Acidification and fisheries and aquaculture: understanding impacts, economics and adaptation

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What is at stake?

- Over **500 million** people depend – directly or indirectly – on fisheries and aquaculture for their livelihoods
- Aquatic foods provide essential nutrition for **4 billion people** and at least 50% of animal protein and minerals to 400 million people in the poorest countries.
- Fish products are among the most **widely-traded foods**, with more than 37% by volume of world production traded internationally.

Drivers of change

Affecting biological processes

Pollution/Water quality

Climate

Acidification

Overfishing

Altered habitats

Etc…

Affecting human choices

Governance and politics

Legal systems

Technological change

Markets

Capital/labor flows

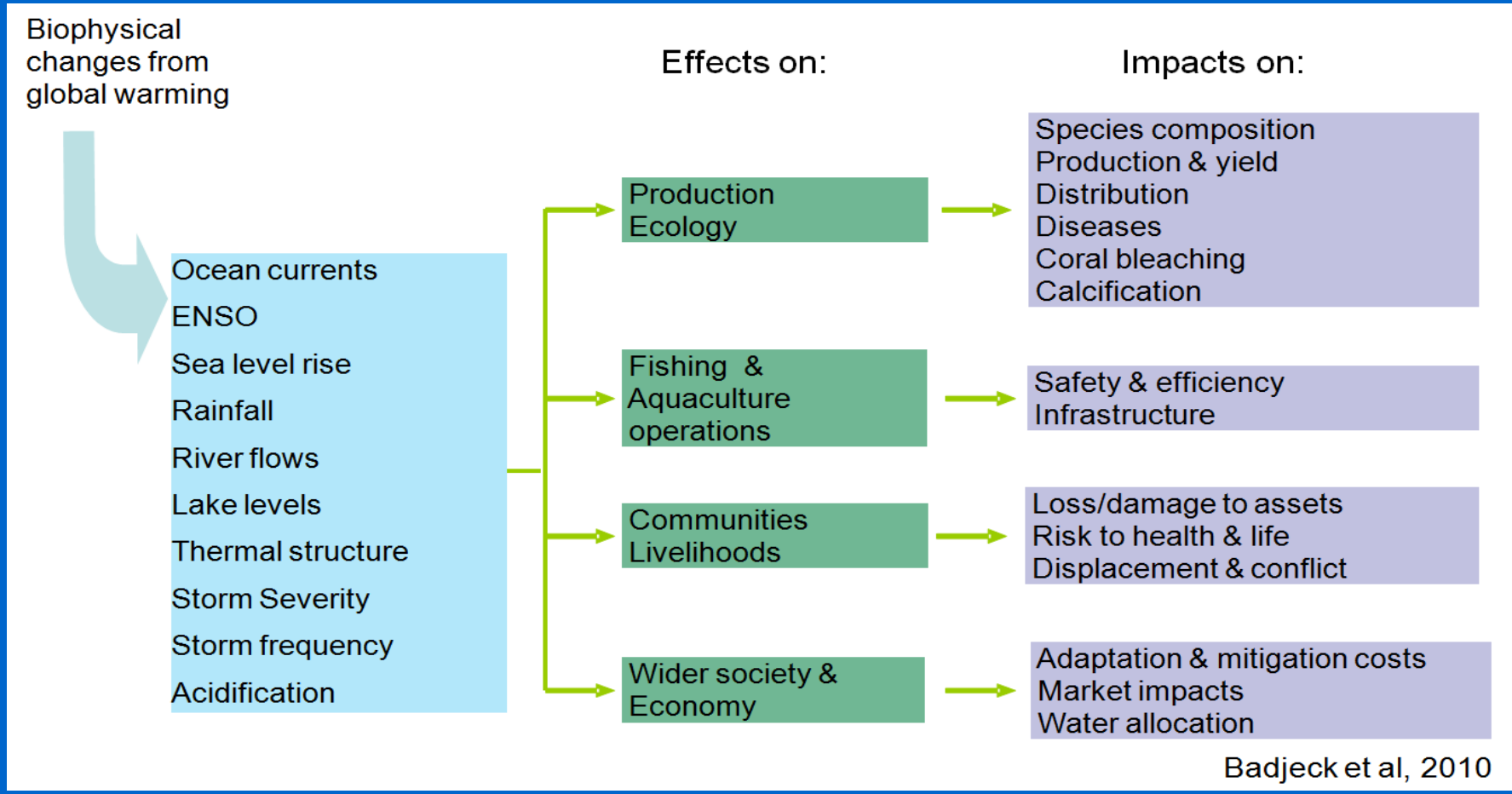
Demographics

Culture

Etc…

Fisheries and Aquaculture systems

CC impacts on fisheries and aquaculture

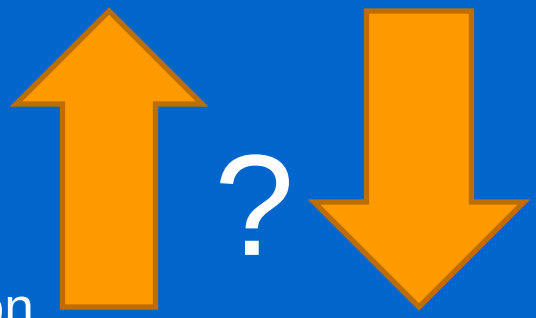


Badjeck et al, 2010

Acidification impacts on FI&AQ species

Direct physiological effects

- Alteration, reduction/inhibition of growth of calcified structures (adult and larvae)
- Acid-base balance
- Otolith development
- Basal metabolic costs
- Aerobic scope
- O2 consumption
- Thermal tolerance
- Gamete maturation and activation
- Fertilization success
- Egg hatching
- Embryonic development
- Olfactory behavioral responses

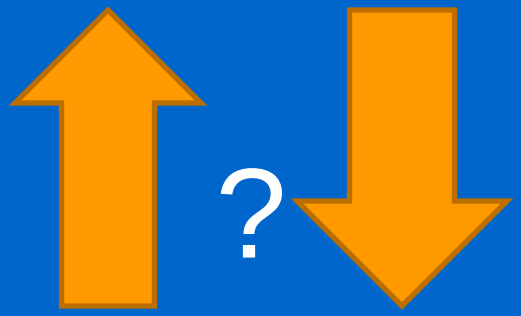


Le Quesne and Pinnengar 2011

Acidification impacts on FI&AQ systems

Indirect effects

- predator or prey abundance
