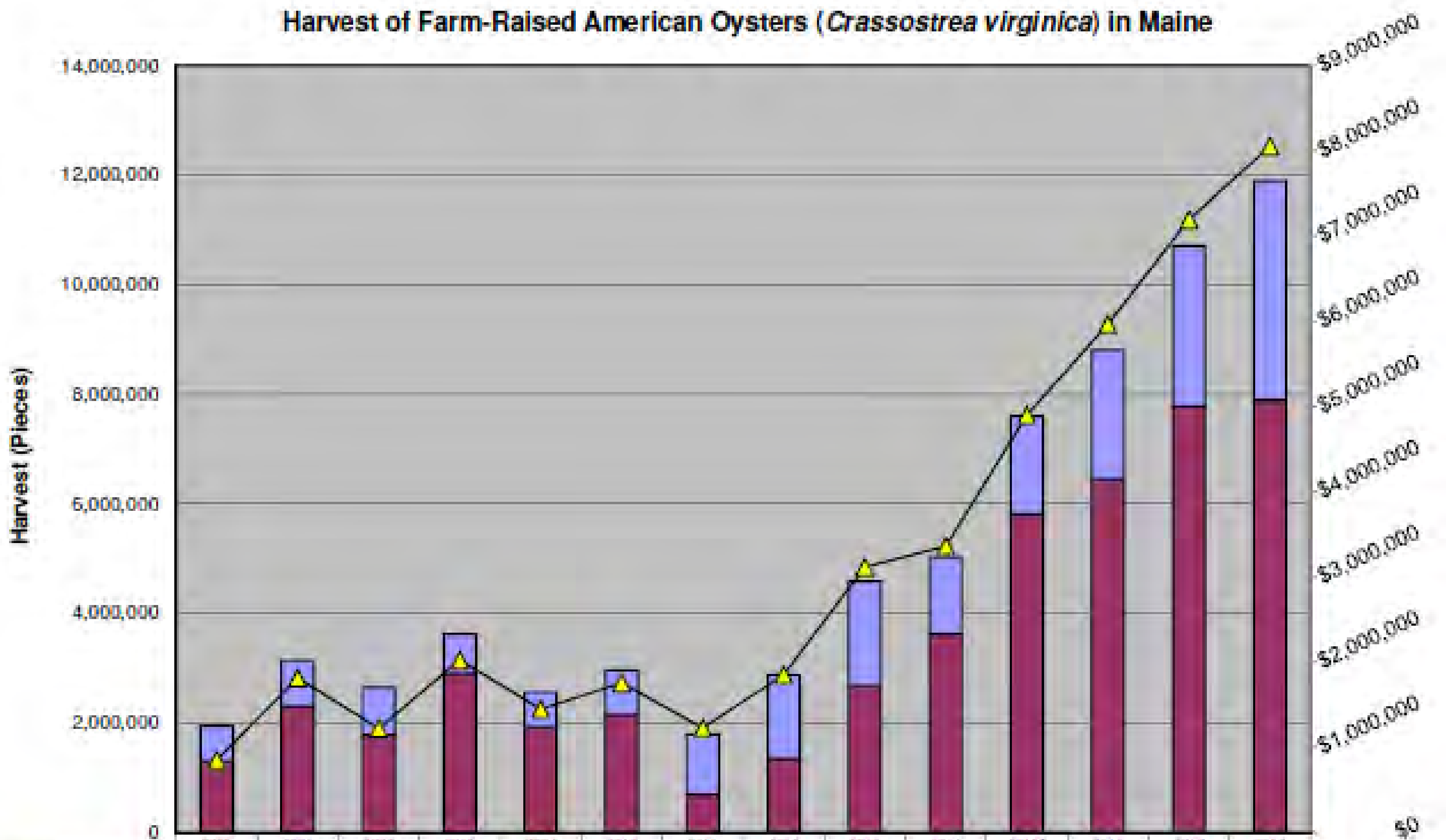
Winnegance Oyster

manomet

Background

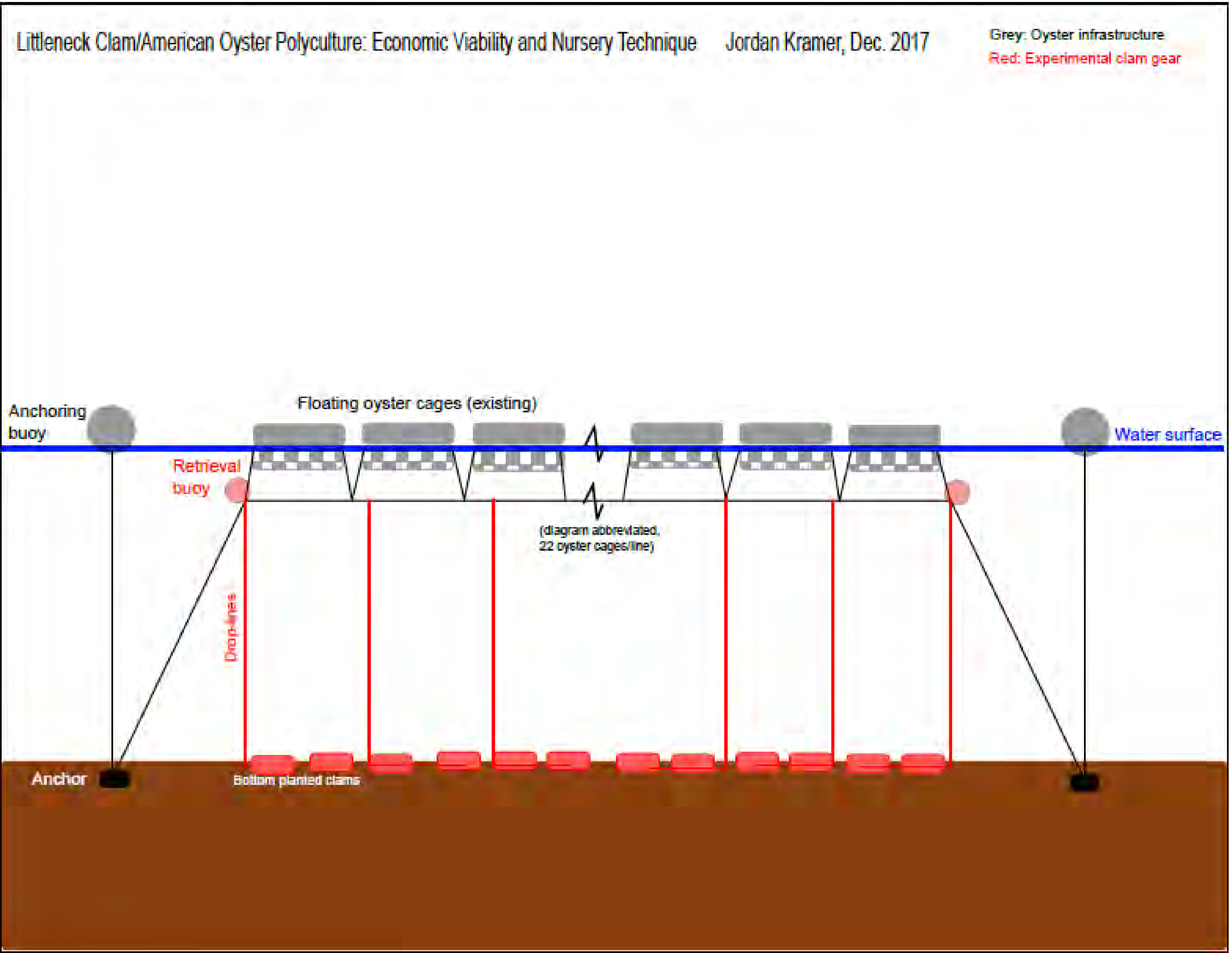


- Quahog aquaculture relatively new for Maine
- Warming ocean temps favorable for quahog growth
- Oyster aquaculture rapidly growing



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015*	2016	2017	2018
Other Location	650,044	837,138	875,067	728,073	833,894	820,047	1,103,901	1,522,652	1,900,640	1,404,861	1,788,685	2,356,755	2,941,792	3,992,948
Damariscotta River	1,291,494	2,306,290	1,777,798	2,896,714	1,925,700	2,140,279	687,500	1,353,162	2,681,997	3,618,669	5,811,629	6,447,636	7,774,405	7,898,517
Total Harvest	1,941,538	3,143,428	2,652,865	3,624,787	2,559,594	2,960,326	1,791,401	2,875,814	4,582,637	5,023,530	7,600,314	8,804,391	10,716,197	11,891,465
Total Value ($)	$848,338	$1,832,677	$1,220,531	$2,024,575	$1,447,378	$1,754,744	$1,225,472	$1,851,331	$3,113,775	$3,359,665	$4,898,154	$5,964,214	$7,193,325	$8,054,957

* *DMR began collecting LPA harvest data in 2015.*



- Additional crop within existing footprint
- Utilizes different part of water column (different food resources)
- Little or no added disturbance to habitat, wildlife, recreation, or traditional wild harvest fisheries

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Background

Goal: Investigate the viability of quahog and oyster polyculture at multiple sites in midcoast Maine.

Objective 1: Measure growth and survival of quahogs on 4 farms; measure environmental variables
Objective 2: Conduct economic and market analysis
Objective 3: Conduct outreach to grow industry knowledge and market development

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Brunswick
Long Reach Oyster
Harpswell
4.34 km


August 2019


Edgecomb
Westport
Boothba
Southport
ster
Georgetown Oyster LLC
Georgetown
Google Earth

