

# Realities, opportunities, and innovations in ocean/aquatic food systems to better integrate knowledge across professions

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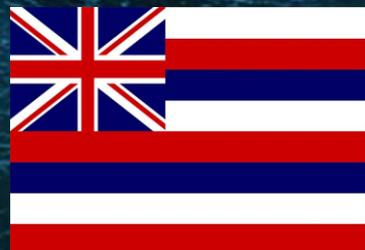
**EARTH**  
**OCEAN FOOD SYSTEMS**  
— ETHOS —

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# Ocean Food Systems and Hybrid Seafood Production: Transdisciplinary Case Studies of Cod, Eels, Salmon, and Lobster

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## RESEARCH NOTE

Conservation Science and Practice

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# Global principles for restorative aquaculture to foster aquaculture practices that benefit the environment

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Junning Cai<sup>3</sup> | Ling Cao<sup>4</sup> | Megan Reilly Cayten<sup>5</sup> | Barry Antonio Costa-Pierce<sup>6</sup> |  
Yun-Wei Dong<sup>7</sup> | Steffen Cole Brandstrup Hansen<sup>8</sup> | Shurong Liu<sup>4</sup> |  
Qing Liu<sup>9</sup> | Colin Shelley<sup>10</sup> | Seth J. Theuerkauf<sup>1</sup> | Lisa Tucker<sup>1</sup> |  
Yue Wang<sup>9</sup> | Robert C. Jones<sup>1</sup>



**Ocean/Aquatic Food Systems:  
Integrating Fisheries, Aquaculture, Trade**



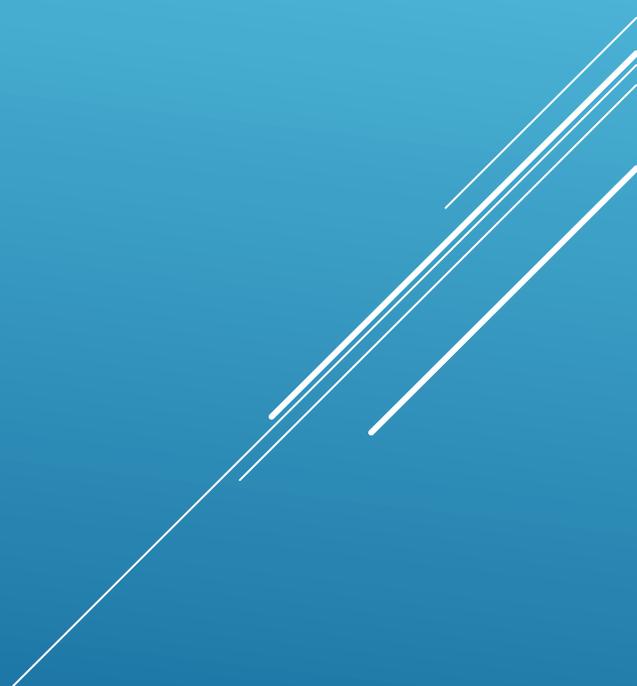
**Taxonomy of Ocean/Aquatic Food  
Systems**

