Strategies for Building Capacity of Integrated Multi-Trophic Aquaculture (IMTA) in the Gulf and U.S. Caribbean Regions:

Development of Sustainable Production, Post-Harvest Processing, and Value-Add Methods for Tropical Seaweed Species

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Gulf States Marine Fisheries Commission
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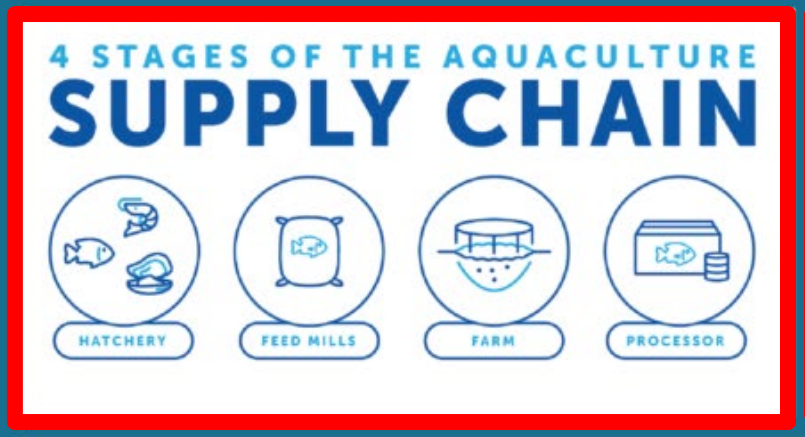
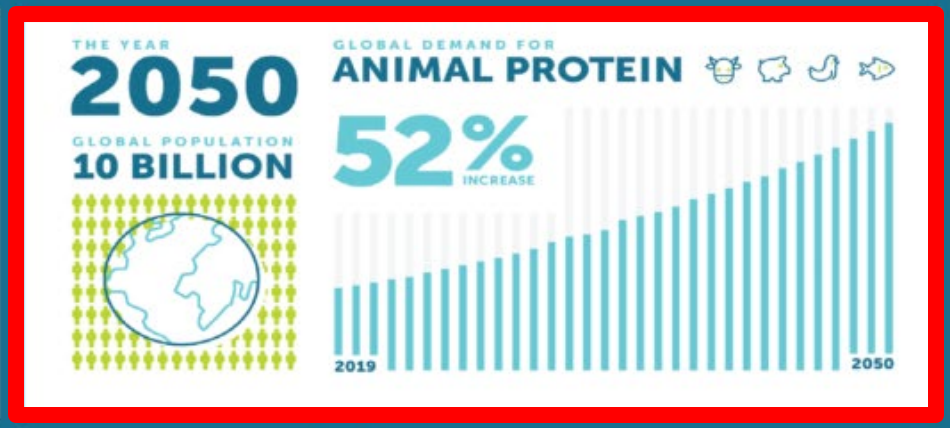
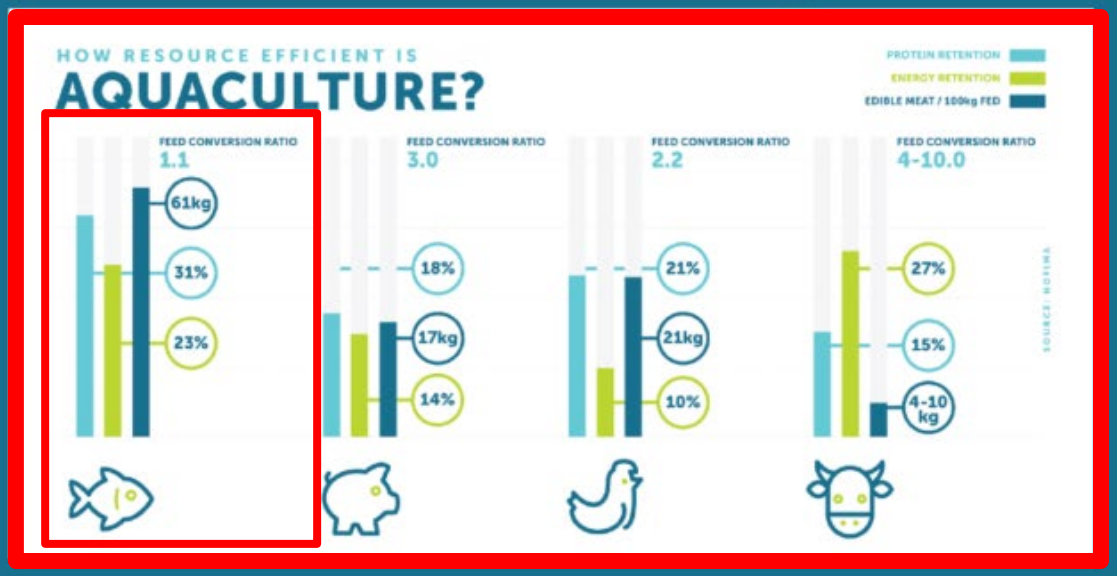
Global Seafood Projections and the Role of Aquaculture





