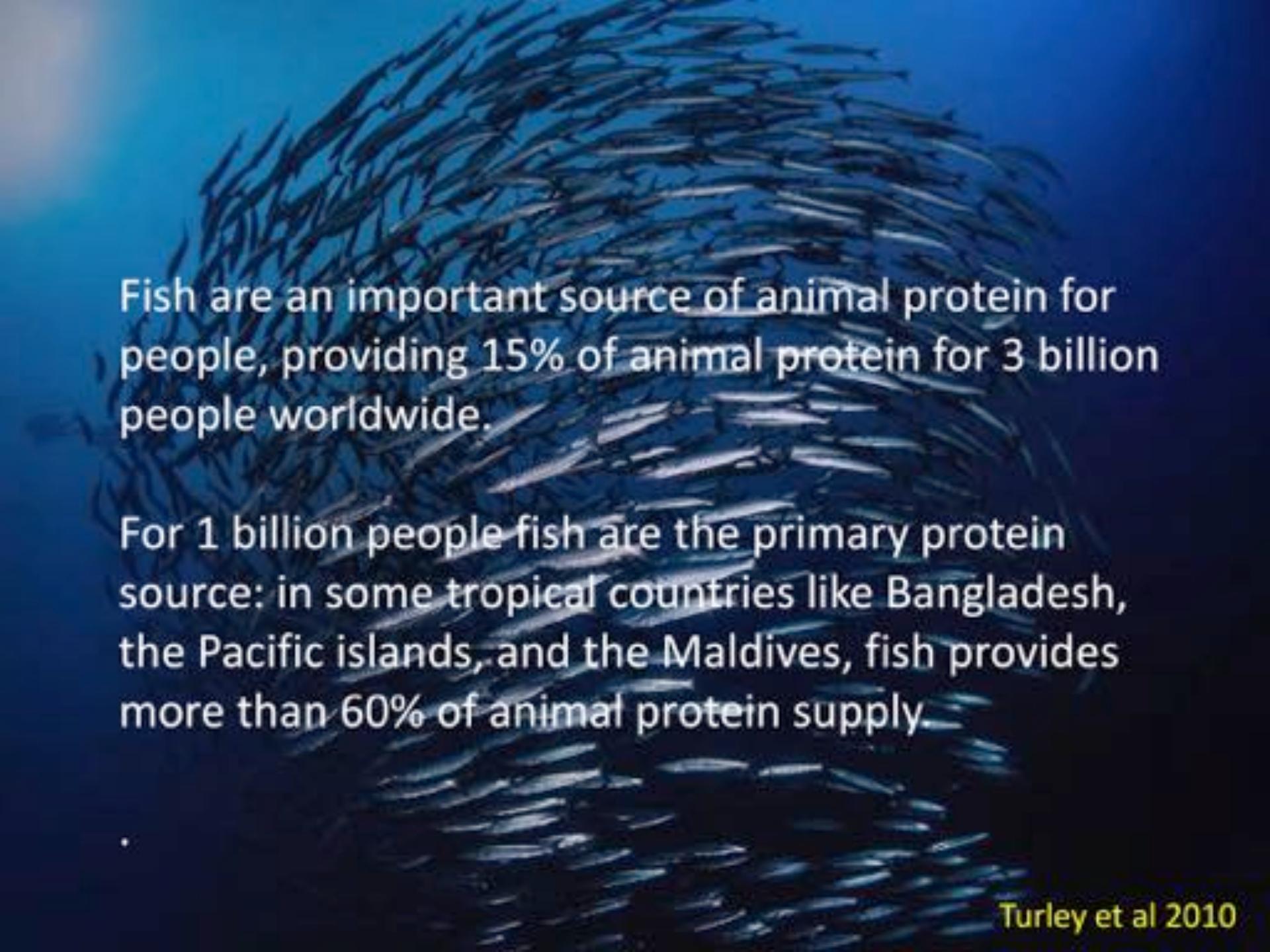


Fisheries & Aquaculture

ES 383

Colby at Bigelow, September 2019



A large school of fish, likely sardines or anchovies, swimming in a dense, swirling mass against a dark blue background.

Fish are an important source of animal protein for people, providing 15% of animal protein for 3 billion people worldwide.

For 1 billion people fish are the primary protein source: in some tropical countries like Bangladesh, the Pacific islands, and the Maldives, fish provides more than 60% of animal protein supply.

Ye olde Gulf of Maine

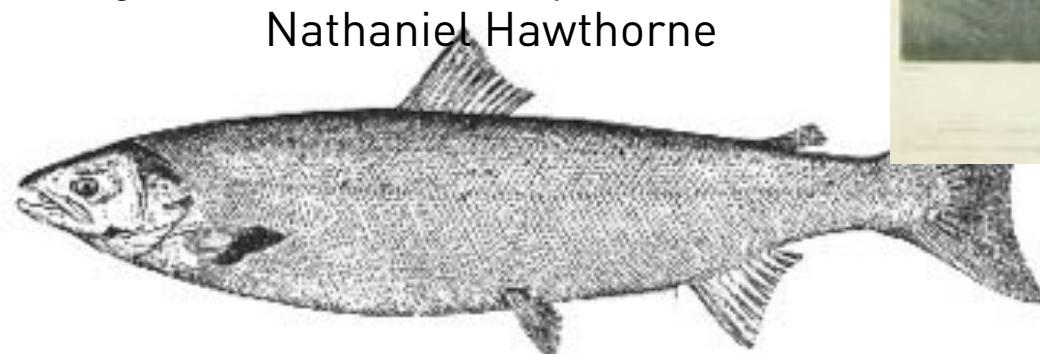


... cod appeared so thick that a person "could walk across their backs."

John Cabot (NL)

"...caught a black-spotted trout that was almost a whale. It weighed... eighteen and one-half pounds."

Nathaniel Hawthorne



Hunters in small watercraft pursued right whales from shore

Pre-colonial

2000 years ago: oyster shell middens

- Abenaki fished in summer
- discarded shells (12 – 20 inches in length)
- Preserved CaCO₃ shells
- give archaeological / climate record



Pre-colonial

Whaleback midden

- Damariscotta ("river of many fishes")
- 30 feet high
- over 1000 years
- mostly destroyed for chicken feed in the 1880s

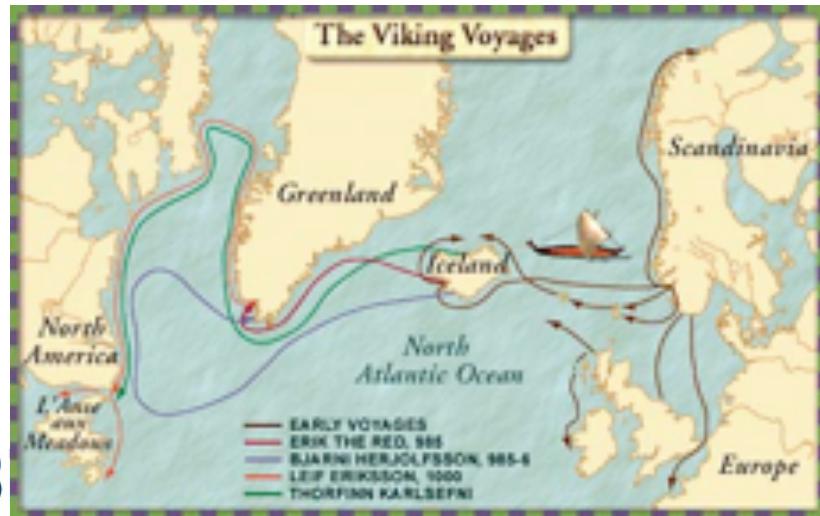


Pre-colonial

Vikings and Basques

Basques fished the abundant cod stocks

- summer settlements salted and dried cod for shipment



European Settlers in New England



Early 1600s

John Smith established fishing villages on Maine islands

Monhegan I.,
Damariscove I.
Principally cod



Settlers in New England

Pilgrims settled in Plymouth because they were intrigued by “Cape Cod” on John Smith’s map

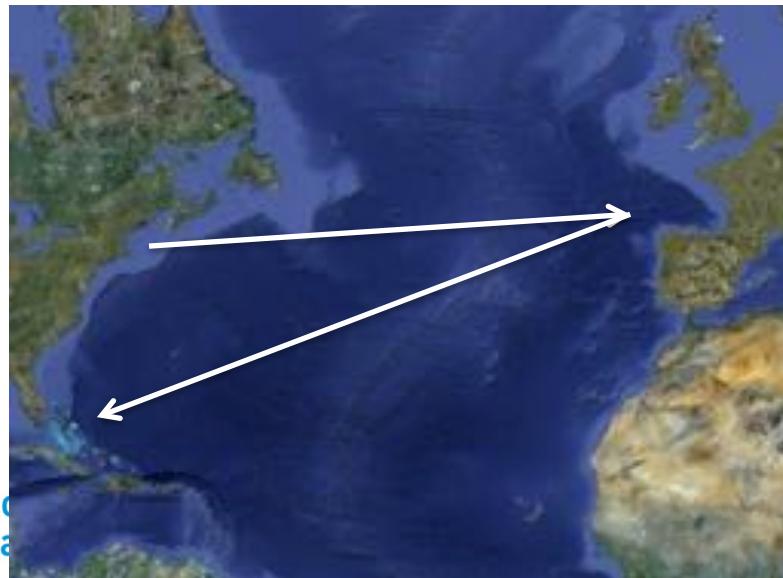
- knew nothing of fishing
- as they starved, British ships were filling their holds with fish just offshore

Learned fishing from natives

- cod as large as people
- could sometimes pull them up in large baskets
- ate lobster in desperation

Triangular trades

- cod
- rum
- slavery



Steven A. Murawski, NEFSC

Early 1900s

Fishing from schooners and dories
Baited lines pulled by hand

→ Shift to steam and trawling

1920s-1930s

- Technologies for freezing
- Market for a filet
- Shift from cod to haddock



Mid1900s

"It is only in the last few years when the fishing fleet has suffered from a marked scarcity of haddock that the folly of (the) belief in the inexhaustibility of nature has become potent". William Herrington Transactions of the American Fisheries Society

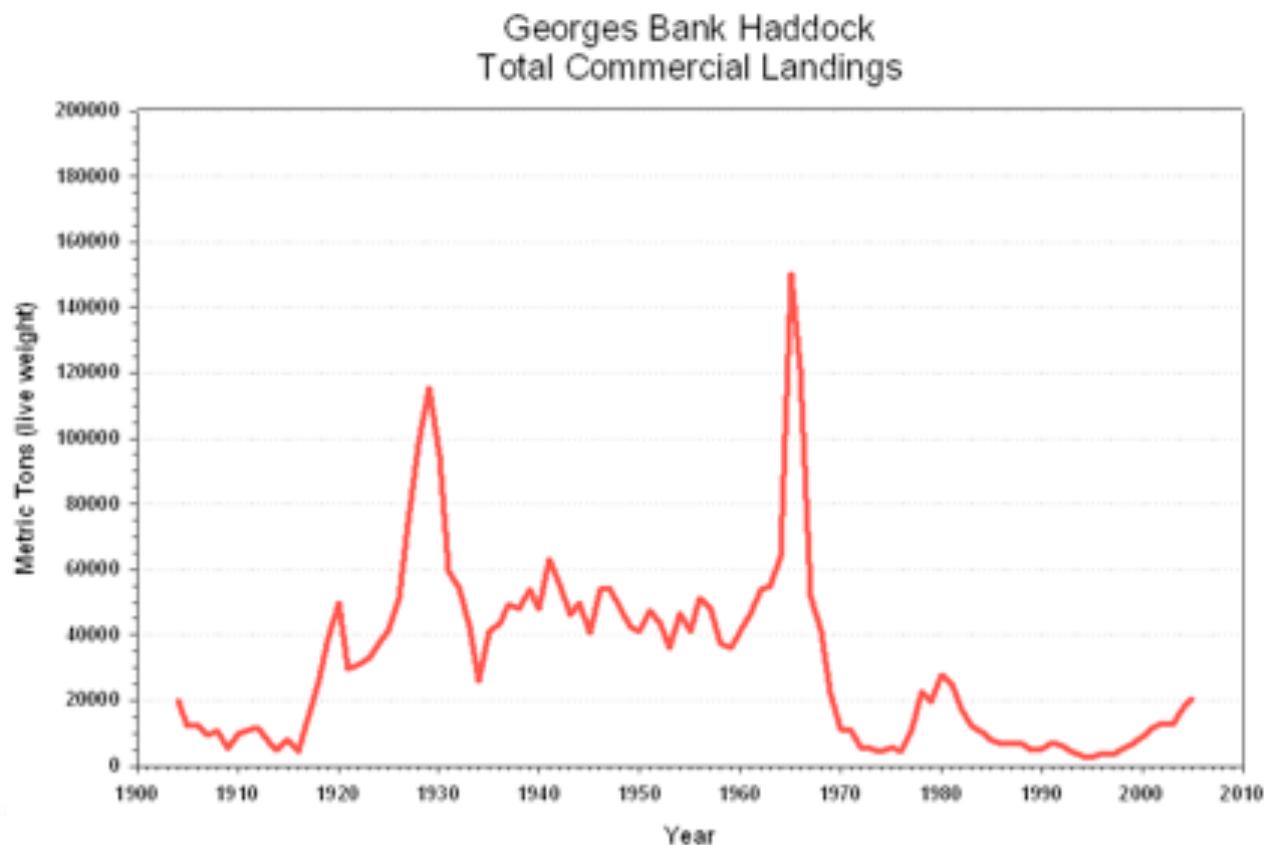


Figure 2.7. Total commercial landings of Georges Bank Haddock, 1904-2005.

Late 1900s

1960-1976

- Foreign fleets of factory trawlers fishing groundfish
- Collapses of many groundfish stocks
- Magnuson-Stevens Act: U.S. jurisdiction out to 200 miles
 - ... Also put in place fisheries management schemes

1977-1984

- U.S. fishery grew dramatically,
 - ... assuming there were unexploited stock left by foreign vessels

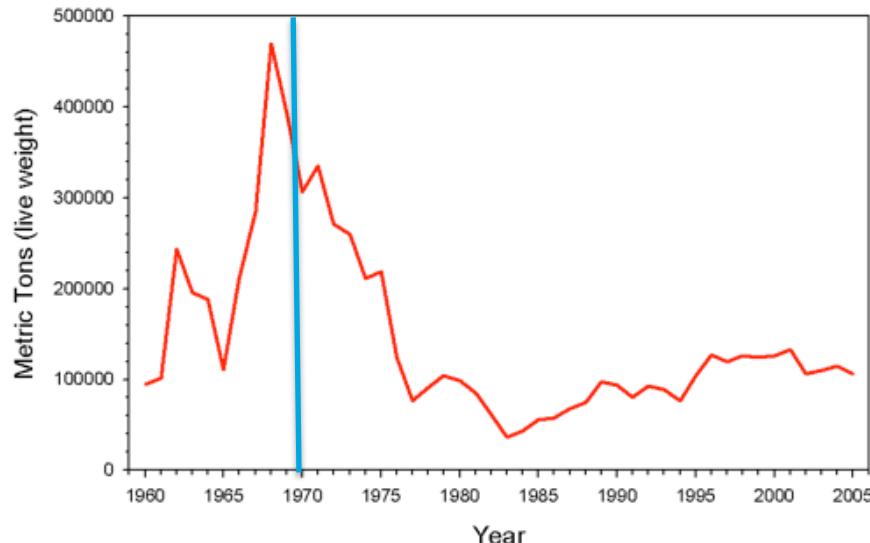


Figure 22.2. Total commercial landings of Gulf of Maine-Georges Bank Atlantic herring (NAFO Div. 5Y and 5Z), 1960-2005.