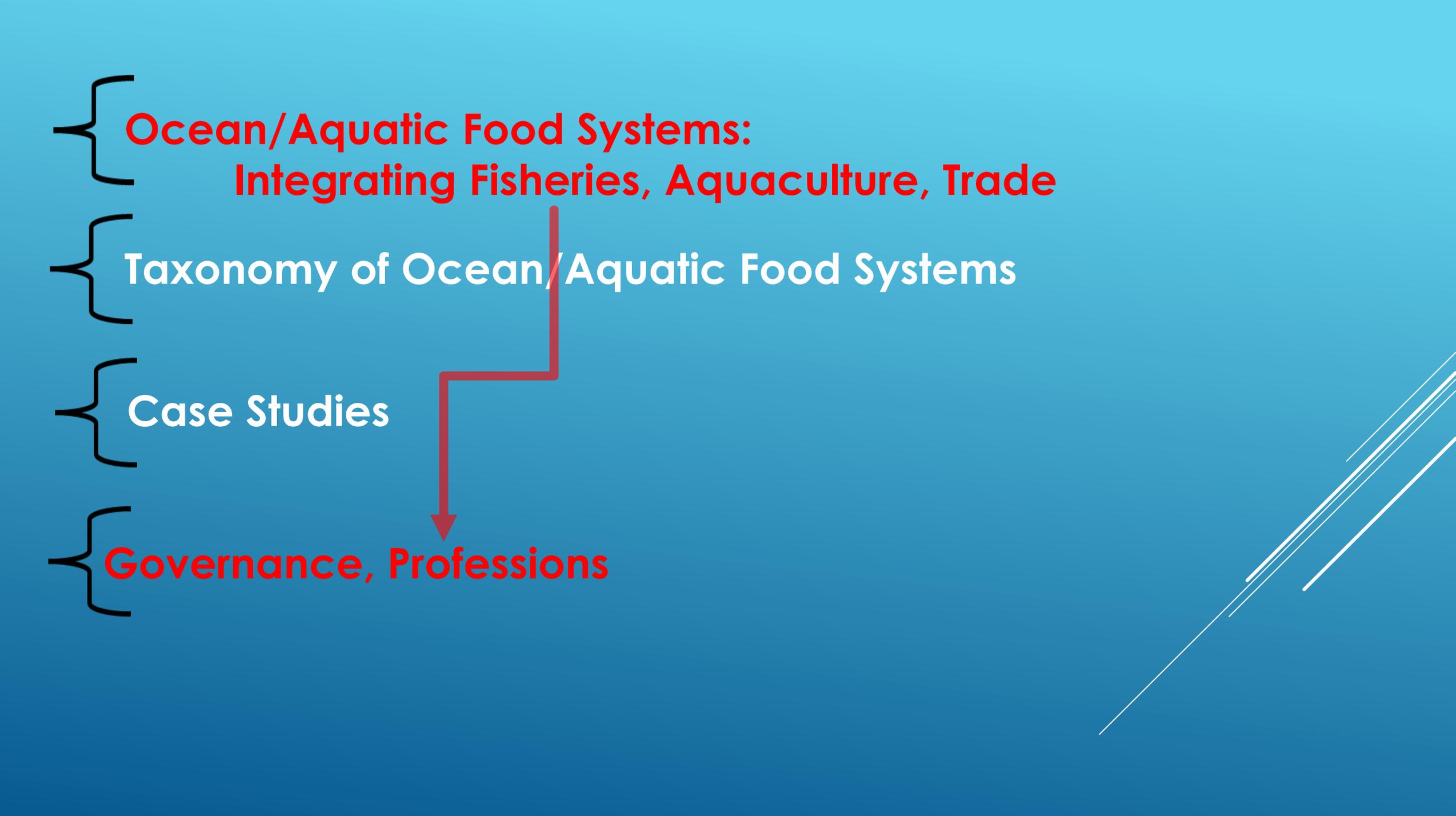


**Case Studies**



**Governance, Professions**





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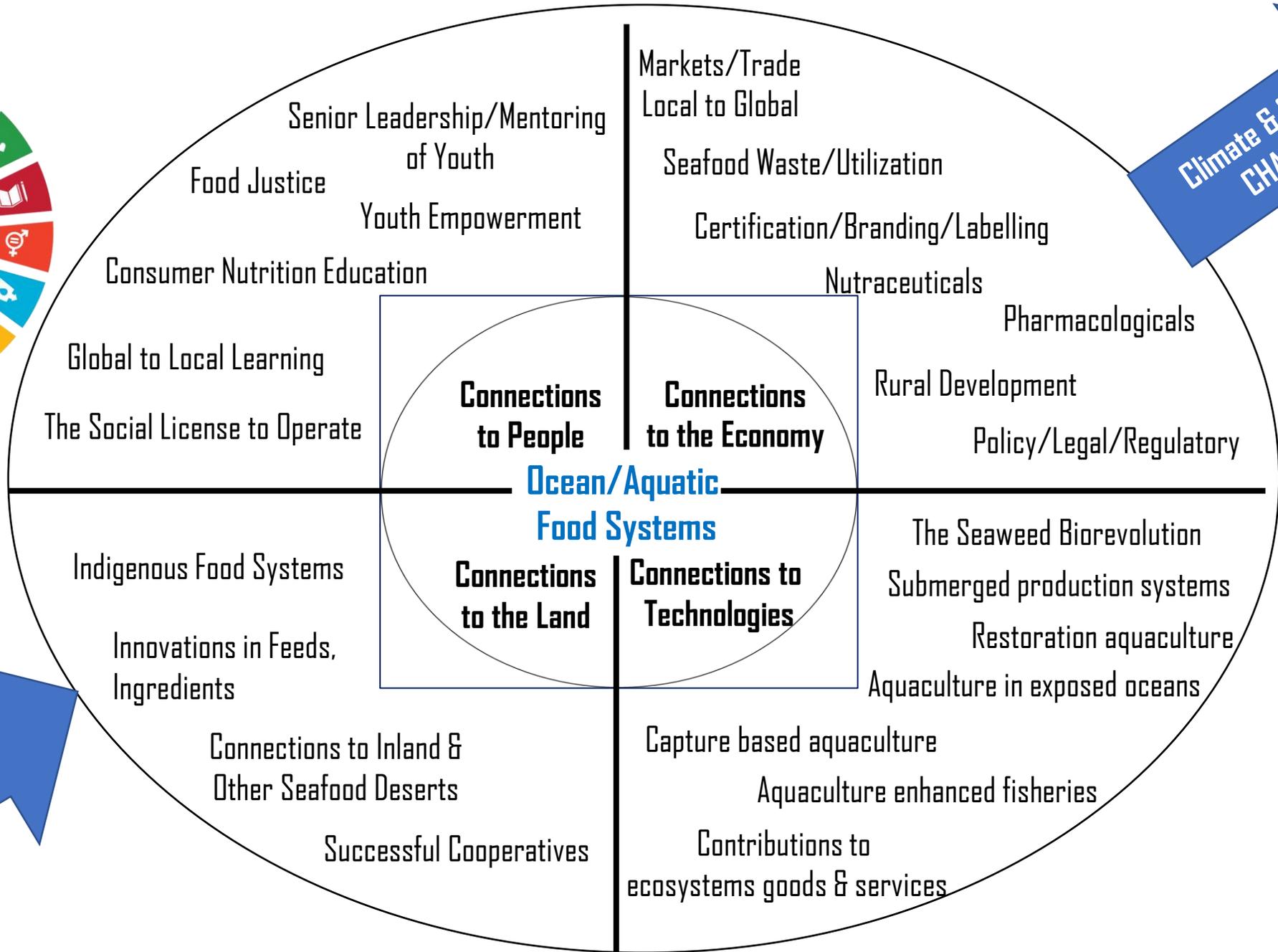
**Case Studies**

**Governance, Professions**

Fisheries, Aquaculture and Trade Systems  
Interact as  
**Complex Social-Ecological Systems**  
with

**LOCAL TO GLOBAL  
CONNECTIONS  
THEY ARE**

**“Ocean/Aquatic Food Systems”**



## **OAFS ARE DISRUPTIVE!**

**They require radically changed science, education, management, and development institutions and policies... that are in contrast to current binary fisheries and aquaculture management approaches which do not fit the current OAFS realities, or opportunities, or accelerate innovations, plus poorly integrate knowledge across professions...**

**2020-2030's are  
"The Decades of Doing"**



## NEW PROFESSIONS

**Schools, Institutes/Centers of  
Aquatic/SeaFood**

## NEW GOVERNANCE

**Ministry of Food**

- Agriculture
- Fisheries
- Aquaculture
- Food Trade

**2021**

**Ministry of Fisheries and Agriculture**  
“primary industry”



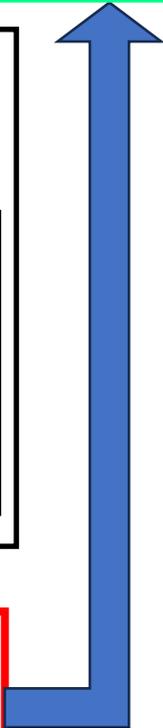
**Ministry of Food**  
All Food Production