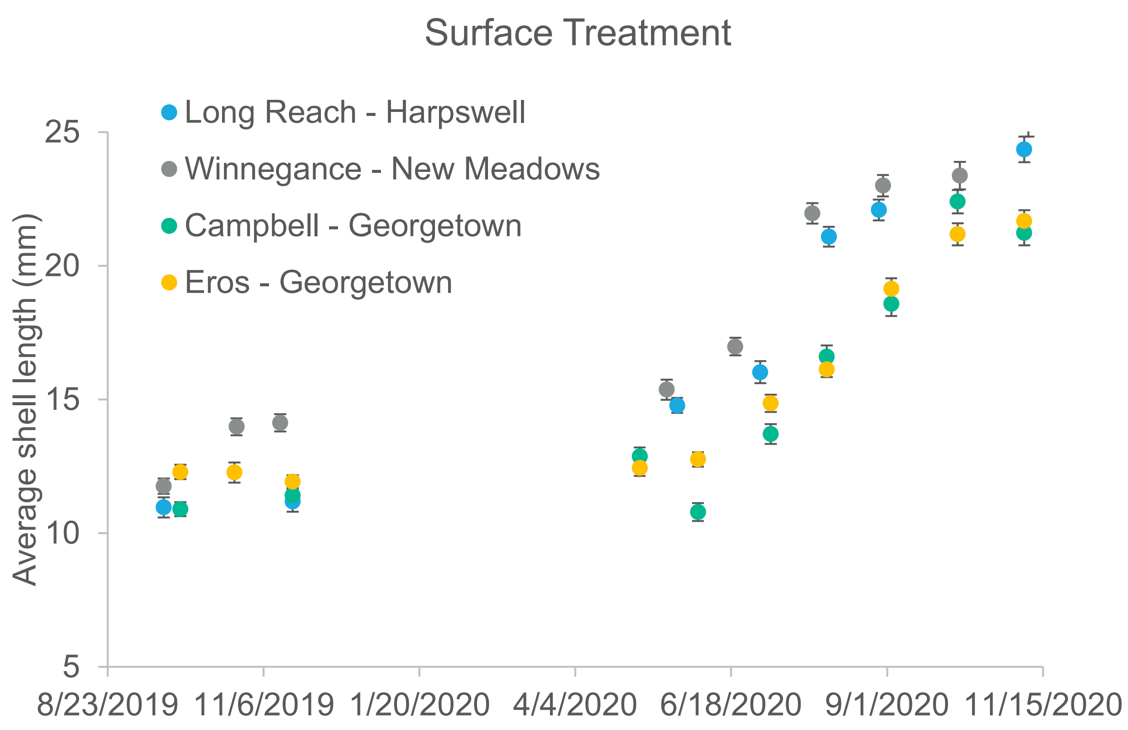
September 2019

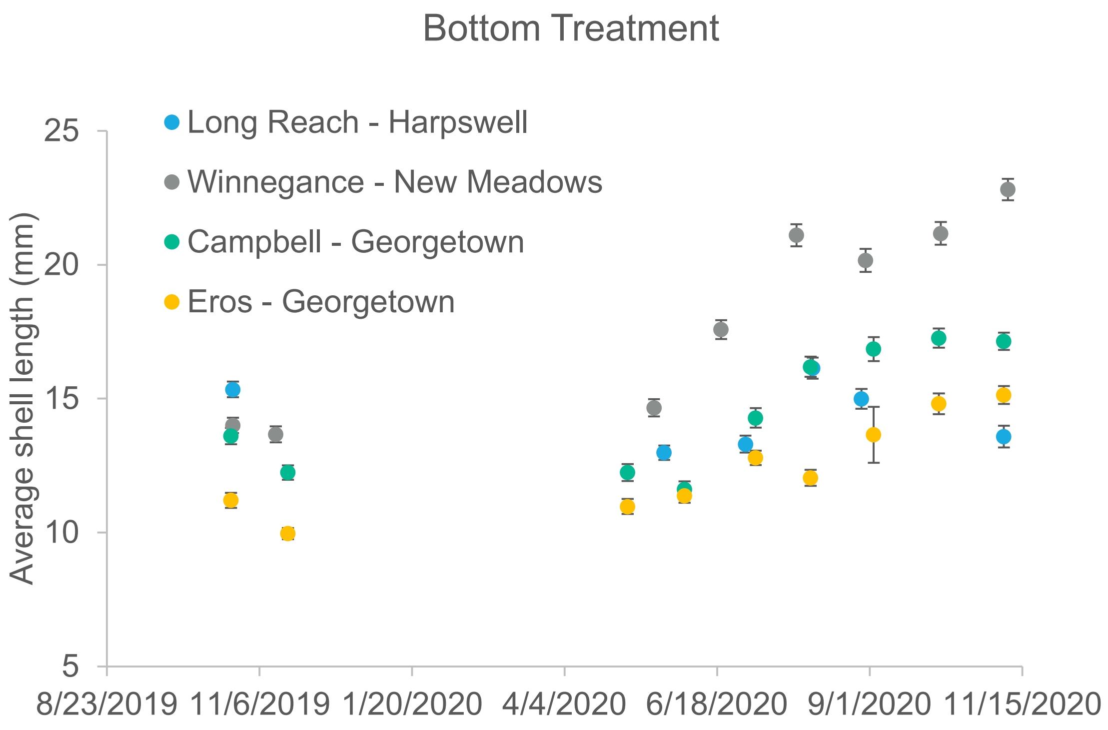
- Surface and bottom treatments
- 5,000 5-15 mm seed/bag

Monthly measurements (Sept-Nov 2019, May-Nov 2020):

- Growth
- Mortality
- Environmental variables

Results





Ideal market size ~38-45 mm shell length

Estimated time to market (from 1 mm): 2 ½-4 growing seasons

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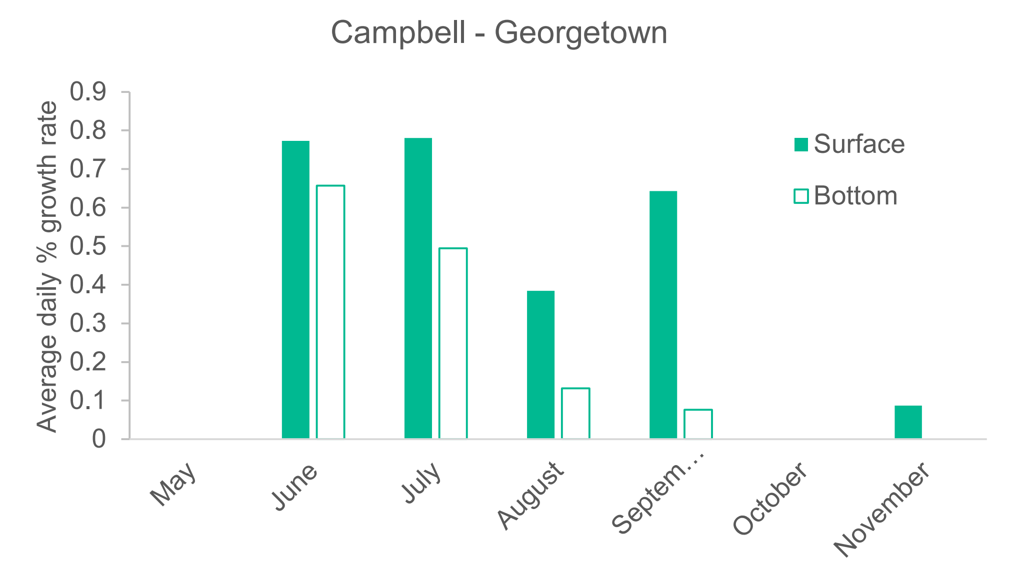
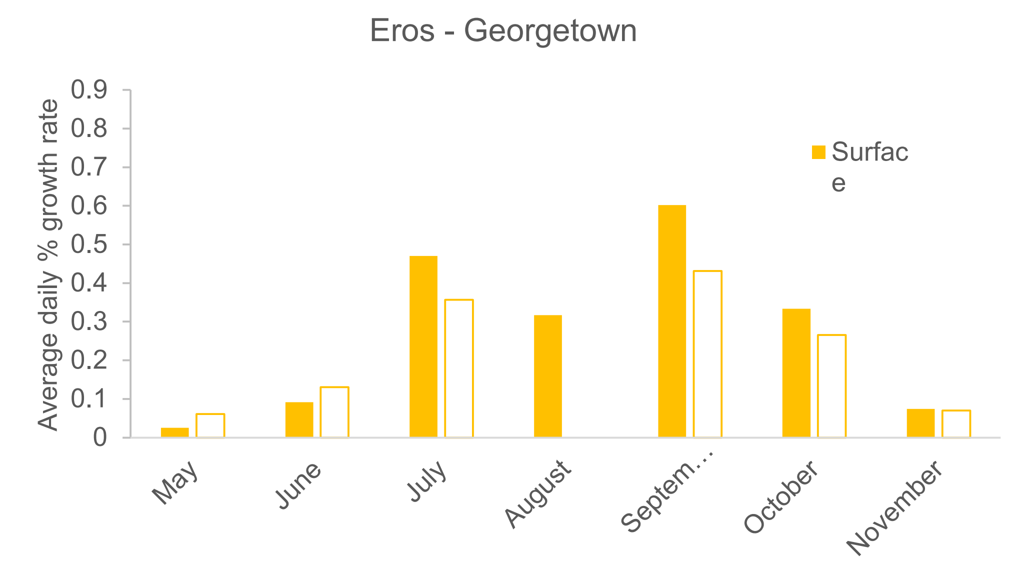
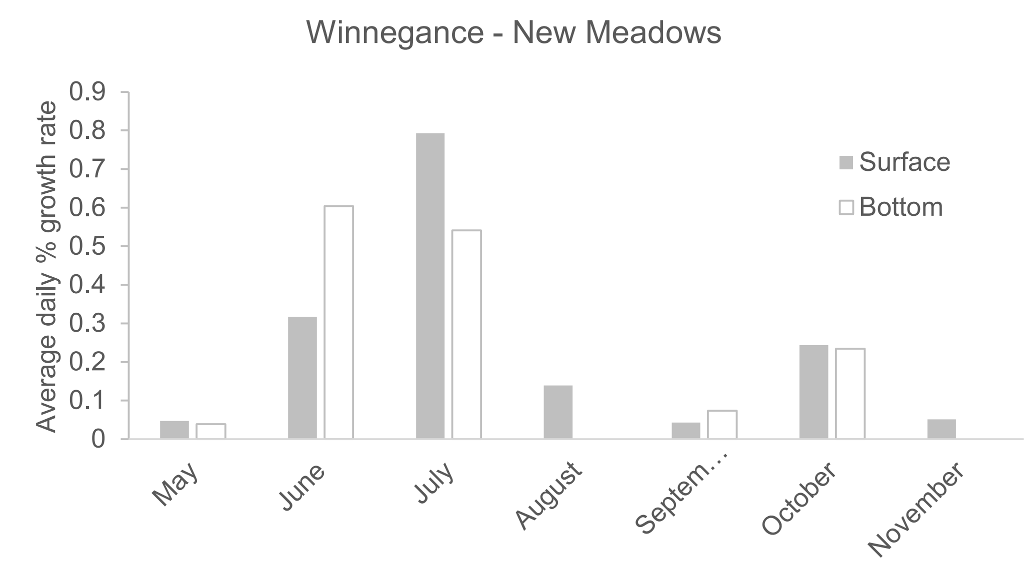
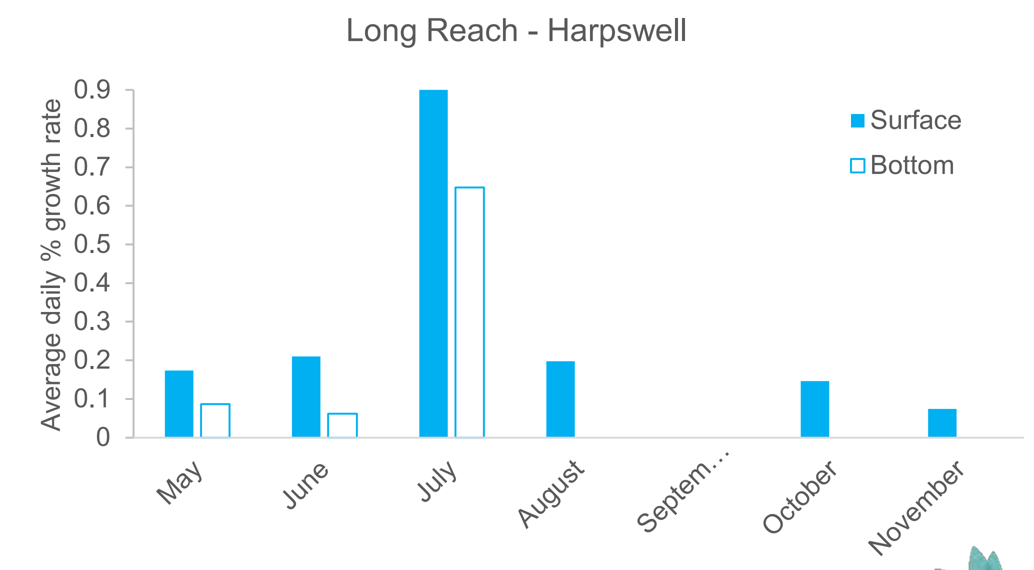
Results