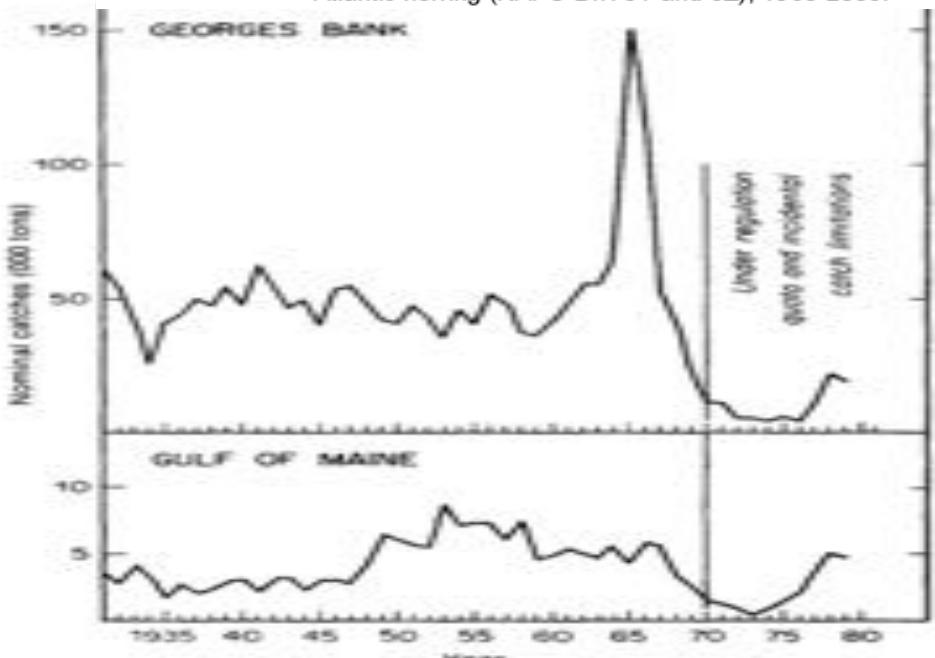
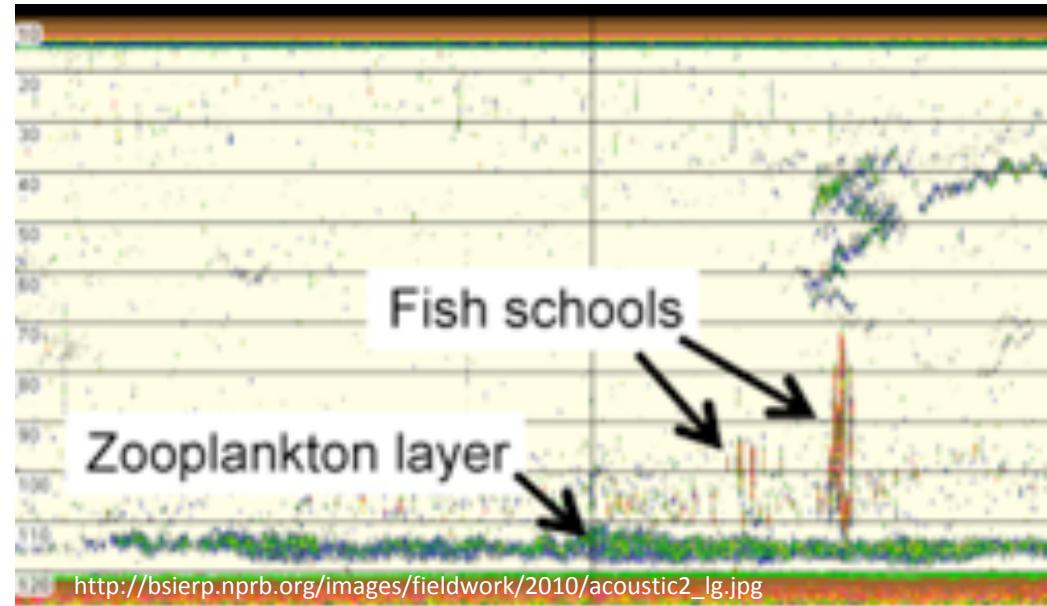
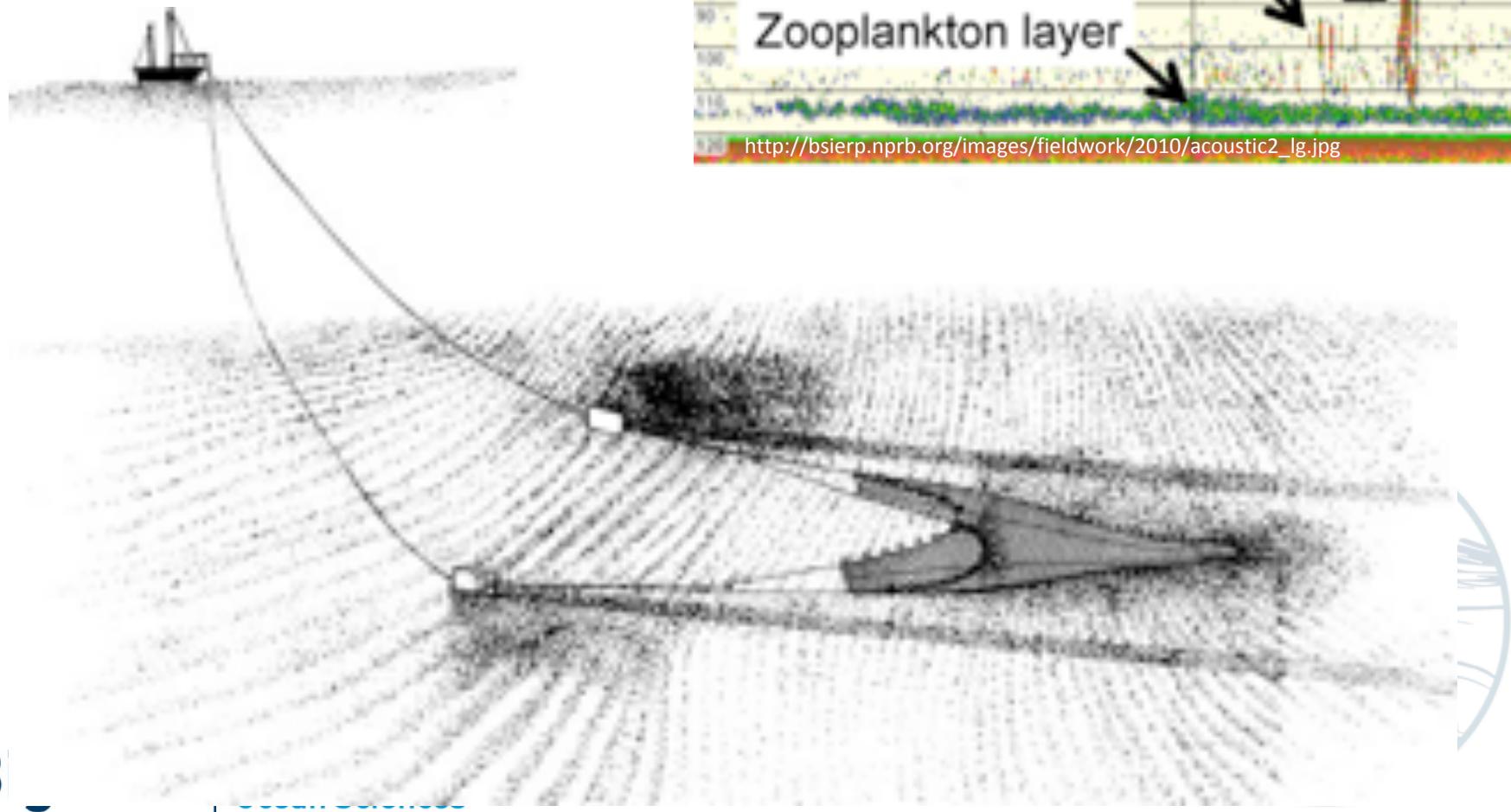


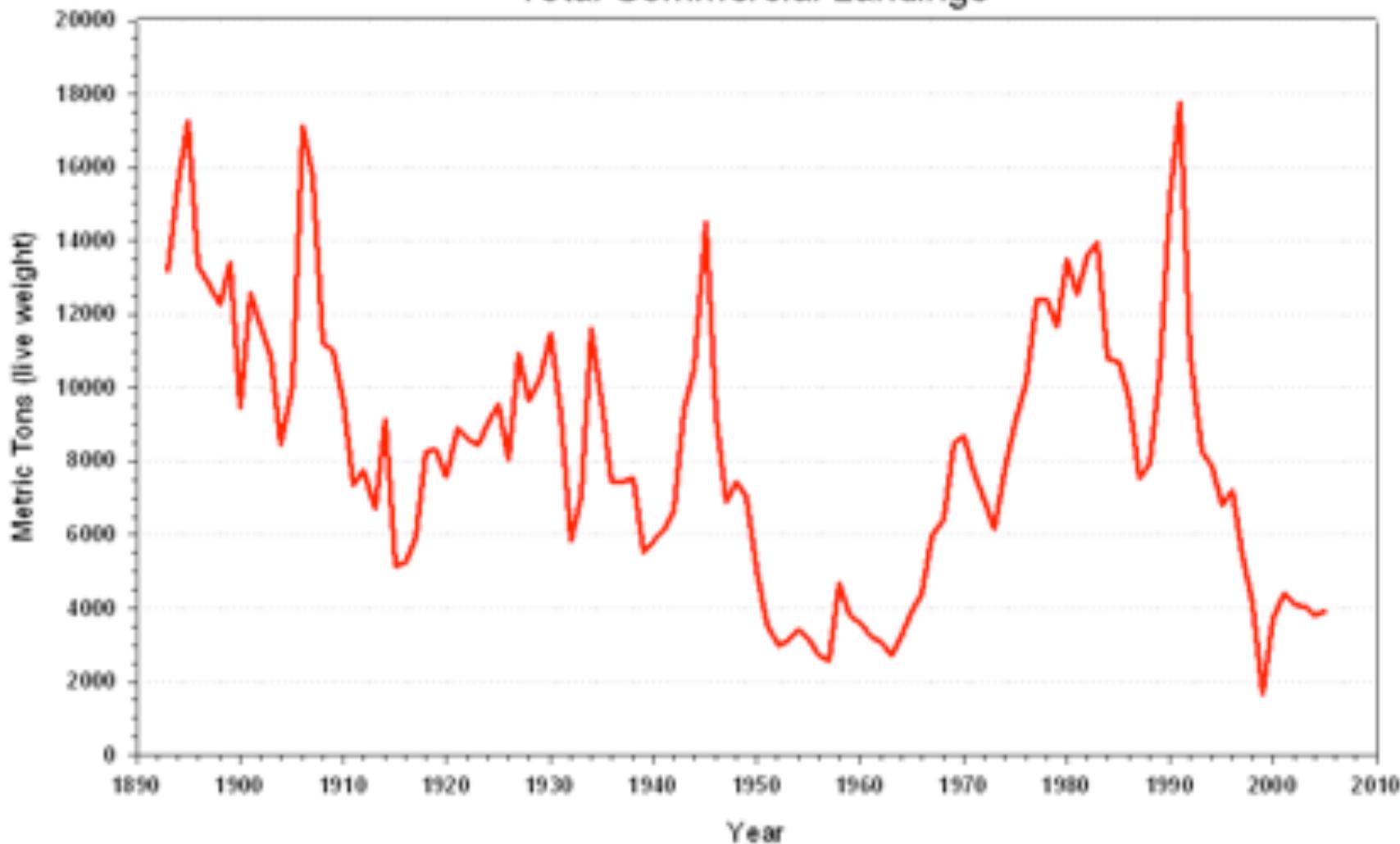
Fig. 3. Trends in nominal catches of haddock from Georges Bank and Gulf of Maine areas, 1935-79.
Clark 1982

Late 1900s



Late 1900s

Gulf of Maine Cod Total Commercial Landings

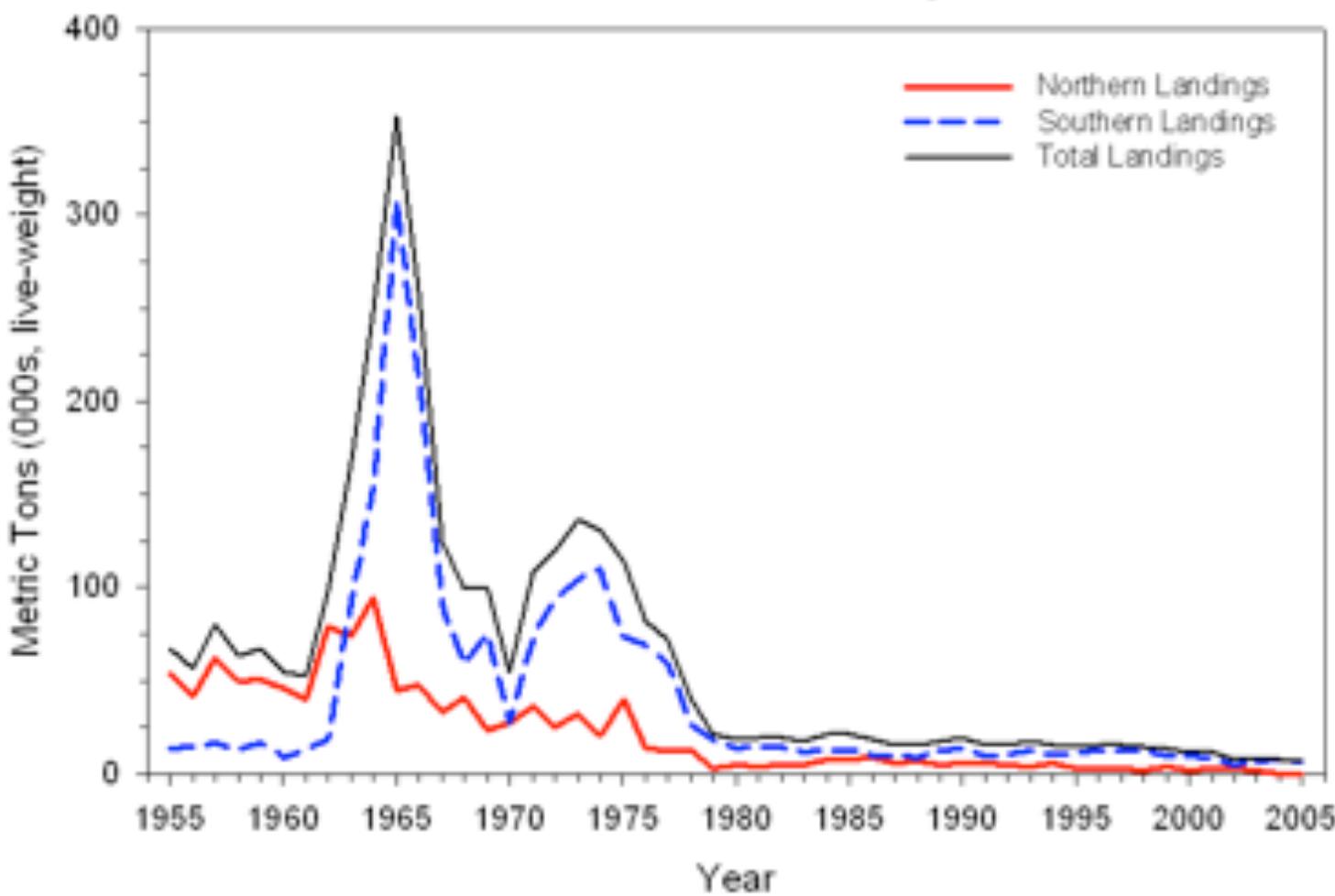


BigE

Figure 1.2. Total commercial landings of Gulf of Maine cod (NAFO Div. 5Y), 1893-2005.