- Fisheries
- Aquaculture
- Agriculture



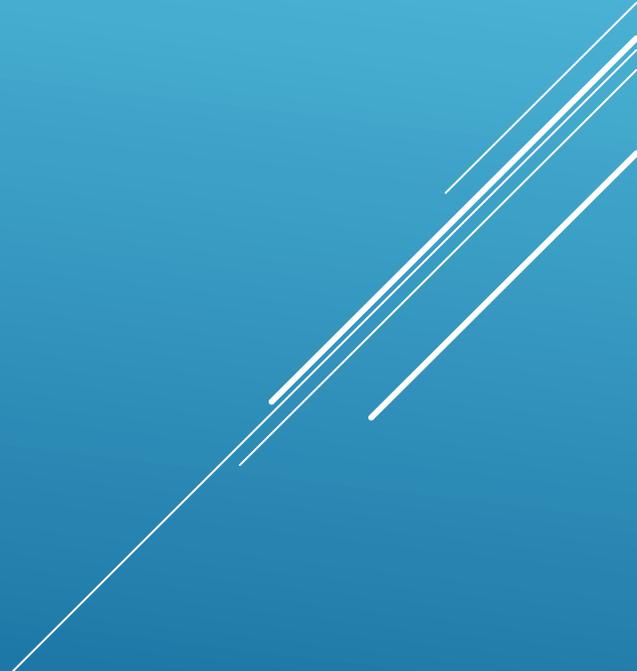
**Administration and surveillance for agriculture, aquaculture, and fisheries remain separate**

Directorate of Fisheries <a href="https://island.is/en/o/directorate-of-fisheries">https://island.is/en/o/directorate-of-fisheries</a>	Icelandic Food and Veterinary Authority (Agriculture, Aquaculture, Animal Welfare & Health) <a href="http://www.mast.is/en">http://www.mast.is/en</a>
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**Merge administration and surveillance to encompass the entire value chain of foods**

Courtesy of Dr. Ögmundur Knútsson  
Director  
Iceland Directorate of Fisheries



**Ocean/Aquatic Food Systems:  
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**Taxonomy of Ocean/Aquatic Food Systems**

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**“FISHERIES”**



**“AQUACULTURE”**



**OCEAN/AQUATIC FOOD SYSTEMS**



FAO. 2012. *The State of World Fisheries and Aquaculture*. FAO, Rome.

**Fisheries and aquaculture interact with increasing intensity as fishers shift from fishing to aquaculture and by competing in the same markets with similar products**

**The need to integrate planning and management of the two sectors seems vital to their future development and sustainability.**



**“FISHERIES”**

**is a**

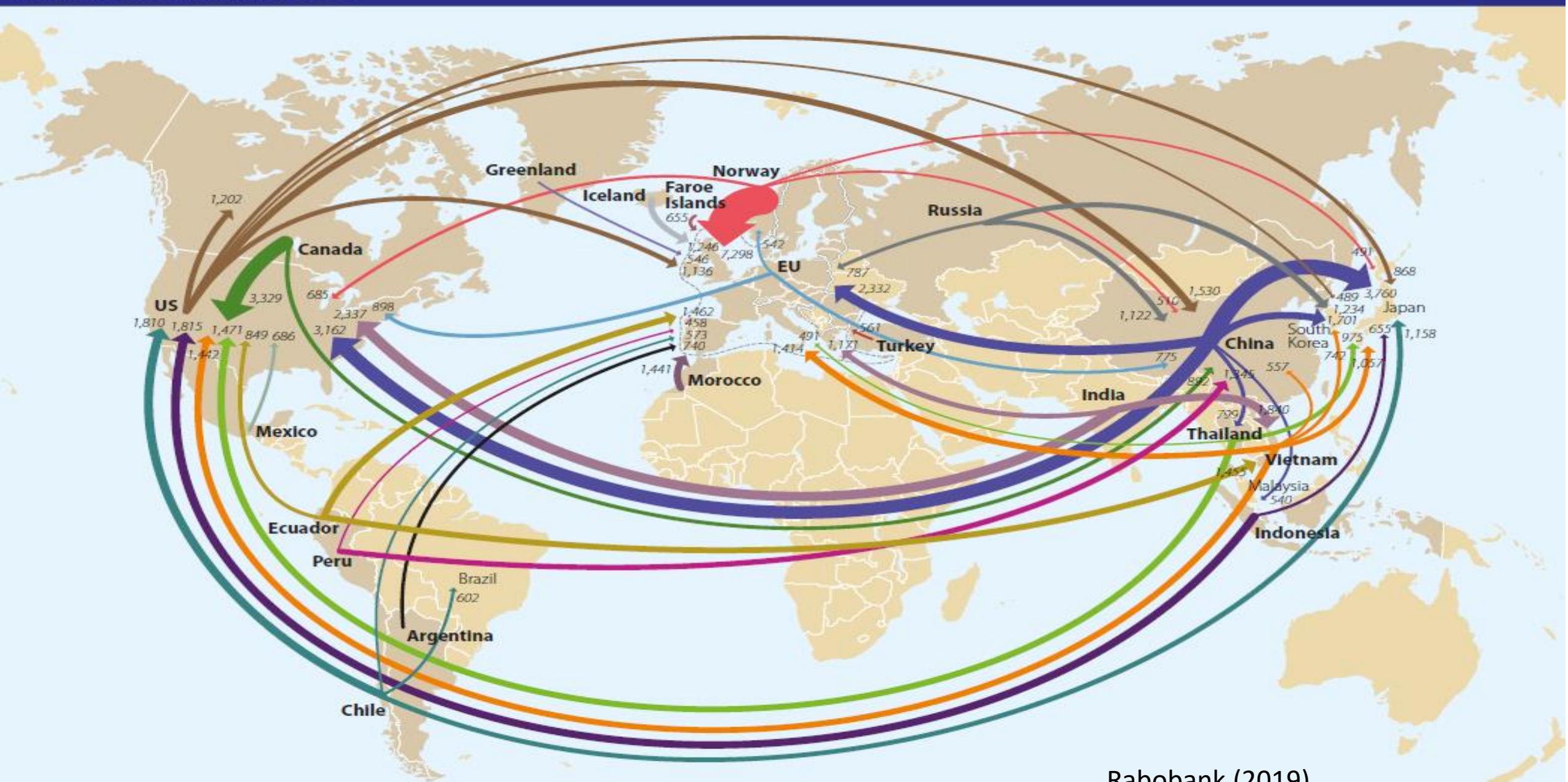
***Continuum* of Capture and Culture Fisheries**

