

# So what do we DO about ocean acidification?

Sarah Cooley  
Ocean Conservancy  
September 22, 2014  
CCPO Seminar, Old Dominion University

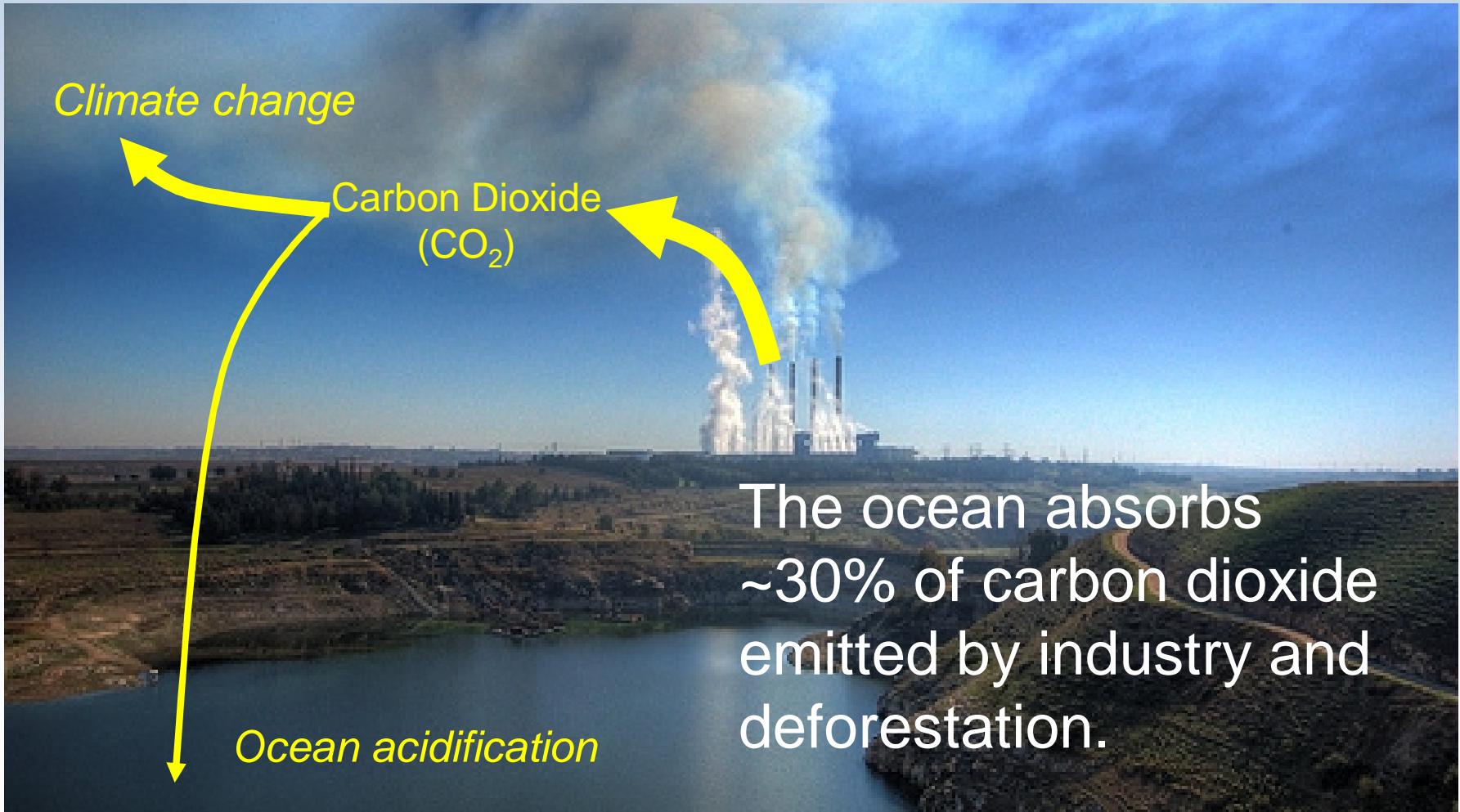


# Today's talk

- What is ocean acidification?
- How can it “touch” human communities?
- What has happened already?
- What actions have been taken?
- What’s next?

# **WHAT IS OCEAN ACIDIFICATION?**

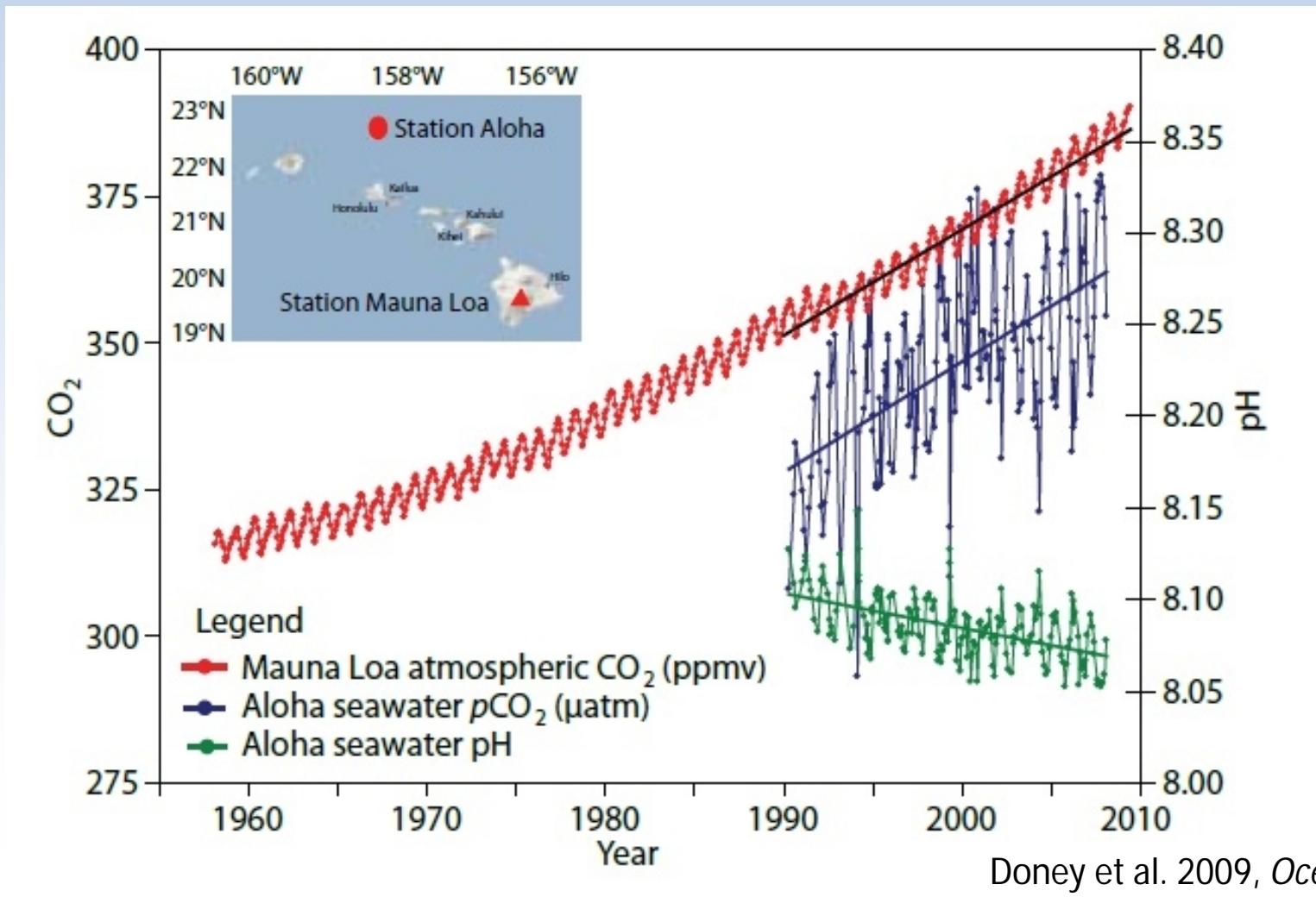
# What is ocean acidification?



Sarah R. Cooley ([scooley@whoi.edu](mailto:scooley@whoi.edu))

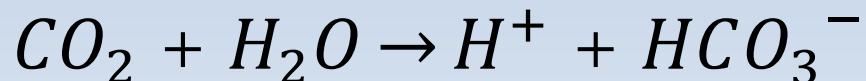
# Ocean acidification: the data

About 25% of anthropogenic atmospheric CO<sub>2</sub> dissolves in the ocean.

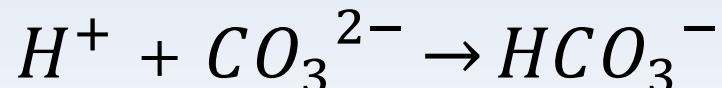


# It all boils down to two equations

- Dissolving CO<sub>2</sub> in water releases H<sup>+</sup> ions.

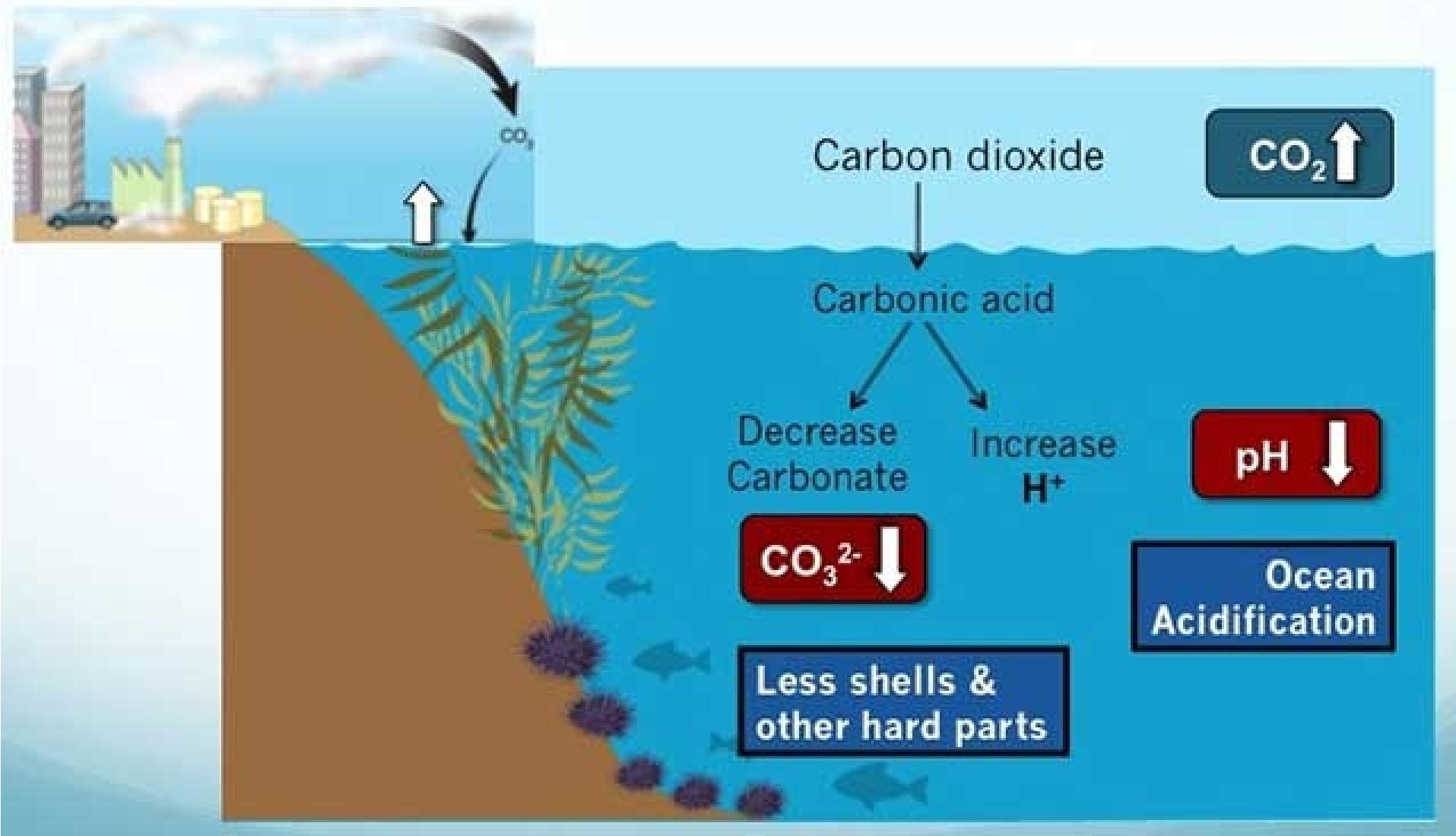


- Some of the H<sup>+</sup> ions released scavenge carbonate ions from the water.

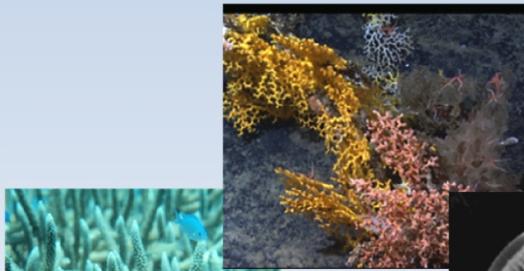
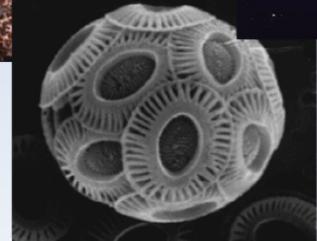


*Both the H<sup>+</sup> gained and CO<sub>3</sub><sup>2-</sup> lost makes life harder for many marine creatures.*

# Ocean acidification: bottom line



# Organisms harmed by OA



Warm- & cold water corals

Plankton & zooplankton

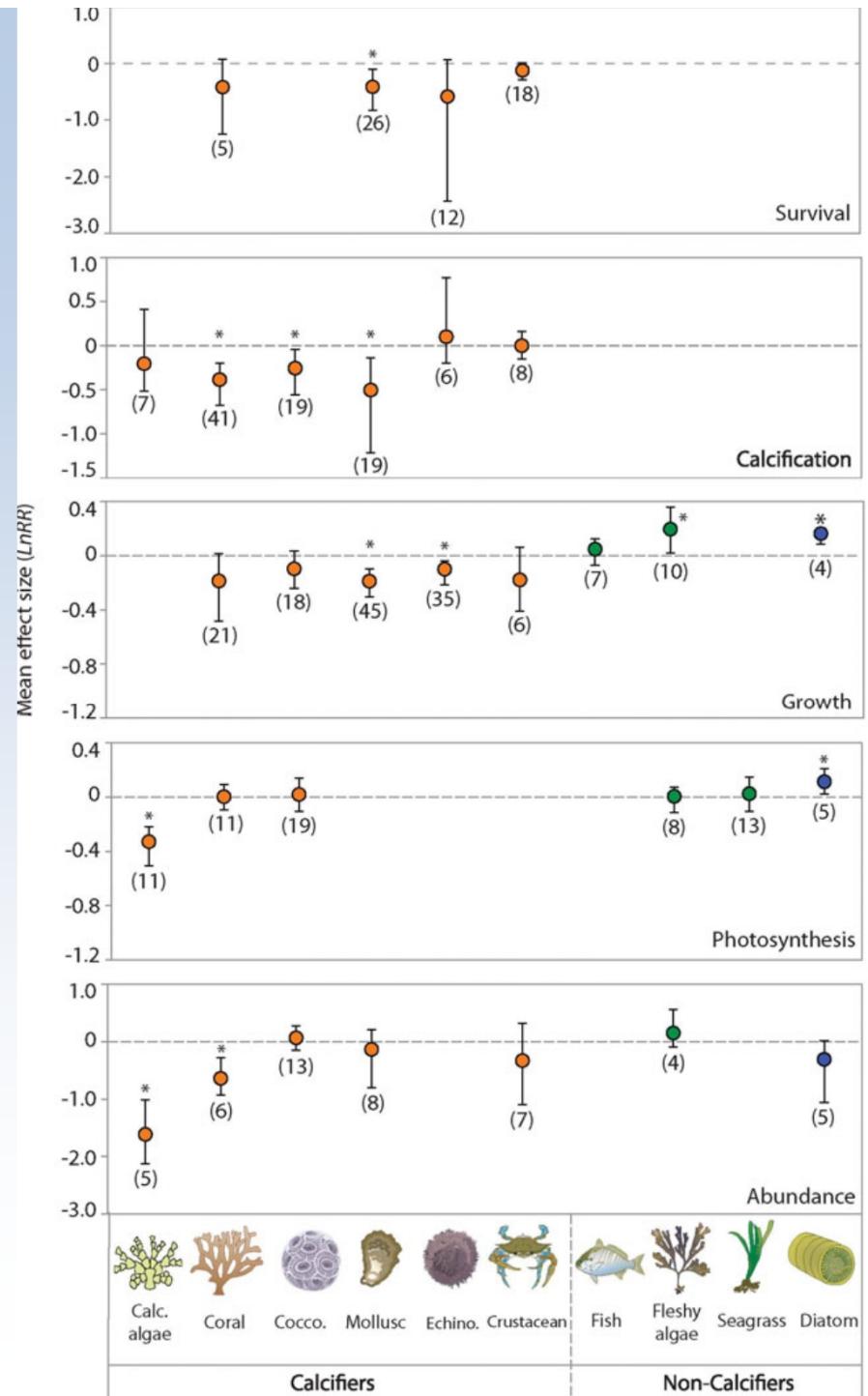
Many mollusks; some fish, crustaceans, squid, sharks