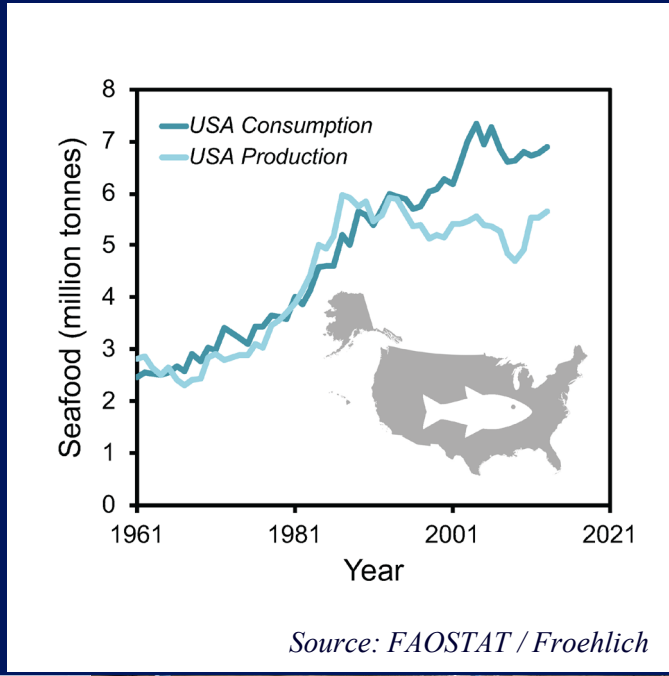


Global Aquaculture Alliance

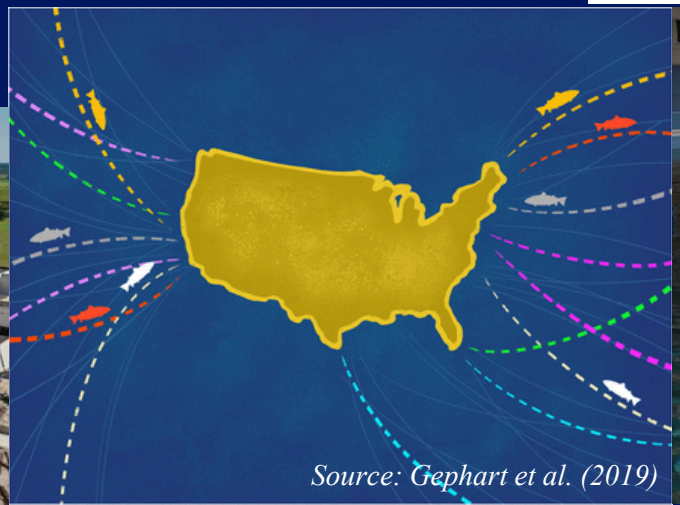
Learn more at www.aquaculturealliance.org

US Seafood Production

- US imports majority of seafood consumed
  - Need for increased domestic production
- Opportunity with "farm-to-table" aquaculture production
  - Farms being built close to markets
    - Example: Atlantic Sapphire, Ideal Fish, TransparentSea



Source: FAOSTAT / Froehlich



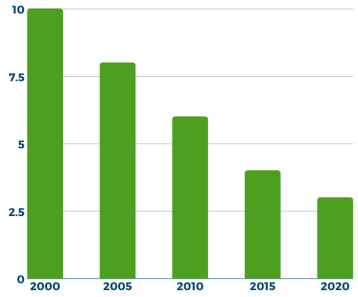
Source: Gephart et al. (2019)

Aquaculture in the U.S.: Social License Considerations

REDUCING WILD FISH IN FISH FEEDS

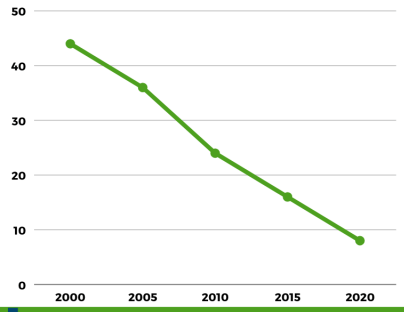
OVER THE PAST TWO DECADES RELIANCE ON WILD FISH HAS DRASTICALLY DECREASED.

GLOBAL AVERAGE OF FISH OIL% IN FISH FEEDS



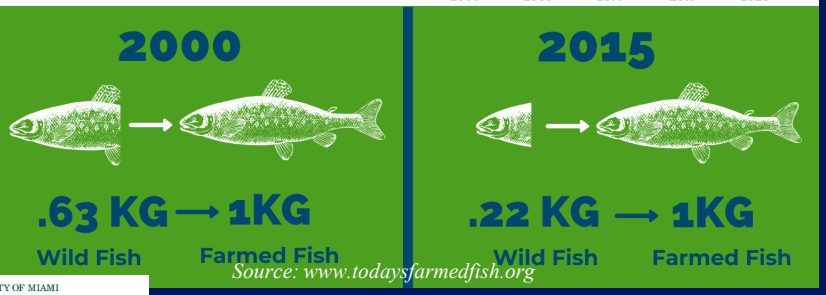
FISH MEAL ALTERNATIVES

Fishmeal usage is declining alongside fish oil usage. Sustainable replacements like insects, yeast, and soy reduce dependence on wild fish stocks.