**(Aquaculture) *and Trade***

**for**

**Sustainable Seafood Supplies**

# Trade Flows in Value, 2017



500 → Seafood trade value (USD million)

Arrow colors represent countries and bear no relation to those used in the main map.

Rabobank (2019)



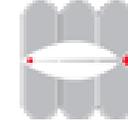
Seafood Expo  
GLOBAL



Seafood Processing  
GLOBAL

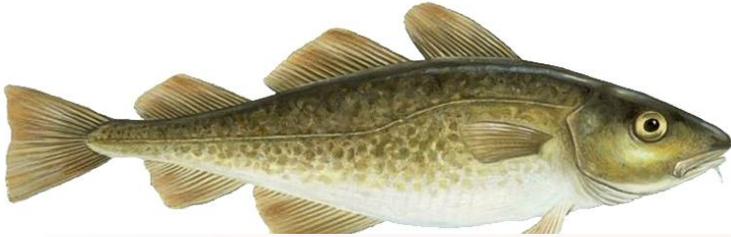


Seafood Expo  
NORTH AMERICA



Seafood Processing  
NORTH AMERICA

**1.3 MMT**



**6.1 MMT**



**“White Fish”  
Market  
~11 MMT**

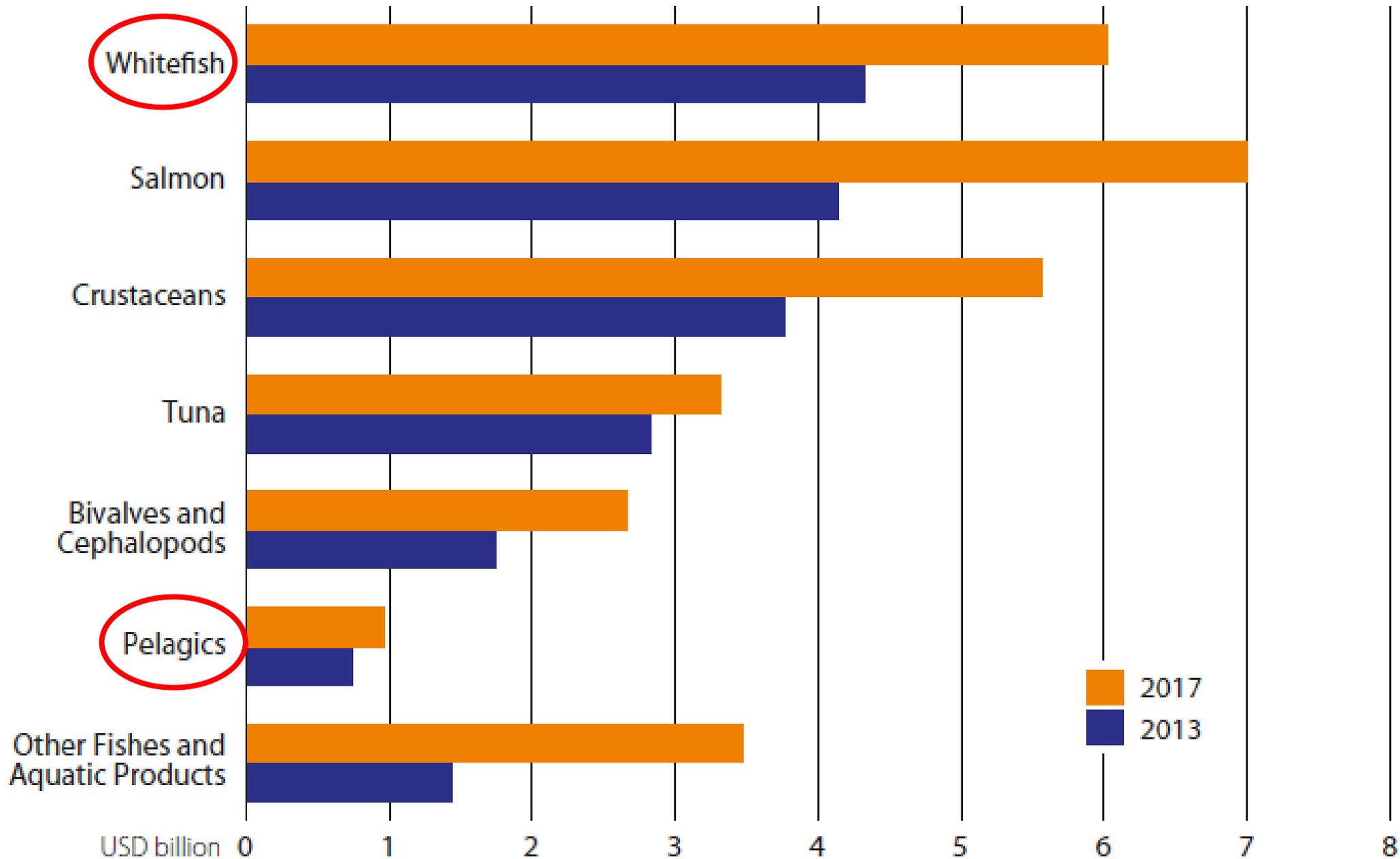
**0.3 MMT**



**3.1 MMT**



# EU Imports by Value, 2013 vs. 2017





**Ocean/Aquatic Food Systems:  
Integrating Fisheries, Aquaculture, Trade**

**Taxonomy of Ocean/Aquatic Food Systems**

**Case Studies**

**Governance, Professions**



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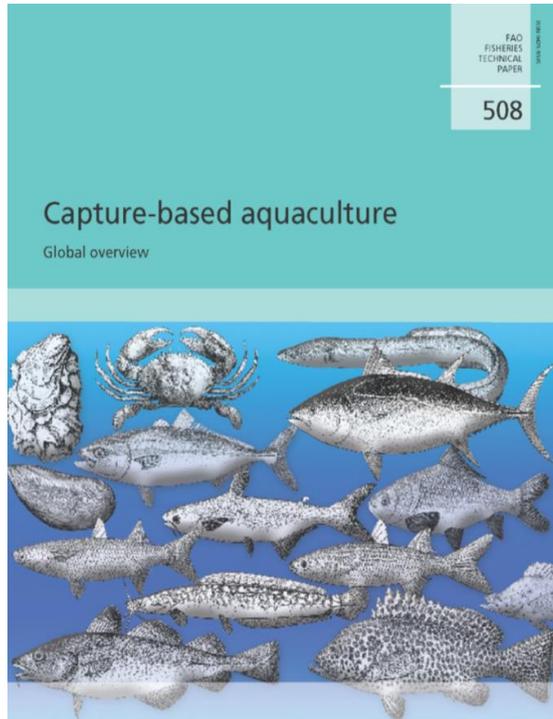