Late 1900s

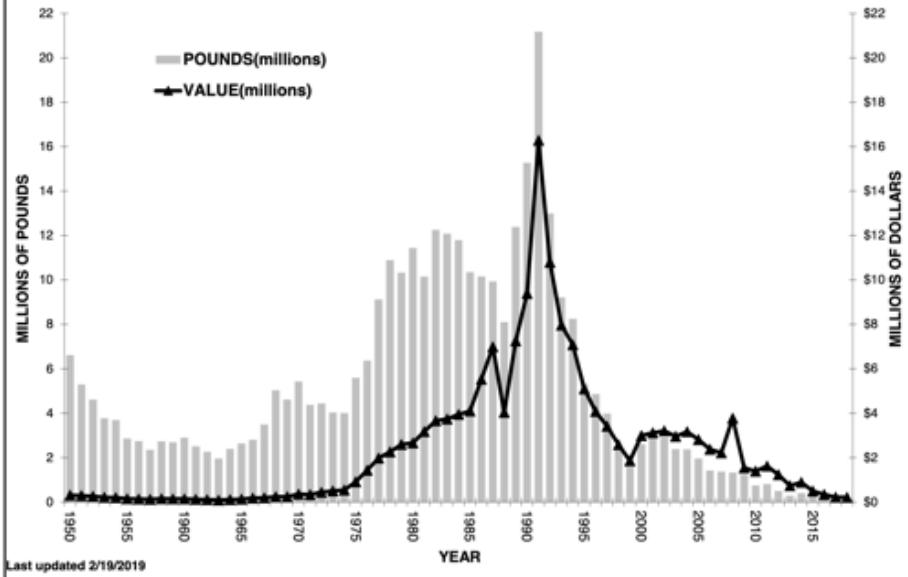
Northern and Southern Silver Hake Total Commercial Landings



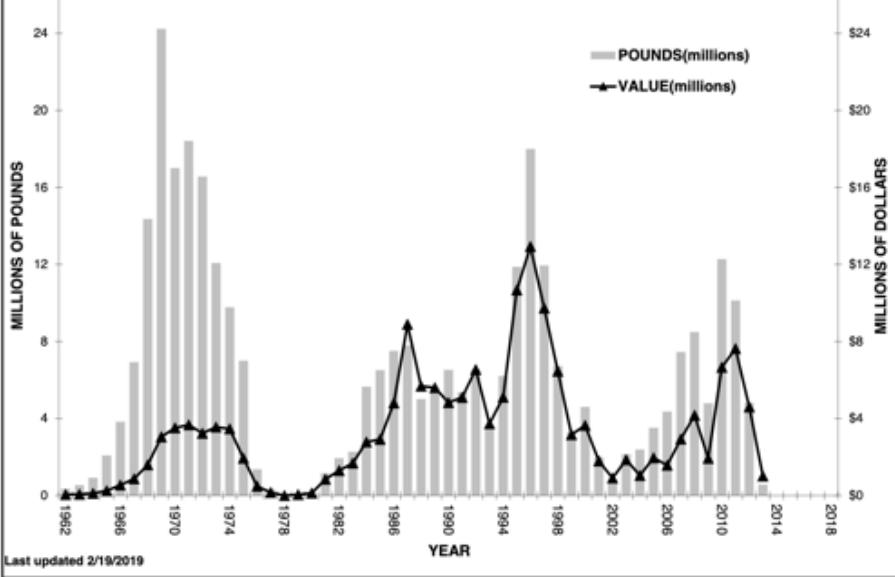
B

Figure 4.2. Total commercial landings of northern and southern silver hake, 1955-2005.

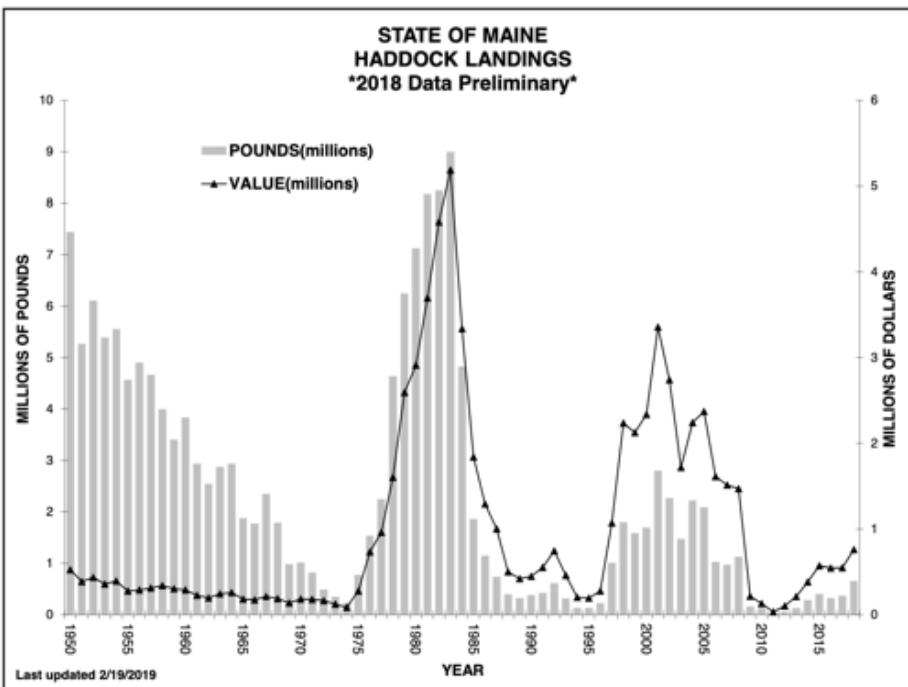
**STATE OF MAINE
ATLANTIC COD LANDINGS**
2018 Data Preliminary



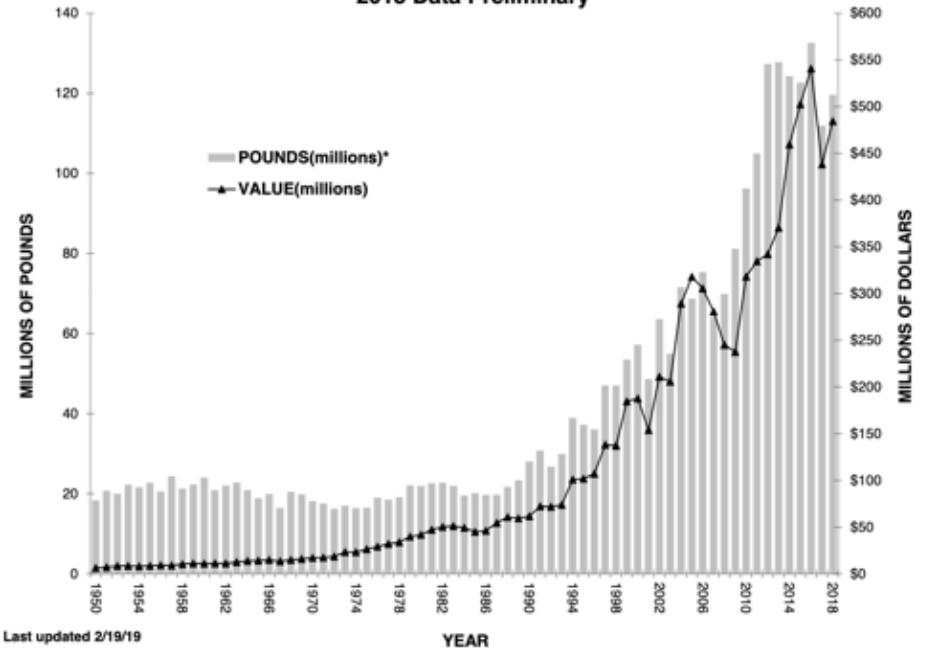
**STATE OF MAINE
NORTHERN SHRIMP LANDINGS**
2018 Data Preliminary



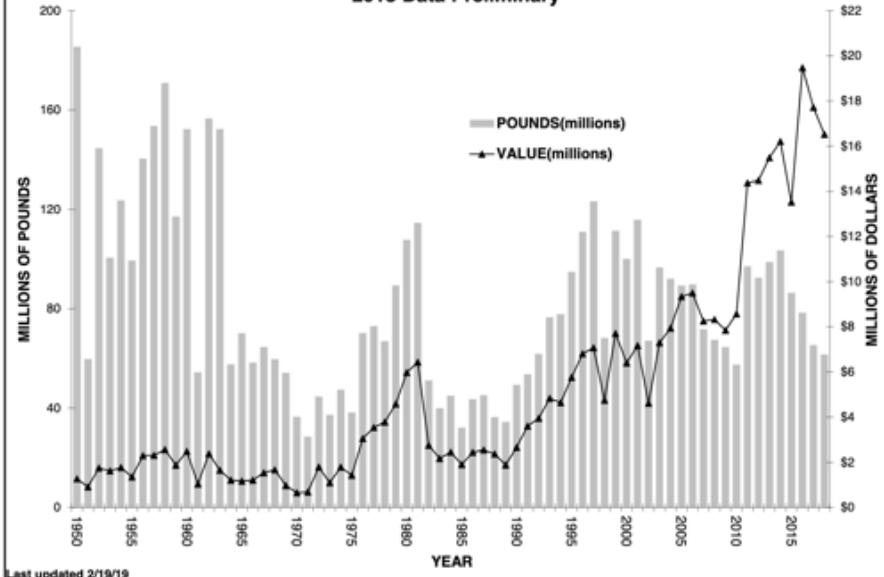
**STATE OF MAINE
HADDOCK LANDINGS**
2018 Data Preliminary



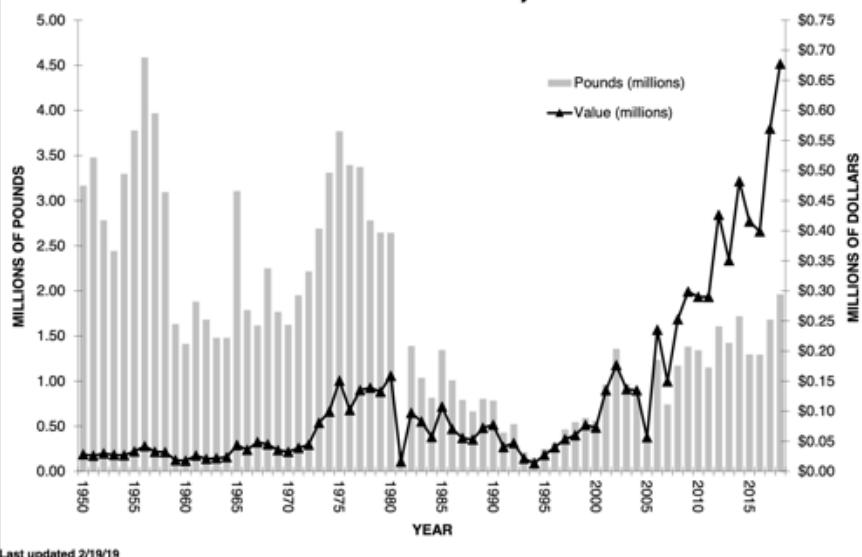
**STATE OF MAINE
AMERICAN LOBSTER LANDINGS**
2018 Data Preliminary



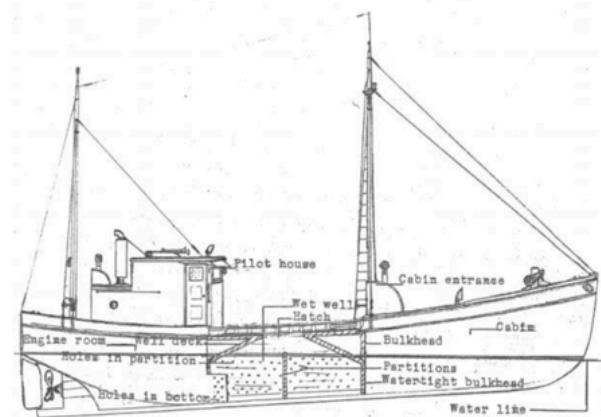
**STATE OF MAINE
ATLANTIC HERRING LANDINGS**
2018 Data Preliminary



**STATE OF MAINE
ALEWIFE LANDINGS**
2018 Data Preliminary



Lobster Industry



WET - WELL - LOBSTER - SMACK

<http://umaine.edu/lobsterinstitute/files/2011/12/Trip-in-a-Lobster-Smack.pdf>

- **1605** - 1st recorded lobster catch. Plentiful (1600-1700s), a ‘paupers’ food.
- **Late 1700s** - Lobster “smacks” introduced, serious lobster industry begins.
 - A smack = vessel built with a well that has the free circulation of sea water to keep lobsters or fish alive until they are unloaded.
 - <1900: Sail smacks,
 - 1900-1950: Power smack,
 - >1950 Modern lobster boat
- **1828** - Maine passed a law banning out-of-state lobstermen.
- **1842** - Lobster canning started in Eastport, expanding the market. In 1843 a one pound can (meat from 3 1/2 pounds of live lobster) sold for 5 cents.
- **1850s** - Lathe pots replace hoop nets – followed in 1930s by wooden parlor traps.
- **1872** - First law banning taking of egg-bearing females ...a conservation measure already practiced by many Maine lobstermen at the time.
- **1874** - 1st laws regulating minimum size (10 1/2 inches overall). This doomed the canners who basically went out of business by 1885. Maine’s minimum size today is 3 1/4 inches and the maximum is 5 inches (carapace).

Lobster Industry

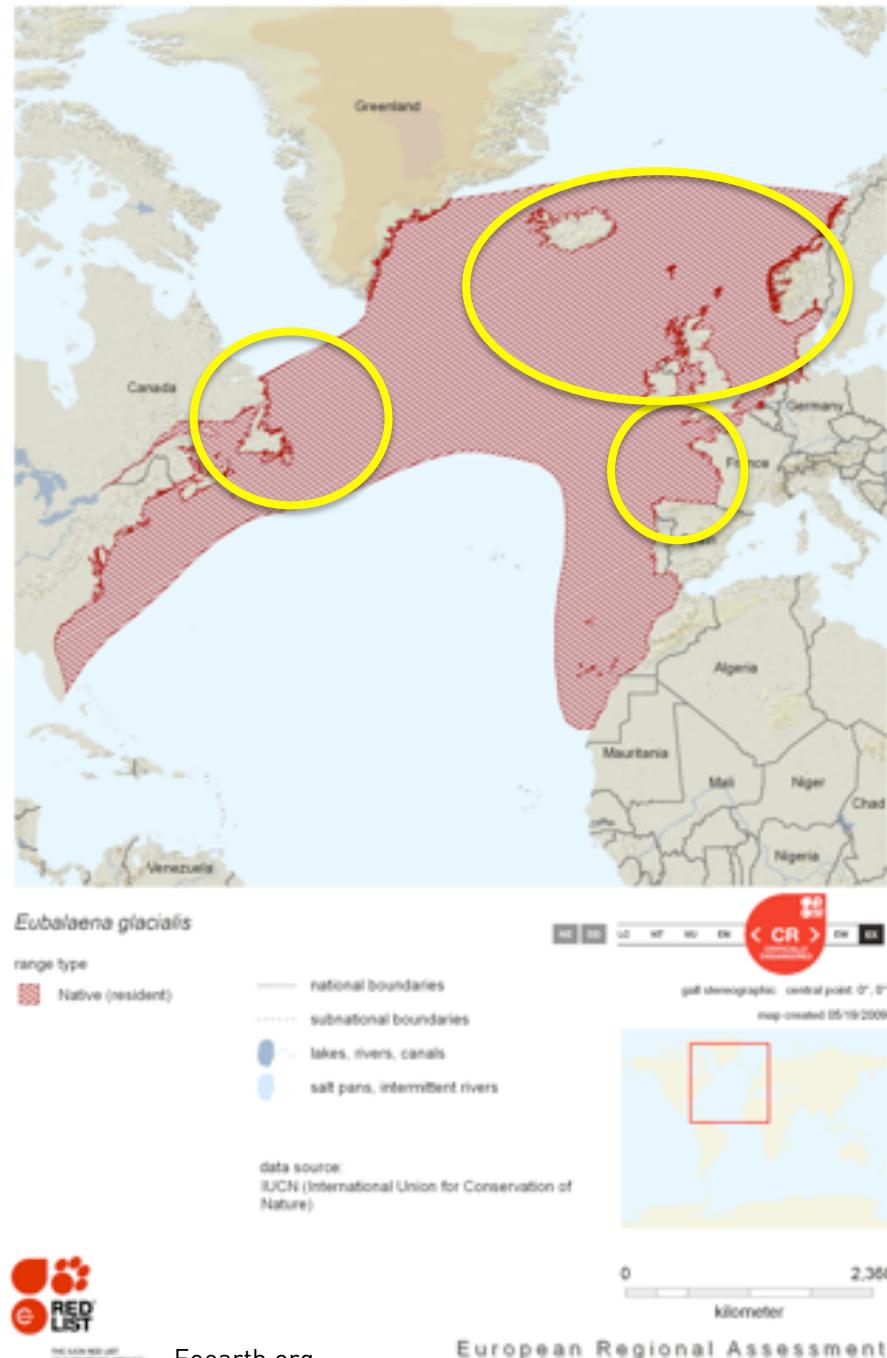
- **1875** — Tidal lobster pounds introduced to store live lobsters for future sale
- **1910** — Engines began replacing sails and oars—hydraulic haulers in 1950s.
- **Early 1900s** — Landings in the U.S. very low. Lobstermen often had to find other ways to supplement their income in these days
- **1940s** — Research began on alternative bait. Early attempts included sanitary napkins soaked in herring oil & kerosene soaked bricks.
 - Herring → most popular bait today (700-800 million lbs. used/yr in the U.S. & Canada).
- **1950s**—Landings began to increase.
 - Co-ops were introduced: 1st in Boothbay, Pemaquid, and Stonington.
 - The Maine Lobstermen's Association organized
- **1950s** — Offshore lobstering becomes more prevalent (20%).
- **1970s** — Wire-mesh traps introduced.
- **1977** — Largest lobster caught off Nova Scotia (44 lbs 6 oz, length of 3 1/2 ft.)
- **1987** — Lobster Institute formed. The Institute was started by industry associations in partnership with the University of Maine. The Lobster Institute's core functions include communications, outreach, research and educational programming.
- **2010** — U. S. lobster catch-116 M pounds (\$399M).
- **2011** — Maine lobster catch – ~103.9 M pounds (\$331M).
- **2012** — warming Gulf and early & repeated shedding depressed prices, 2nd lowest on record (1939)
- **current** — lobster center moved N from Casco Bay to Stonington
 - Today's lobster fishery interacts with whale management