FISH OIL ALTERNATIVES

Fish oil used in feed continues to drop as new alternatives that also produce omega-3's are discovered, such as algae.



Source: www.todaysfarmedfish.org

REVIEWS IN FISHERIES SCIENCE & AQUACULTURE
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Refuting Marine Aquaculture Myths, Unfounded Criticisms, and Assumptions

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Aquaculture North America

Winning social license in Maine

By Lynn Fantom August 23, 2022

Features

A special town meeting in Jonesport, Maine scored a decisive victory for aquaculture in the State of Maine

Voters converged in a high school gymnasium in Jonesport, Maine to defeat a proposed moratorium on large-scale aquaculture on July 20. Photos: Lynn Fantom

University of Miami – Aquaculture Program

Virginia Key, FL

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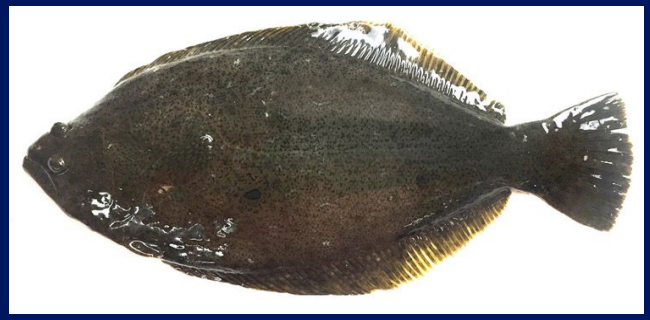

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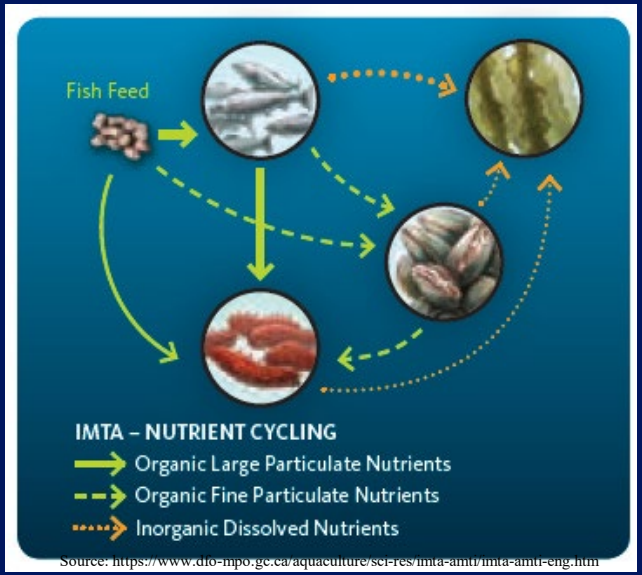
Sustainable Seafood Research & Development

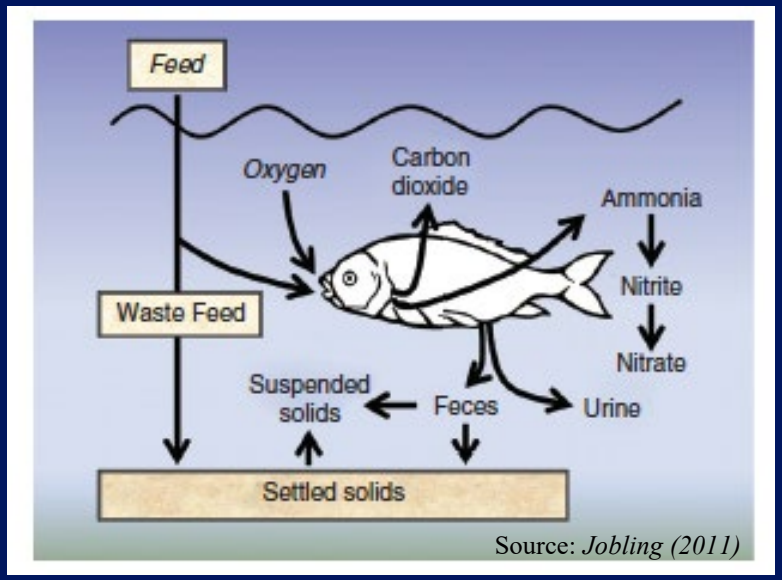
Improving Sustainability of Aquaculture

- How to Improve Sustainability?
  - Environmental
  - Economic
  - Social

- Integrated Multi-Trophic Aquaculture (IMTA)



Source: https://www.dfo-mpo.gc.ca/aquaculture/sci-res/imta-amti/imta-amti-eng.htm