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20% total  
food fish production  
~US\$ 1.7 billion

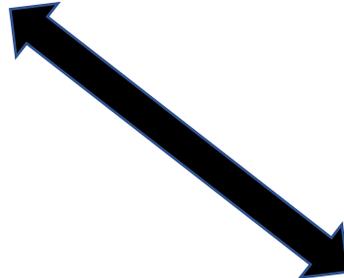


Lovatelli & Holthus (2008)

Review of just 4 case studies/limited  
number of countries  
annual value > **US\$4 billion**

- \*the value of eels as a CBA ~US\$2.3 billion/2 countries
- \*for salmon as an AEF ~\$1.7 billion only one USA state
- \*lobsters as fed fisheries/CBA ~\$825 million for the USA & Vietnam

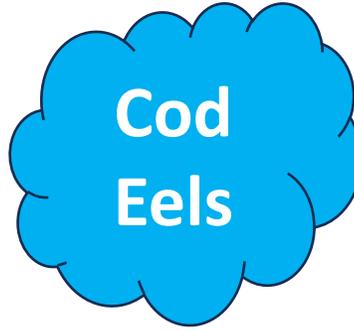
**FED AQUACULTURE  
with HATCHERIES**



**UNFED FISHERIES  
with no HATCHERIES**



**FED AQUACULTURE  
with HATCHERIES**



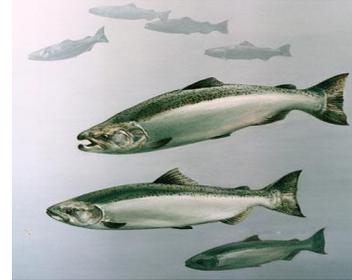
**FED AQUACULTURE  
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“Capture-Based  
Aquaculture” (CBA)

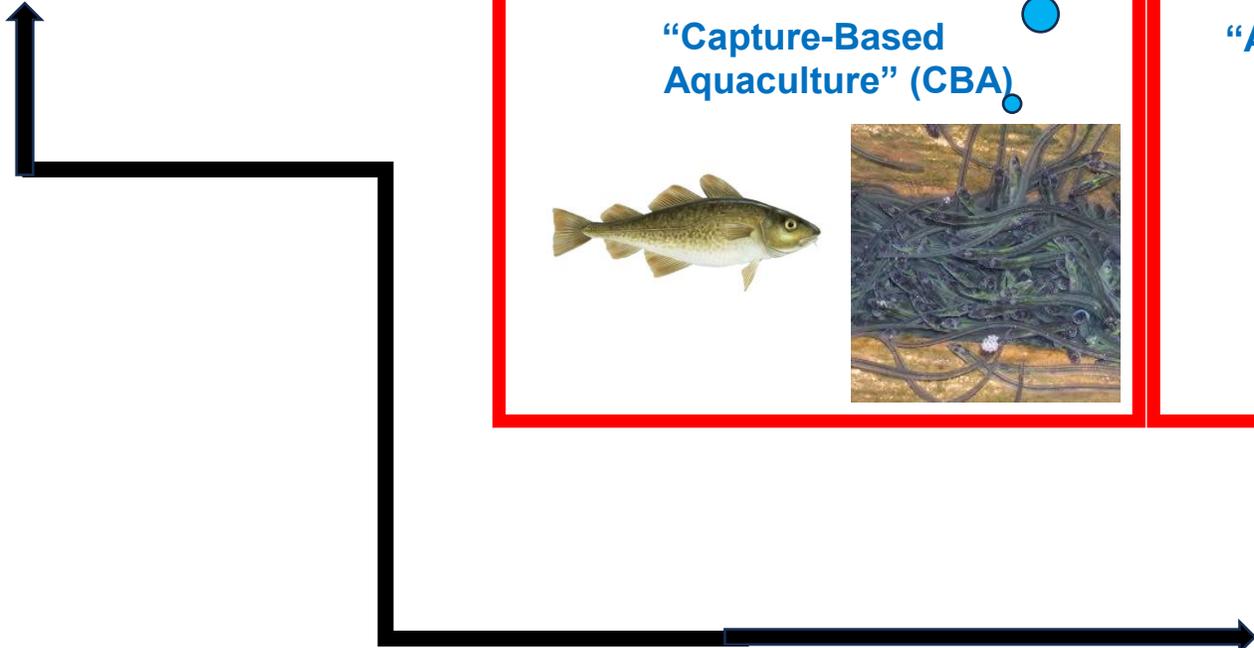


**UNFED FISHERIES  
with HATCHERIES**

“Aquaculture-Enhanced  
Fisheries” (AEF)