# OA's overall effects on marine life

Responses vary among  
taxa and process

Long-term  
consequences of  
responses not known

Kroeker et al., 2013, Global Change Biology



# Observed ecosystem responses

Near a volcanic CO<sub>2</sub> vent



In a coastal lagoon



Wootton et al. PNAS 2008; Photo, U. Washington

Hall-Spencer et al., *Nature* 2008

Vents near coral reefs



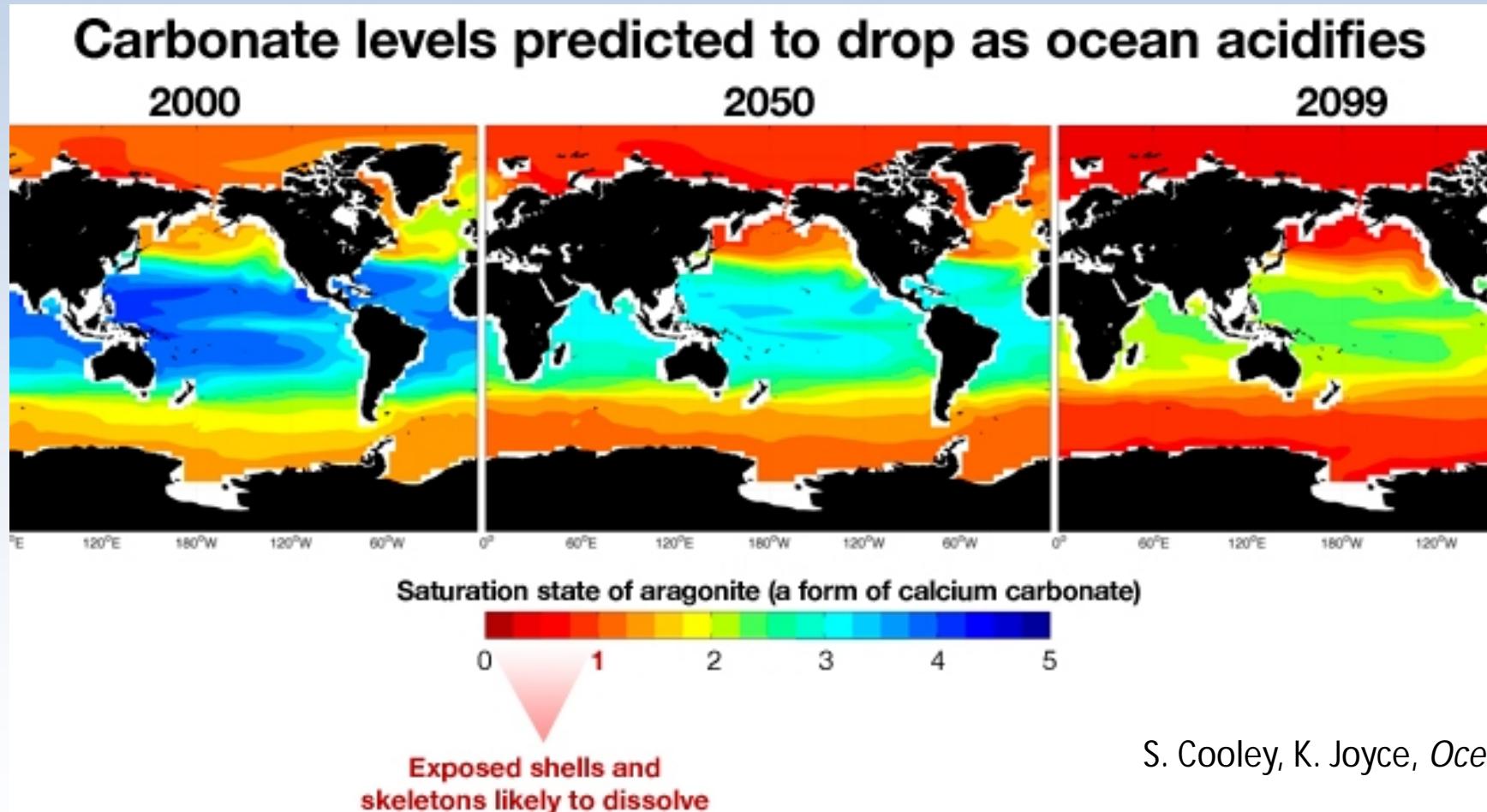
Fabricius et al. *Nature Climate Change* 2011;  
Photo, NOAA

375 ppm  
+1°C

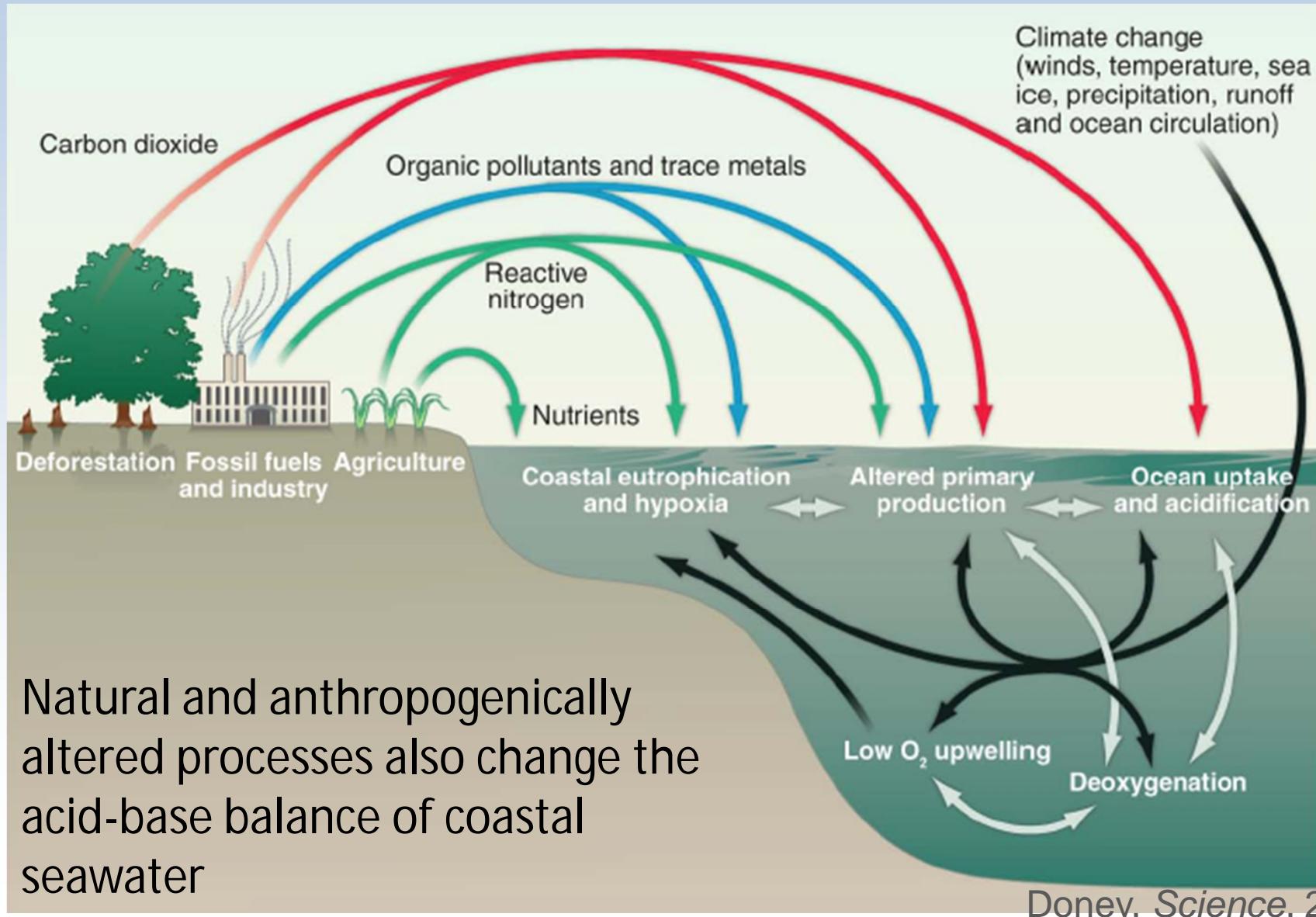
450-500 ppm  
+2°C

> 500 ppm  
> +3°C

# OA Forecasts



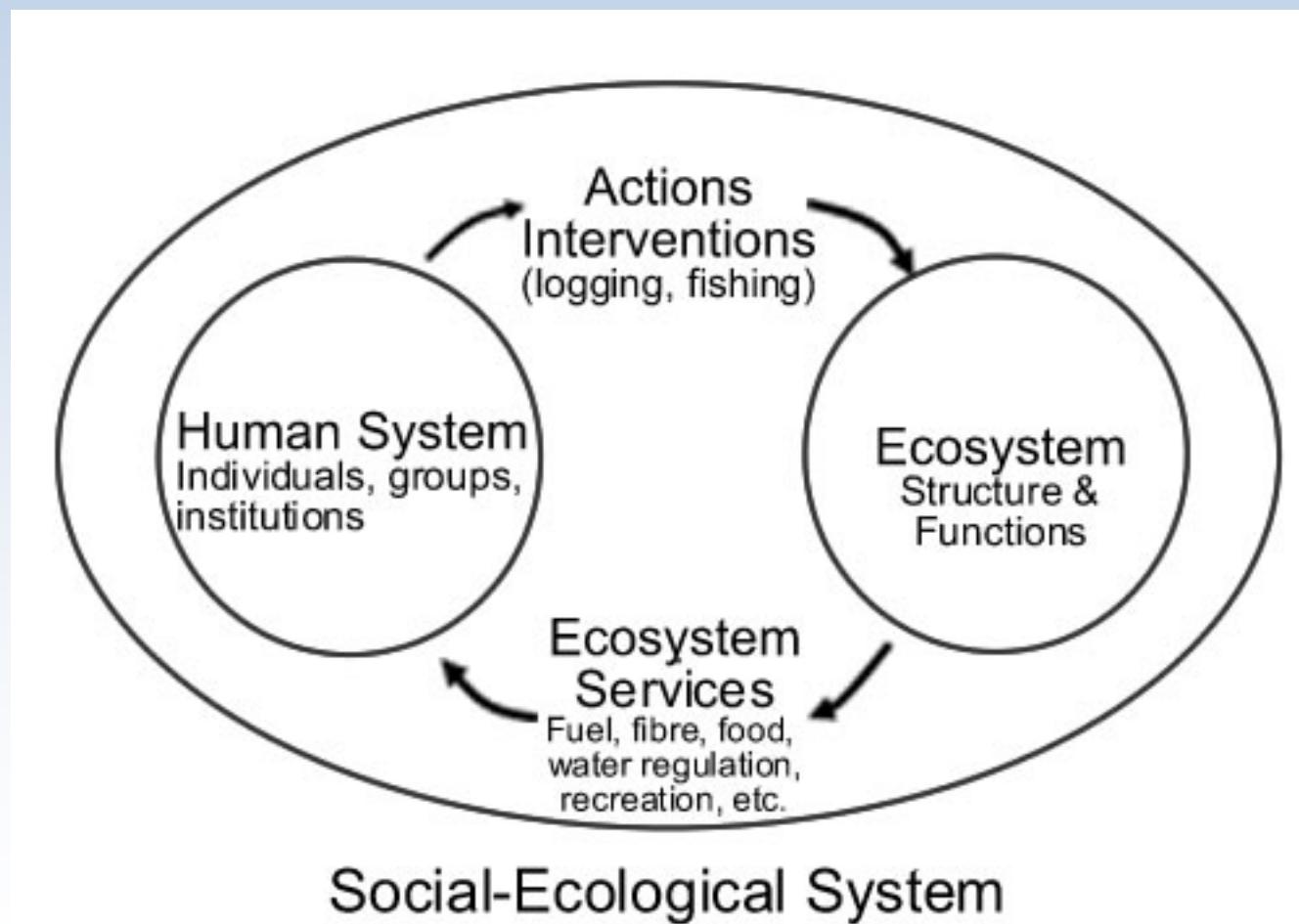
# Ocean acidification doesn't act alone



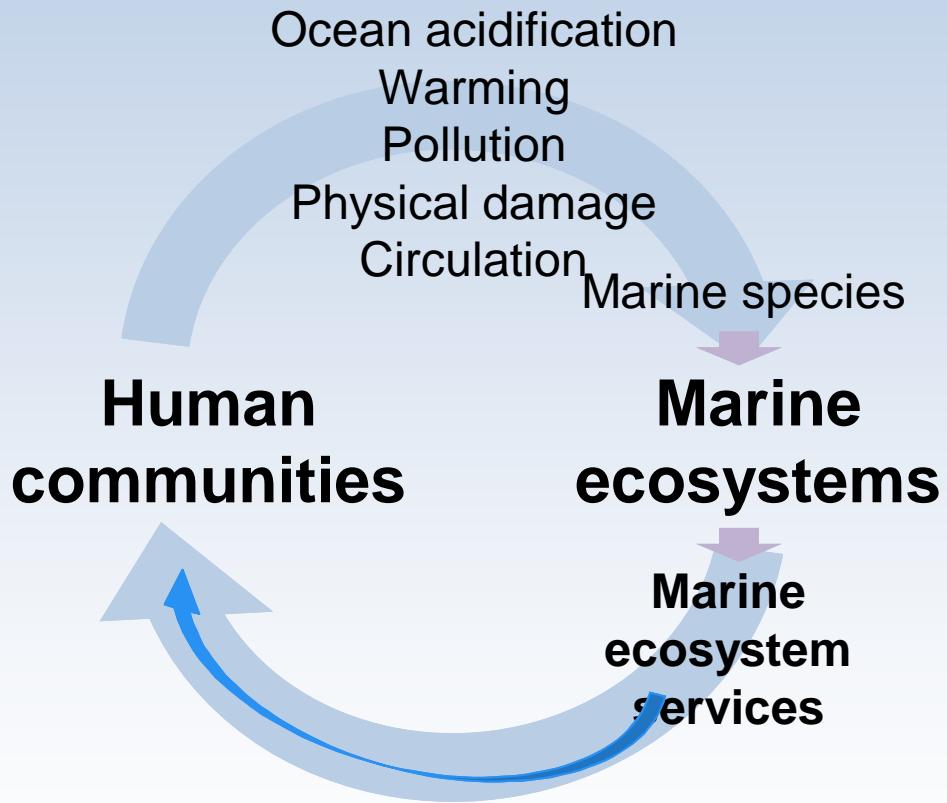
Ecosystem Services • Economics • Culture