Source: *Jobling (2011)*

Benefits of Seaweed Aquaculture

- Mitigation of eutrophication in coastal waters:
  - Potential for removal of Nitrogen and Phosphorus from seawater
- Human health benefits:
  - Through direct dietary consumption
  - Utilization of unique compounds in the pharmaceutical industry
- Reduction of greenhouse gas emissions in terrestrial agriculture:
  - Inclusion of seaweed in cattle feeds reduces methane production

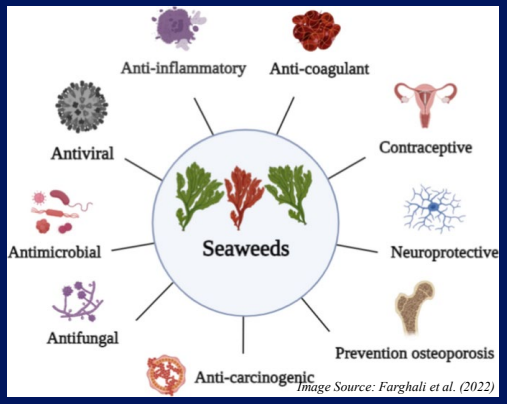
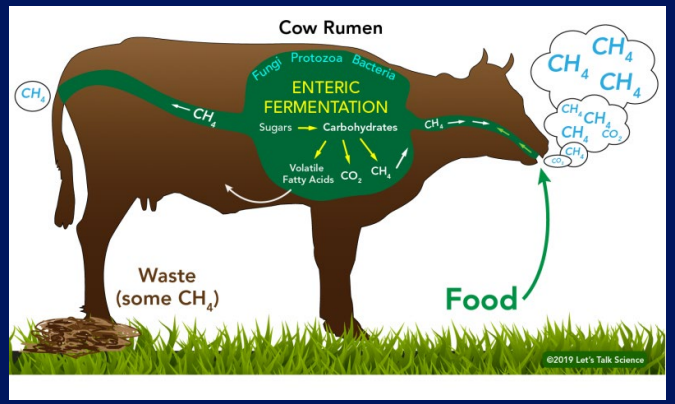


Image Source: Farghali et al. (2022)



Market Potential

- **Many End-Uses of Seaweeds:**
  - Human Consumption:
    - Consumed in many different forms
  - Animal feed:
    - Aquaculture and Terrestrial Agriculture
  - Hydrocolloids:
    - Thickeners/emulsifiers (sustainable)
  - Cosmetics Industry
  - Pharmaceutical Industry / Health Supplements
  - Carbon sequestration:
    - "Blue carbon"

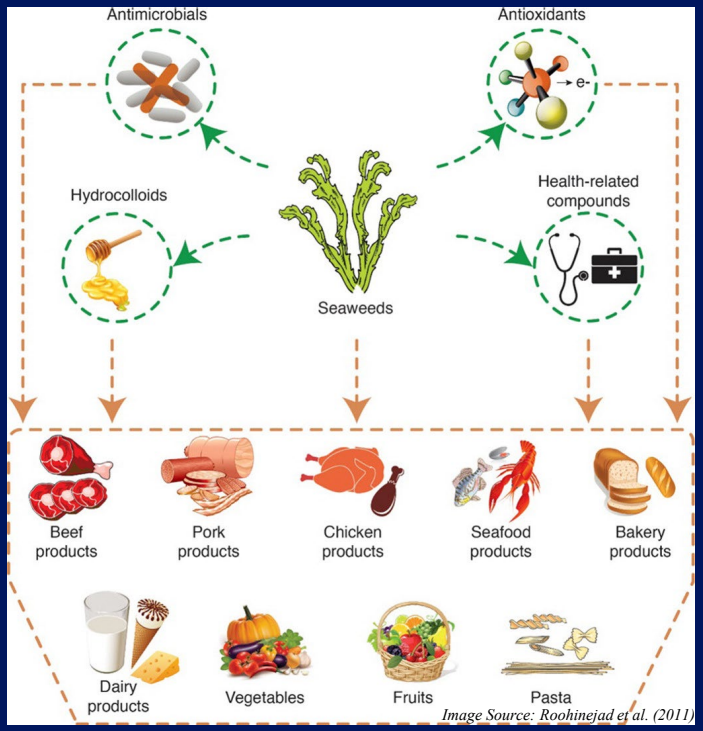
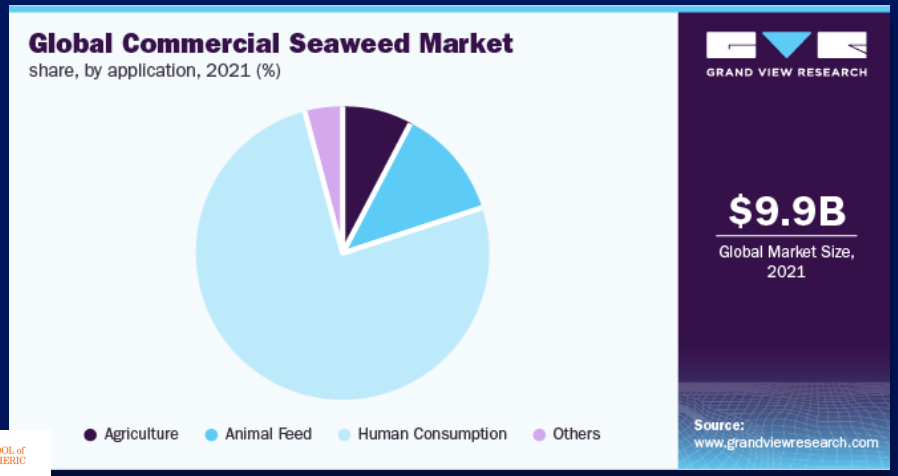
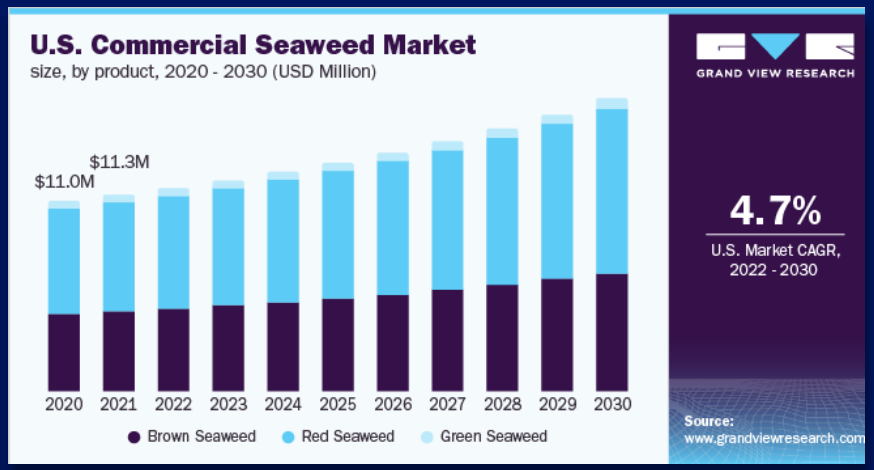