**UNFED FISHERIES  
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**FED AQUACULTURE  
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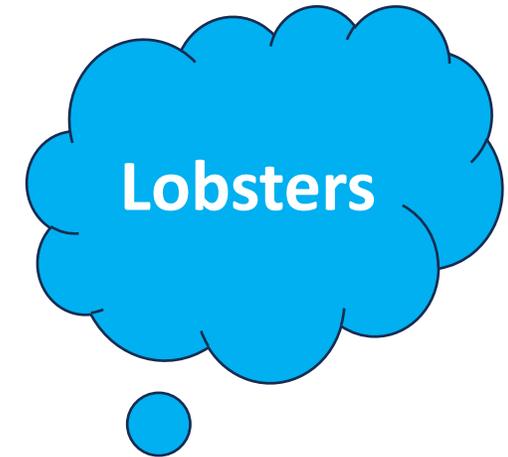
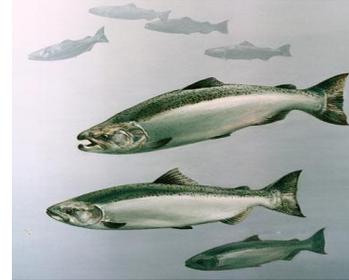
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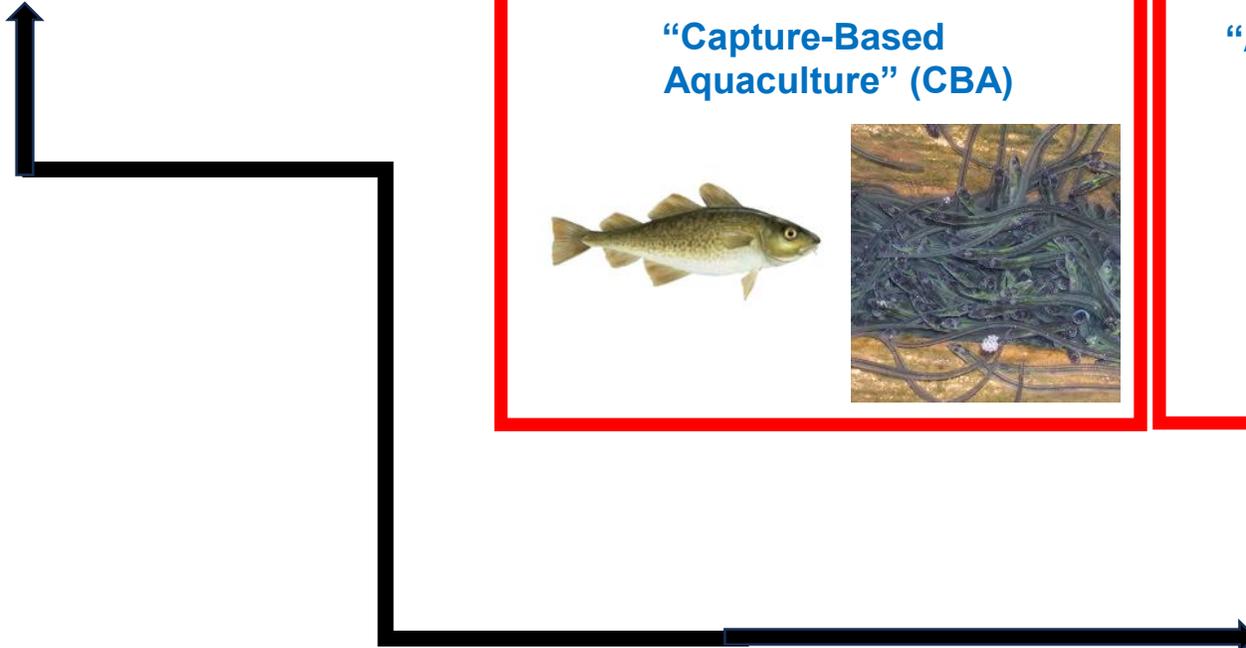
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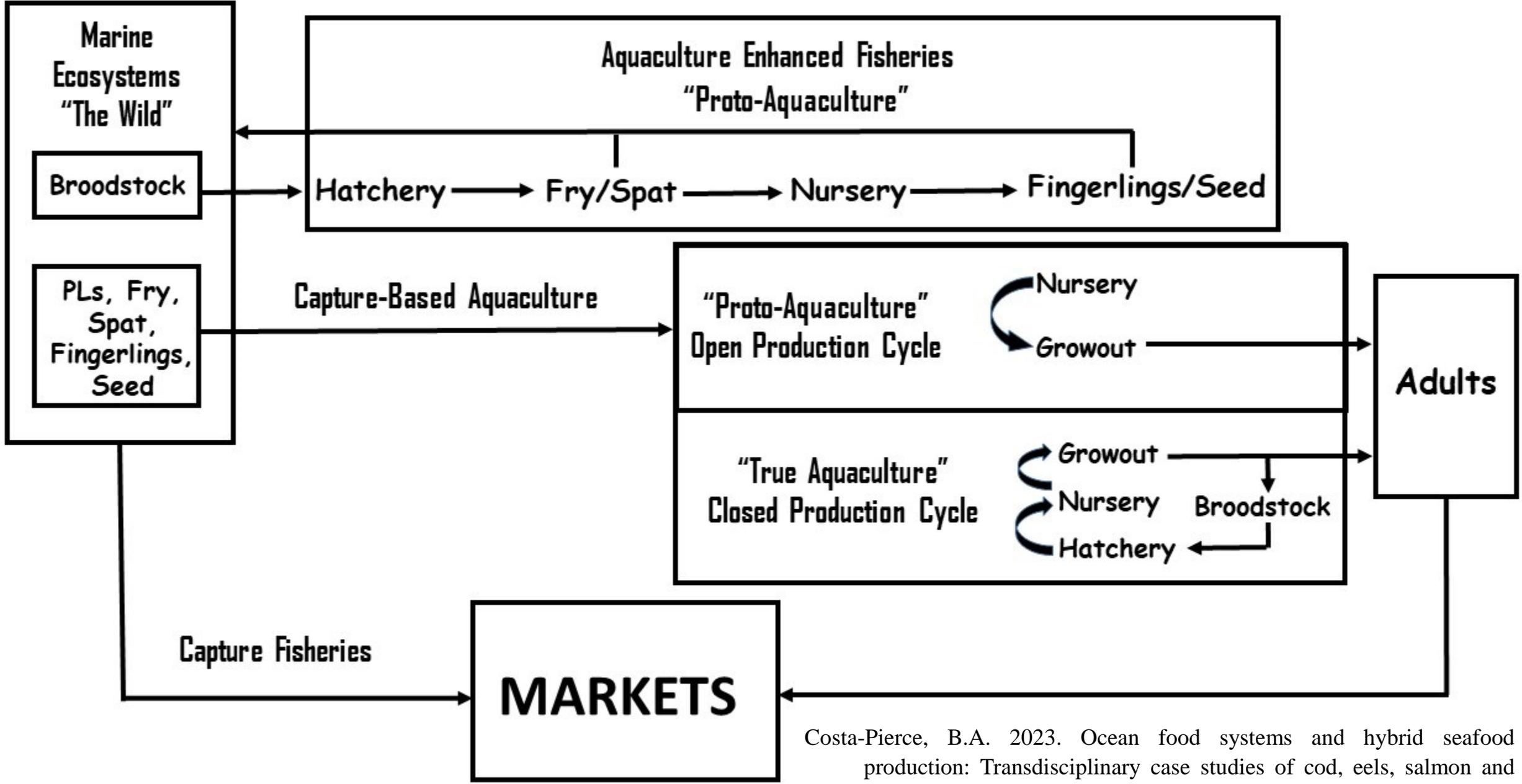