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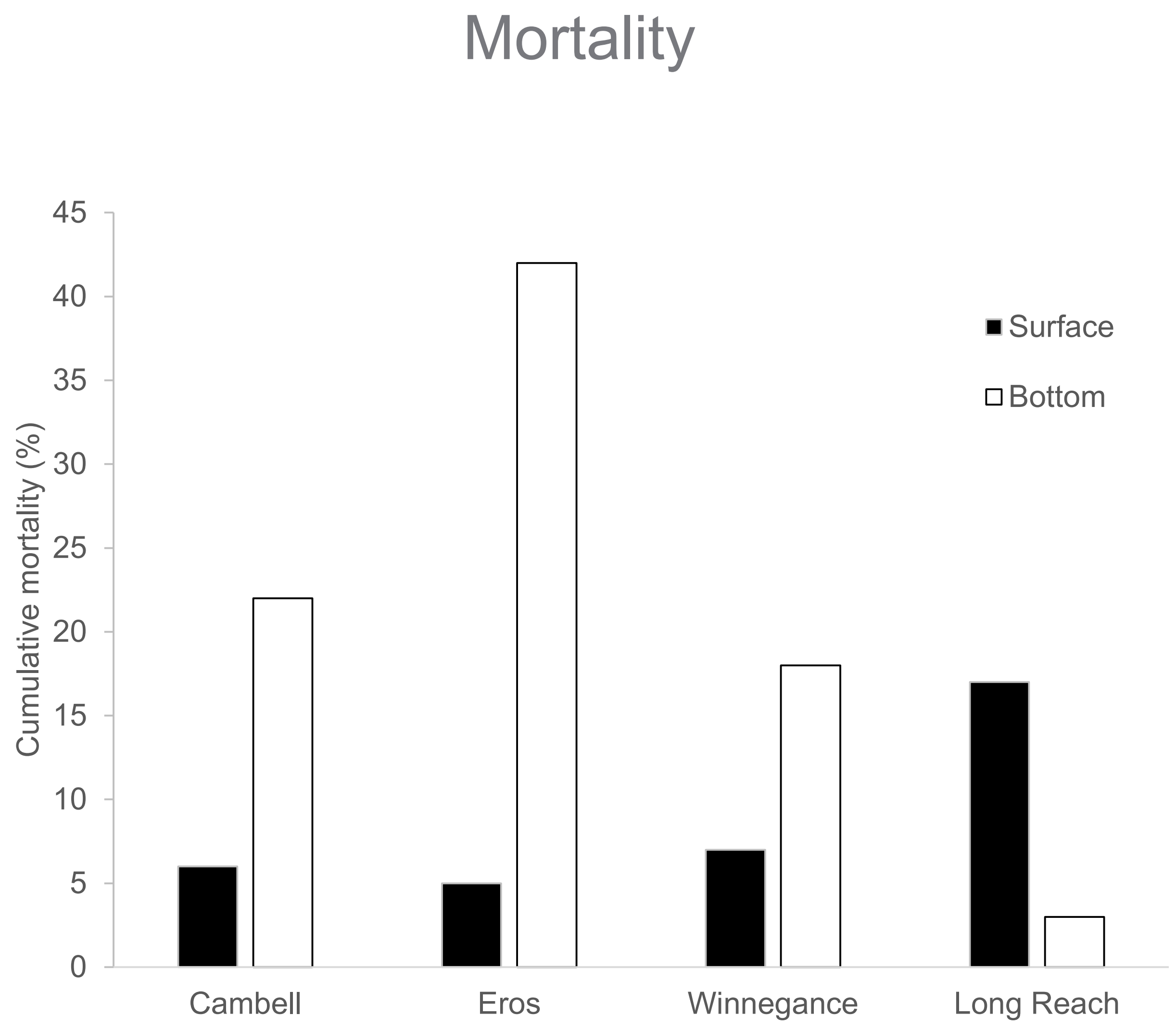
Results



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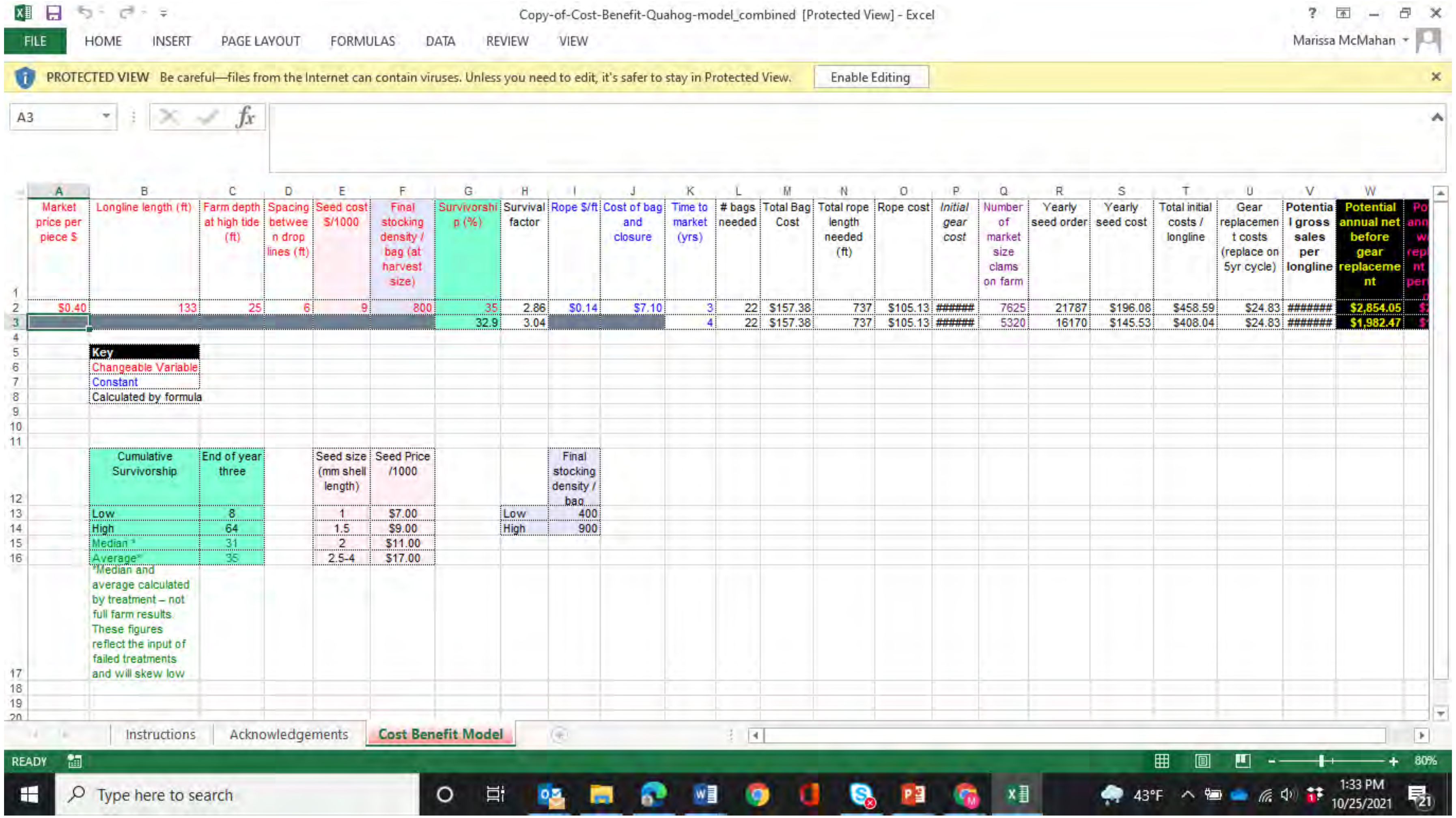
Results

Cost-benefit tool: https://www.manomet.org/project/shellfish-aquaculture



Market price per piece $	Longline length (ft)	Farm depth at high tide (ft)	Spacing between drop lines (ft)	Seed cost $/1000	Final stocking density / bag (at harvest size)	Survivorship (%)	Survival factor	Rope $/ft	Cost of bag and closure	Time to market (yrs)	# bags needed	Total Bag Cost	Total rope length needed (ft)	Rope cost	Initial gear cost	Number of market size clams on farm	Yearly seed order	Yearly seed cost	Total initial costs / longline	Gear replacement costs (replace on 5yr cycle)	Potential gross sales per longline	Potential annual net before gear replacement
$0.40	133	25	6	9	800	35	2.86	$0.14	$7.10	3	22	$157.38	737	$105.13	######	7625	21787	$196.08	$458.59	$24.83	#######	$2,854.05
						32.9	3.04			4	22	$157.38	737	$105.13	######	5320	16170	$145.53	$408.04	$24.83	#######	$1,982.47

Key
Changeable Variable
Constant
Calculated by formula

Cumulative Survivorship	End of year three
Low	8
High	64
Median *	31
Average*	35

*Median and average calculated by treatment – not full farm results These figures reflect the input of failed treatments and will skew low

Seed size (mm shell length)	Seed Price /1000
1	$7.00
1.5	$9.00
2	$11.00
2.5-4	$17.00

	Final stocking density / bag
Low	400
High	900

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Market Assessment

Objective: Explore the barriers and opportunities of establishing a market for farmed quahogs

- Interview shellfish managers along the eastern seaboard to gain an understanding of the supply side of existing regional quahog markets (n = 7).
- Interview Maine-based shellfish dealers to gauge interest and feasibility of developing the demand side of a market for quahog aquaculture on the Maine coast (n = 4).