# **HOW CAN OA AFFECT HUMANS?**

# How does global change affect humans?

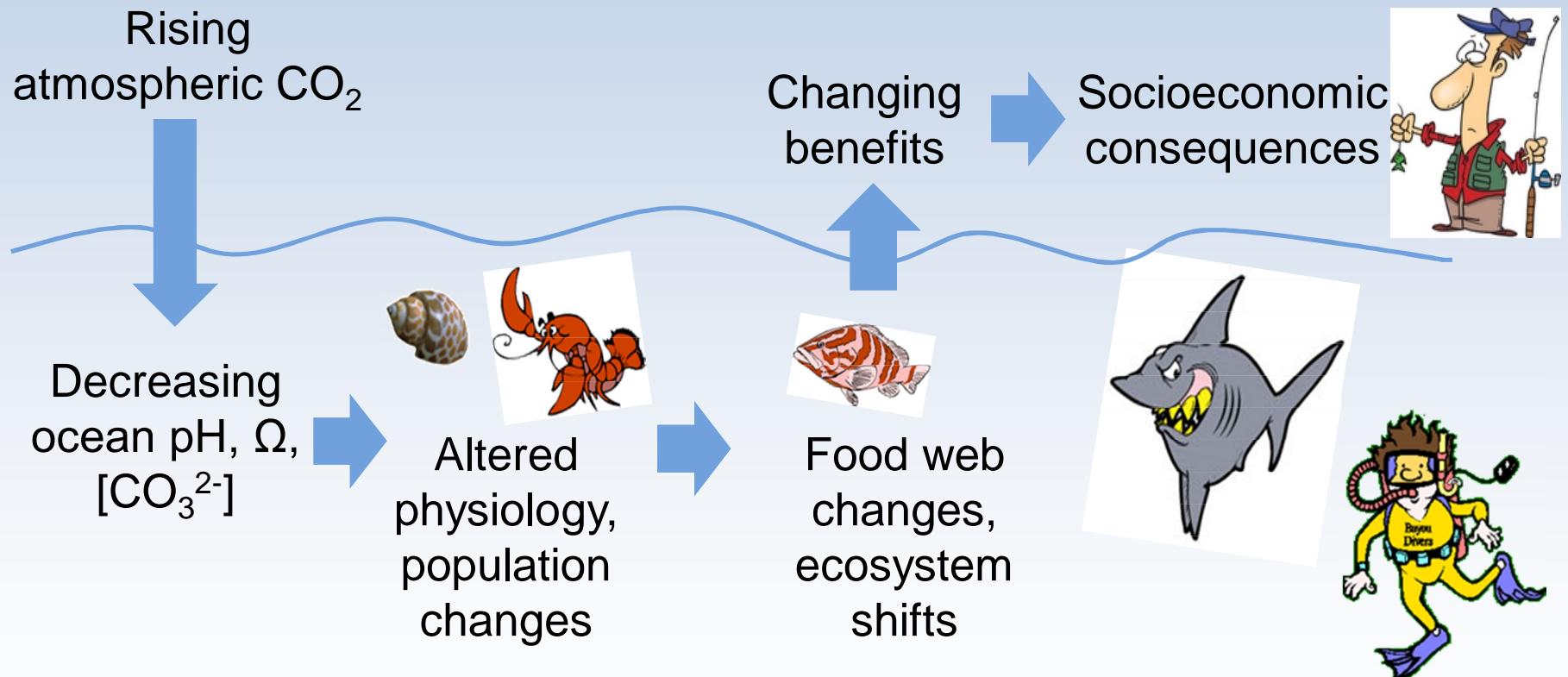


# The land-ocean social-ecological system including ocean biogeochemistry



- OA doesn't act alone
  - Human & natural stressors
- OA's negative effects
  - Marine organisms
  - Marine ecosystem services
- Trace effects BACK to humans

# Biogeochemistry impacting people (Here, ocean acidification)



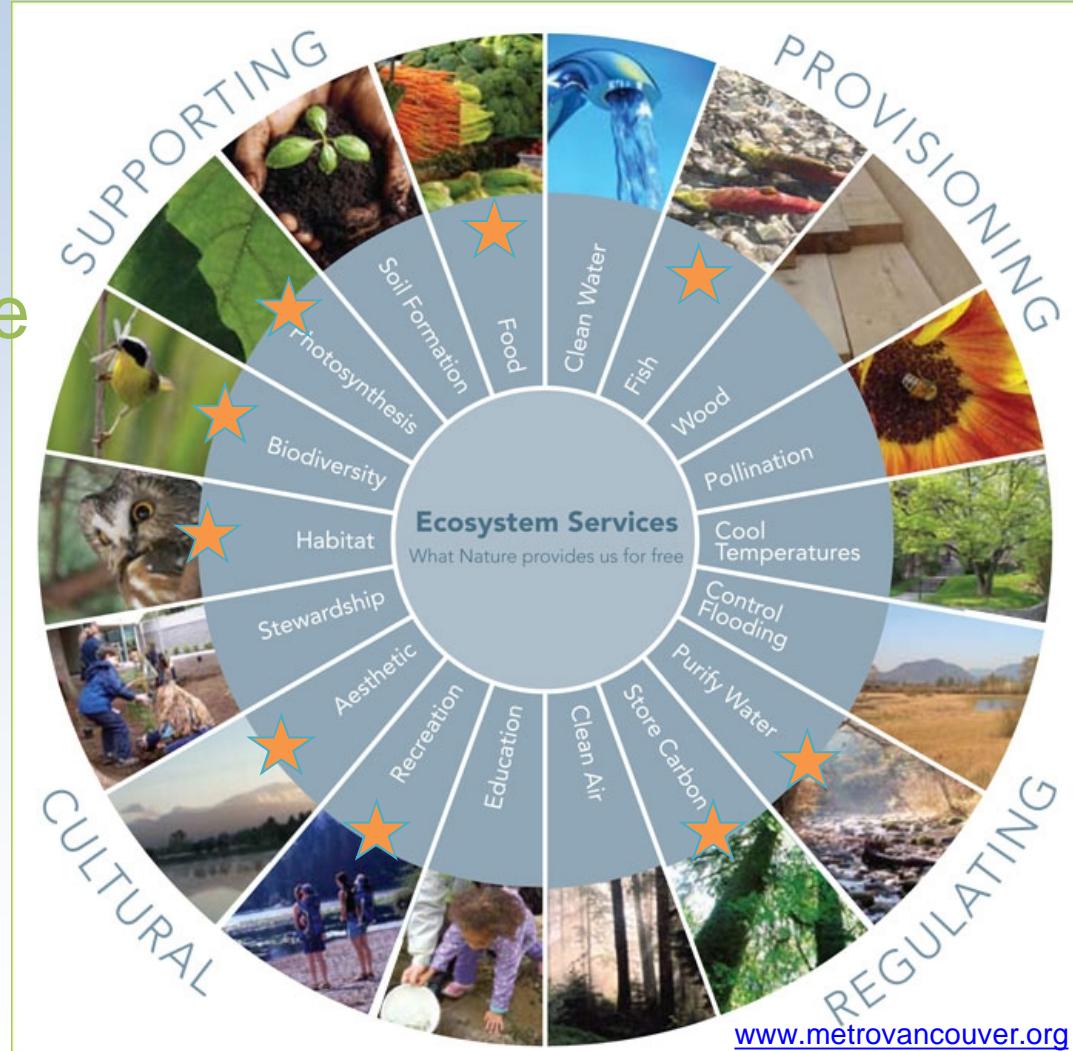
# Benefits from marine systems



# Benefits from marine systems

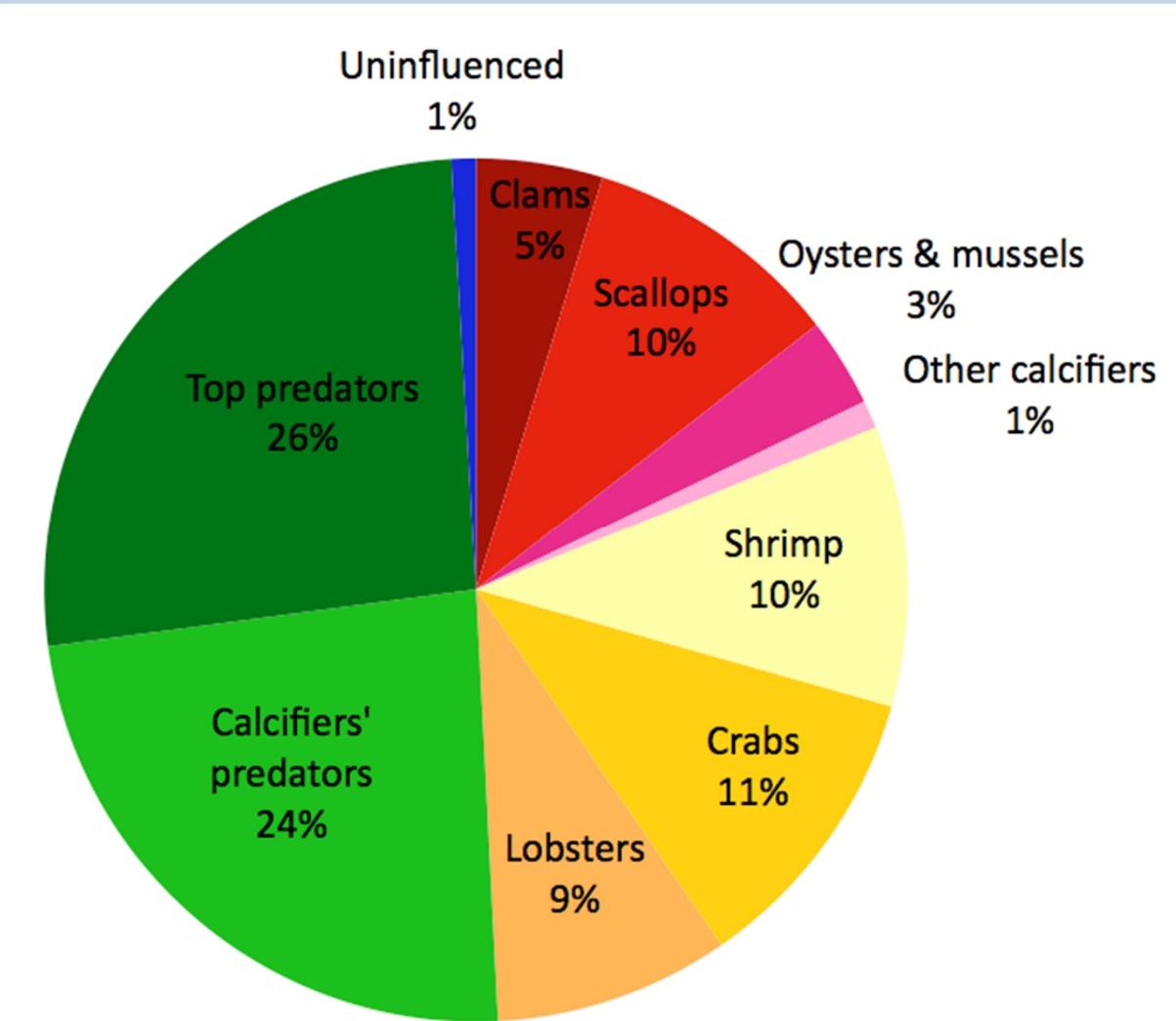
Services  
Coastal zone  
 $\approx \$12.5\text{T}/\text{y}$

Open ocean  
 $\approx \$8\text{T}/\text{y}$



★ OA could alter some services

# US Commercial fishing \$4B dockside each year



Annually, shellfish aquaculture brings in an estimated \$270 million and employs 3,200 people in WA state alone



Photo: Puget Sound Partnership



**Katie Schnafitt**  
**Taylor Shellfish Farms, WA**

“This is a devastating ghost  
lurking in the shadows.”

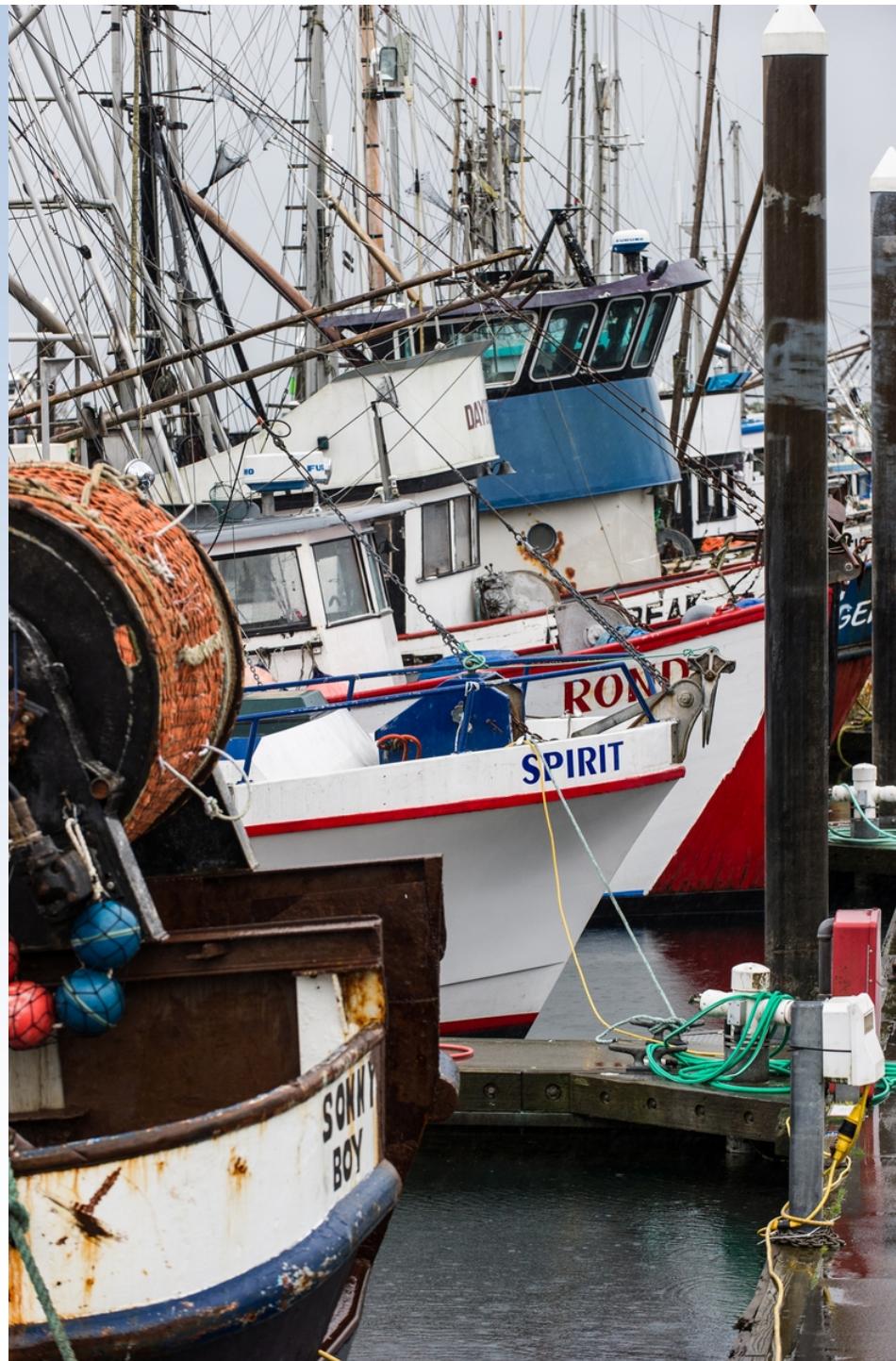
-Donald Waters,  
Gulf of Mexico Fisherman  
Testifying in a Senate hearing on OA  
April 2010