**FED FISHERIES  
with few/no HATCHERIES**



**UNFED FISHERIES  
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Costa-Pierce, B.A. 2023. Ocean food systems and hybrid seafood production: Transdisciplinary case studies of cod, eels, salmon and lobster. *Sustainable Development Research* 5(1):31-43. <https://doi.org/10.30560/sdr.v5n1p31>



Ocean/Aquatic Food Systems:  
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Taxonomy of Ocean/Aquatic Food Systems

**Case Studies: CBA for Eels in Maine, USA**

Governance, Professions

*Anguilla rostrata*







**FAO**

**90-95% of global eel aquaculture production is from wild-caught elvers**

**\*90% of freshwater eel unagi eaten in USA is farm-raised in Asia**  
**\*US increasing its consumption of eels**



# *Aquaculture?*



## BILLIONS \$\$ OVER 50 YEARS

- Sexual maturation complex set of environmental cues
- Do not mature spontaneously
- **Most farmed eels turn out to be male**
- Scientists developed a set of hormone treatments and produced reliable supply of fertilized eggs **but few healthy larvae**
- Leptocephali to glass eels takes **250-300 days in culture vs. 110 to 160 days in nature**
- Survival rates **very low** <10%
- Leptocephali feed on marine snow in nature
- In hatchery we make an expensive, thick, pinkish paste made primarily of shark eggs, soy protein, and vitamins
- Light-wary leptocephali need to be kept in **darkened rooms**
- Paste causes **large water quality problems**
- etc., etc., etc.

# Is a Hatchery Really Needed?

*High Capital, Operating Costs*

# Genetic Issues – Panmixia

*Can Insure Genetic Integrity*

# Can Aquaculture Lead to Fisheries Sustainability?

*The Aquaculture Toolbox*



# *Fisheries –Unregulated*

## *“Wild West”*

### **“bags of cash”**



....a gold rush of sorts is on along the rivers and streams of coastal Maine...since the season began last week, stories have abounded of people making a small fortune in this often hard-luck state. “The first two days of the season were extremely amazing,” said Bill Quinby, an exporter...who shipped about 40 kg (90 lbs.) of elvers to Asia on Tuesday after buying them from Maine fishermen. **“People were making \$30,000, \$40,000 a night.”**

# *Sustainable well managed fishery with well enforced quotas*

**~400 licenses, TAC, limited seasons, entrants**



# Global-local development of closed cycle, capture based eel aquaculture



## AMERICAN UNGAI

- Next generation innovator
- Modest 240 MT capacity in 2500 m<sup>2</sup>, US\$ 7 million
- International collaboration with EU/Japan
- RURAL Waldoboro, a town ~5,000...a town with one of the highest densities of elver fishermen



Ocean Food Systems: Integrating Fisheries, Aquaculture, Trade

Taxonomy of Ocean Food Systems

**Case Studies: CBA for Cod in Norway**

Governance, Professions



Tromsø



# National Centre for Capture-Based Aquaculture



## ***NOT recruitment overfishing***

Live captures – smart fishing

Limits the race to fish and associated market swings

## **Uses “aquaculture’s knowledge-based toolbox”**

- **Fish acclimatization to containment procedures**
- **High quality care re: fish stress, health & welfare**
- **Disease prevention, diagnosis & treatment**
- **Advanced slaughtering & rapid delivery to year-round markets**

## The CBA “**quota bonus system**”

- \***temporary**...tied to the annual capture fisheries quota for cod

- \***evaluated** regularly

- \*CBA offers the **potential for a win-win** for both cod fishing industries and consumers

CBA allows fishing companies **to spread the supply of cod throughout the year**. Cod catches are highest in the January to April period when the highest quality fish the famous “Skrei” migrate from the high Arctic to spawn in the region around Lofoten, Norway.