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Barriers

- Limited social carrying capacity for aquaculture (i.e., NIMBY-ism)
- Environmental constraints (e.g., colder waters = slower growth, biotoxins)
- Regulatory challenges (e.g., length of time for lease approval)
- Need to educate consumers to increase demand and to generate demand for a unique farmed product

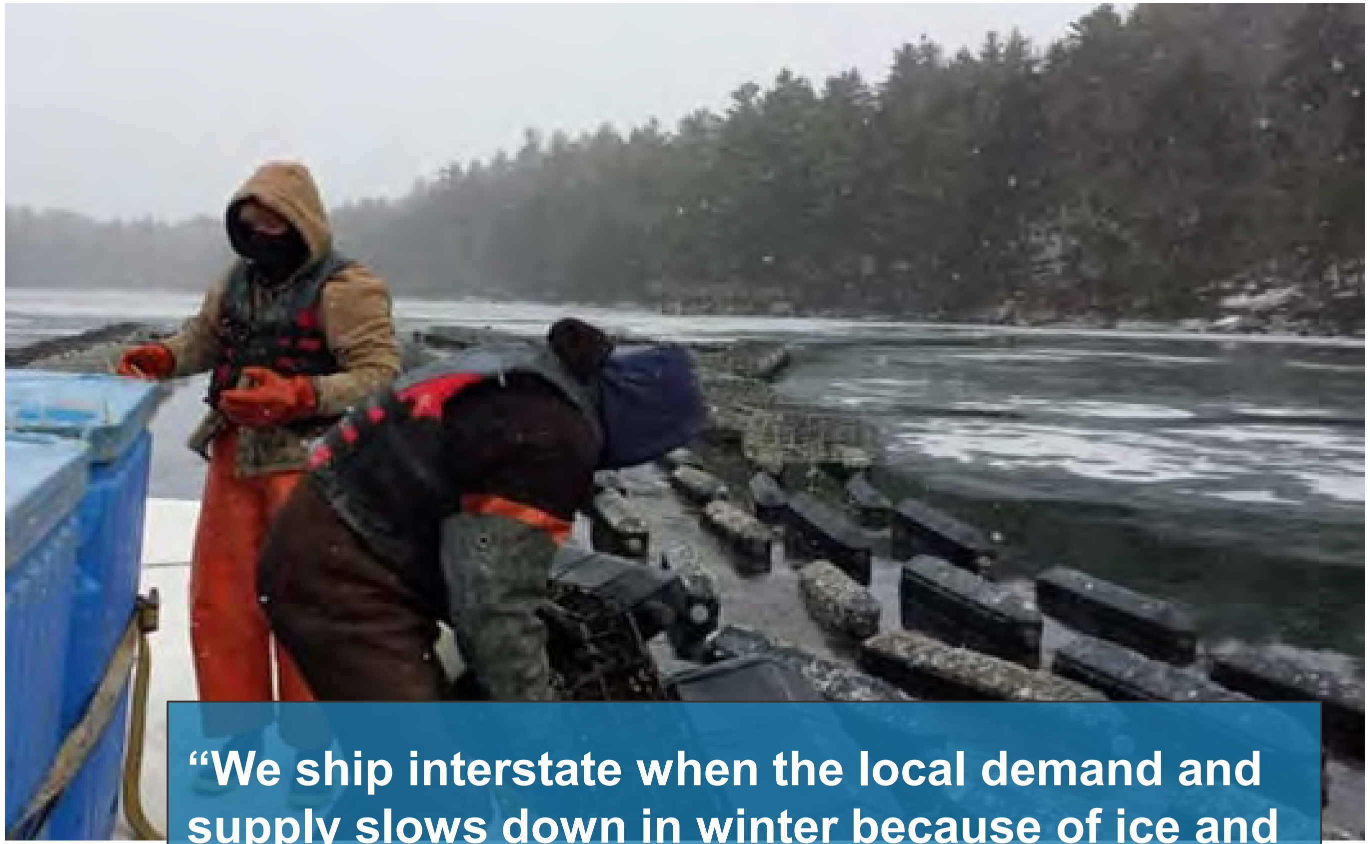
Opportunities

From a farmer's perspective:

- Lower initial investment with this growing technique

From a market perspective:

- Potential to supply product year-round
- Potential to supply a unique product



"We ship interstate when the local demand and supply slows down in winter because of ice and weather for wild fisheries, so a steady aquaculture supply could help fill demand for places like Chicago and Texas in the winter when quahogs are more seasonally popular there….<u>We will always have a demand and want more clams.</u>"

-Current Maine Quahog Dealer

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Conclusions

- Quahog and oyster polyculture is economically viable
  - Low cost to entry
  - Overall high survival
  - Lower effort
- Growing on surface appears more advantageous (faster growth, lower mortality), but competes for space with oysters
- Market demand is promising

Ongoing work/next steps

- SWOT/PESTLE
- How-to guidebook
- Industry outreach
- Chef/consumer outreach

Acknowledgements

Farmer partners: Jordan Kramer, Chad Campbell, Mike Gaffney, Mark Gaffney, Lincoln Smith

Academic partners: Josh Stoll, Francis Eanes, Katie Dobkowski, Rachel Lasley-Rasher, Elizabeth Walker, Michele LaVigne

Students: Stella Moreno, Erica Ferrelli, Natalie Moon, Josie Carter, Andreas Hansen, Brady Orozco-Herman, and Talia Sperduto

Research Technician: Jessie Batchelder

ENAO-Lease or Permit?: Security of Tenure Workshop to Advance Offshore Aquaculture in the U.S. EEZ-NSGLC

S. Otts, C. Janasie

Exploring Options to Authorize Offshore Aquaculture Workshop

Stephanie Otts & Catherine Janasie
National Sea Grant Law Center
Sea Grant Aquaculture Research Symposium
October 25, 2021

Sea Grant Law Center

http://nsglc.olemiss.edu

Who We Are

- One of 34 Sea Grant Programs.
- Based at the University of Mississippi School of Law.
- Established to provide non-advocacy legal research, outreach, and education services to Sea Grant network.
- Follow us on Twitter (@SGLawCenter) and Facebook (@nsglc)!

Project Overview

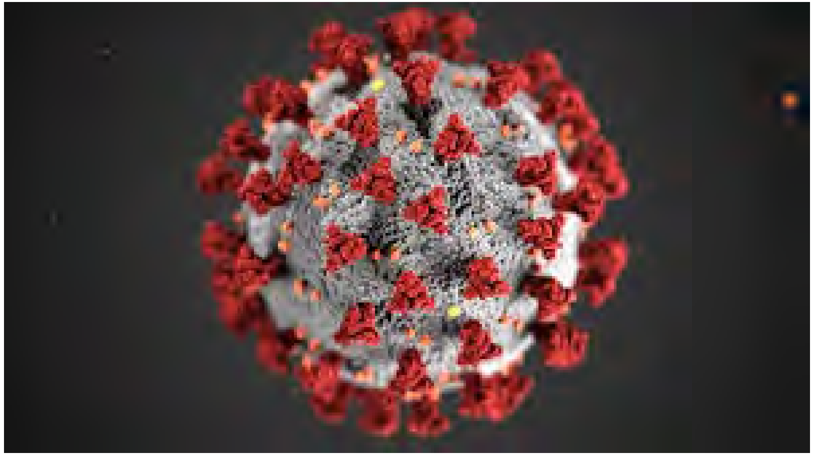
- Funded through NOAA Sea Grant “Exploring New Aquaculture Opportunities” Competition in 2019.

- Project Objectives:
    - Assess the current state of the debate regarding security of tenure for offshore aquaculture;
    - Convene a collaborative learning workshop to engage stakeholders in discussions of policy preferences, property rights, and research needs associated with providing security of tenure for offshore aquaculture; and
    - Publish workshop proceedings to share information on potential property-related options for marine aquaculture in the EEZ.

Participants

- Representatives from federal agencies (NOAA, BOEM, EPA)
- Congressional Staffers (Sen. Wicker's Office)
- Representatives from Industry (NAA, SATS)
- Academics (marine law and policy professors)

And then COVID-19!



1.5 day workshop turned into 5 virtual sessions spread over 9 months.

NSGLC Research Pre-Workshop

- Literature review of relevant law, policy, and economic scholarship.
- Backgrounder document: “Authorization Options for Use of Federal Waters for Offshore Aquaculture”

Workshop Process

- **May 5, 2020**: options to grant property rights for aquaculture in federal waters
- **May 12, 2020**: needs of government and industry relative to the mechanism to grant property rights
- **May 13, 2020**: evaluate options
- **September 24, 2020**: Update on research and prepare for comments
- **February 9, 2021**: refine findings/observations

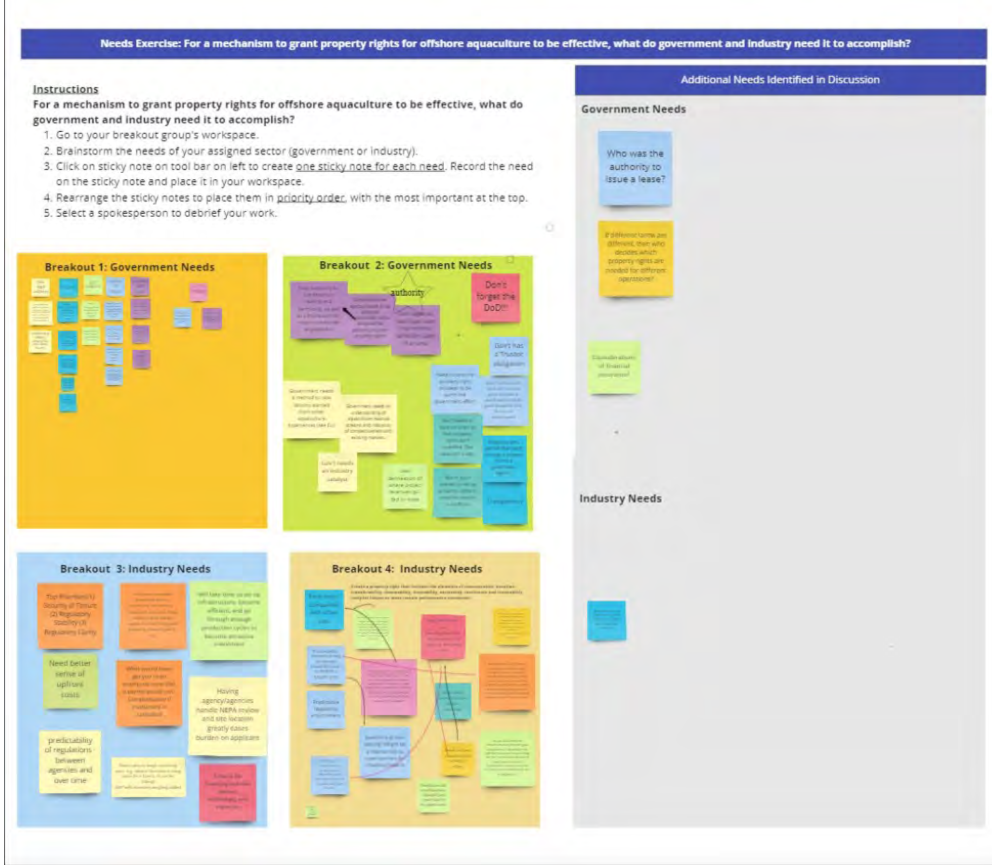
Decision to go Virtual

- Initial Hesitation
  - Strong preference from some Steering Committee members and participants to postpone until in-person was feasible.