# Taylor Shellfish Farms

*100 Years of Farming the World's Best Oysters*

**Marco Pinchot**  
Taylor Shellfish  
Farms, WA







**"That trans-generational  
dependence on seafood,  
you can't put a price tag  
on that."**

**Micah McCarty  
Makah Tribe, WA**

# They don't want to be next, either



Peru



New Zealand



Hong Kong



Thailand

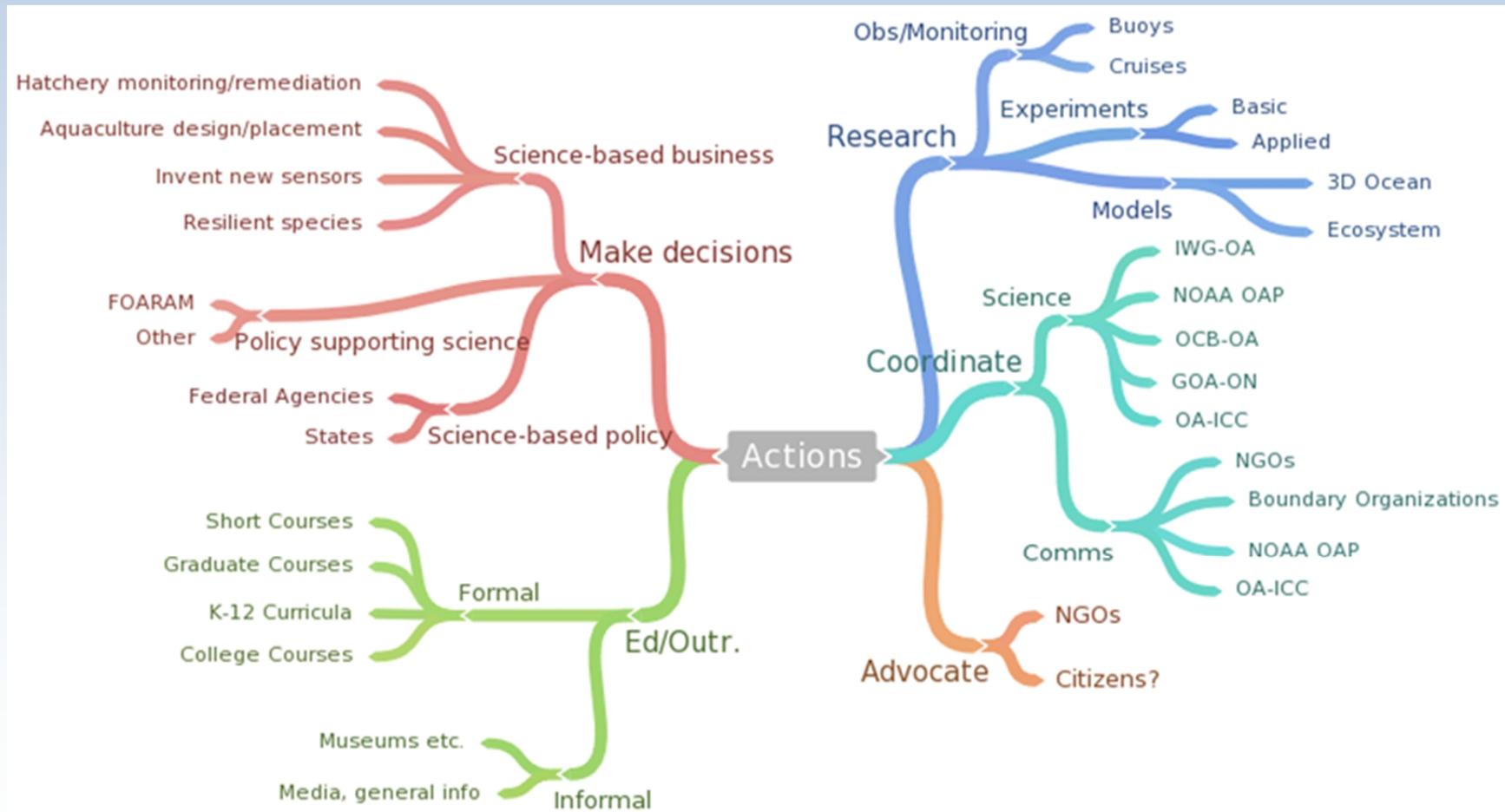


Photos: A. Valauri-Orton

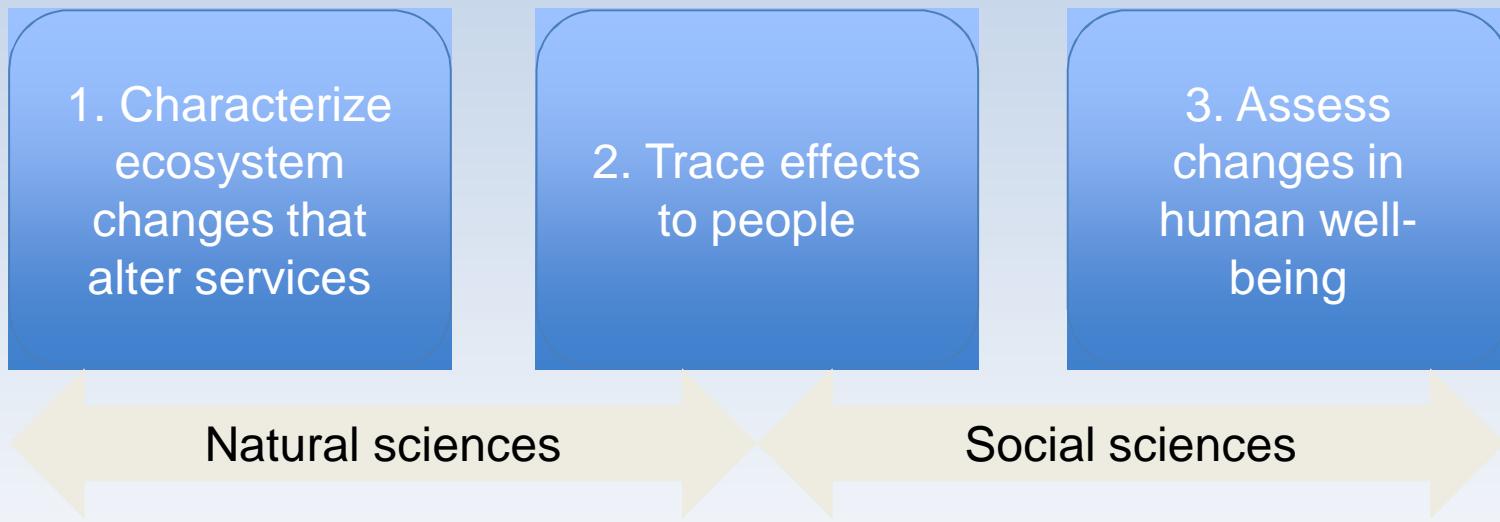
Research • Policy • Adaptations

# **WHAT ACTIONS HAVE BEEN TAKEN?**

# Activities around OA



# How do we quantify OA's effects?



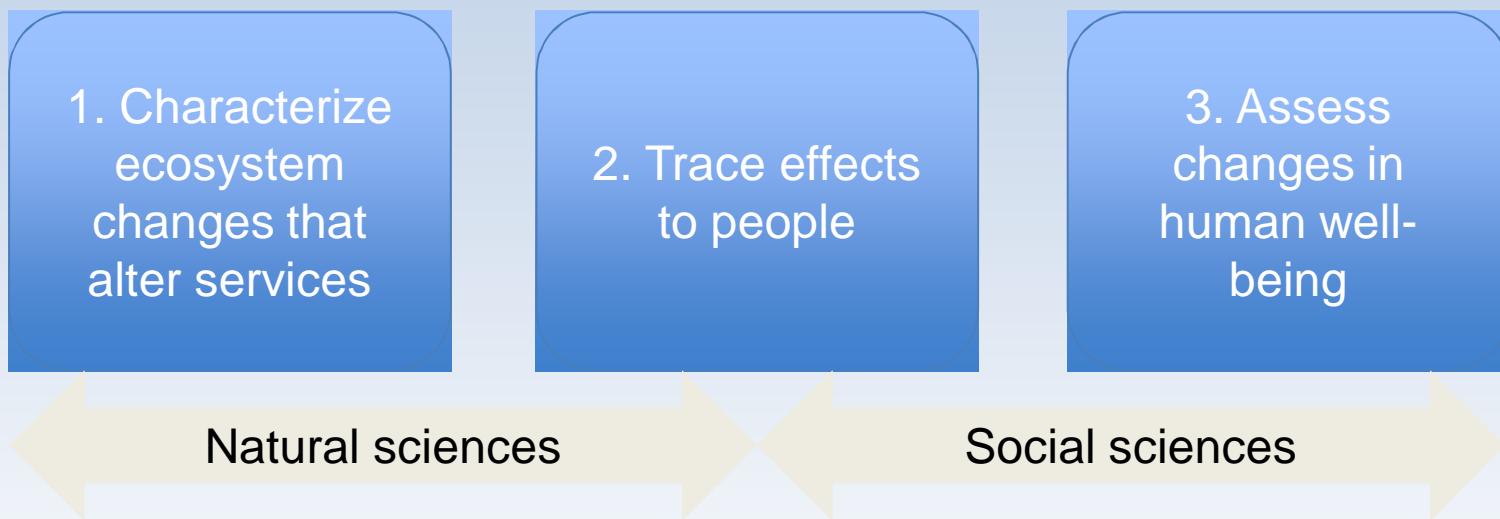
Organism responses  
Biogeochemical shifts  
Ecosystem function  
(Too numerous to list!)

# How do we quantify OA's effects?



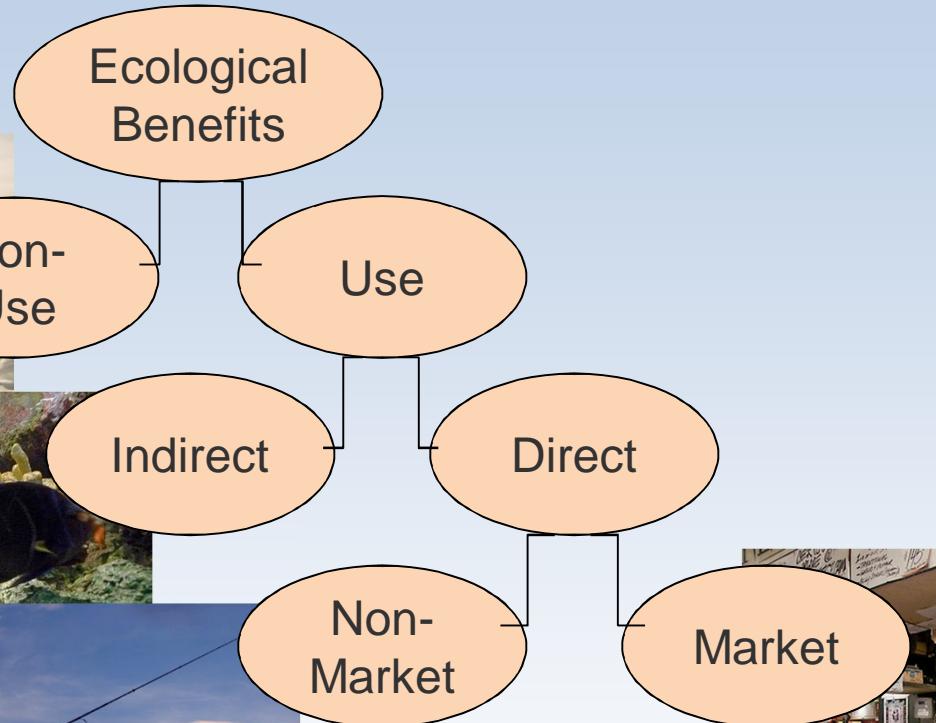
Changes in:  
harvests  
storm protection  
recreation  
water quality

# How do we quantify OA's effects?



Valuation (economic):  
Costs of lost harvests  
Damages to shoreline  
Lost tourism revenue

# Valuing ecosystem services

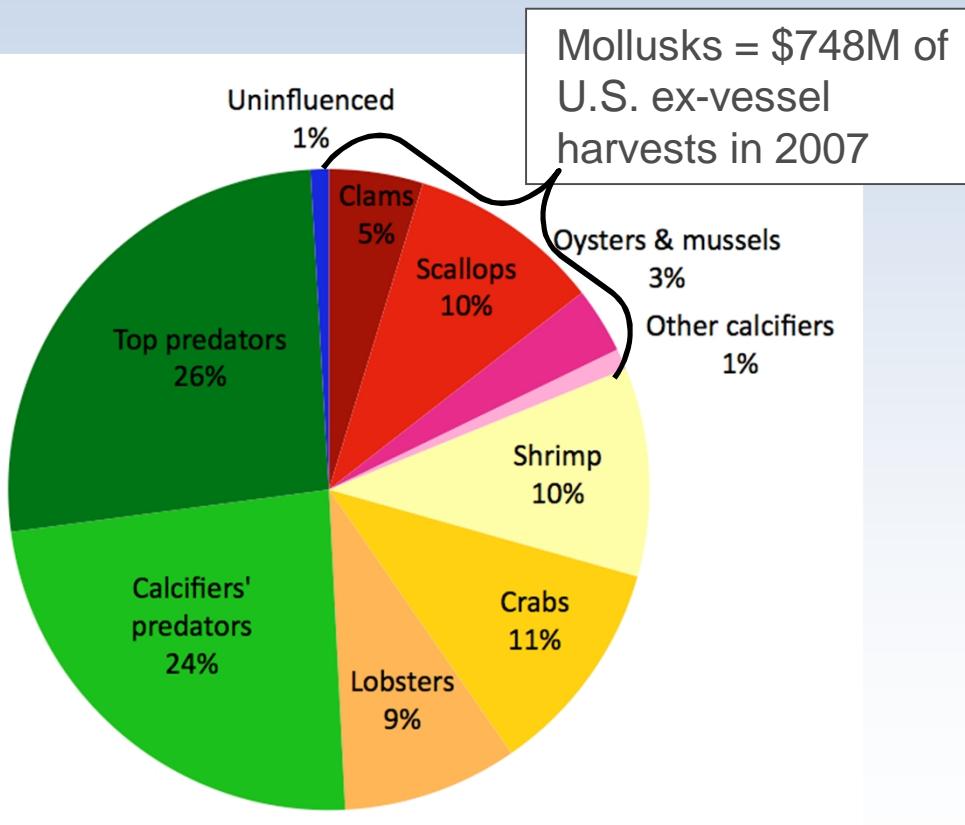


Ease of attaching dollar value

Public goods

Private goods

# OA's possible economic impacts



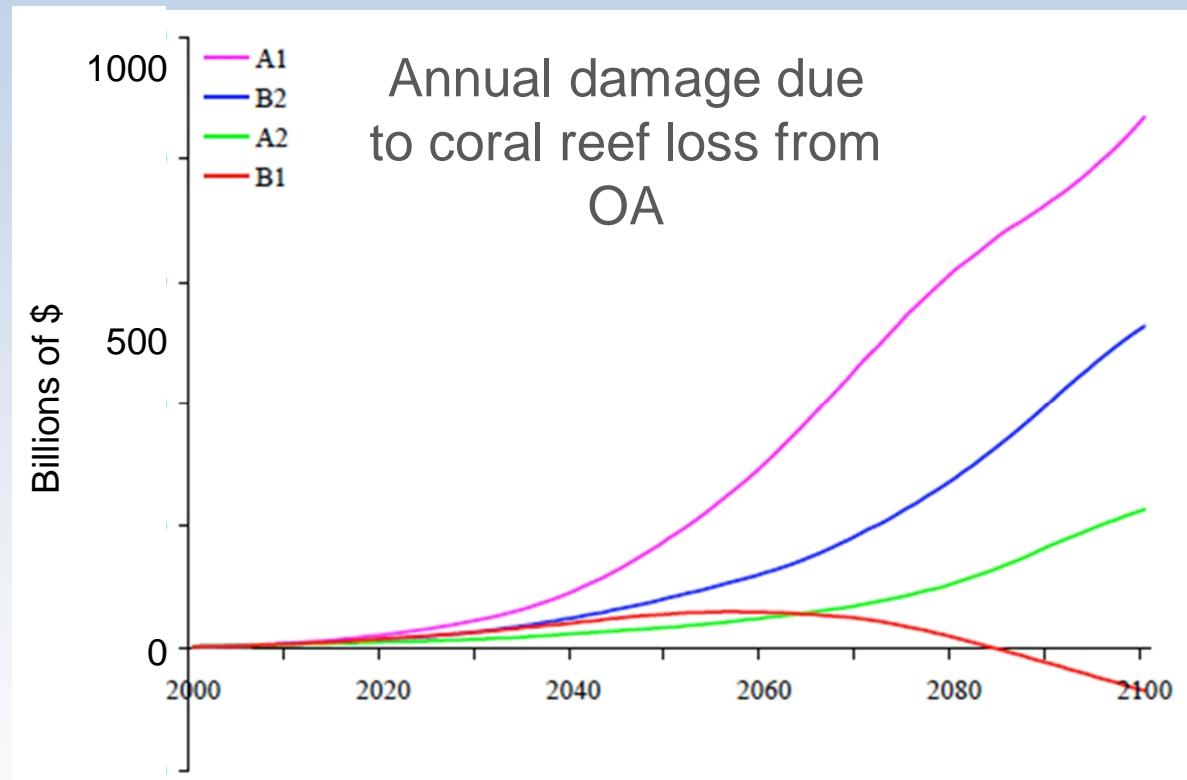
## U.S. mollusk harvests

- Assume a 0.1-0.2 unit pH decrease by 2060 = 6-25% lower harvests
  - Annual losses of \$75-187M
  - NPV losses through 2060 of \$1.7-10B

# OA's possible economic impacts

## Coral reefs

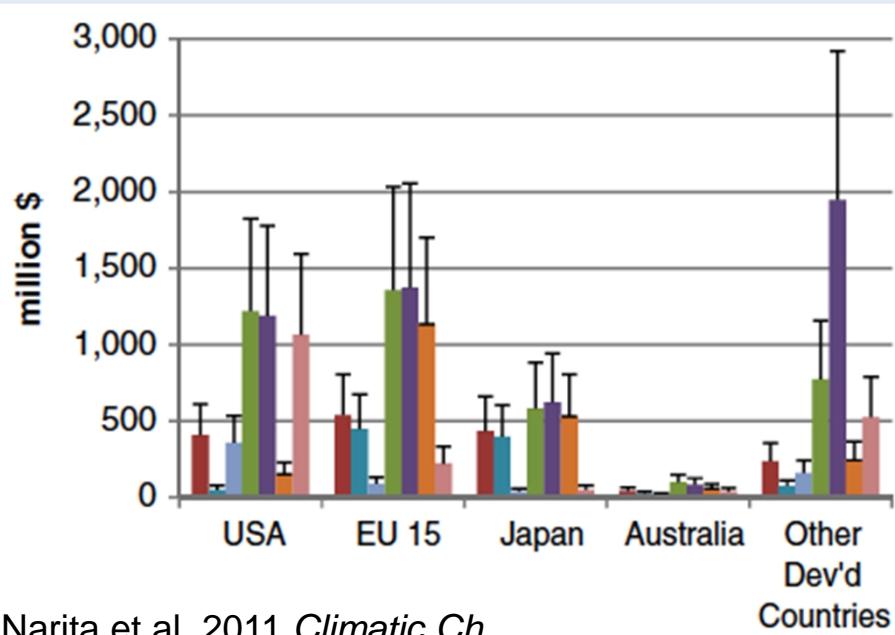
- Value coral reefs via meta-regression
- More information needed on relation of coral cover to OA
- Results strongly driven by importance of reefs for tourism – nonmarket services underestimated?