Image Source: Roohinejad et al. (2011)





Advancing Regional IMTA Development in the Gulf of Mexico and U.S. Caribbean

- **Challenges:**
  - Many different species of macroalgae (seaweed)
    - Which are the best ones to grow in IMTA systems in the region?
  - Lack of viable processing techniques and technologies for seaweed products in the region
    - What are the best processing techniques and value-add procedures that will yield economic viability of seaweed mariculture operations?
  - A need for consumer / end-user education about domestically-produced seaweed products
    - Why should U.S. distributors and consumers eat seaweed products?

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Initial Work: Assess IMTA Biomitigation Potential

- Assess the capacity of local macroalgae species to biomitigate enriched effluent from marine finfish aquaculture

Source: Lohroff et al. (2021)

IMTA: Biomitigation Potential

- Significant removal of nutrients from seawater

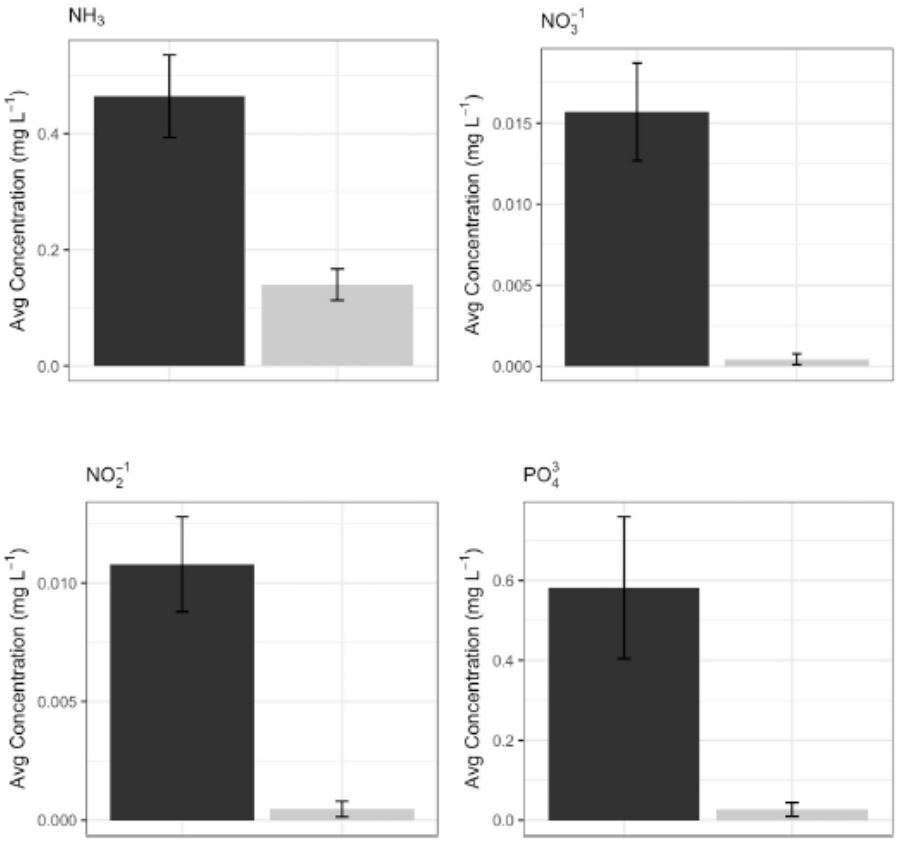

Fig. 1. Dissolved nutrient concentrations (mg L^{-1}) of incoming effluent water vs. outgoing water from macroalgae tanks receiving marine finfish effluent water (i.e. "experimental tanks"). Error bars represent standard error of the mean (SE). Dark bars represent mean incoming values while light bars represent mean outgoing values of both replicate trials. Control groups were completely excluded from the figure due to no measurable presence of nutrients in incoming control water throughout the experimental period.

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Evaluating the potential bioextractive capacity of South Florida native macroalgae *Agardhiella subulata* for use in integrated multi-trophic aquaculture (IMTA)

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Source: Lohroff et al. (2021)

IMTA: Keys to Expansion in the Gulf of Mexico and U.S. Caribbean Regions

- Assess promising species for culture in the regions
- Understand the value of different macroalgae species suitable for IMTA-type systems from:
  - The market perspective
  - The cultural and ecosystem services perspectives
  - Post-Harvest techniques and technologies

Current Project Overview

- **Objectives:**
  - Determine aquaculture performance of various native tropical seaweed species under commercially-relevant IMTA culture conditions
  - Pilot-Scale IMTA system: Yellowtail Snapper and four species of seaweed (*Agardhiella subulata, Caulerpa racemosa, Gracilaria caudata., Ulva lactuca)*

- **Specifically:**
  - Bioextractive Capacity
  - Market Potential
  - Identification of Top Species
  - Post-Harvest Processing
  - Value-Add Techniques