- As COVID-19 Pandemic worsened and restrictions continued, NSGLC decided to move forward. Some reasons why included:
  - Desire to move project forward and avoid indefinite delays.
  - Net positive effect on participation (broader and more)

How do you restructure a 1.5 day in-person meeting to a virtual setting?

- Professional facilitator was key
- Use of Miro, an online whiteboard
  - Allowed more participant interaction
  - Facilitated participation from those unable to use Zoom
- Breaking down and spreading agenda out over several separate engagements.



Sea Grant Law & Policy Journal

Volume 11:1

Sea Grant Law Center

The University of Mississippi School of Law

Sea Grant Law & Policy Journal

Volume 11:1

Table of Contents

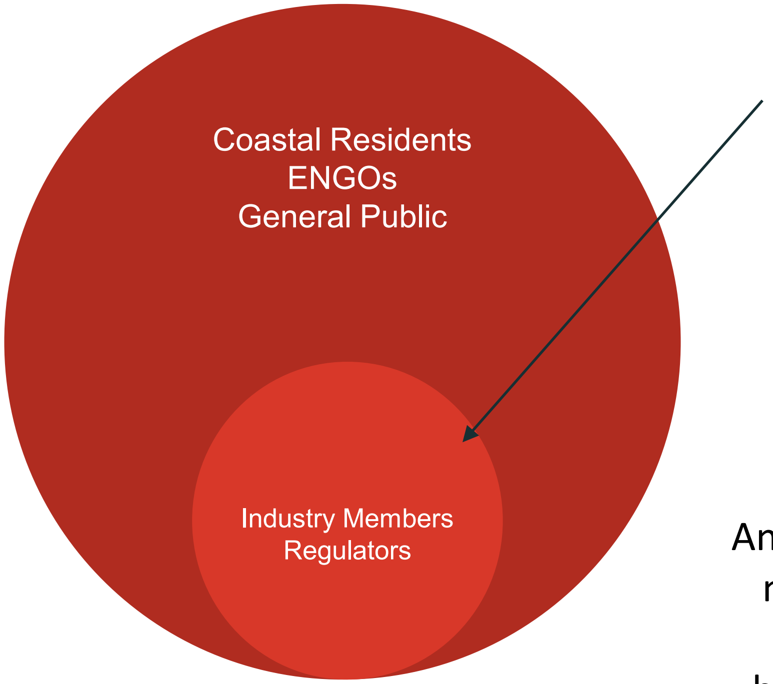
Cover Photo: Dane Klinger

Key Observations

Photo Credit: Spencer Black, NPS Photo

Stakeholder Engagement

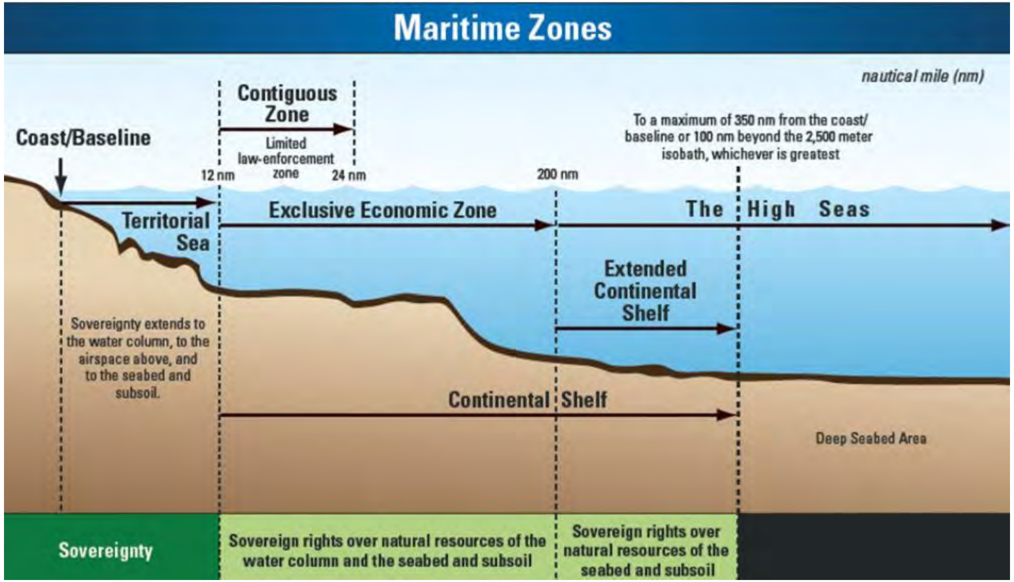
Observations reflect only one piece of a broader conversation about the future of offshore aquaculture in the U.S.



Only two stakeholder groups were in the room.

Any authorization process will need to provide for robust public engagement and balancing of public interest.

Determining Property Rights Offshore



Comparing APPLES to ORANGES!

Image courtesy of the NOAA Office of Ocean Exploration and Research

Authorization Mechanism & Authorizing Agency

- Permitting regimes exist which can be used to permit aquaculture, BUT
  - They were not designed for aquaculture
  - They do not address rights of occupancy

- Only U.S. EPA & U.S. Corps of Engineers currently have direct permitting authority over offshore aquaculture.

- Leasing authority (i.e., oil/gas or wind) generally rests with Department of Interior.

Criteria & Granting Property Rights

Characteristics of property rights mechanism matter more than what the instrument is called.

Public Engagement

Compensation

Fees and Financial Assurances

Permit ⟷ **Lease**

Transferability

Property Interest Granted

Right to Exclude Others

Duration

Enforcement

Comparative Analysis

Categories:

- Duration
- Property Interest Granted
- Right to exclude others
- Transferability
- Enforcement
- Financial
- Public Engagement
- Legal classification of instrument by court
- Compensation

Models:

- Special Coral Reef Ecosystem Fishing Permit
- Rivers and Harbors Act Section 10
- Clean Water Act Section 402
- Grazing permits/leases
- Outer Continental Shelf Lands Act leases
- Gulf Aquaculture Permit
- AQUAA Act

	Needs		Existing Authorization Mechanisms for Offshore Aquaculture		
	Government	*Industry*	*Special Coral Reef Ecosystem Fishing Permit (Kampachi Farms - 2011/2013/2016)*	*RHA § 10 (Catalina Sea Ranch - 2014)*	*CWA § 402 NPDES (Ocean Era - 2020)*
Agency	-	-	NOAA Fisheries (Commerce)	U.S. Army Corps of Engineers (Defense)	U.S. Environmental Protection Agency
Duration	The length of term needs to be reasonable and similar to authorizations for other offshore activities. Must account for uncertainty regarding future conditions or policy changes. Instrument should be renewable subject to certain terms and conditions.	The length of term needs to be long enough to align with standard industry production cycles and business models. Must account for expectations of investors to minimize barriers to financing. Should have flexibility to provide shorter durations for research and pilot demonstration projects. Provide for renewal if terms and conditions of lease have been adhered to by operator.	Varies. Permit issued to Kampachi Farms in 2013 had a 1-year term. Permit issued in 2016 had a 2-year term. Permit contained no language regarding renewal.	Usually 5 years, but can be issued with longer terms. Renewable for another 5-year term upon request. Per CSR's permit, "[I]f you need more time to complete the authorized activity, submit your request for a time extension" at least one month before the permit expires.	5 years. Permit indicates that permittee must apply for new permit at least 180 days before expiration of current permit if they wish to continue operations.
Property Interested Granted	Instrument must be grounded in clear statutory authority to convey stated property interests. Must account for government's trustee and environmental responsibilities, as well as the rights of other resource users. Instrument should limit constitutional takings liability.	Instrument should convey sufficient property interest to create a tangible asset that is recognized as producing economic value. Must account for need of operators to use instrument as collateral for loans or other financial reasons (i.e., investment capital), as well as for acquiring commercial insurance. Must convey geographic area large enough to account for operational needs.	Authorizes holder to culture and harvest specific number of fish in a specific location using specific equipment (i.e., an aquaculture net pen). Expressly states that "[n]othing in the permit shall be construed to convey any property rights in either real or personal property, or any exclusive privileges [...]."	Grants holder the right to undertake activities as set forth in the permit, i.e. build structure in navigable US waters. Because these permits authorize activities that can interfere with navigation, they are necessarily place-based and authorize occupancy of a particular space. Permit expressly states that it "does not grant property rights or other exclusive privileges."	Authorizes holder to discharge pollutants from a point source, here an aquaculture net pen, into waters of the US. Permit expressly states that it "does not convey any property rights of any sort, or any exclusive privilege."
Right to Exclude Others	Instrument must provide for the protection of navigation, public access rights, and public and private safety. In addition, instrument should authorize government access and entry for inspections and other enforcement activities.	Instrument must provide exclusive right to conduct aquaculture operations in designated area. Should recognize operator's private property rights in structures, gear, and stock, and allow operator to limit or restrict access to prevent theft and property damage. Instrument should provide for safety buffer zones around authorized aquaculture operations to ensure safety of navigation and protect property or life at sea.	Permit and applicable regulations do not contain any provisions concerning permittee's ability to exclude unauthorized vessels or persons from permitted site.	Permit does not grant any right of exclude others from permitted ocean space. Permitted activity may not interfere with the right of the public to free navigation on all navigable US waters. Per CSR's permit, Corps allowed to inspect authorized activity "at any time deemed necessary."	Permit does not convey any right to exclude others from area where permitted activity is authorized. Per permit terms, EPA may, upon presentation of credentials "and other documents as may be required by law," (1) enter permittee's facility or place where records are kept; (2) access, and at reasonable times copy, records required by permit; (3) at reasonable times, inspect any facilities, operations, equipment or practices regulated or required by permit; and (4) at reasonable times, sample and monitor substances and parameters at any location for purposes of assuring statutory and permit compliance.

Government Interest

- Federal government doesn't own land in traditional sense.
  - Holds and manages lands for the benefit of all citizens.

Public trust responsibilities limit the rights and privileges government can convey to commercial operations.