# OA's possible economic impacts

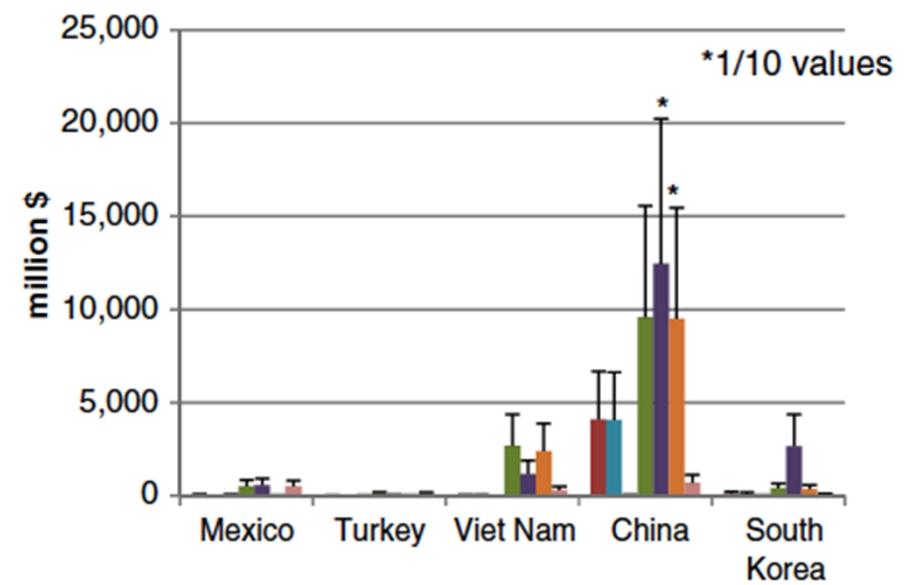
## Global mollusk harvests

- Production losses from OA could be USD\$6 B annually with constant demand



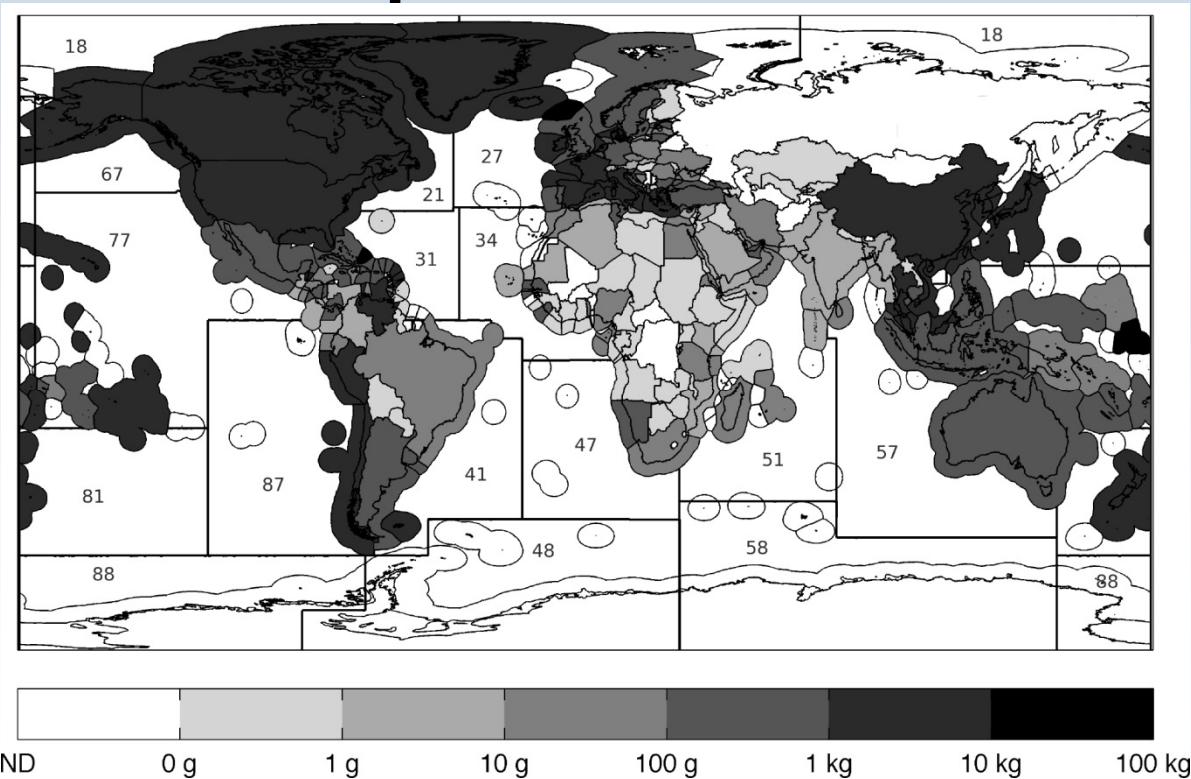
Narita et al. 2011 *Climatic Ch.*

Colors indicate different harvest/economic scenarios



# OA's possible socioeconomic impacts

- Per capita annual mollusk production

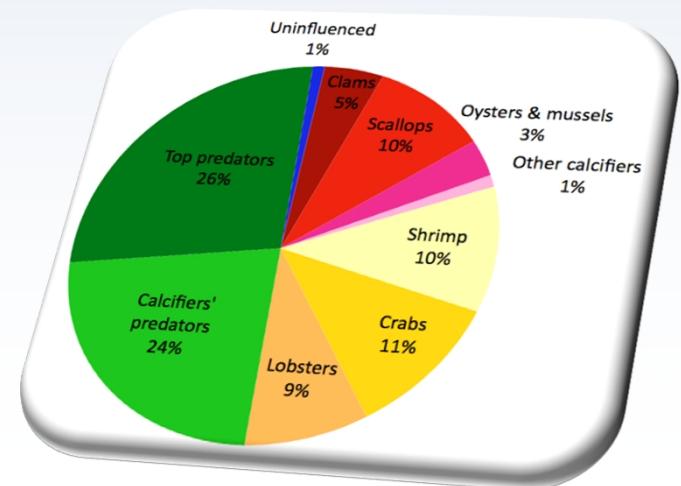


2007 data from U.N. FAO;  
Cooley et al. 2012 *Fish and Fisheries*

- Analysis included
  - Mollusk production, consumption patterns
  - Nutritional status
  - Projected population
  - National adaptability
  - Years until large chemical change
  - Low latitude & developing nations hardest hit

# Limitations of early economic studies

- Specific scenarios
- Lots of assumptions
- Scale problems
- Lack of data
- Broad generalizations
- Doesn't get at cultural issues



# Socioeconomic studies under way

## Models

- Decisionmaking simulated
- Dynamic biological responses
- More realistic OA responses
- Multiple environmental factors



## Risk assessments

- Environmental drivers
- Human exposure, dependence
- Human adaptive capacity

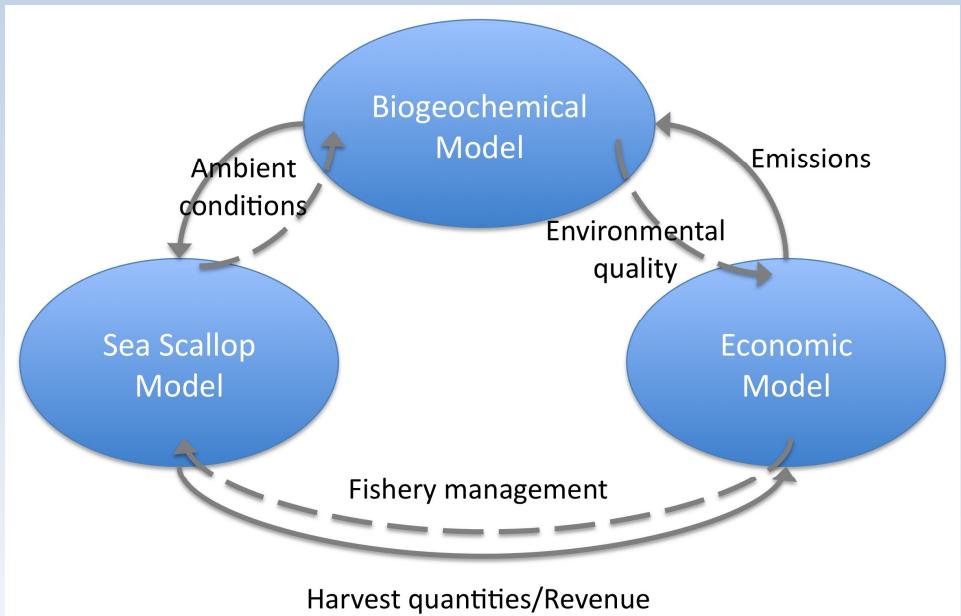
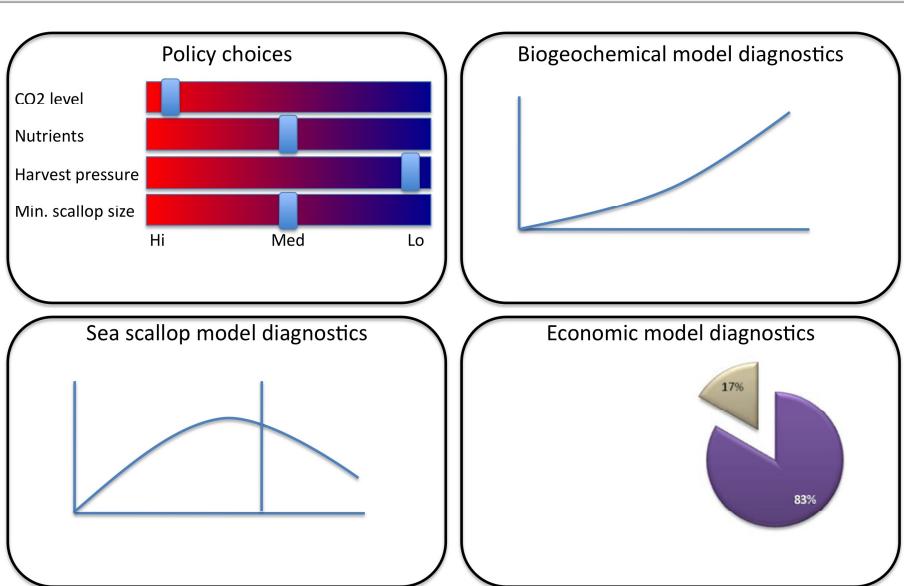




# OA: Developing an Atlantic Sea Scallop Integrated Assessment Model

*Sarah Cooley (OC), Scott Doney (WHOI), Jon Hare (NOAA)*

Goal 1: Develop a simple IAM for the commercial sea scallop fishery in the NE U.S. that includes ocean acidification & other stressors

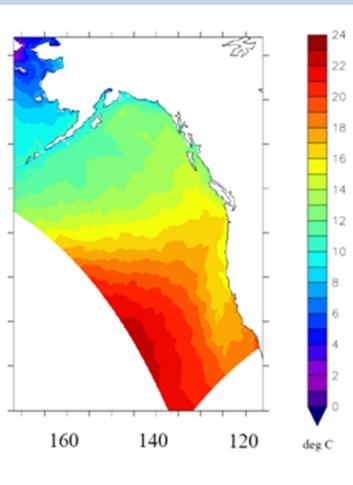


Goal 2: Use IAM to inform a decision-support “dashboard” for policymakers



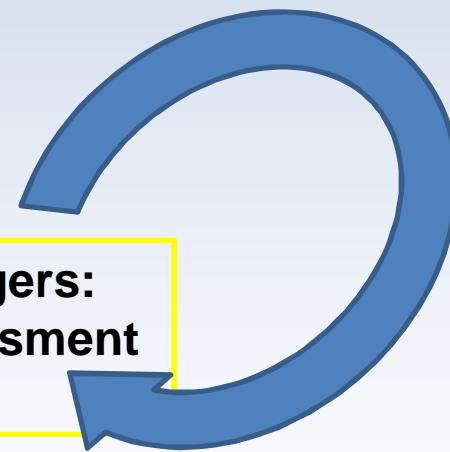
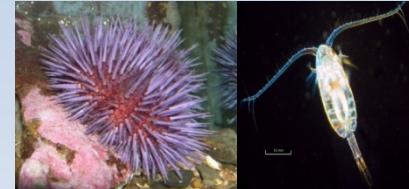
# Vulnerability Assessment of California Current Food Webs and Economics to Ocean Acidification

Isaac Kaplan (NOAA), Shallin Busch (NOAA), Elizabeth Fulton (CSIRO), Jerry Leonard (NOAA), Albert Hermann (JISAO), Chris Harvey (NOAA), Tim Essington (UW), Paul McElhany (NOAA)