Right whales

1100s – Basque hunt in the Bay of Biscay

1400s – Basques, Dutch, Danish, British, Norwegians hunting in Iceland, Norwegian, and British waters

1500s – Tens of thousands of whales taken in western N. Atlantic by Basques (many possibly bowheads)



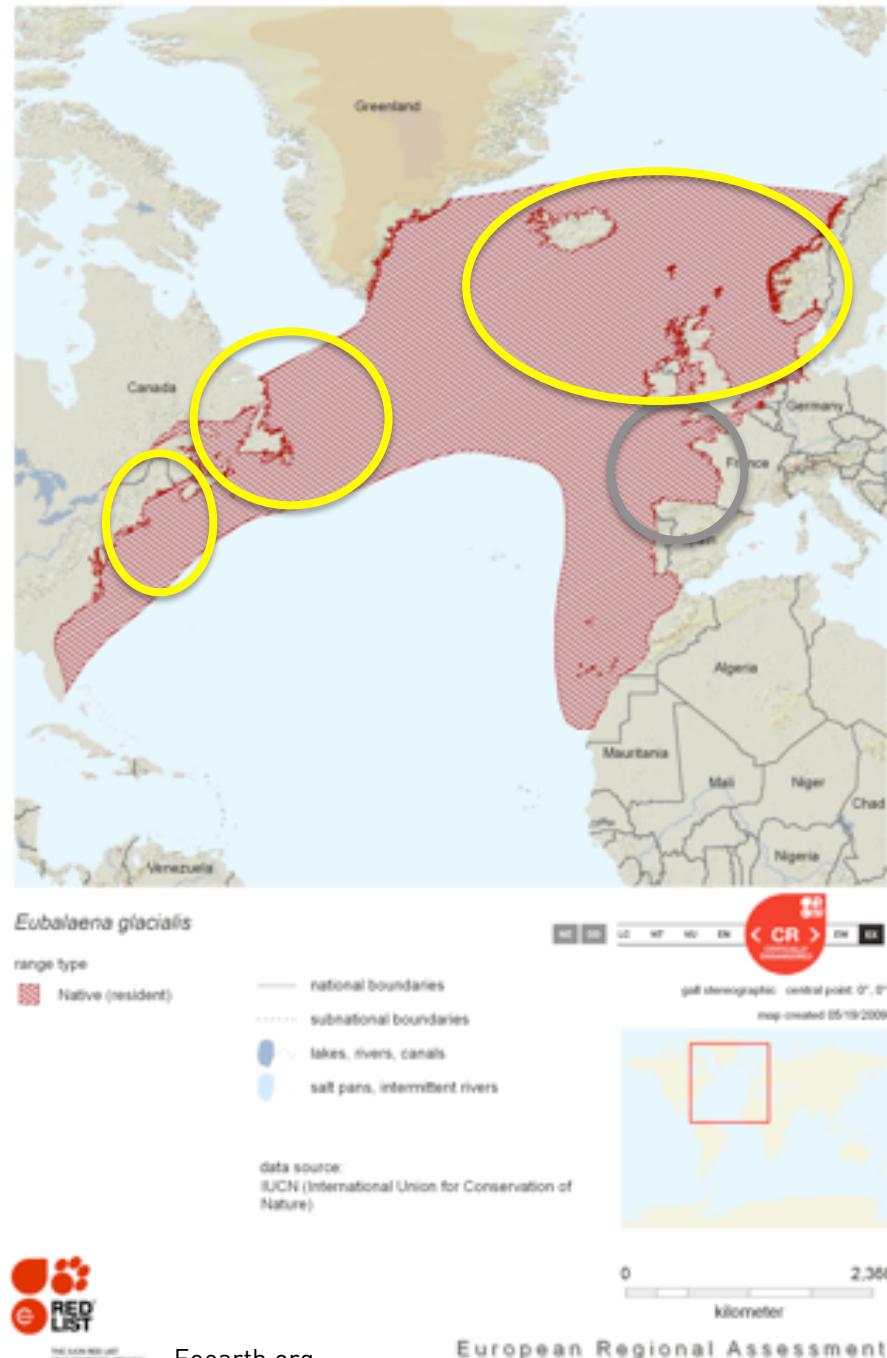
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Right whales

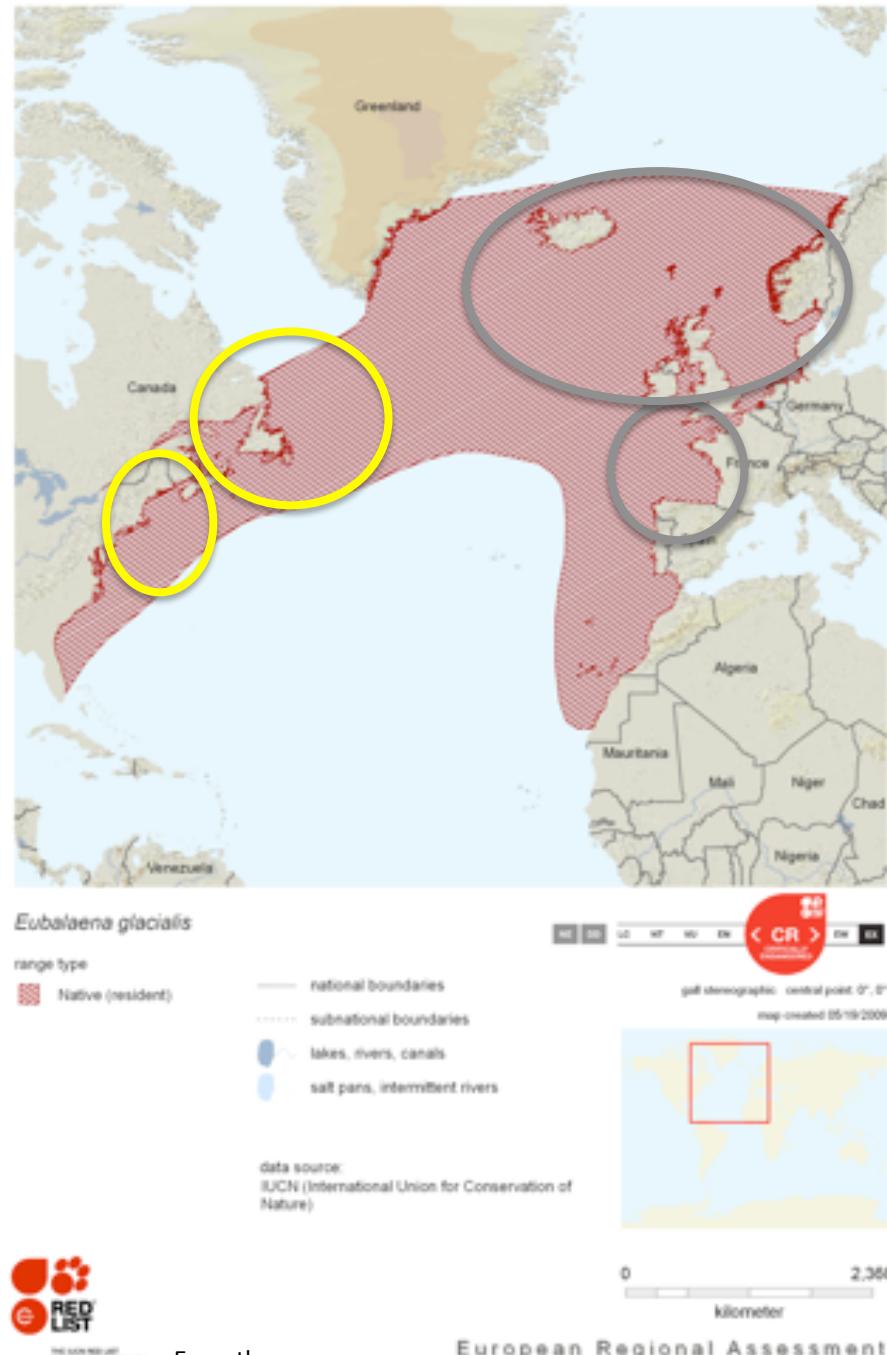
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1700s – eastern stocks declining / depleted



Right whales

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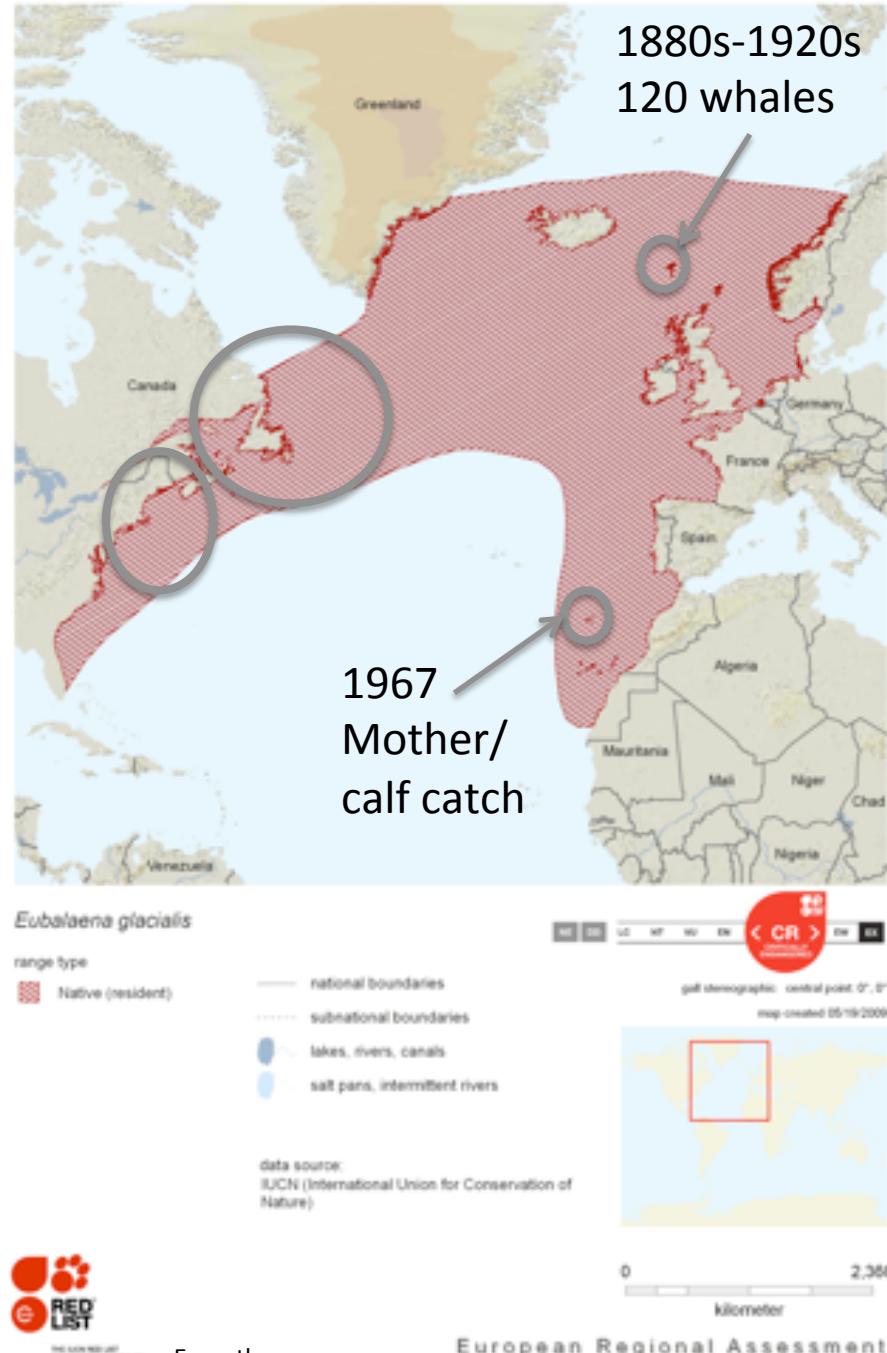
1500s – Tens of thousands of whales taken in western N. Atlantic by Basques