Use as Collateral

Workshop participants noted the need for industry to attract investors for offshore aquaculture operations. Concerns have been raised that permits can’t be used as collateral.

- Legally, both permits and leases have economic value that is recognized by investors and can serve as collateral for financing.
    - Federal regulations for grazing permits state explicitly that permits may be used as collateral.
- Whether particular investors or lenders will accept such instruments as collateral is unknown and likely extremely variable.

Questions?

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ENAO-Developing new oyster sterilization technology to avoid triploid summer mortality-MDSG

T-T. Wong, Y. Zohar, L. Plough, D. Webster, F. Moser

Developing new oyster sterilization technology to avoid triploid summer mortality

Ten-Tsao Wong

Department of Marine Biotechnology/IMET, University of Maryland Baltimore County

Co-PIs: Dr. Louis Plough, Mr. Donald Webster,

Dr. Yonathan Zohar, Fredrika Moser

NOAA

Sea Grant

Sea Grant Aquaculture
Research Symposia
Oct 25 - Nov 3, 2021

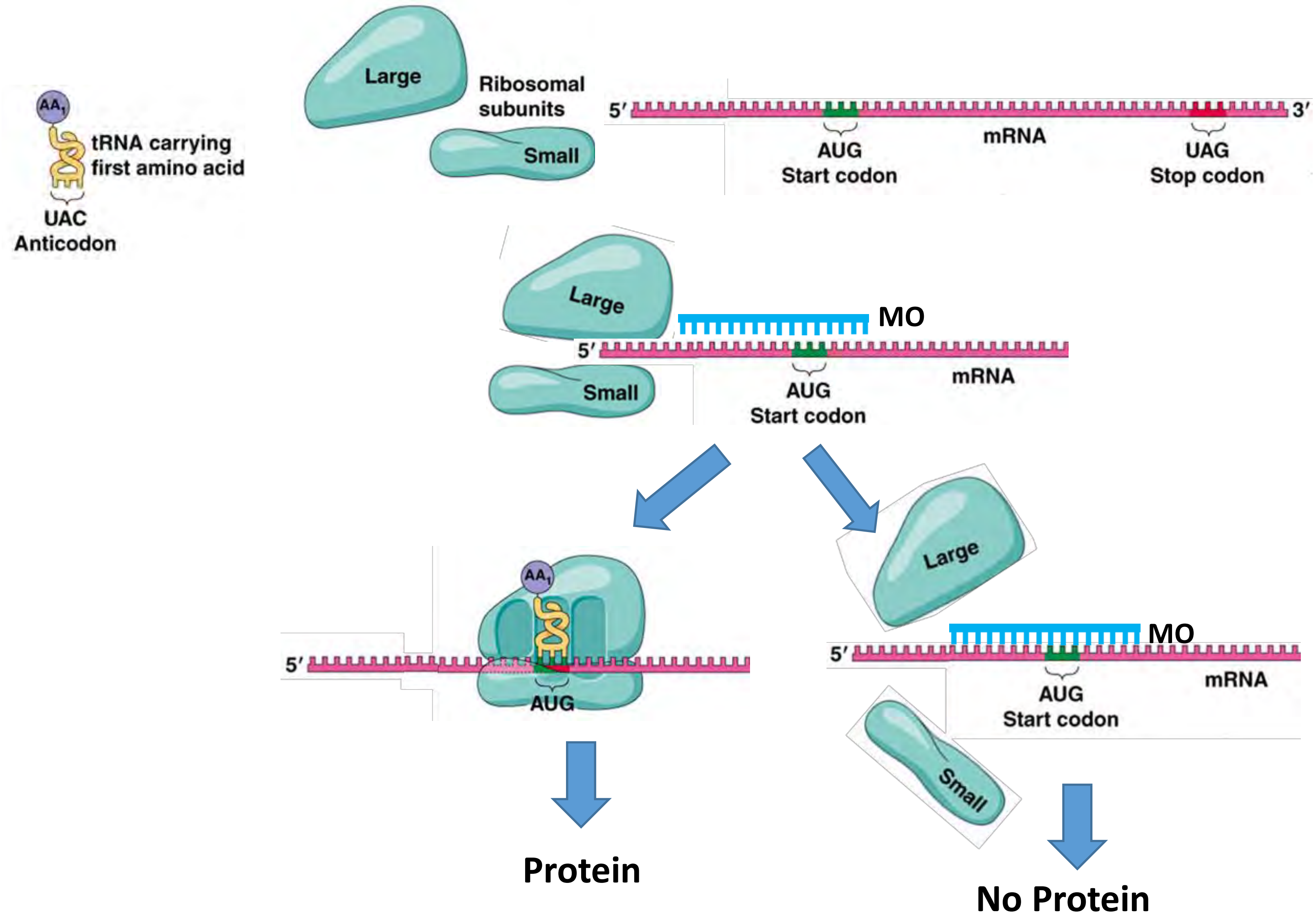
Importance of oyster sterilization

- **Genetic containment to minimize ecological risk and achieve environmentally-responsible aquaculture practices.**
- **Sterilization enhances growth by increasing food energy conversion to muscle growth instead of gonadal development.**
- **Sterilization prevents sexual maturation that can cause deterioration of meat quality and increase susceptibility to stress and disease.**
- **Sterility is a means for producers to safeguard valuable farmed strains against unauthorized propagation.**

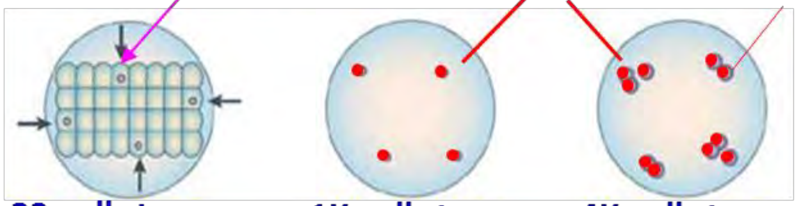
In a simple sentence: Sterilization is to block the production of functional germ cells, sperm and eggs.

Our sterilization works started from fish and expect to be extended to the oyster.

Anti-sense Morpholino oligomer (MO) technology



Sterilization by bath immersion to silence deadend gene



Deadend (Dnd), a germ cell specific protein, is essential for PGC development.

Morpholino oligomer (MO) is an anti-sense technology that transiently blocks gene expression.

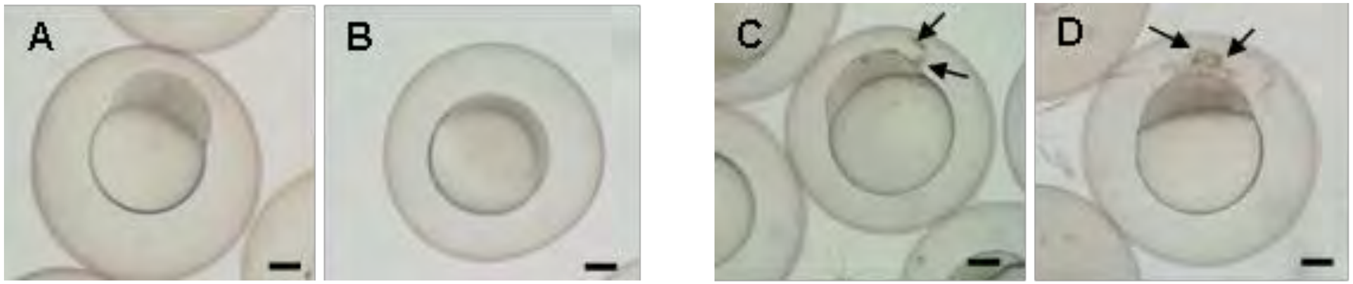
Vivo* is a molecular transporter that triggers endocytosis.

Dnd mRNA 5'——ATG——AAAAAAAAAAAAA3'

IIIIIIIIIIIIIIIIIIIII Dnd-MO (25 nts, 10 KD, It is big and not able to pass through chorion)

IIIIIIIIIIIIIIIIIIIII* Dnd-MO-Vivo (Vivo is able to carry Dnd-MO across chorion)