**Regional  
Ocean  
Modeling  
System**

**Meta-analysis → biology**



**Information to fishery managers:  
Integrated Ecosystem Assessment  
And Fishery Council**

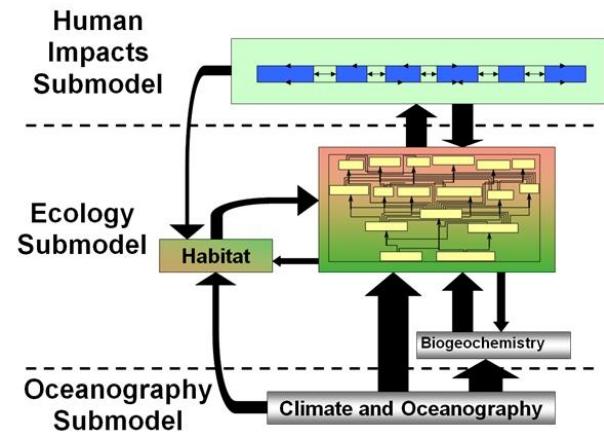


**Spatial economic impacts:  
input-output model**

**JOBS INCOME**



**Atlantis ecosystem**

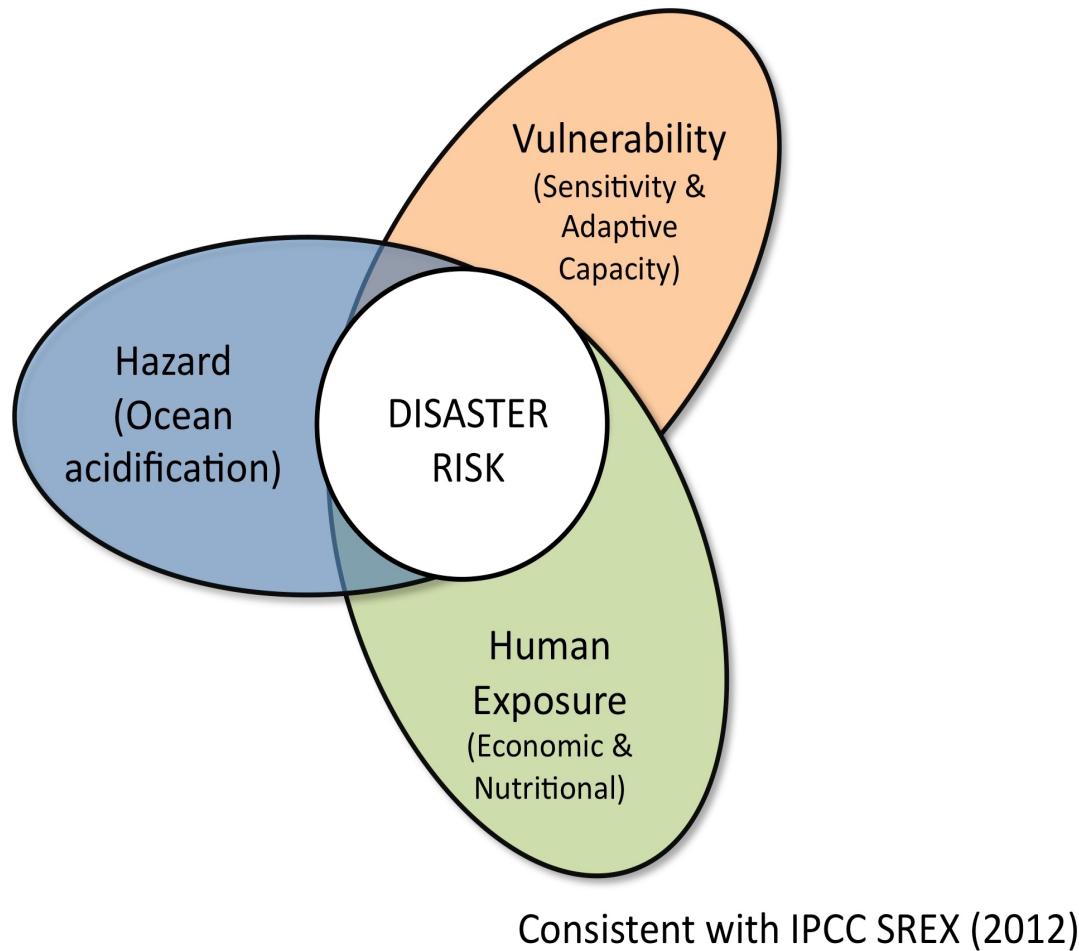


**Fisheries stocks**

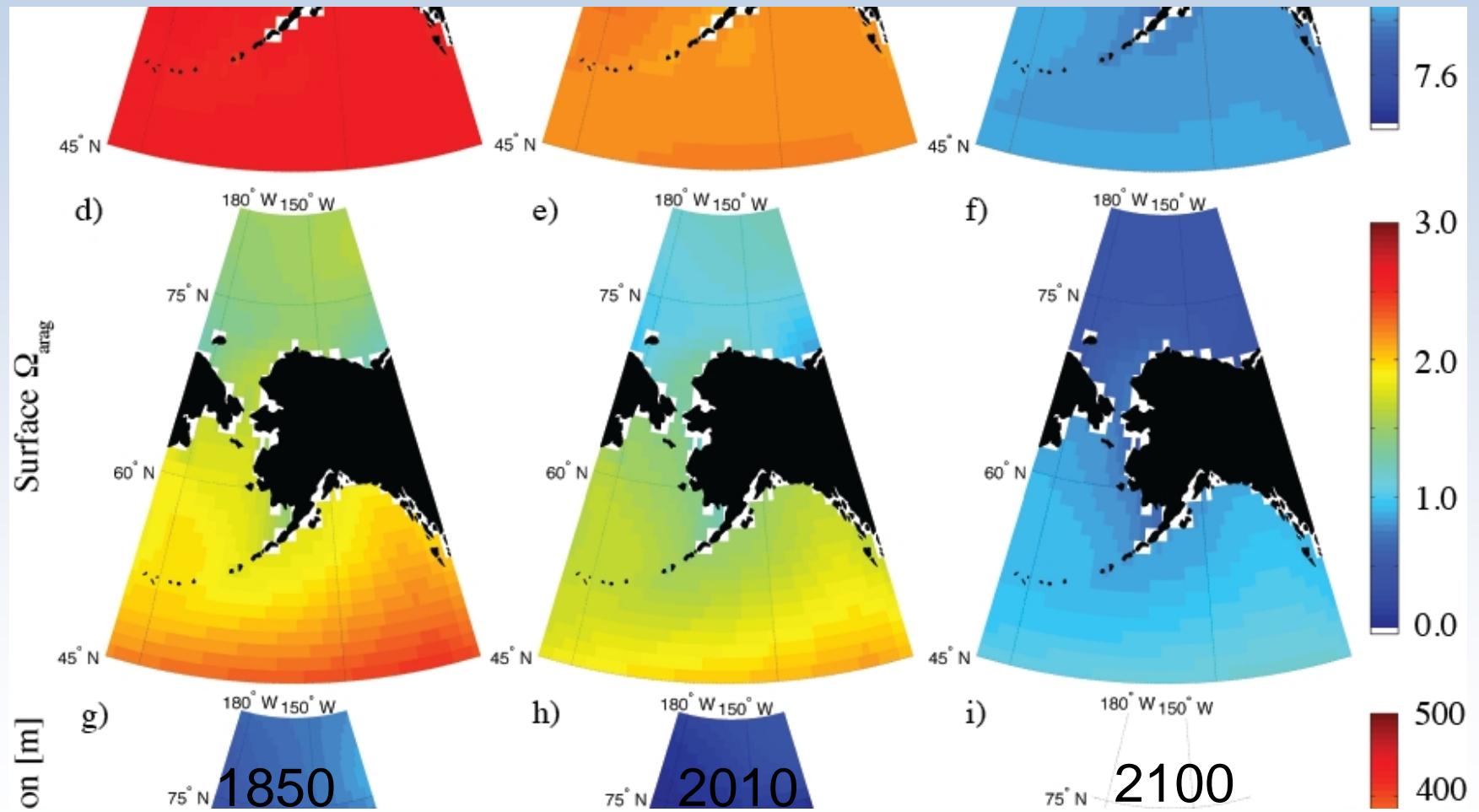


Kaplan & Levin 2010

# Alaska fisheries risk assessment



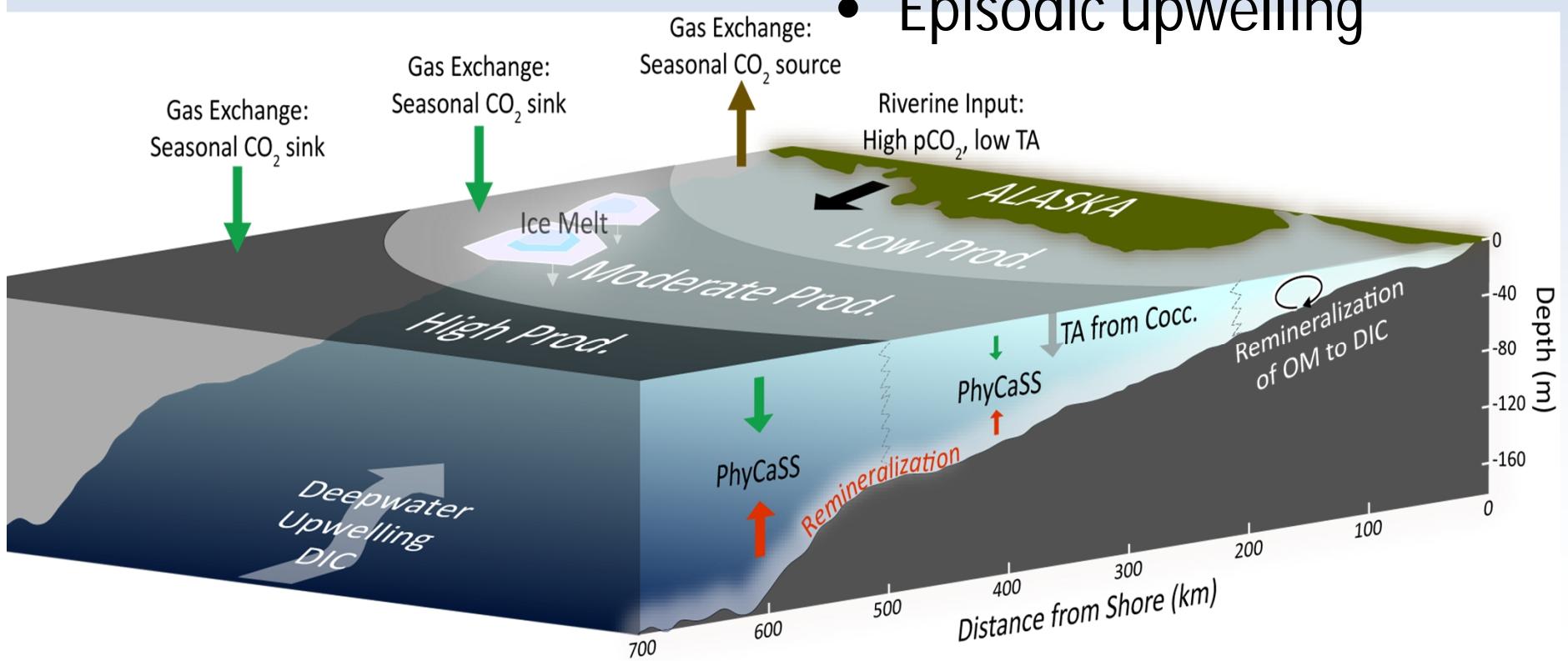
# CESM projections of saturation state: RCP 8.5

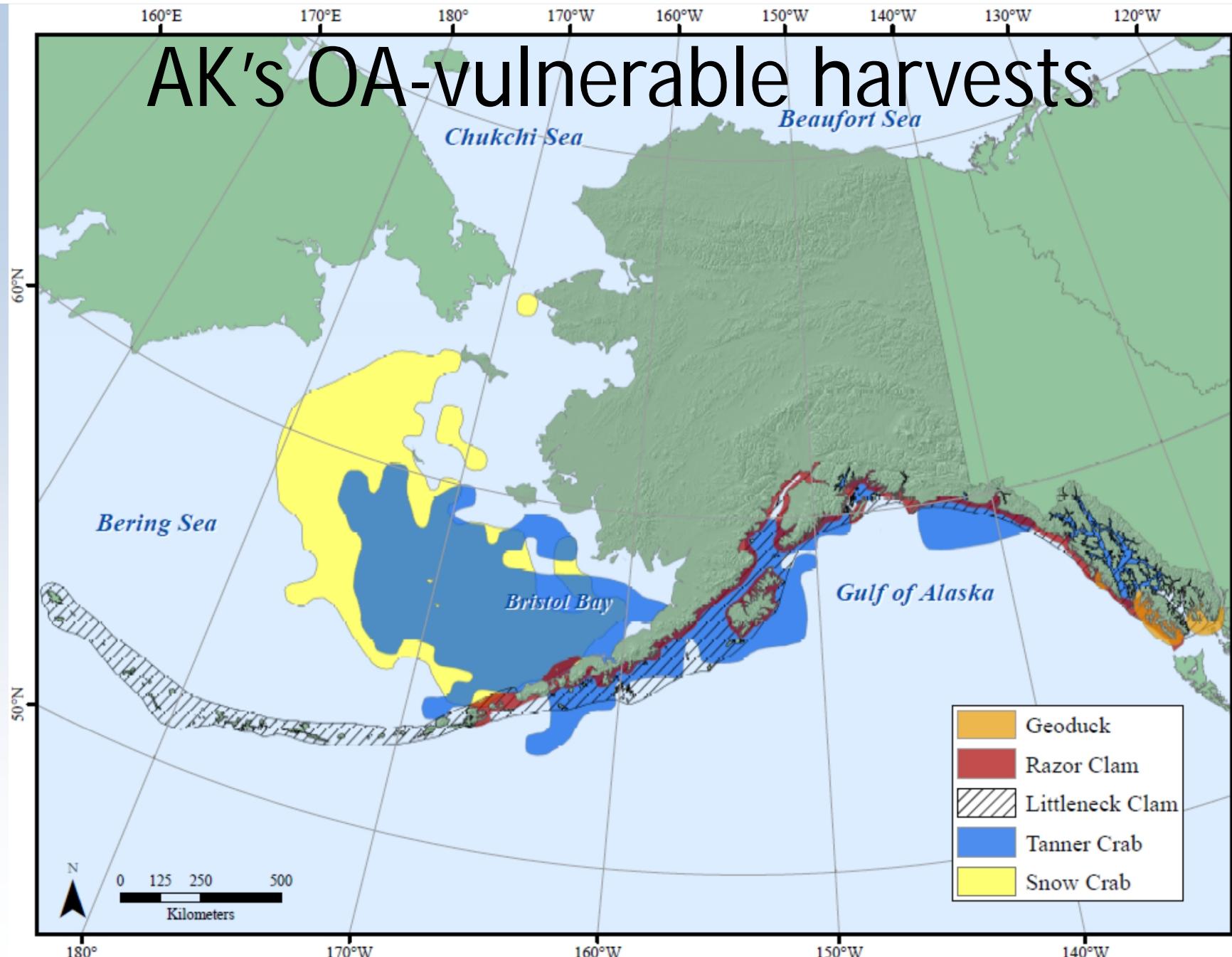


(Mathis, Cooley et al. 2014)

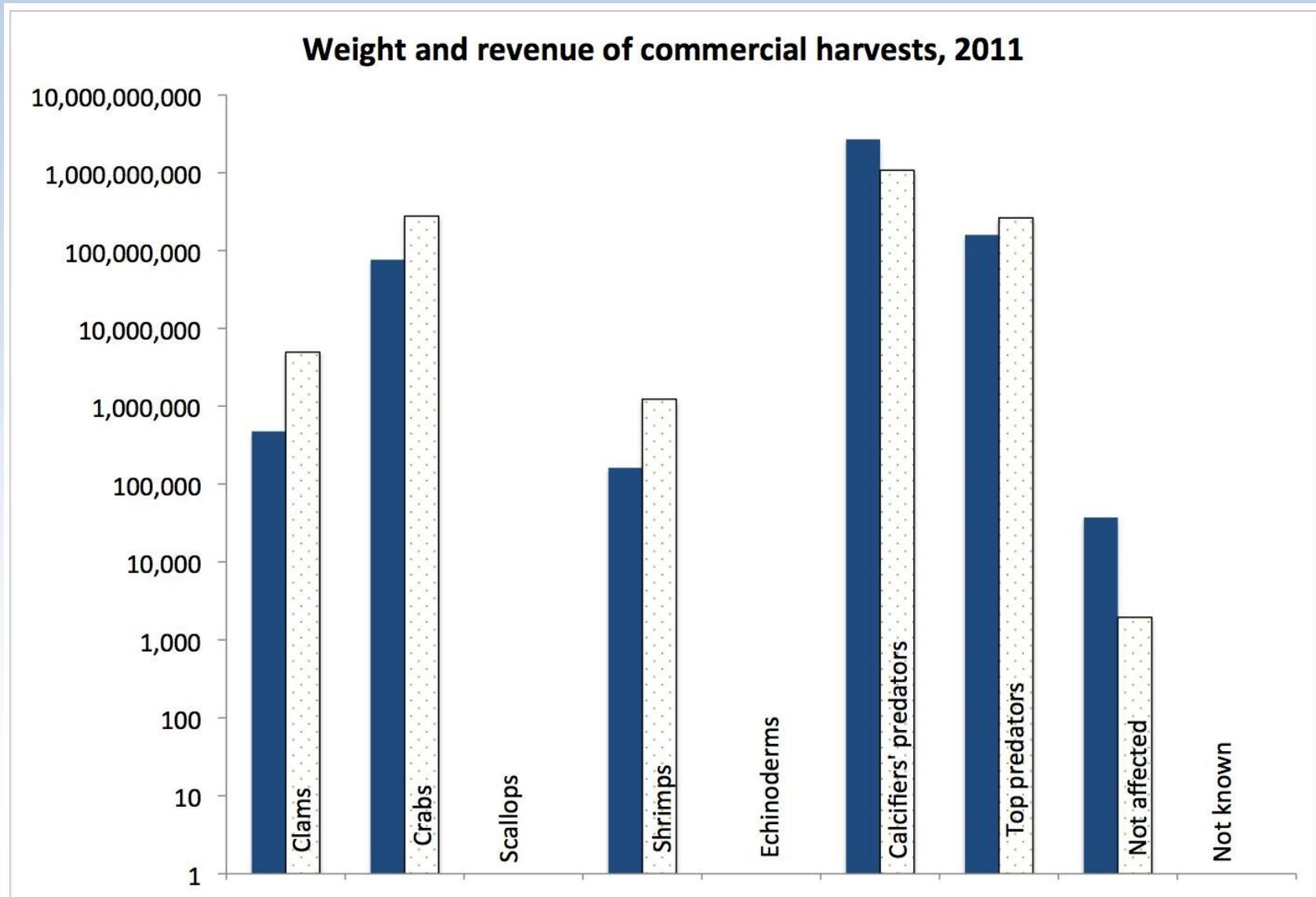
# Additional regional risk factors for OA