Yellowtail Snapper *(Ocyurus chrysurus)*


A. subulata *C. racemosa* *G. caudata* *U. lactuca*

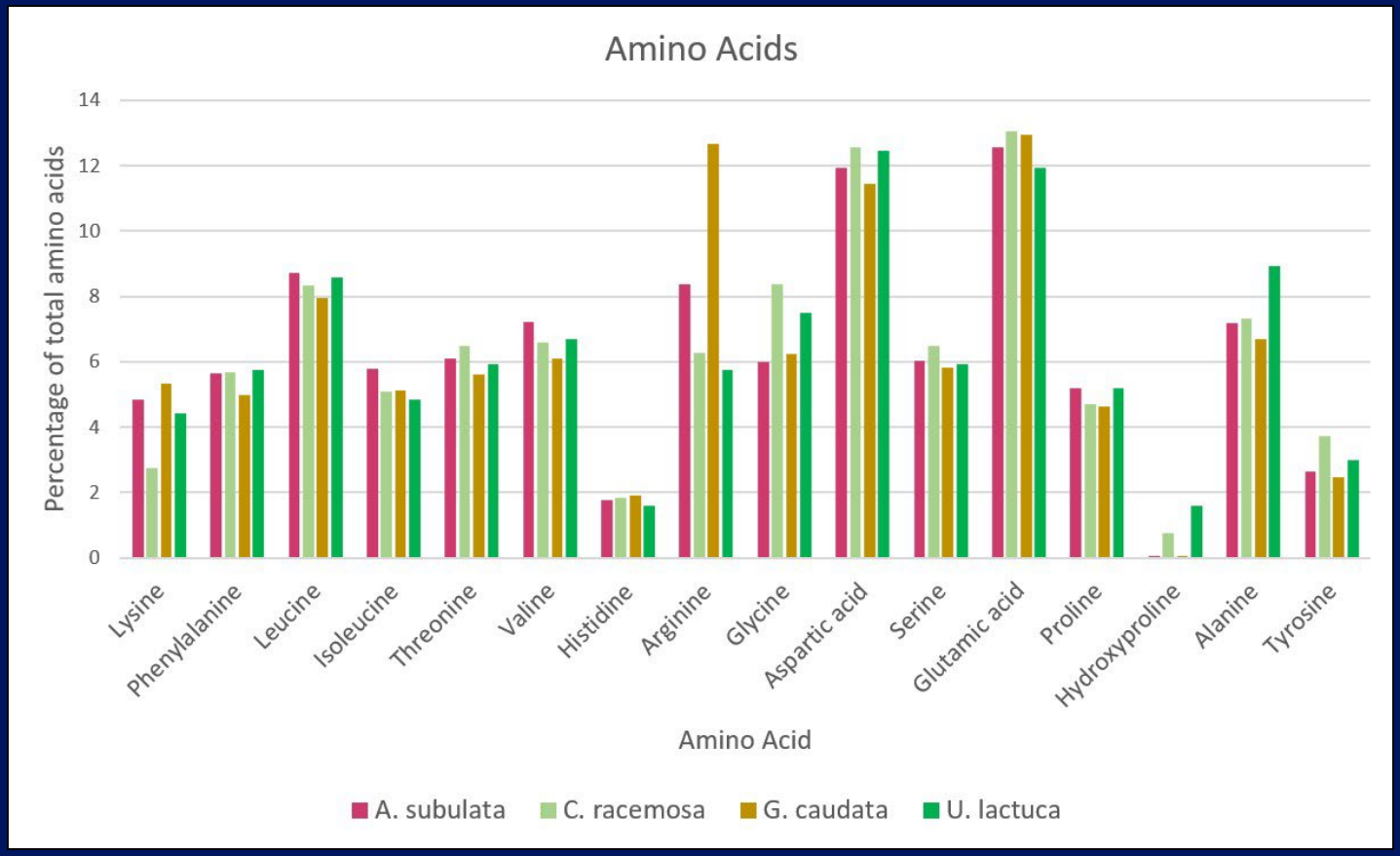
Analysis of Selected Seaweed Species

	As (Relative basis %)	As (Sample basis %)	Cr (Relative basis %)	Cr (Sample basis %)	Gc (Relative basis %)	Gc (Sample basis %)	Ul (Relative basis %)	Ul (Sample basis %)
PUFA's	12.17	0.26	4.6	0.12	2.37	0.03	0	0
Omega 3	12.67	0.27	19.52	0.49	2.79	0.04	10.10	0.11
Omega 6	17.21	0.36	11.55	0.29	33.39	0.46	3.38	0.04

- Polyunsaturated Fatty Acids (PUFA), omega-3, and omega-6 content of each species, with relative % out of 100% fatty acids, and based off sample size.
- *Agardhiella subulata* (As), *Caulerpa racemosa* (Cr), *Gracilaria caudata* (Gc), and *Ulva lactuca* (Ul)

Source: Lasco et al. (2023 - In preparation)

Analysis of Selected Seaweed Species



- Amino acid type and percentage in each seaweed species