1600s – Shore based whaling in the U.S. took thousands of right whales

1700s – eastern stocks declining / depleted

1800s – continued catch / decline

1900s – sporadic catches

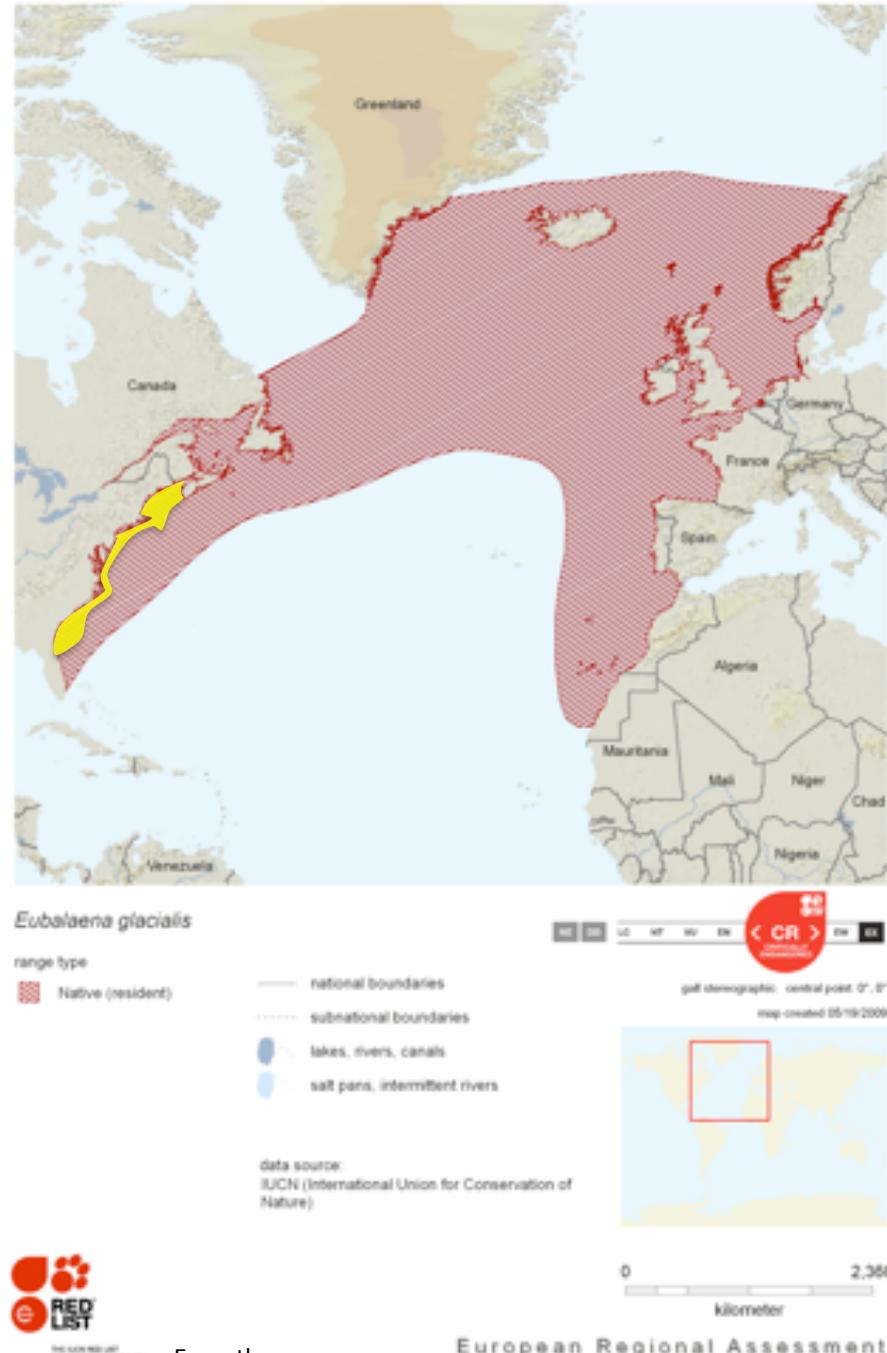


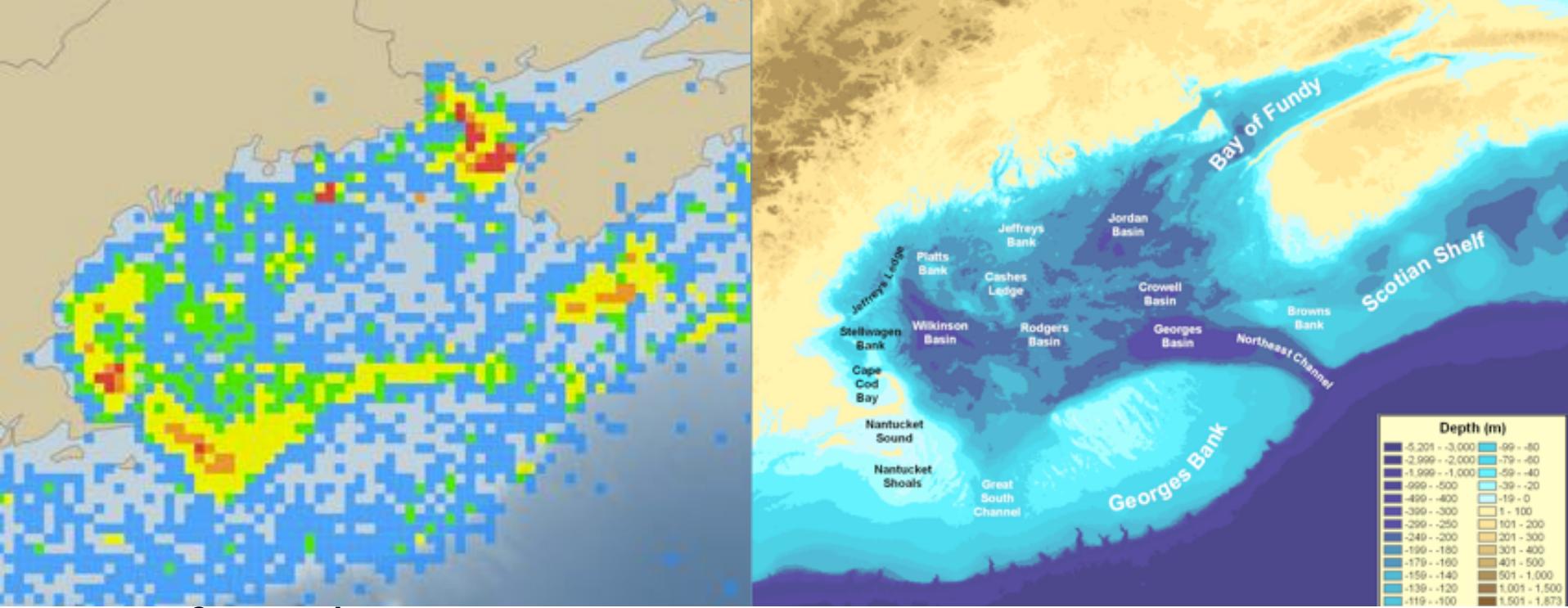
Right whales

1982 – International Whaling Commission adopted a moratorium on commercial whaling world-wide

Currently ~400 right whales in Atlantic

All feed in the Gulf of Maine





Current threats:

- Ship strikes
- Gear entanglements
- Climate effects on food resource

1990s – forecasts were dire
extinction predicted

2000s – forecasts more positive
population appears to be on a positive trajectory

2010s – whales not found in usual locations... shift to Canada
→ ***Conflict with Maine lobster fishery***



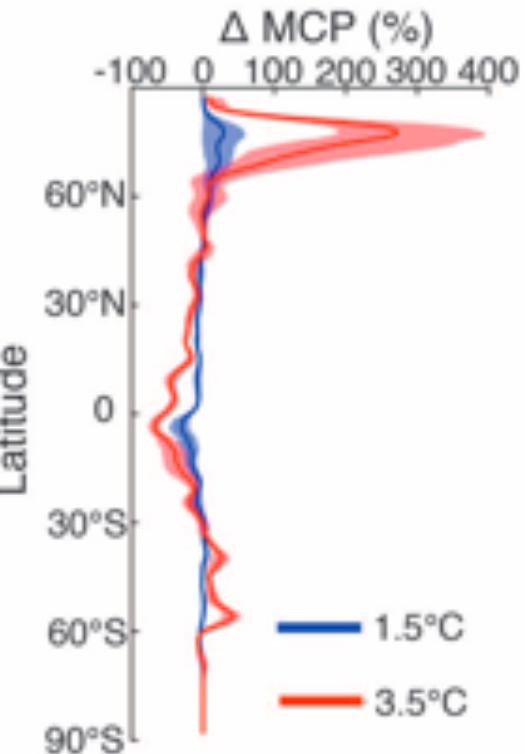
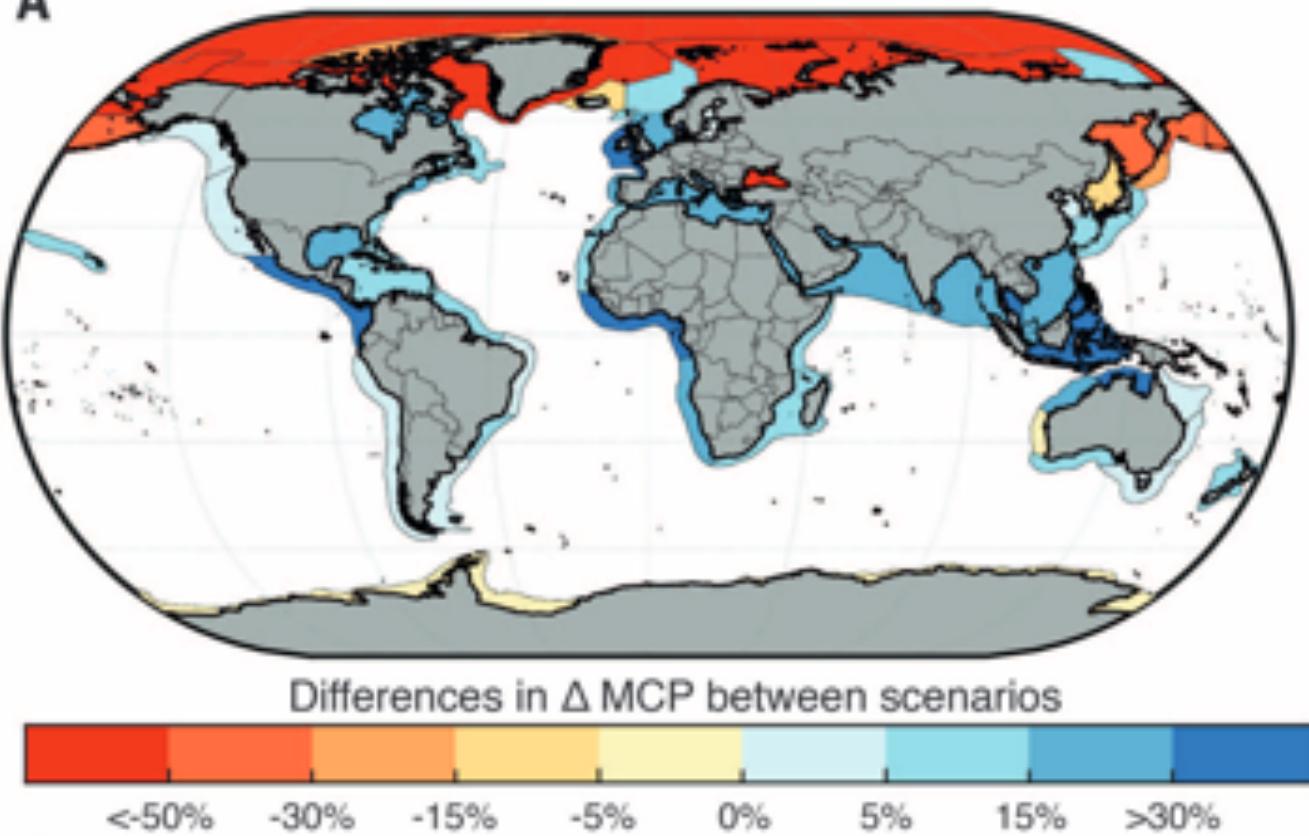
How will temperature changes affect fish?

- ↑ temperatures stress fish metabolism:
 - Solubility of O₂ decreases as temperature ↑
- Temperature influences enzymatic reactions:
 - hormonal and nervous control of digestion, respiration, osmoregulation
- Temperature increases susceptibility to diseases
- ↑ temperature reduces O₂:
 - reduces fish growth & diversity
- ↑ temperature causes changes in sex ratios and spawning times
- Toxic substances (e.g. cyanides) can ↑ toxicity as temperature ↑



How will temperature changes affect fish?

A



Cheung 2016



How will pH changes affect fish?

- Originally thought: ↓pH will have little effect
 - Fish can avoid areas of low pH.
 - Fish were thought to have efficient acid-base regulatory mechanisms
- Now: Fish can be directly and indirectly impacted by low pH.
 - Direct → changes in metabolism, growth, behavior (orientation, balance)
 - Indirect → changes in susceptibility to predation, recruitment & survival, food webs
 - Short term → respiration, blood circulation, nervous system function
 - Long term → reduced growth rate, reproduction,
- Egg and larval stages are particularly susceptible.
- Lower pH causes acidosis (acidity) in tissue and body fluids of fish
- Harmful at both species and population levels



How will pH changes affect fish?

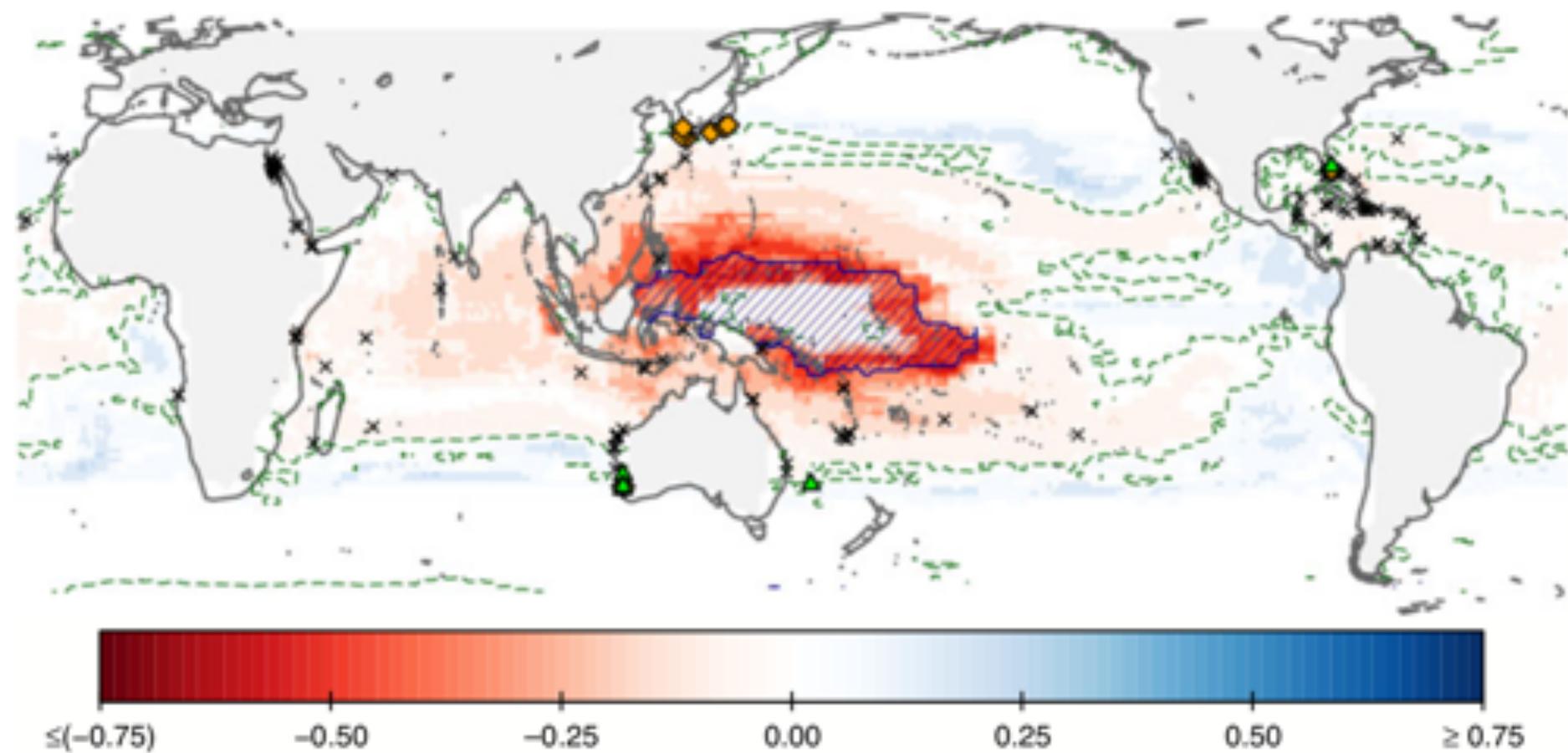
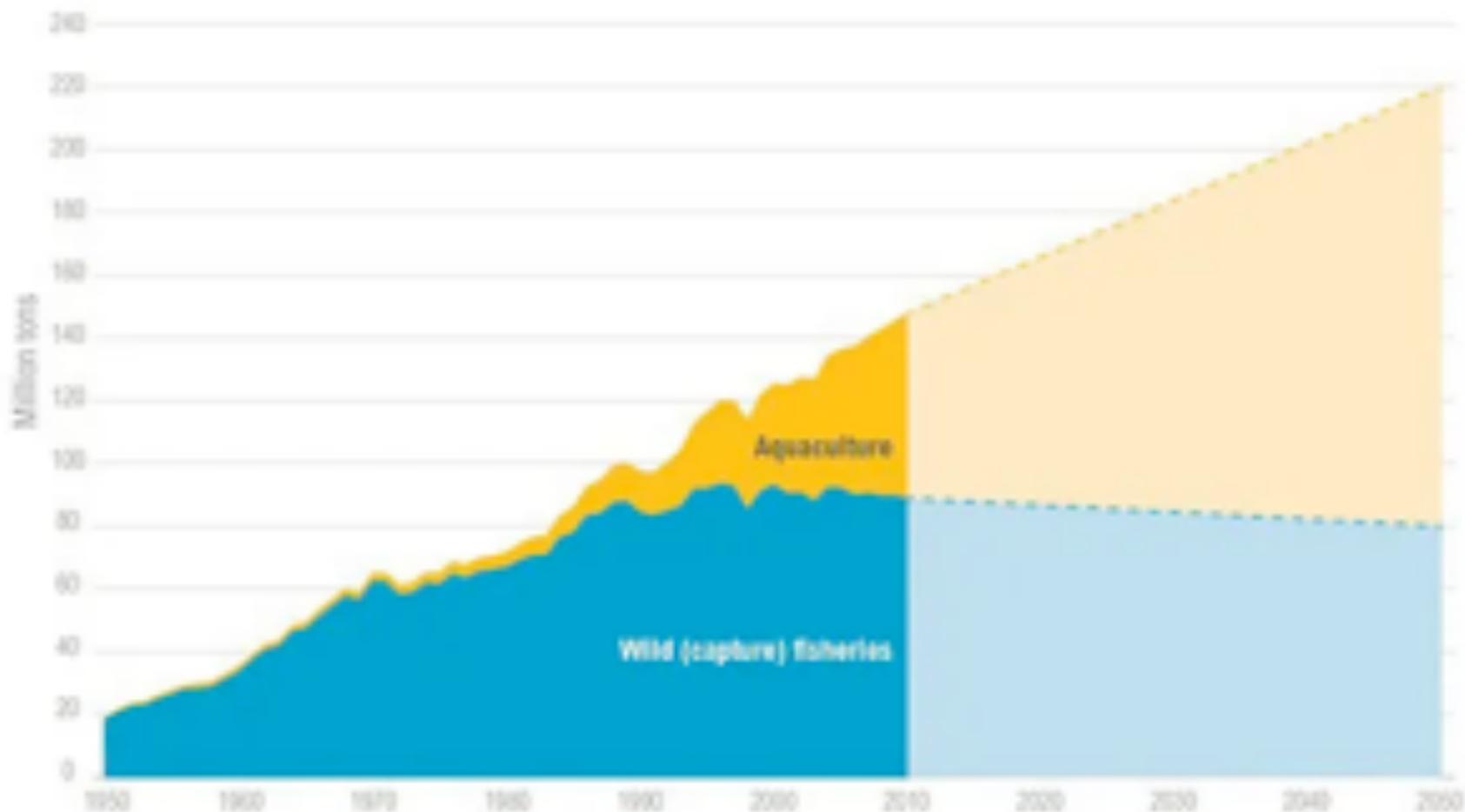