Dnd-MO　　　　Dnd-MO-Vivo

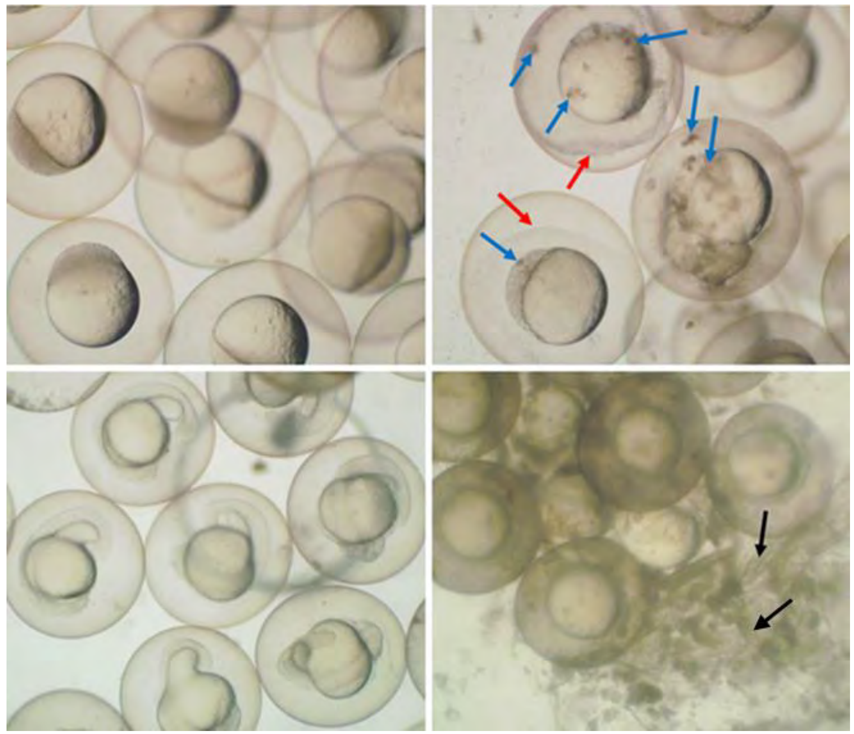


Chorion permeability enhancement

Vivo and Vivo-like compound incubation

10 µM | 100 µM

Incubation time: 1hr, 18 hrs

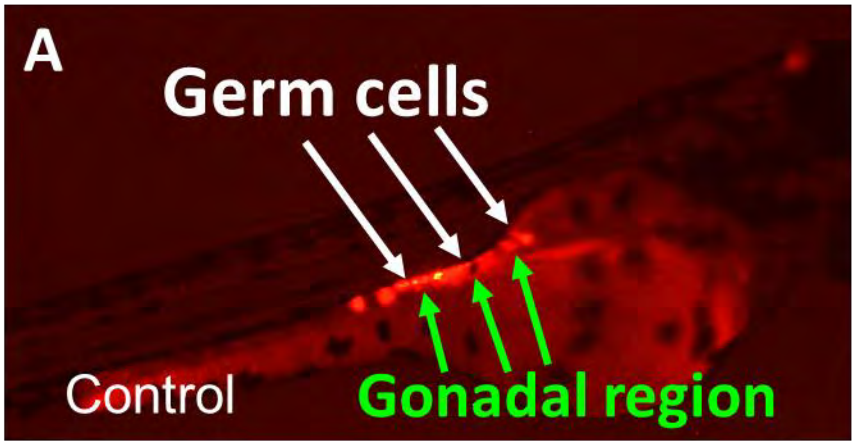


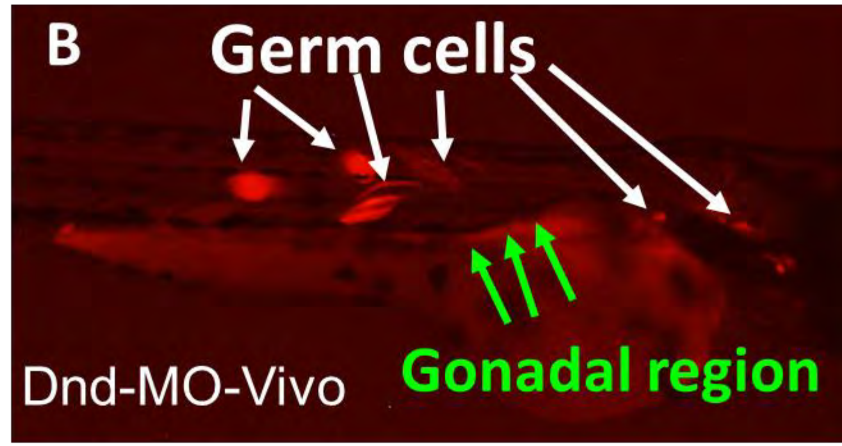
→ Aggregates

→ Shrinking of inner membrane

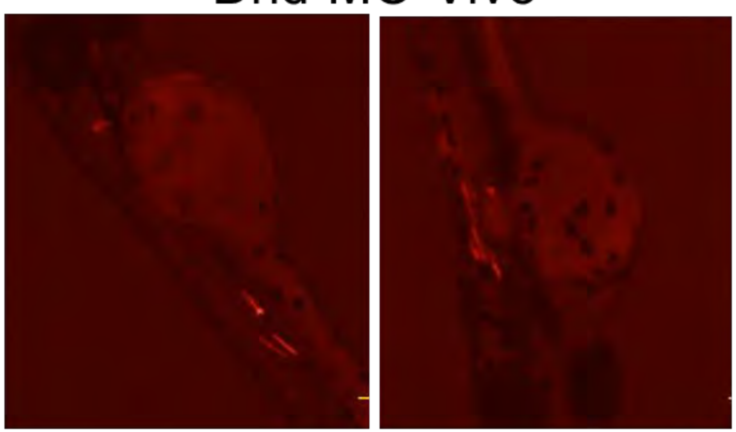
→ Broken chorion

Dnd-MO-Vivo disrupted germ cell development in zebrafish

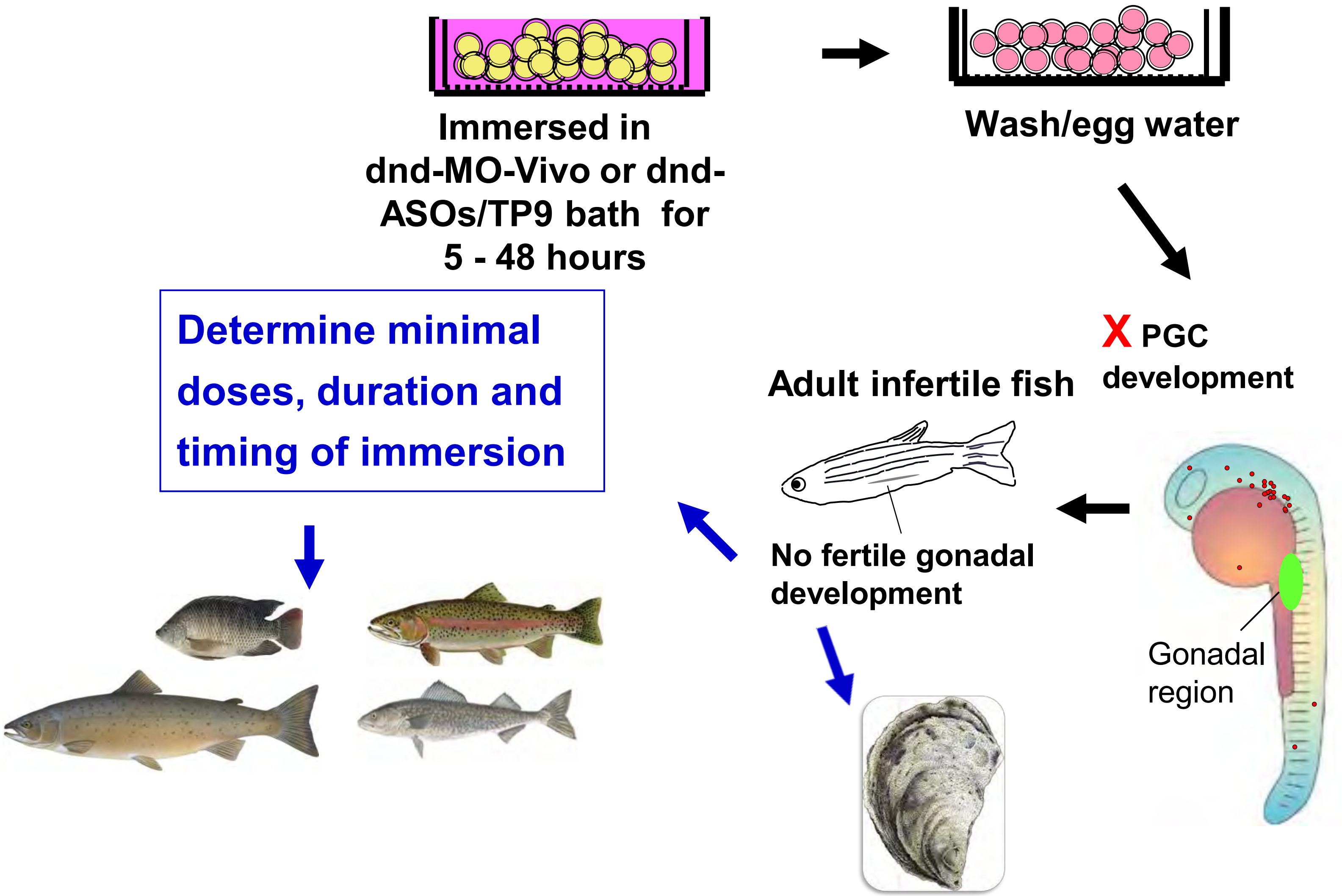




Dnd-MO-Vivo



A flow chart diagram of dnd-MO-Vivo bath immersion



Production of sterile oyster

Why sterile oyster:

- Summer mortality.
- Loss of flavor and texture due to spawning.

Triploid:

- Brook stock :♂tetraploid × ♀diploid:
- Sensitive for sub-optimal condition.

Critical components for bath-immersion method:

- Identify genes that are indispensable for oyster germ cell development.
- Optimize MO-Vivo immersion protocol for oyster.

Why sterile oyster?

Development of gonad and spawning in summer can cause

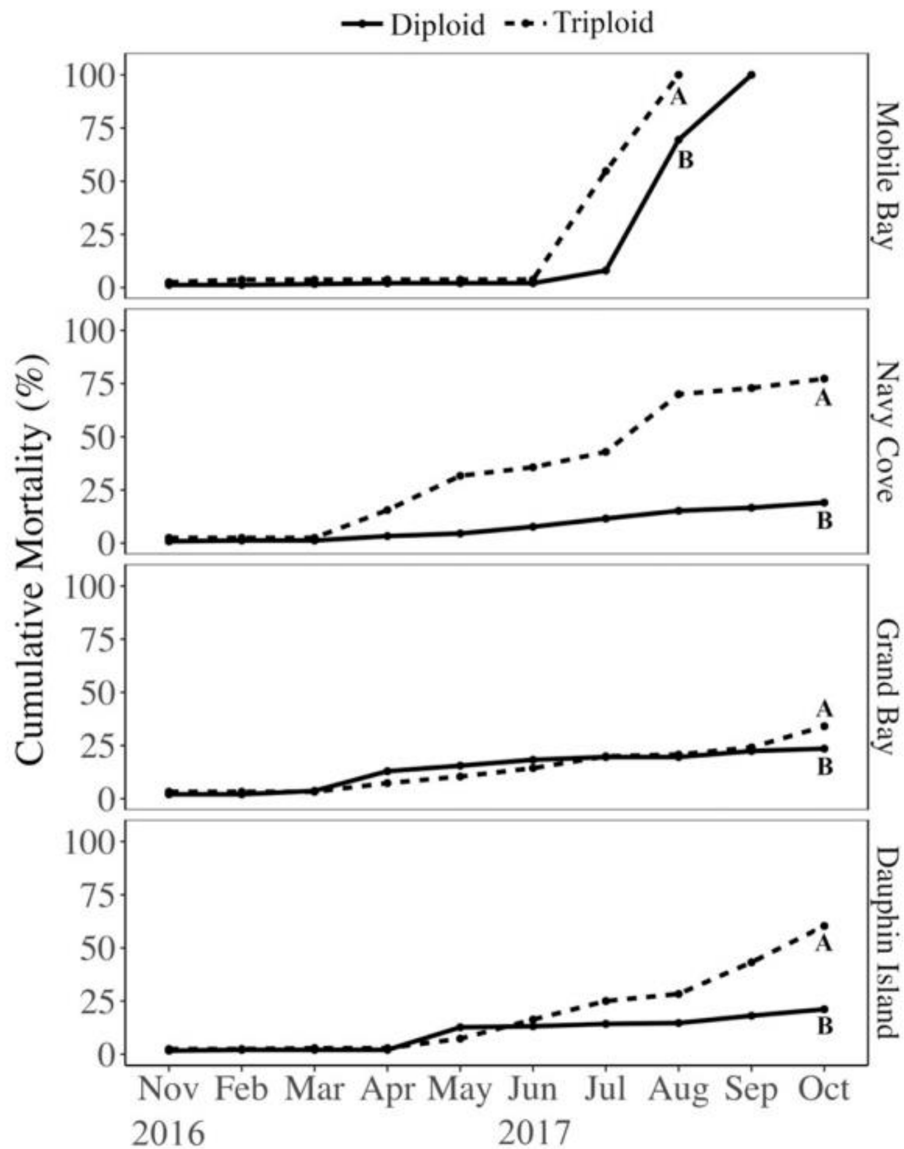
- Sale decline
- Reproduction-related summer mortality