Hermansen (2017)...“**It’s still in the early stage with actors involved being the pioneers**”, and that: “It remains to be seen whether CBA for cod can survive without the quota bonus”. Pettersen et al. (2023) concluded that, with an average price premium of 26% for CBA cod compared to wild cod, combined with reductions in the CBA quota bonus, that this price premium was “**not sufficiently large to incentivize further development of the CBA branch of the Norwegian cod industry.**”

**FED AQUACULTURE  
with HATCHERIES**



# More CBA Evolution

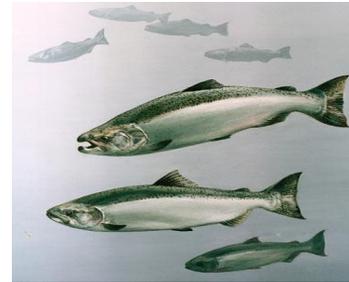
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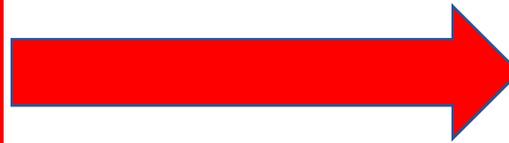
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# More Evolution

## Restorative Aquaculture

### UNFED Bivalve AQUACULTURE with HATCHERIES



### UNFED Bivalve FISHERIES



FLYING  
POINT  
NEWCASTLE, ME

MOOKIE  
BLUES  
WALPOLE, ME

WILD  
OYSTERS!  
DAMARISCOTTA  
RIVER

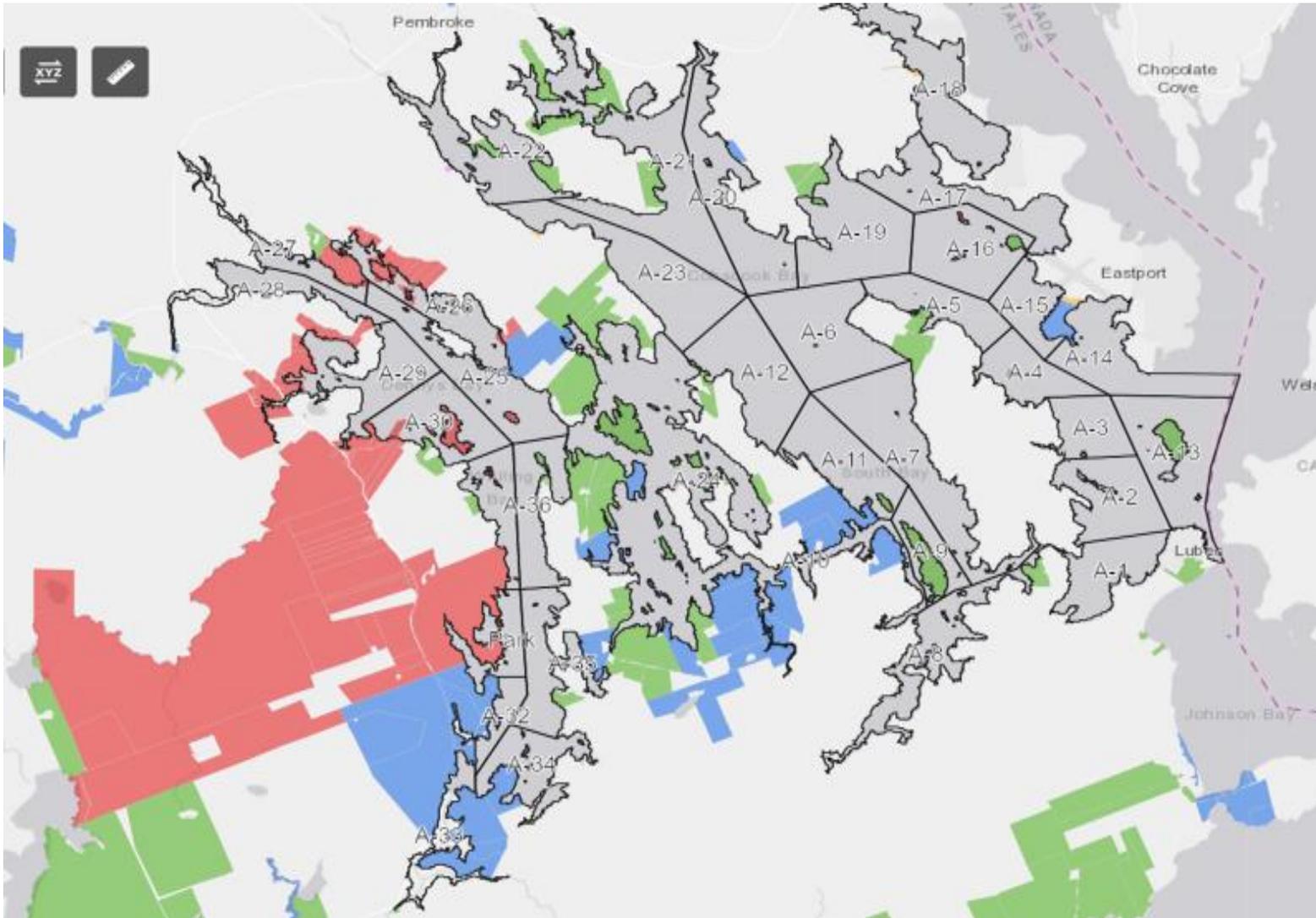
WOLFE'S  
NECK  
CASCO BAY, ME

NONE SUCH  
SCARBOROUGH, ME



# Seaweeds?

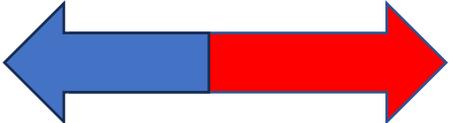
*Mostly Fished in EU (Norway) & NoAmerica...*



# Seaweeds?

*Mostly Fished in EU (Norway) & NoAmerica...*

# Farming?

Aquaculture  Fishery





Thank you !  
Tusen Takk !  
Mahalo !  
Muchas Gracias !