Fig. 5 Projected change in suitability for coral reef ecosystems between 1990 and 2070 under the A2 scenario, considering simultaneous changes in aragonite saturation and surface ocean temperature. The projected response has been averaged across both 'OPT' models and the MaxEnt_{SIM} model (models defined in Table 1; BRT_{SIM}'s results were excluded from the average, as discussed in the text and Data S3). Green dashed line indicates null projected change, whereas the hatched pattern identifies areas with novel conditions where projections are less reliable, due to a significant impact of the chosen extrapolation method (as explained in Methods). The sites of past (green triangles) and present (orange diamonds) range expansion of coral are also indicated, based on data from Lighty *et al.* (1978), Veron (1992), Marsh (1993), Vargas-Ángel *et al.* (2003), Greenstein & Pandolfi (2008), Woodroffe *et al.* (2010), and Yamano *et al.* (2011). Black crosses indicate coral reef distribution during the last interglacial period (data from Kiessling *et al.*, 2012).

Aquaculture

Aquaculture Is Expanding to Meet World Fish Demand



Source: Historical data 1950–2010: FAO, 2014, "FishStatJ." Rome; FAO, Projections 2011–2050; Calculated at WRI, assumes 10 percent reduction in wild fish catch between 2010 and 2050, and linear growth of aquaculture production at an additional 2 million tons per year between 2010 and 2050.

See www.wri.org/publications/improving-aquaculture for full paper.



WORLD RESOURCES INSTITUTE

2012 AQUACULTURE PRODUCTION VALUES

VALUE

\$1.2
billion dollars

20%

of total U.S.
seafood production
& fishery products by value



PRODUCTION

594
million pounds

15th
in global
aquaculture
producer

MARINE SPECIES HIGHLIGHTS

Oysters
\$136 million
35 million pounds

Clams
\$99 million
10 million pounds



Mussels
\$9 million
0.7 million pounds

Shrimp
\$6 million
0.4 million pounds

U.S. Marine
aquaculture is growing at
8%
per year
(2002-2012)

REGIONAL MARINE HIGHLIGHTS

Pacific
48%
by value

Northeast
31%
by value

Gulf of Mexico
13%
by value

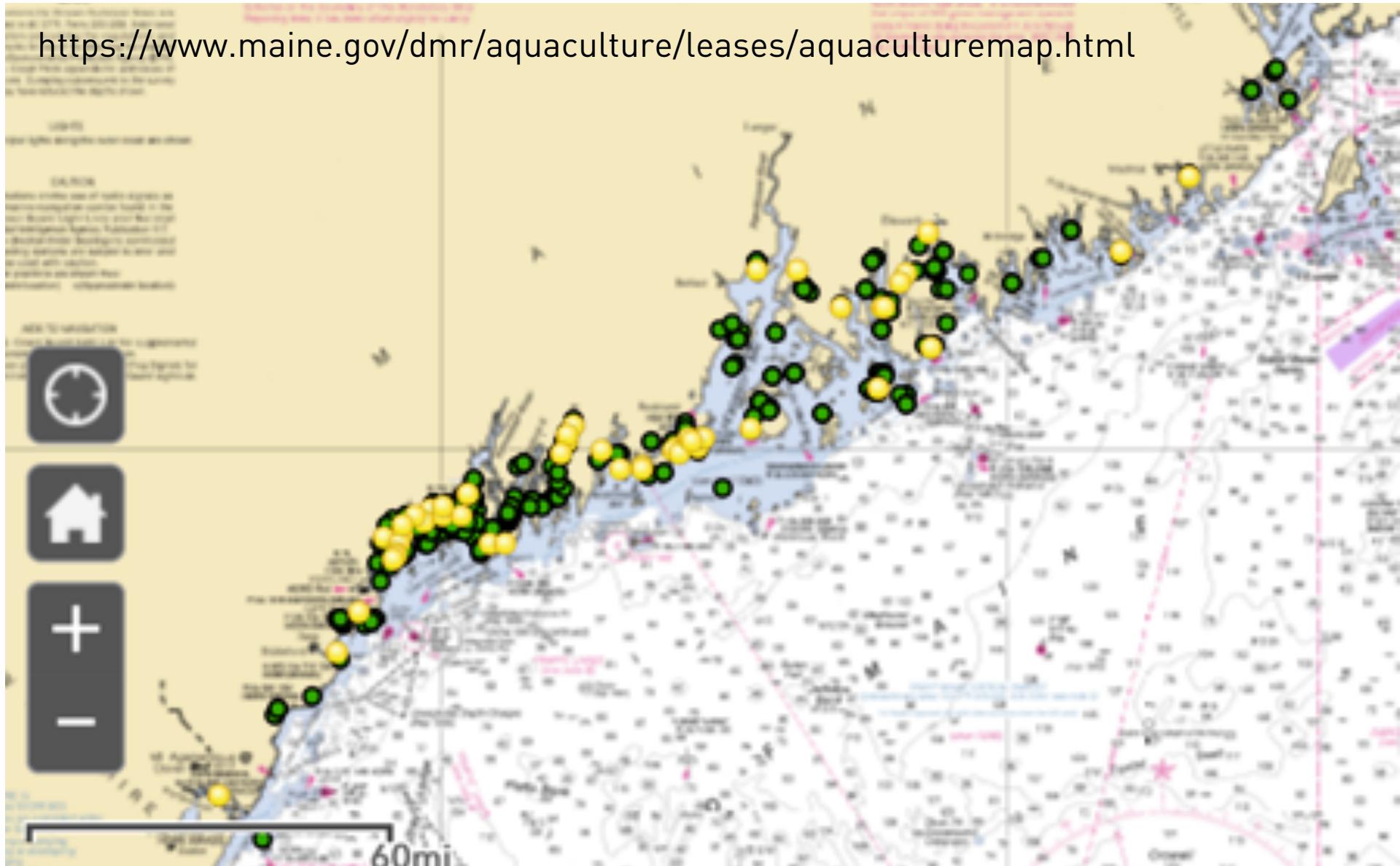
Southeast
8%
by value



NOAA FISHERIES

Maine lease sites

<https://www.main.gov/dmr/aquaculture/leases/aquaculturemap.html>



Timeline of aquaculture in Maine: <https://cpb-us-w2.wpmucdn.com/wpsites.maine.edu/dist/1/43/files/2015/03/ARI-Timeline-1lrxai4.pdf>