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Source: Lasco et al. (2023 - In preparation)

Stakeholder Guide for Native Species of the Gulf of Mexico and U.S. Caribbean

PARAMETER OF INTEREST	BEST SPECIES	GOOD ALTERNATIVE SPECIES
AMMONIA	*Agardhiella*	*Ulva*
PHOSPHORUS	*Caulerpa*	*Agardhiella*
CO_2	*Ulva*	*Agardhiella*
DO	*Ulva*	*Agardhiella*
pH	*Ulva*	*Agardhiella*
PROTEIN	*Caulerpa*	*Agardhiella*
TOTAL CARBOHYDRATES	*Ulva*	*Gracilaria*
FIBER	*Caulerpa*	*Ulva*
PUFA'S	*Agardhiella*	*Caulerpa*
OMEGA 6	*Gracilaria*	*Agardhiella*
OMEGA 3	*Caulerpa*	*Agardhiella*
AMINO ACIDS	*Caulerpa*	*Agardhiella*
BIOMASS	*Agardhiella*	*Ulva*
CALCIUM (CA)	*Caulerpa*	*Agardhiella/Ulva*
MAGNESIUM (MG)	*Ulva*	*Agardhiella*
IRON (FE)	*Caulerpa*	*Agardhiella*

Source: Lasco et al. (2023 - In preparation)

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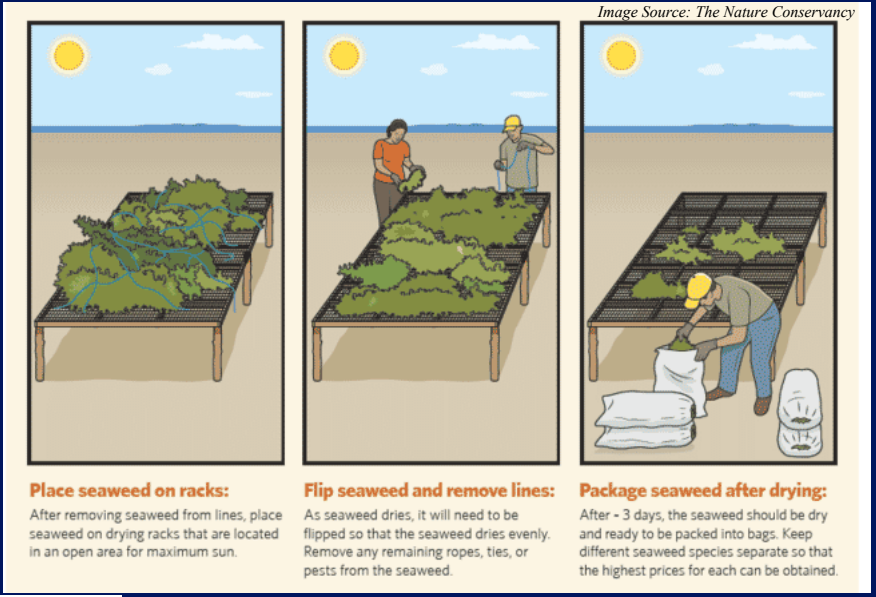
Have Seaweed – Now What?