- Ice melt
  - Low pH, low  $\Omega_{\text{ar}}$
  - Accelerating
- Intensely seasonal biological production/export
- Episodic upwelling



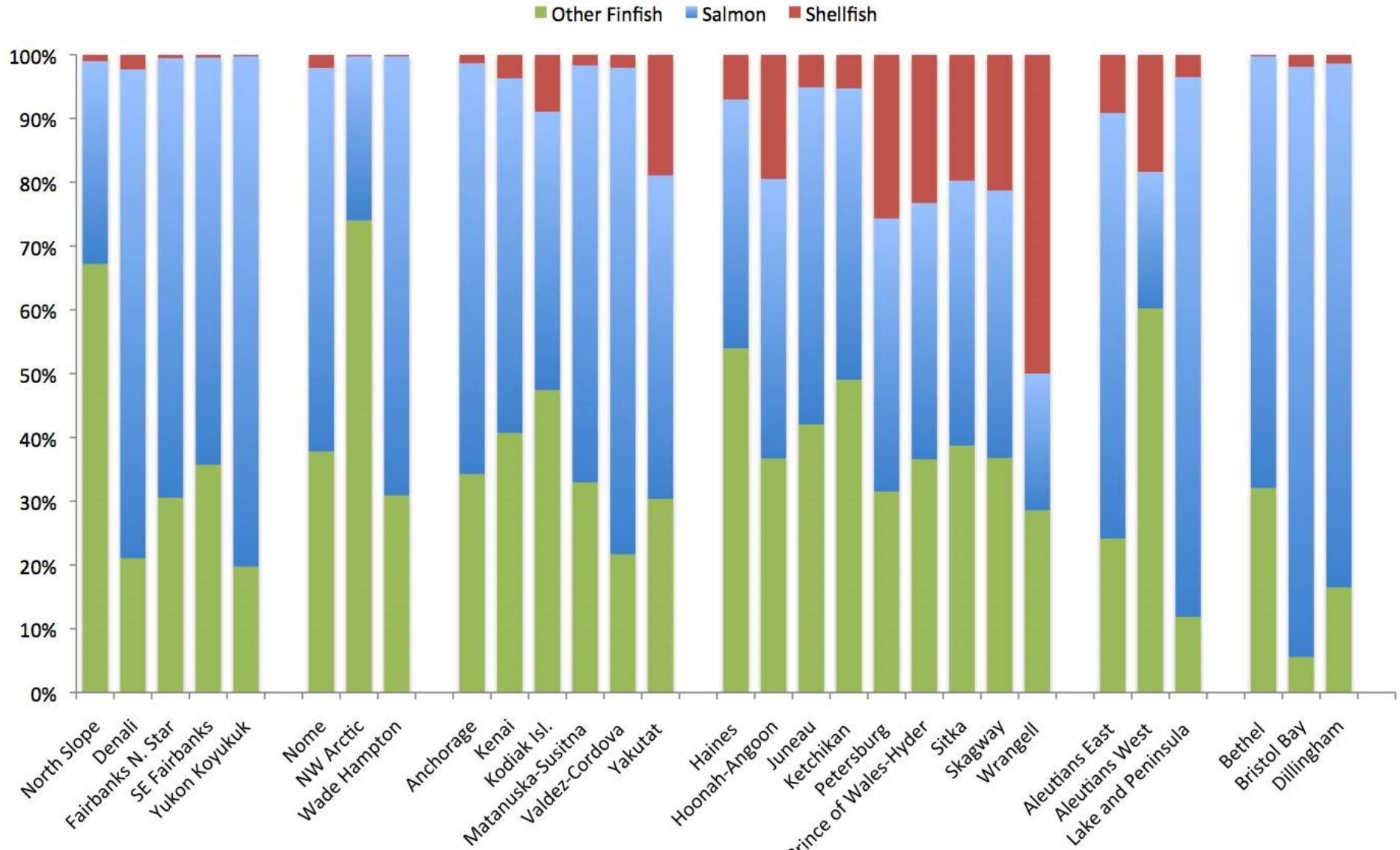


# AK's commercial harvests

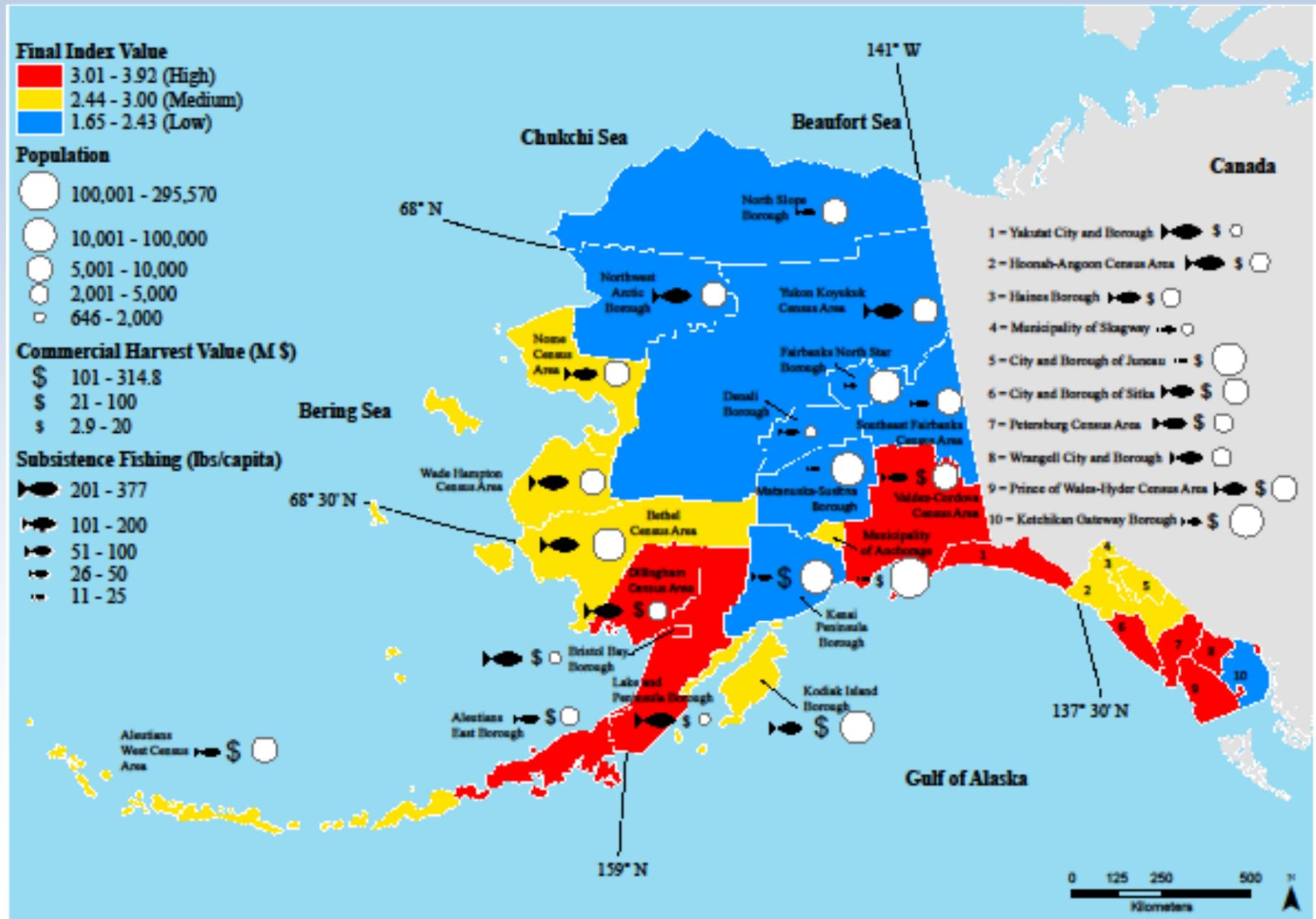


# AK's subsistence harvests

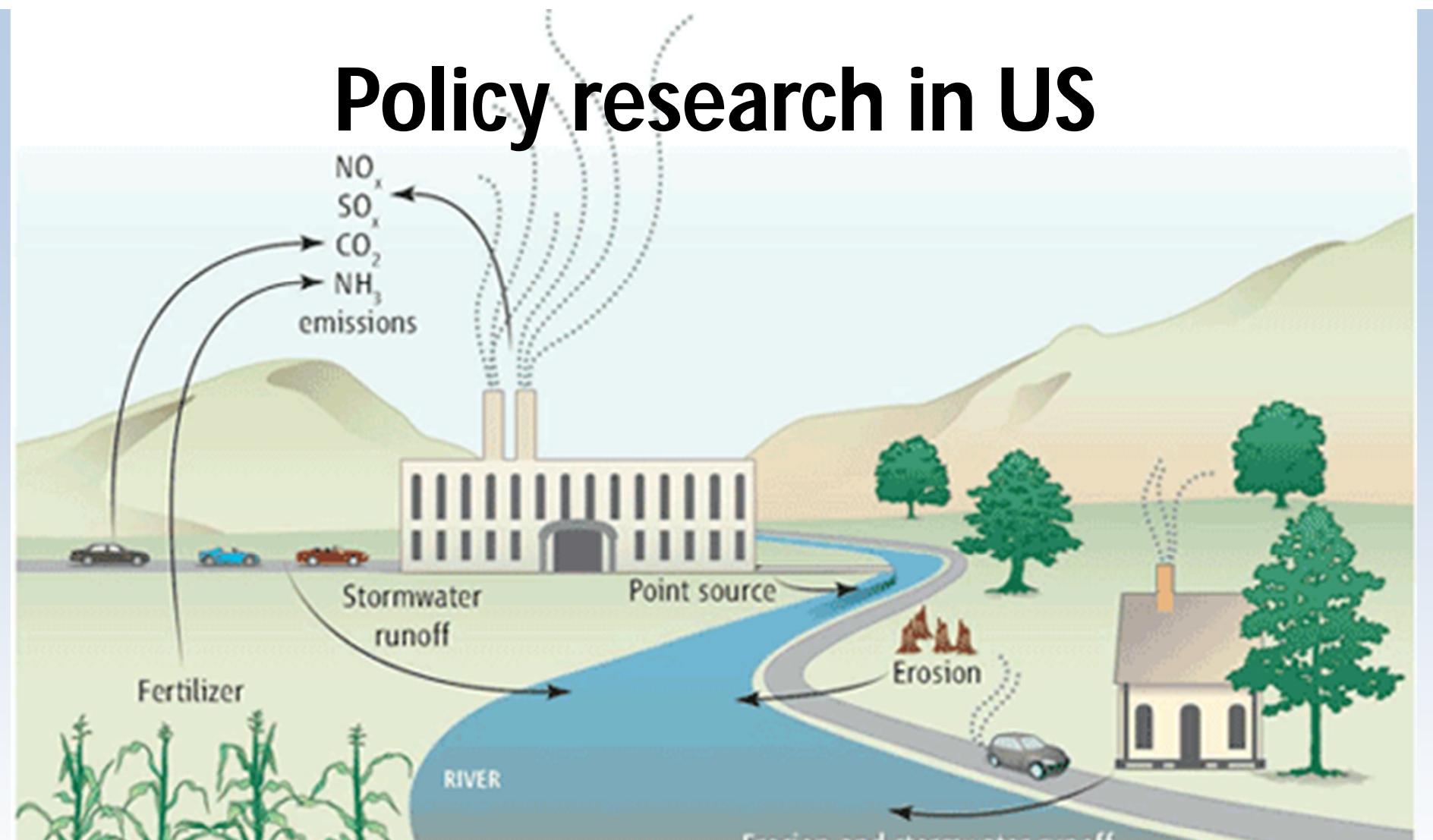
## Subsistence catch composition, by weight