Before spawning

After spawning

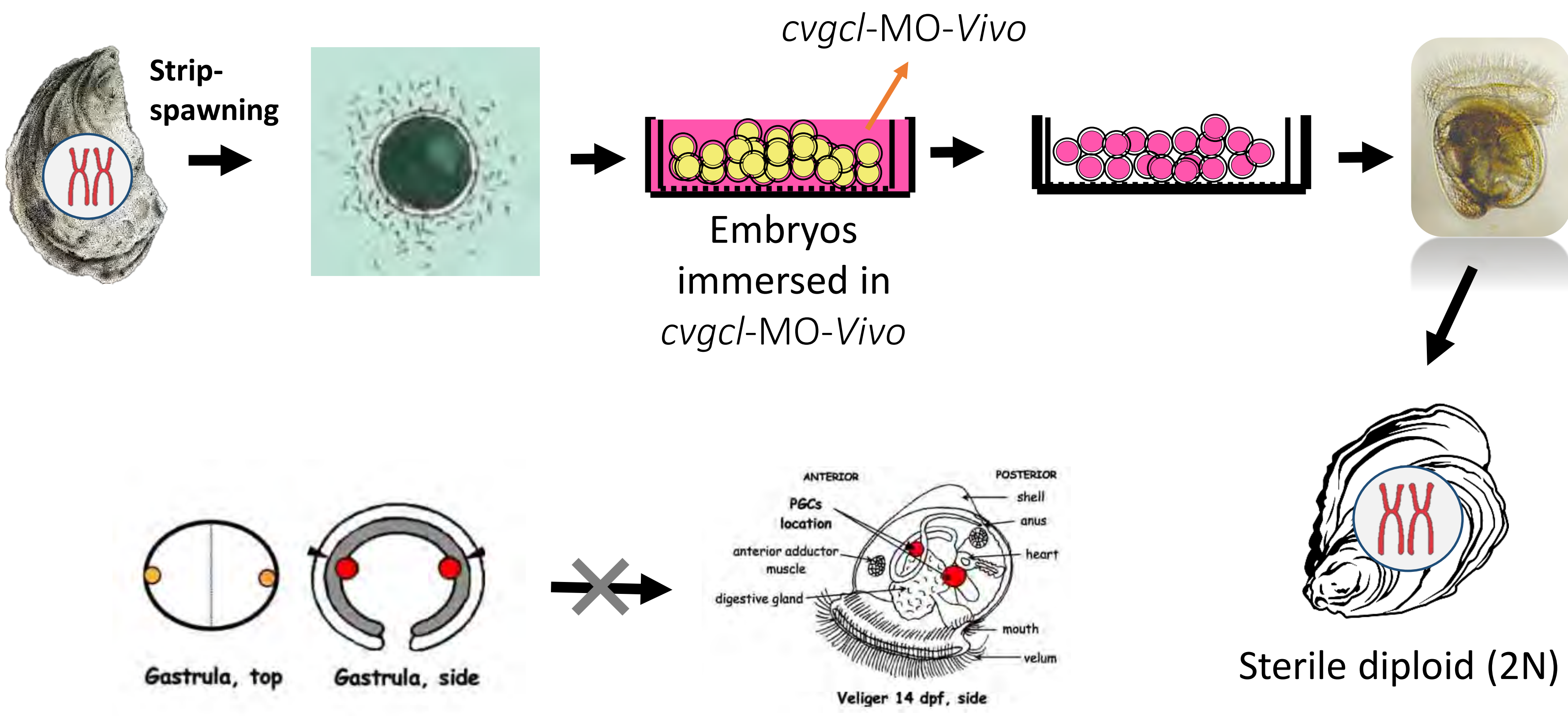
Triploid oyster

- Growth advantage but may cause higher stress-related mortality than diploid oyster



Wadsworth et al. 2019

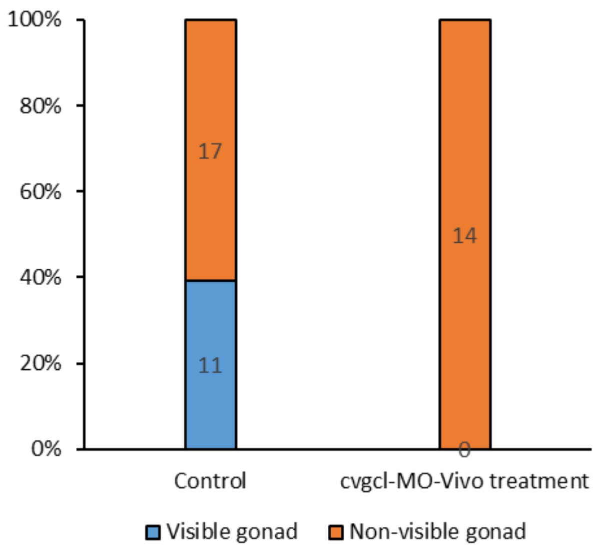
cvgcl-MO-*Vivo* treatment

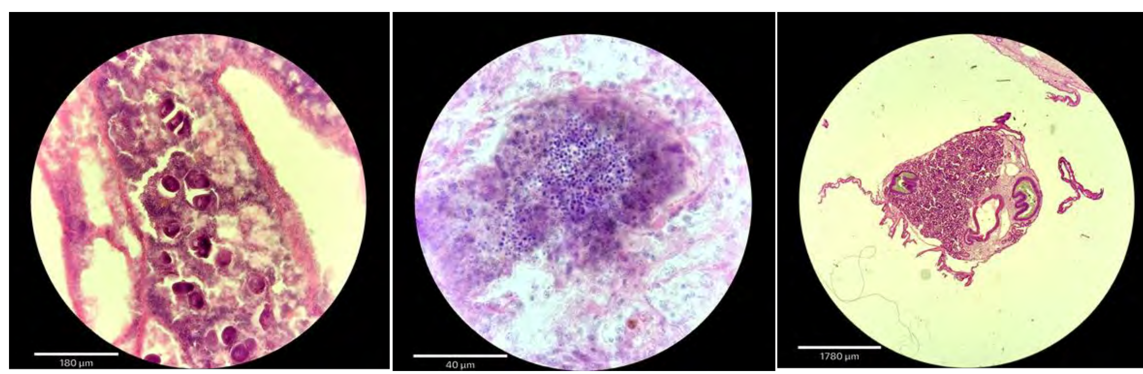


Target gene	MO sequence
gcl	ACTACTAAATCTGTTTCCCATCAGT
vasa	CACGACCTCTACCTCCCATTTAGAC
nanos	AAAGCCGTGTTCTGTACTGAGCCAT
wunen1	GACAGCATTGCTTCTCTCTACAACC
wunen2	CTAATTTCCTCTCCATGACAATGCA

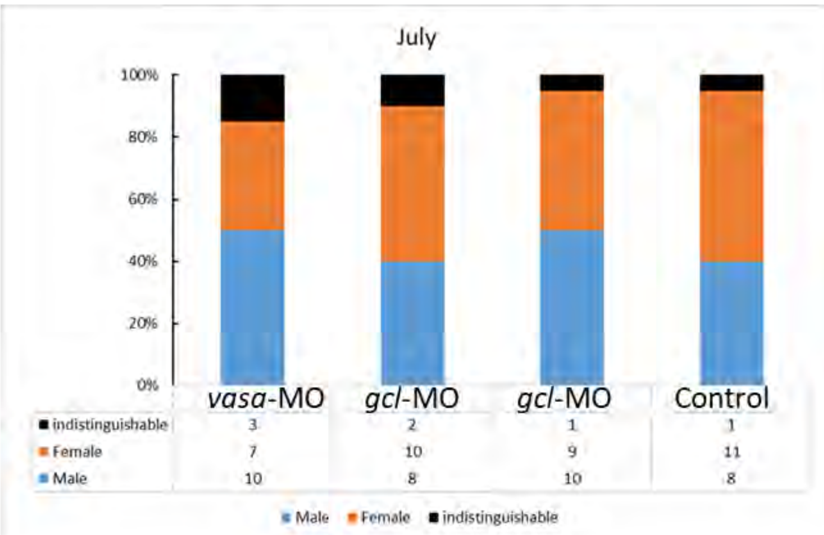
cvgcl-MO-*Vivo* treatment

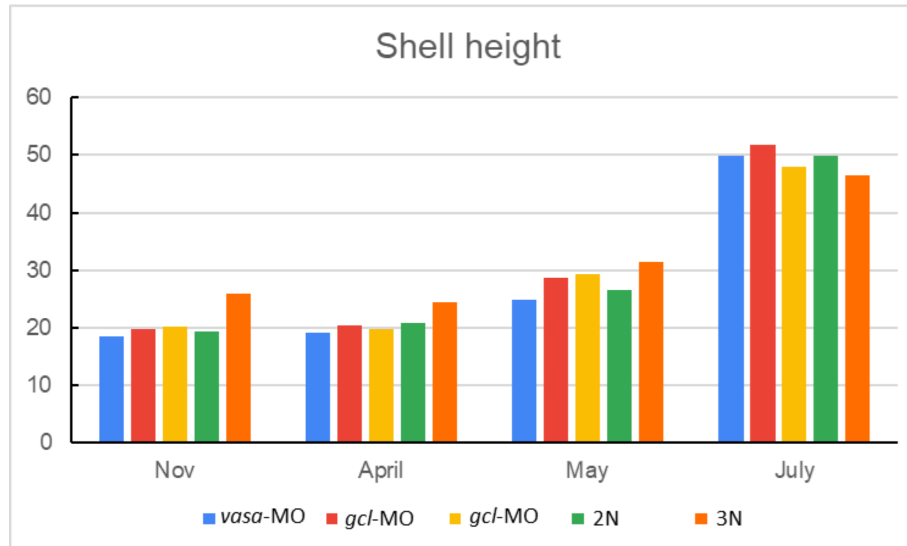
- Treatment groups deployment
- Sterility evaluation:
  - Delayed sampling until end of June
  - More than half spawned
  - Spent VS Sterile ?





Sterility induction and growth





Outreach

2020
Aquaculture America 2020, Sterility in Aquaculture special session, Honolulu, HI, Feb 9-12.
2021
The 113th Annual Meeting of National Shellfisheries Association March 22 – 25.

We presented our oyster sterility work to Chesapeake Bay Commission.

Summary

- **Immersion-based MO delivery can be an alternative sterilization technology to triploidization.**
- **More comprehensive sterility assessment and related studies are on the way.**
- **CPP based immersion is a more tractable approach to monitor the delivery of MO.**

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