- Drying / Processing Techniques and Technologies for Seaweed:
  - Needs to be economically viable for U.S. producers and markets



Post-Harvest Processing Research: Shelf Life of Harvested Seaweed

- Improving processing of seaweeds for fresh direct consumption
- Post-Harvest Processing:
  - Refrigeration
  - Freezing
  - Blanching
  - Drying
    - Solar
    - Freeze Dry
    - Forced Air
- Assessment Techniques:
  - Aerobic plate counts
  - Bacterial contamination
  - Heavy metals testing

Post-Harvest Processing Research: Sensory Assessments

- Sensory Attributes:
  - Color
  - Odor
  - Taste
  - Ease of Use in Culinary Applications

Opportunities for Increased Resiliency for Working Waterfronts

- IMTA has great potential for integration in working waterfront communities
  - Can help address challenges in coastal communities
- Diversification of seafood products and markets

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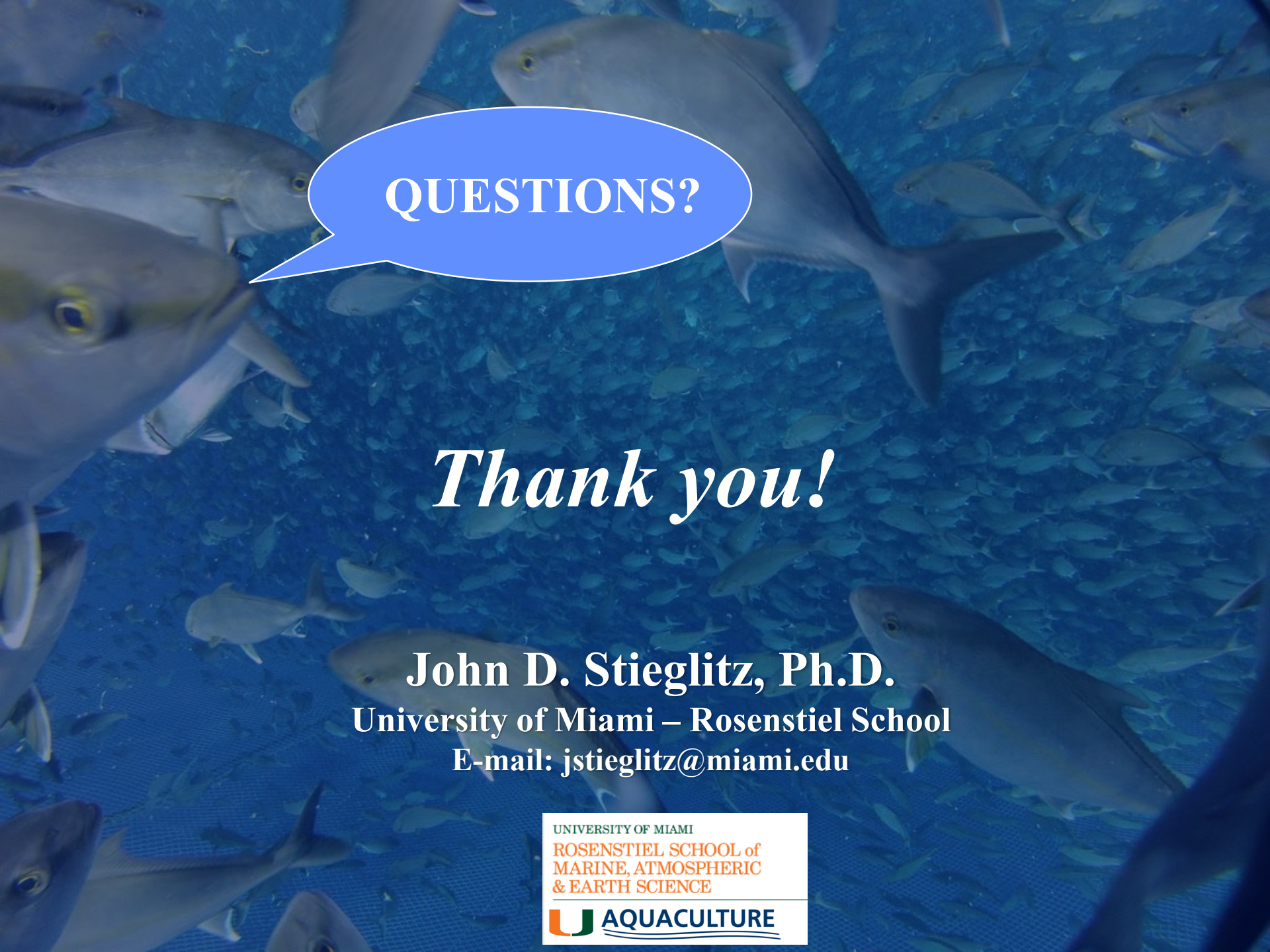

Thank you!

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