# AK's overall risk from OA

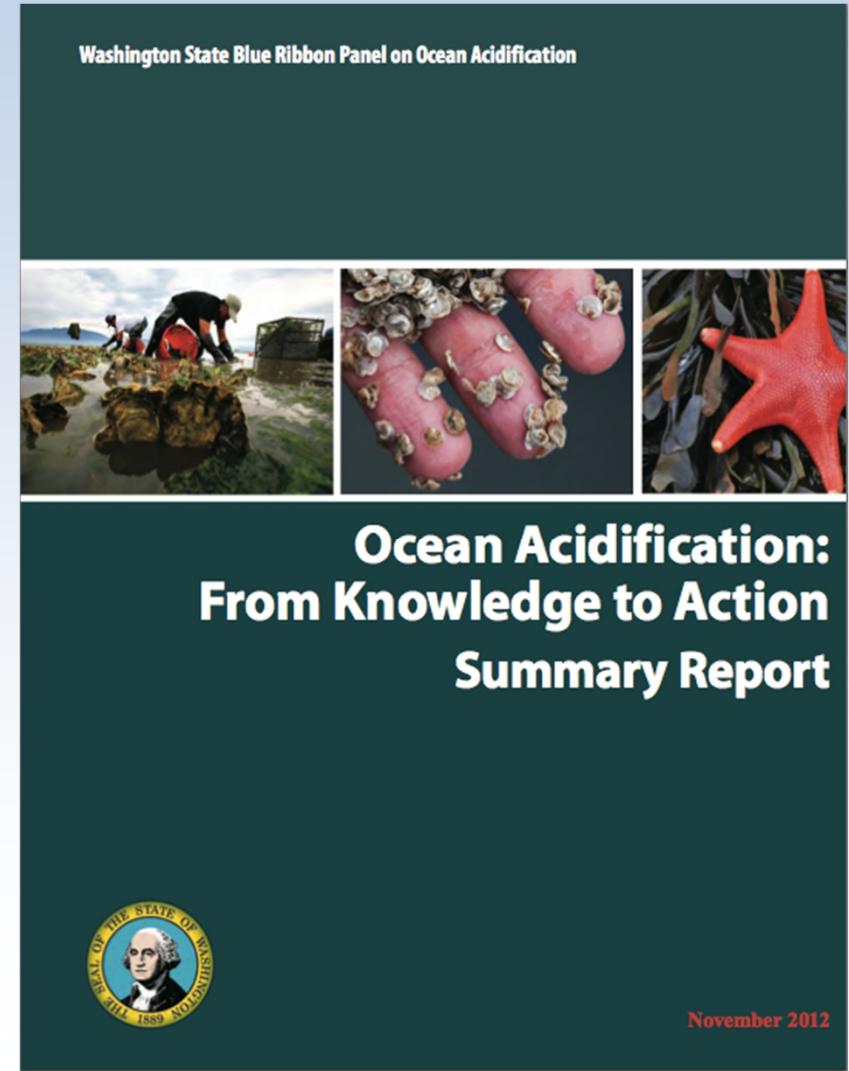


# Policy research in US

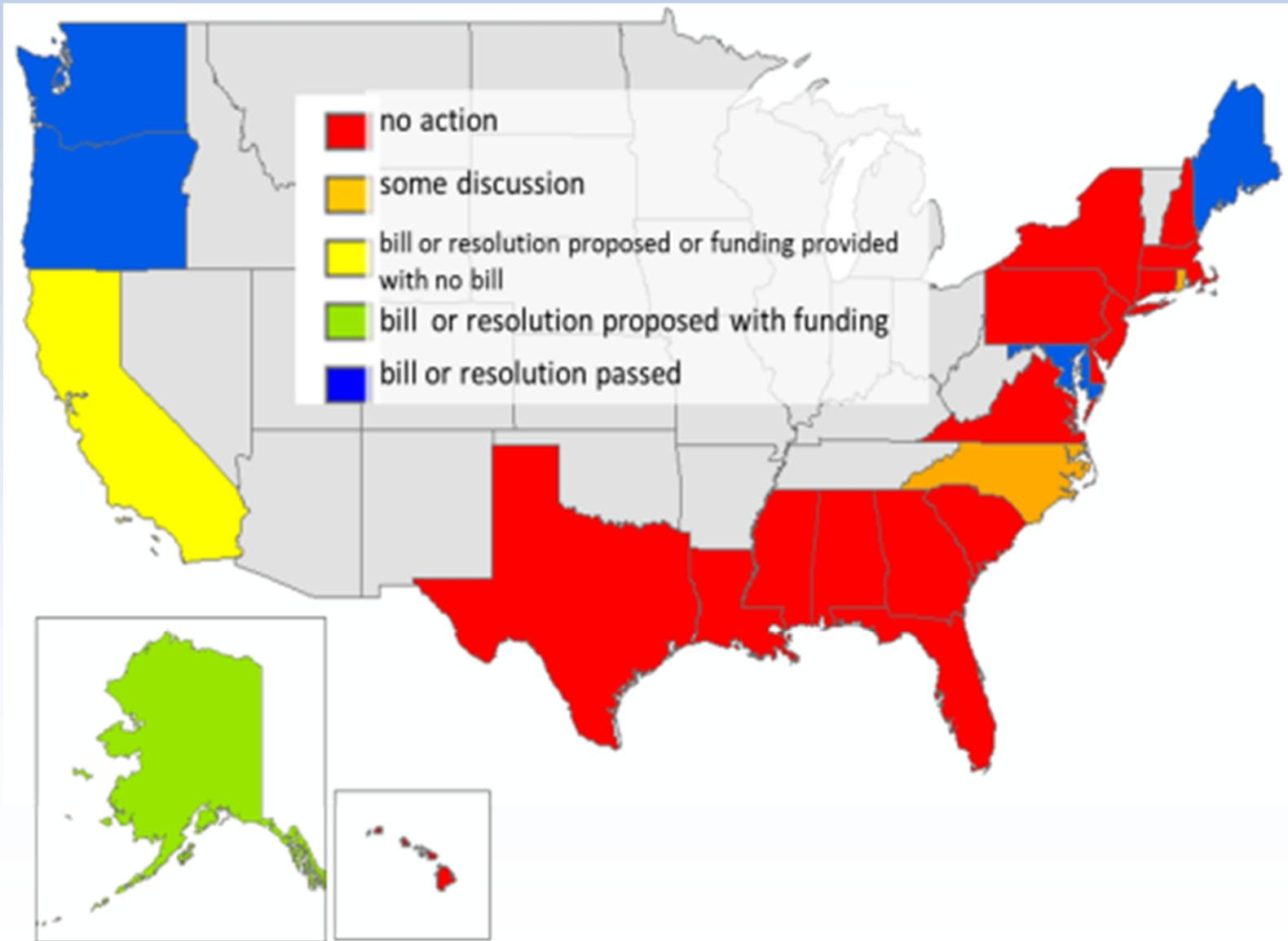


# WA State Blue Ribbon Panel: most comprehensive response to date

- Response to multiple years of OA-driven oyster larval mortality affecting a multi-million dollar industry:
- Outcomes
  - Scientific & organizational recommendations
  - Executive order on early actions
  - Proposed budget funds monitoring, research, coordination.

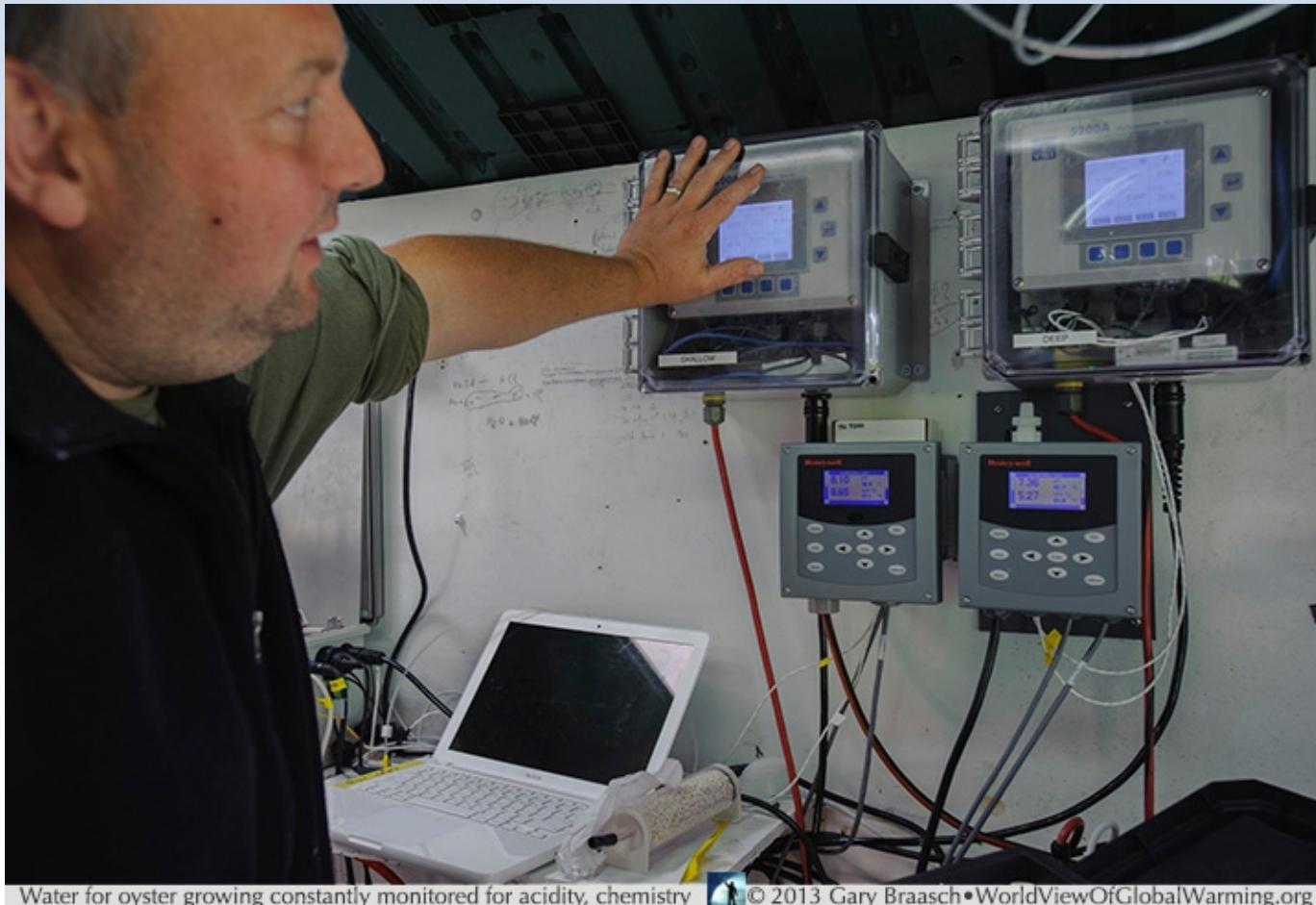


# State legislative status on ocean acidification



# Industry adaptation

- Taylor Shellfish Hatchery, among others, now monitors water intakes' pH

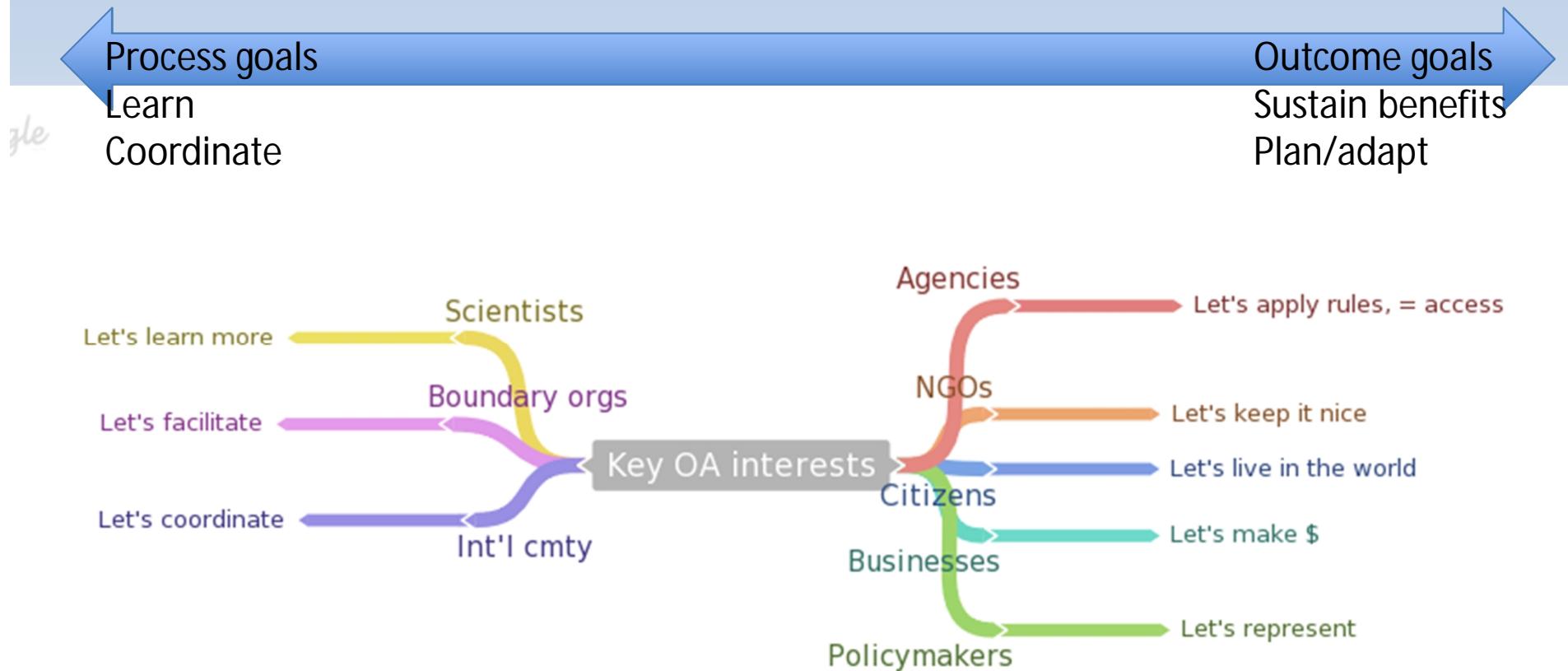


Water for oyster growing constantly monitored for acidity, chemistry © 2013 Gary Braasch • WorldViewOfGlobalWarming.org

Research • Policy • Adaptation

# WHAT'S NEXT?

# A note about people's goals



No group has primary emphasis on future planning & adaptation.

# What is the OA community saying?

1. CUT ATMOSPHERIC CARBON DIOXIDE.
2. Take steps to prepare for OA



# What kinds of steps?

- 10 ways states should engage  
(Kelly, Caldwell, Harvard Env. Law Review 2013)
  - Water quality (5 items; CWA etc.)
  - Air quality (1 item; CAA etc.)
  - Leverage existing programs (2 items; NERRS, State NEPA review)
  - Smart growth planning (1 item)
  - Power to enforce (1 item)

# What kinds of steps?

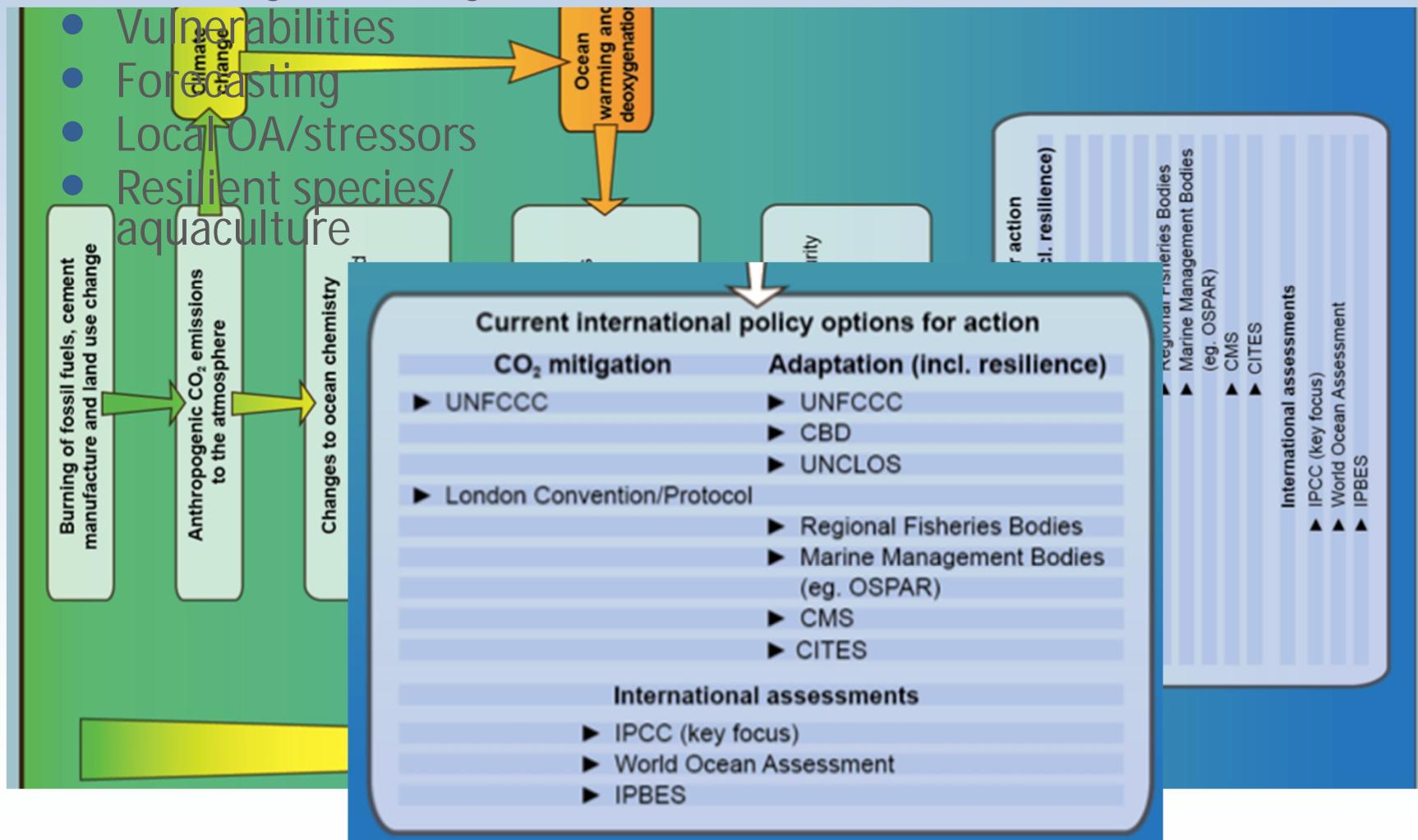
- Opportunities for action  
(Strong et al. Bioscience 2014)
  - Evaluate threats by state
  - Leverage interstate coalitions/form new
  - Develop coordinated obs. network
  - Education/outreach
  - Coordinate with international
  - Integrate OA into CC planning
  - Enforce WQ regulations
  - Consider OA in environmental impacts
  - Include marine genetic diversity

# OA in the US

- State actions: WA, ME, MD
  - Study commission, recommendations, follow-up
- Federal bills related to OA in committee
  - OA technology prize act: foster tech innovation (bipartisan)
  - Coastal communities act: investigate vulnerability to OA
- FOARAM reauthorization
  - Directs federal agencies to work together on research, planning, education, coordination, communication

# OA internationally

- Mitigation plus:
  - Planning/financing



# Pending intellectual challenges

## Oceanographic

- How does OA relate to other marine stressors?
- Can we generalize about ecosystem responses to OA?
- How much does OA negatively impact ecosystem services?

## Socioeconomic

- Which ecosystem services are vulnerable to OA?
- How can we best value services and quantify losses?
- What scales are most informative for coupled ocean-human analyses?

# Challenges to acting

- Specifics needed from science
  - Coastal OA
  - Multiple stressors
  - Social-ecological analysis, impacts
- Communications/strategy issues
  - Risk of policy/environmental “burnout” from chipping away at such a big, nested issue
  - Very different motivation for OA sub-communities
  - Communications disconnects

# Conclusions

- OA is happening, has affected shellfish growers
- Research on socioeconomic effects: modeling, risk assessment
- Policy & adaptation moving forward
- Decisions will be made under high uncertainty
- Need for inclusiveness and holistic approaches



Ocean Conservancy

# Thank you!



- Collaborators: S. Doney, S. Colt, J. Cross, J. Ekstrom, W. Evans, R. Feely, J. Hare, D. Hart, C. Hauri, T. Hurst, R. Kelly, H. Kite-Powell, T. Klinger, N. Lucey, J. Mathis, L. Pendleton, L. Suatoni , J. Roberson, J. Watters
- Thanks to J. Roberson, J. Watters, S. Busch for slides



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