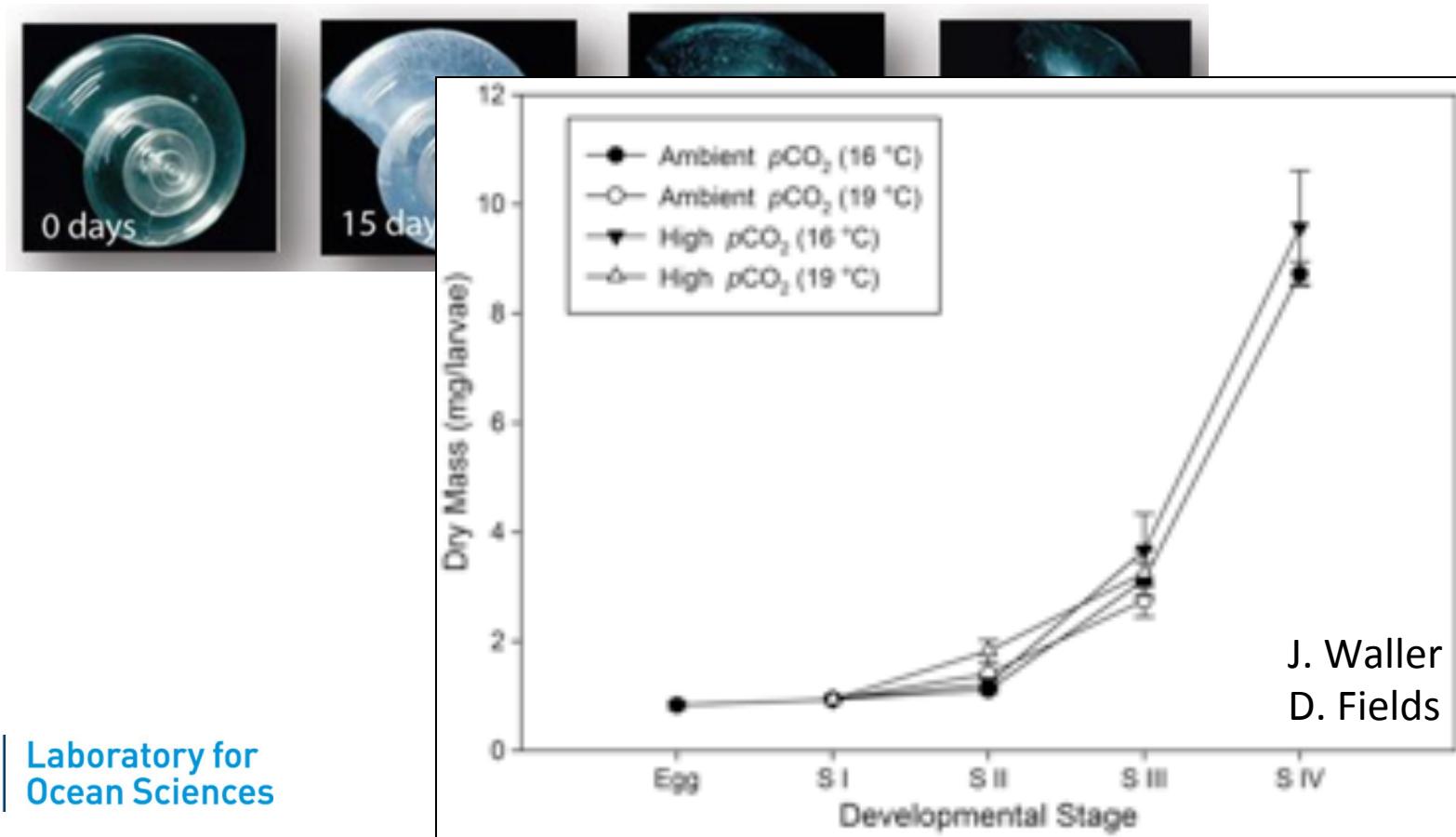
Aquaculture concerns

- Ocean acidification
 - Shell dissolution



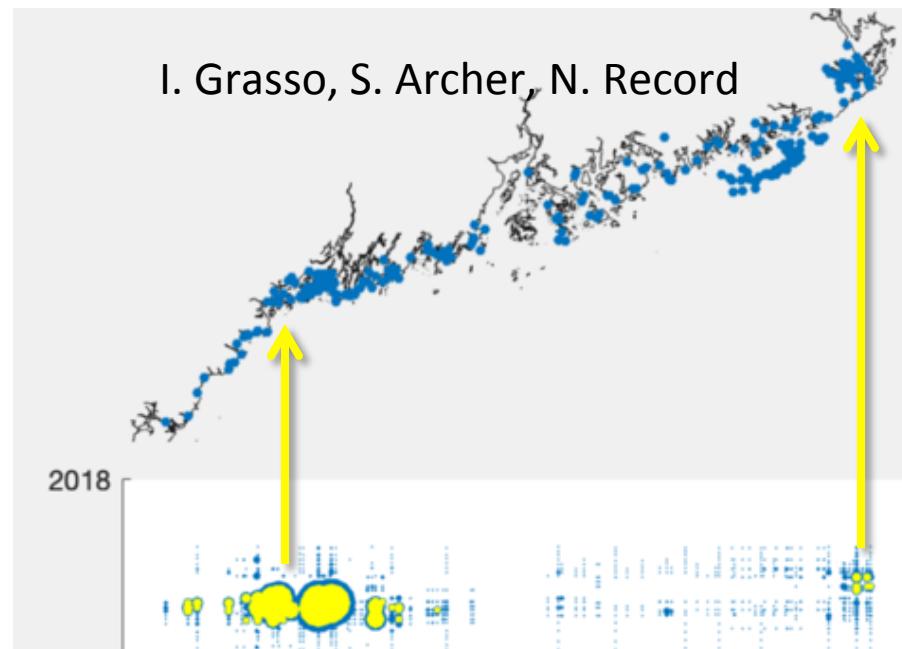
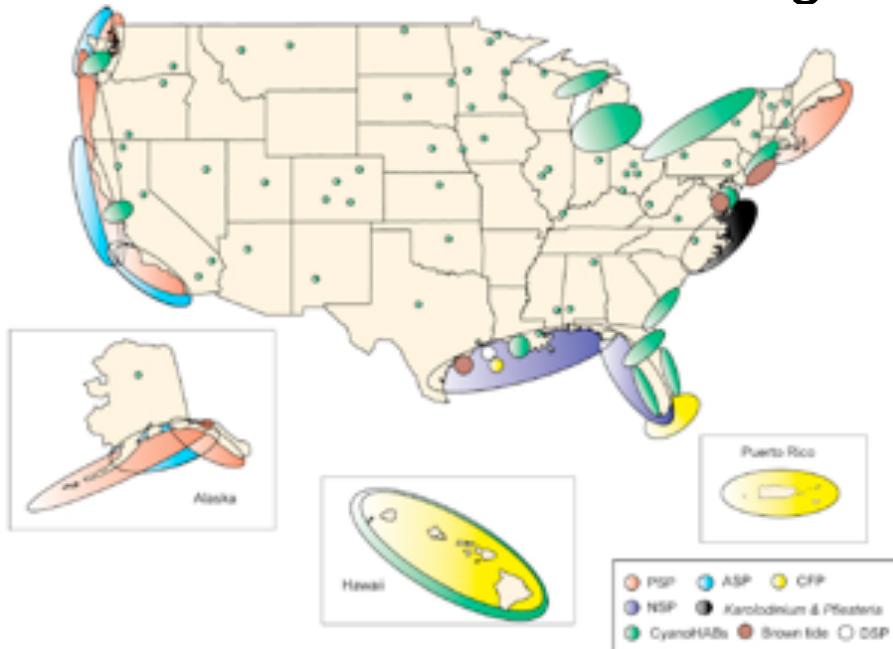
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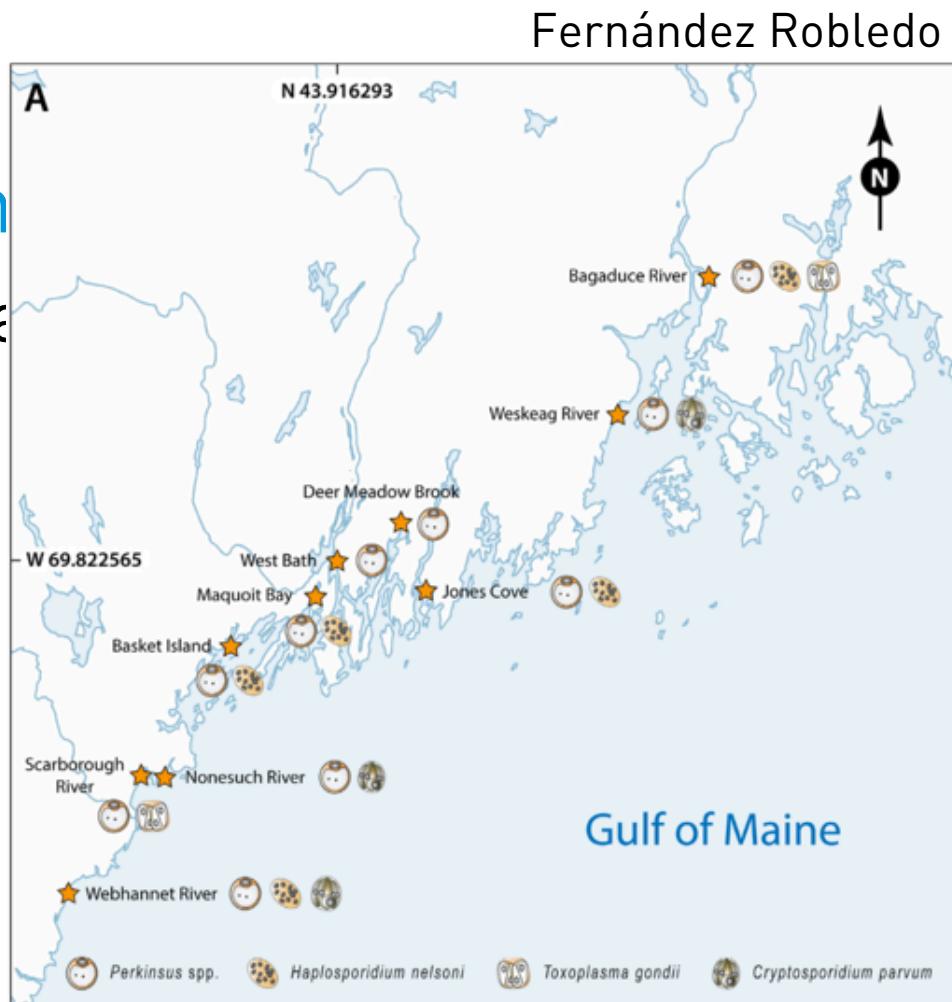
Aquaculture concerns

- Ocean acidification
 - Shell dissolution
- Harmful algal blooms (HABs)
 - Includes toxic algae and bacteria



Aquaculture concerns

- Ocean acidification
 - Shell dissolution
- Harmful algal bloom
 - Includes toxic algae a
- Protozoan parasites



Kelp potential

- No concerns of drought
- No manufacture of nutrients
- Buffers ocean acidification
- Buffers storm surge (potentially)
- Ecological benefits
- Carbon uptake
- Healthy
 - ...but... it's kelp

Management & Policy



What is Ecosystem Management?

- **Ecosystem management** is a process that aims to conserve major ecological services and restore natural resources while meeting the socioeconomic, political and cultural needs of current and future generations.
- Modern and preferred way of managing natural resources and ecosystems.
 - EM: "A strategy or plan to manage ecosystems to provide for all associated organisms, as opposed to a strategy or plan for managing individual species" (FEMAT, 1993).
 - EM: "The careful and skillful use of ecological, economic, social, and managerial principles in managing ecosystems to produce, restore, or sustain ecosystem integrity and desired conditions, uses, products, values, and services over the long term" (Overbay, 1992).
 - EM: "To restore and maintain the health, sustainability, and biological diversity of ecosystems while supporting sustainable economies and communities" (EPA, 1994).



Some general challenges

- 1) fundamental public and private values and priorities are in dispute, resulting in partially or wholly mutually exclusive decision alternatives;
 - 2) there is substantial and intense political pressure to make rapid and significant changes in public policy;
 - 3) public and private stakes are high, with substantial costs and substantial risks of adverse effects (some also irreversible ecologically) to some groups regardless of which option is selected;
 - 4) the technical facts, ecological and sociological, are highly uncertain;
 - 5) the "ecosystem" and "policy problems" are meshed in a large framework such that policy decisions will have effects outside the scope of the problem.
- Solving these kinds of problems in a democracy has been likened to asking a pack of four hungry wolves and a sheep to apply democratic principles to deciding what to eat for lunch. Given public choice problems with these characteristics, no wonder discussions of ecosystem management tend to focus on process and not substance. (Lackey 1998)



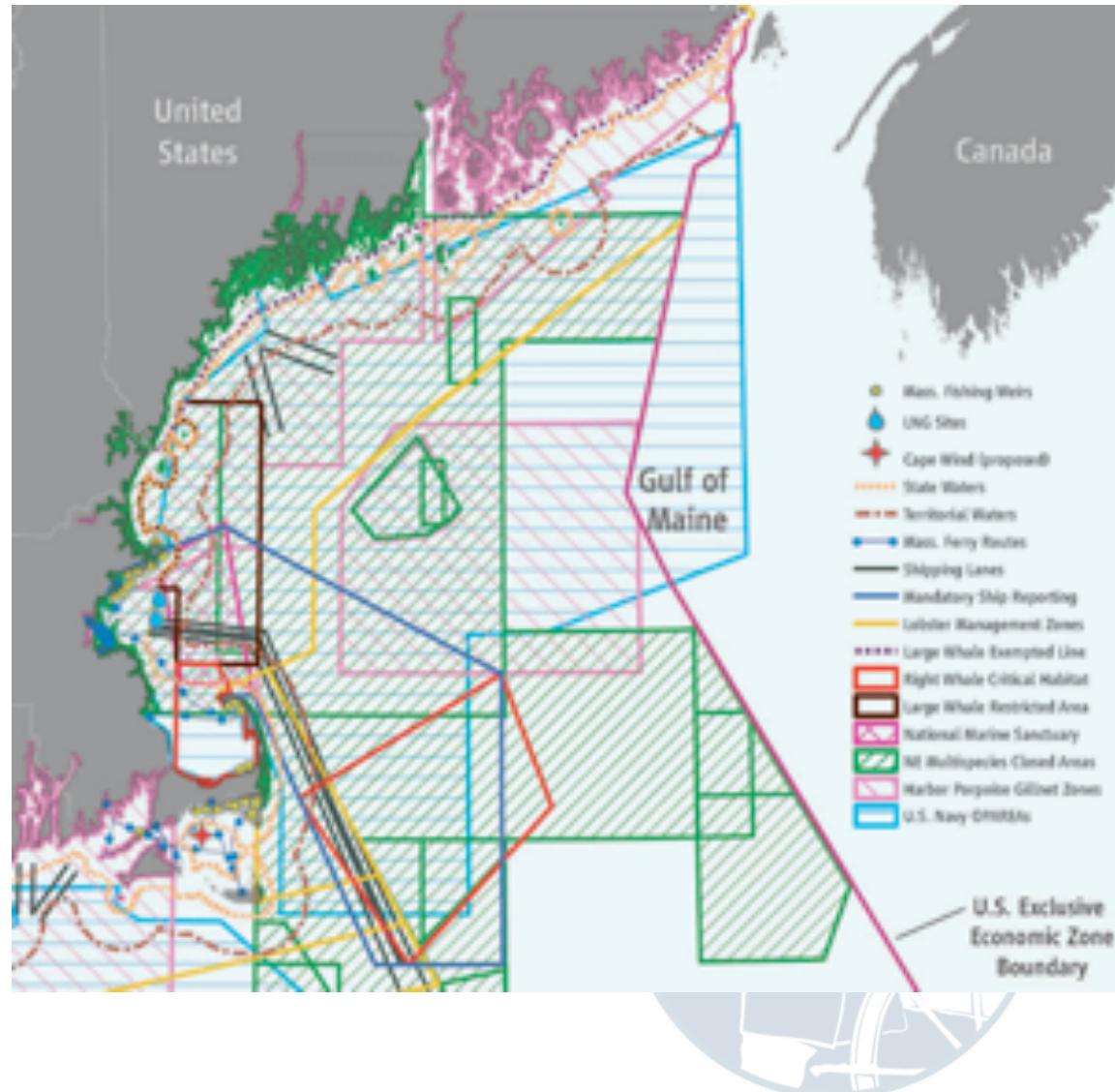
Some specific challenges

- 1) Jurisdiction/governance (towns, counties, states, countries, etc)
- 2) \$
- 3) Clear goals, with involvement of stakeholders
- 4) Training/scientists/communicators
- 5) Available data
 - What kind?
 - From where? (Source)
 - From when? (Historical Data)
- 6) Adaptive Management (since often can't predict outcomes, manage to maintain ecological integrity) (shifting baseline, or 'learning by doing')



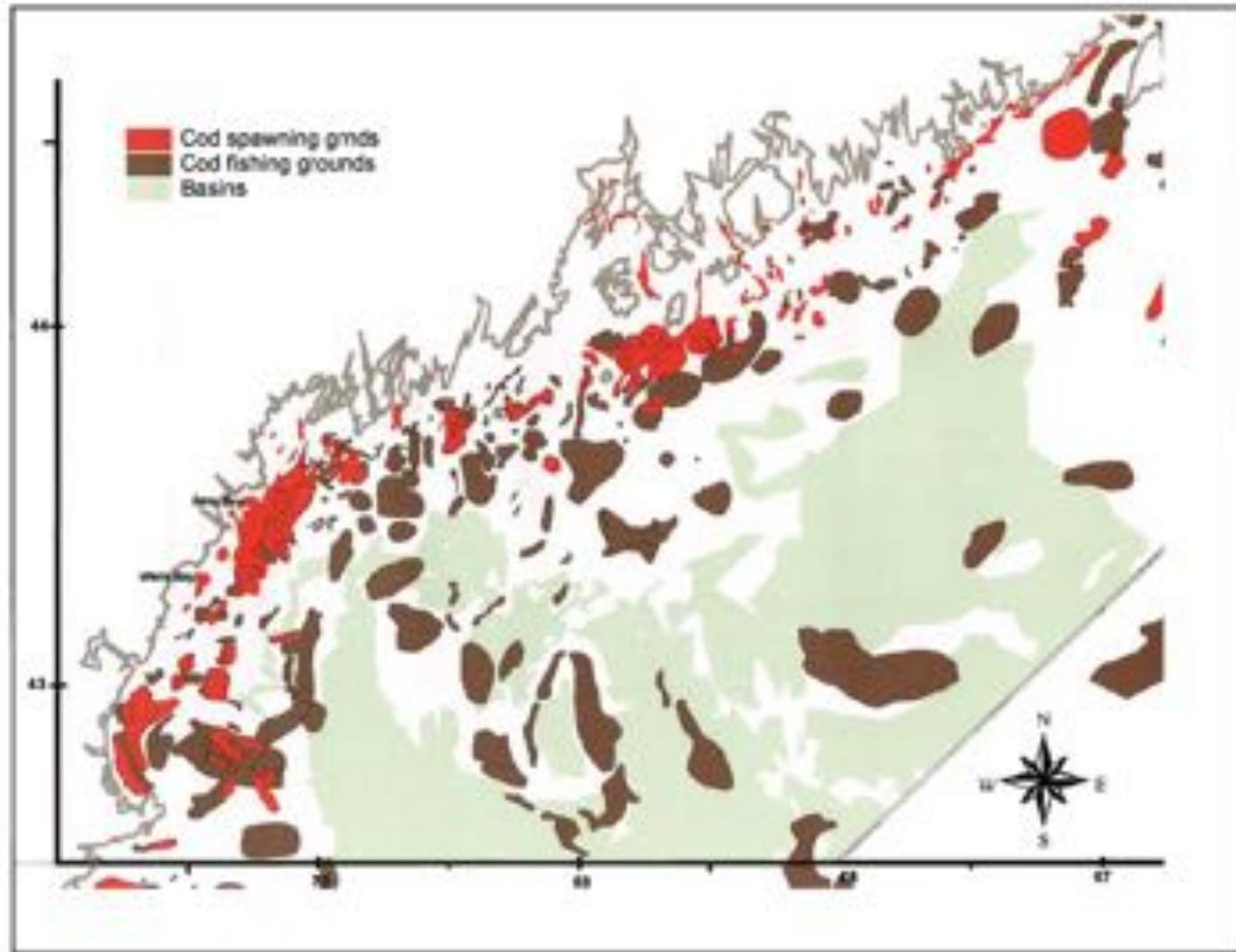
Primary tool: Marine Spatial Planning

- Marine spatial planning (MSP) is a process that brings together multiple users of the ocean – including energy, industry, government, conservation and recreation – to make informed and coordinated decisions about how to use marine resources sustainably.
- Typically top-down, but requires buy-in to work
- ***Hard to account for ocean dynamics***



Spatial planning difficulties: top-down

Figure 2a. Historical fishing grounds and spawning areas of Atlantic cod in the Gulf of Maine were used to create an X-Y plot for tracking Atlantic cod movements.

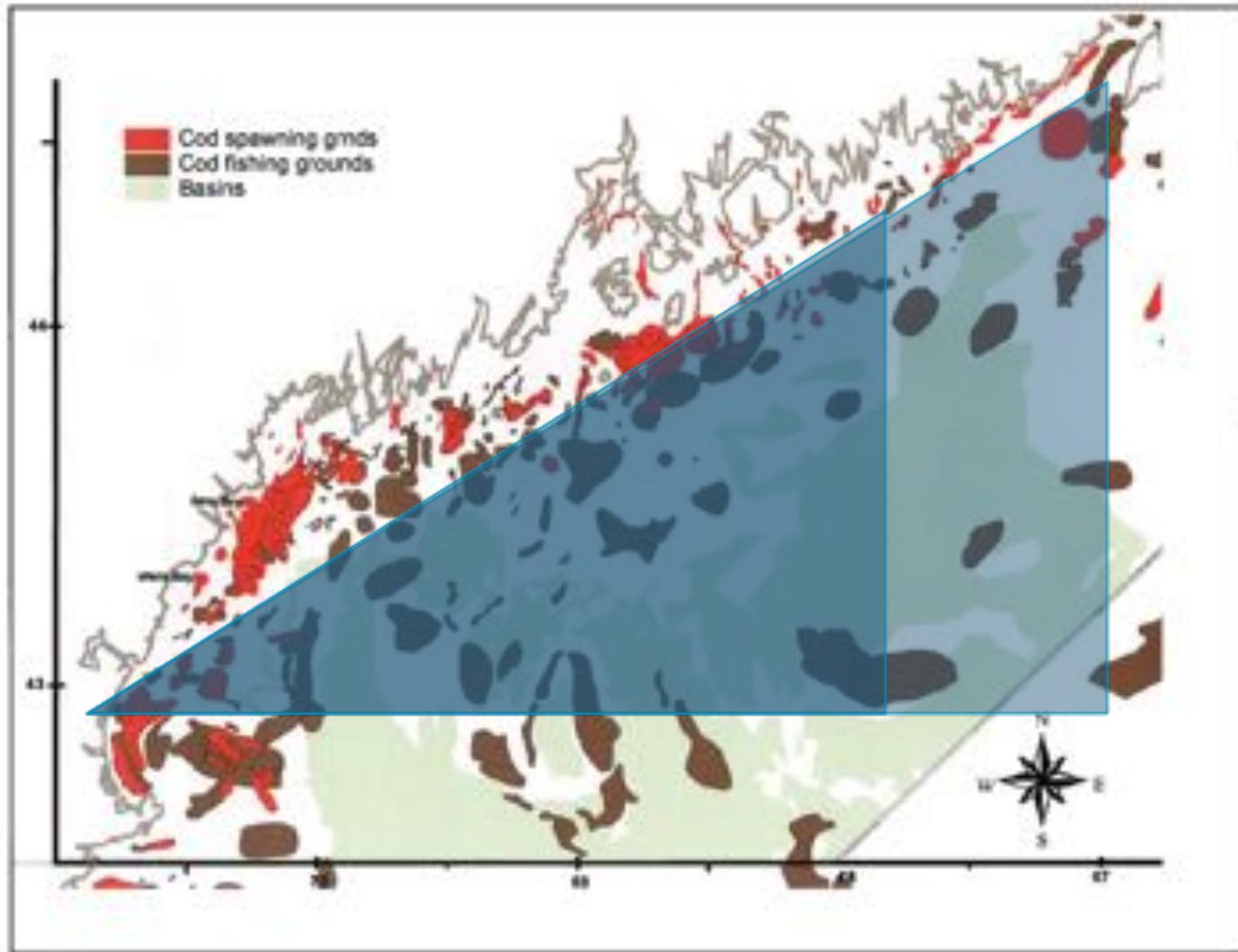


Ames 2004



Management difficulties: top-down

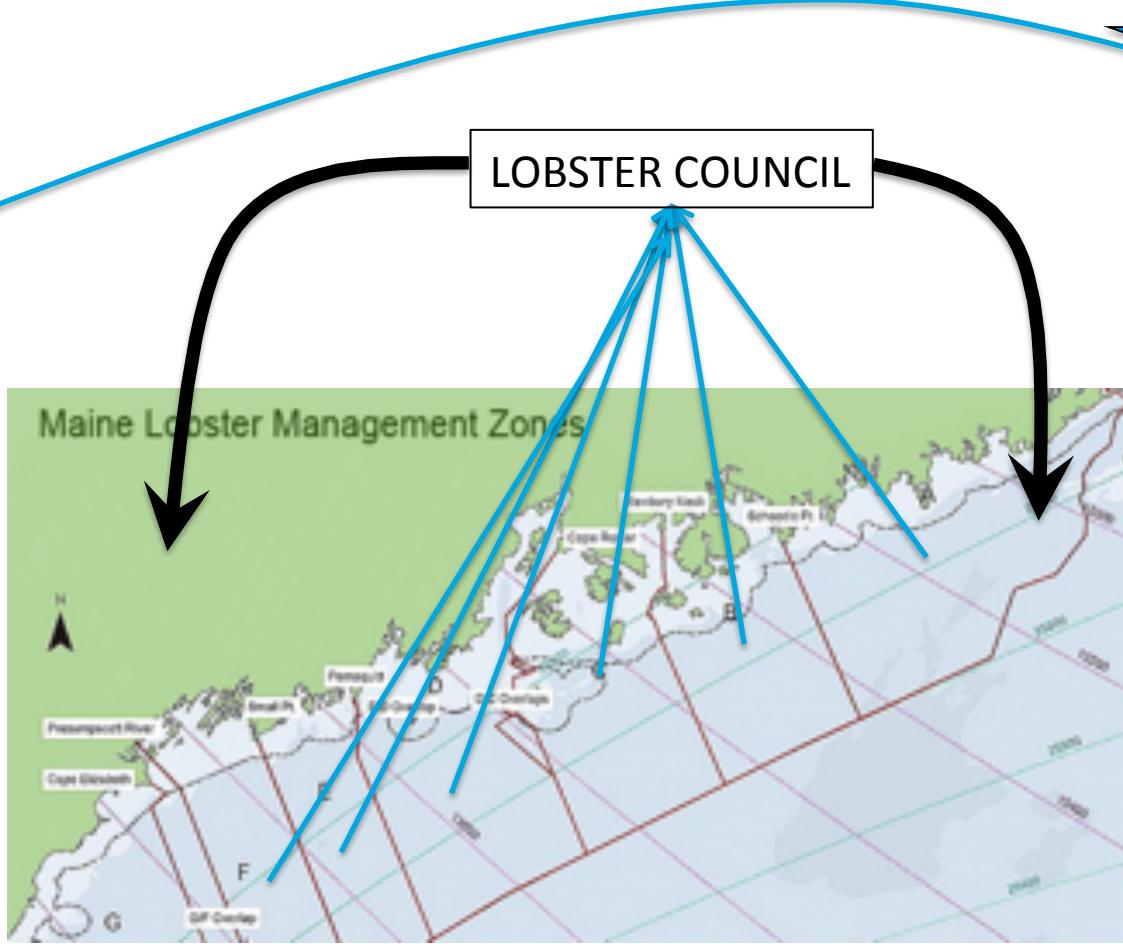
Figure 2a. Historical fishing grounds and spawning areas of Atlantic cod in the Gulf of Maine were used to create an X-Y plot for tracking Atlantic cod movements.



Did we fish down our stock by 25%, or did we lose 25% of our substocks?



Alternatives to top-down



State & Federal

Rebuilding plans
Management plans
Regulations

Conservation practices:
- Notching females with eggs
- Maximum size

Defend turf & law (e.g. diving)

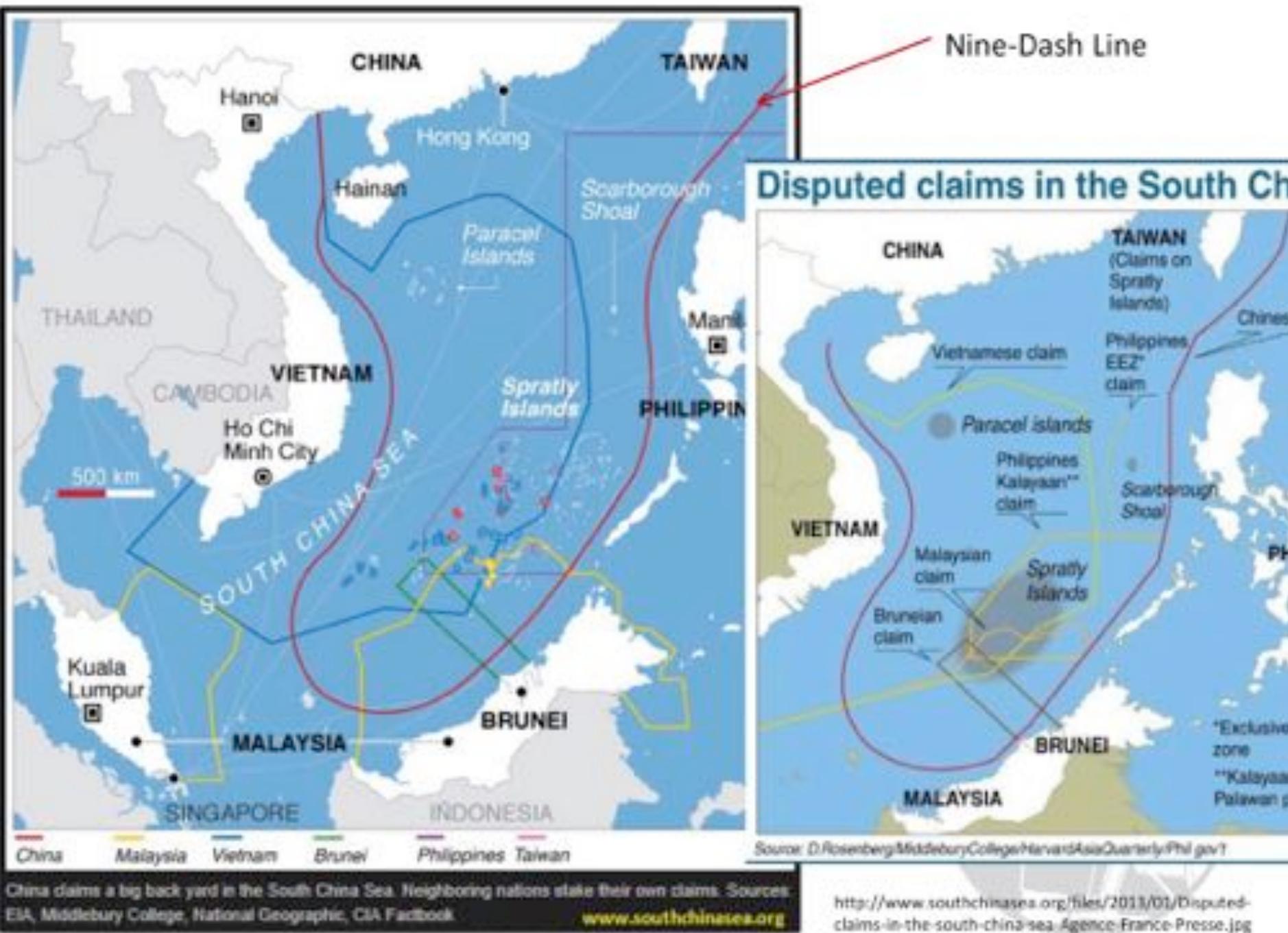


Nation-building & Territory Issues

- **South China Sea:**

- Traditionally a strategic backwater of the Pacific, regarded as an 'American Lake' and Australia's 'special patch' (Zhang 2007).
- China, Malaysia, The Philippines, Taiwan and Vietnam all claim sovereignty over multiple islands
- China claims almost all of the South China Sea, including islands more than 800 miles (1,200 kilometers) from the Chinese mainland, despite objections from neighbors including the Philippines, Malaysia, Brunei and Vietnam.





Itu Aba: Taiwan



Gaven Reed: China

114,000 acres of new land



Fiery Cross Reef: China

200 troops, radar. Increase from 0.08 to 0.96 km²



Johnson Reef: China

Submerged reef with platform, now +100,000 m²



Note: Vietnam and Malaysia also have significant reclamation and construction programs on these reefs. China is the only country building 'new' lands.

Nation-building & Territory Issues

- 1947: **Nine-dash line**: China publishes a map outlining it's claims to the South China Sea. Map shows the nine-dash line, the basis for China's current claims.
- 1974: **Occupation**. China occupies the Paracel Islands, seizing a small Vietnamese garrison. It has built a military installation with airstrip and harbor. Paracel Islands are also claimed by Taiwan and Vietnam.
- 1988: **Conflict**. Chinese and Vietnamese sailors fight over Johnson South Reef, for a physical presence in the Spratlys. (64 Vietnamese sailors killed).
- 2002: **Declaration of Conduct**, China and members of ASEAN sign a Declaration on the Conduct of Parties of the South China Sea. Eases tension but not legally binding.
- 2005-06: **Airstrip**. China builds 1,200 m airstrip on Itu Abu Island, the largest island in the Spratlys.
- 2009: In **UN submission**, China claims sovereignty over the islands in the South China Sea and surrounding ocean. Attaches a map of the Nine-dash line. Vietnam and Malaysia object.
- 2012 (Nov): **China passports**. Philippines and Vietnam object to new Chinese passport that contains a map of China's disputed maritime claims in the South Pacific

<http://www.cnn.com/2016/09/08/asia/south-china-sea-scarborough-shoal-philippines-china/index.html>



Nation-building & Territory Issues

- 2013 (Jan): **Court case.** Philippines files a case with the Permanent Court of Arbitration in the Hague. Seeks right to exploit seas to 200 nautical mile economic exclusion zone as defined by the Law of the Sea. China refuses to participate.
- 2013 (April): **Tourism.** Chinese tourists start visiting the Paracels.
- 2014 (May-July): **Oil rig dispute.** China moves an oil rig near Paracels. Anti-Chinese riots in Vietnam. Vietnam boats approach rig and are stopped by Chinese. China removes rig a month early.
- 2014 (Nov): **Airstrip capable island.** Satellite images suggest China is building an island in Paracels big enough for an airstrip.
- 2015 (Feb): **Island building.** Satellite images show China rebuilding land on 5 islands in a 'methodical, well planned campaign' to create a chain of air and sea capable fortresses (HIS Jane's Defense Weekly)
- 2015 (May): **US plane warned.** Chinese navy warns US plane carrying CNN crew 8 times as it flies over Paracels.
- 2016: (June): **China says 'reclamation' almost finished.** (US: China 'reclaimed' 3,000 acres since 2014)
- 2015-16: **US tests 'freedom of navigation'.** US sends warship to w/i 12 nm. China warns US
- 2016 (Jan): **Commercial flights.** China lands 1st commercial flights on Paracels.
- 2016 (Feb): **Missiles deployed.** China deploys surface to air missiles and fighter jets to Paracels as Obama meets with ASEAN leaders. Obama calls for halt of construction and militarization.

<http://www.cnn.com/2016/09/08/asia/south-china-sea-scarborough-shoal-philippines-china/index.html>

Nation-building & Territory Issues

- 2016 (July): **International tribunal** rules against Chinese claims in the South Pacific and that they unlawfully restricted fishing. China says it has no binding authority.
- 2016 (Oct): Duterte offers to set aside maritime dispute with China, China announces \$24B in aid and investment in Philippines.
- 2017: **China stations 'research vessels'** in disputed area close to Philippines and controls fishing within Scarborough Shoal, within Philippines EEZ.
- 2017: **Philippines plans 'low grade'** military updates in dispute island to help maintain and 'lock' claims to islands.
- 2017 (Sept): Australia starts joint military exercises with Japan, South Korea and Vietnam.
- Currently: Southeast Asian nations pursuing bilateral agreements with China.

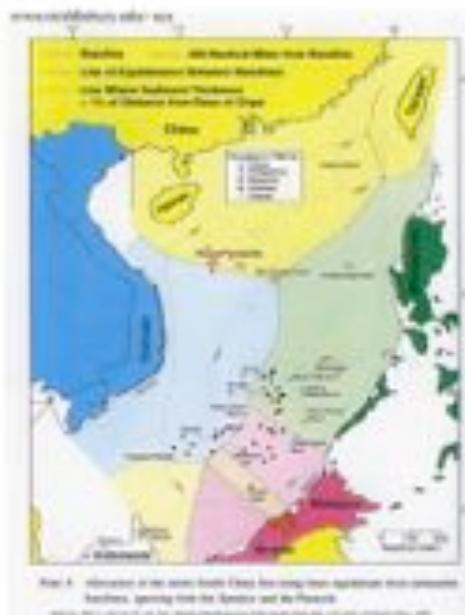
<http://www.cnn.com/2016/09/08/asia/south-china-sea-scarborough-shoal-philippines-china/index.html>

Motivations:

- Economic growth (internal stability) – raw materials & resources (natural gas & minerals in PNG)
- Countering US containment efforts
- Blocking Japan's aspirations for an international role
- Isolating Taiwan
- Access to Pacific ports for China's blue water fleet



Proposed Resolutions



Full Allocation w/o consid-
eration of Spratlys & Paracels



Full Allocation w/ consid-
eration of Spratlys & Paracels



200 mile boundary w/o
consideration of Spratlys
& Paracels



200 mile boundary w/
consideration of Spratlys
& Paracels

The ocean doesn't know management boundaries

- Management of global tuna stocks: ICCAT, IATTC, etc.
- US & Canada: Right whale conservation, grey zone, etc.
- Disputed rights to portions of the melting Arctic
- Island nations facing sea level rise
- Many others...