- habitats (esp coral reefs)
- nutrient recycling
- bentho-pelagic coupling
- primary production by phytoplankton



Impacts on food and livelihood security, economies

- ability to respond to changes in demand
- coastal protection from reef systems (and mangroves?)
- changes in fishing ranges
- changes in micronutrients?
- increased risks to aquaculture investments (e.g. decreased productivity and growth rates, increased mortality)
- local decrease in production may not mean increase in prices, etc

What do we know about social and economic impacts of acidification?

- OA not included in most climate change economic impacts studies
- Few economic studies but number growing
- High uncertainty in biophysical and socioeconomic systems
  - Variability in organism responses, ecosystem responses,
  - Variability in development pathways and responses in both developing and developed countries

A note on the uncertainty of impacts

Global trends and projections	→	Local trends and projections	→	Impacts on biophysical systems	→	Responses of social-ecological systems
?		??		???		????

Daw et al, 2009

Mollusk fisheries examples

- Increasing demand, especially developing countries
- Global mollusc fishery (capture and aquaculture) could loose up to 6 billion USD by 2100 (Narita et al. 2012)
- Other studies have different results due to different OA impacts on calcification, survival, etc. (e.g. Cooley & Doney 2009)
- Already seeing impacts (Whiskey Creek oyster hatchery, Oregon, USA, Barton et al. 2012)

Mollusk fisheries example (cont'd)

Social and economic impact estimations will depend on, e.g.:

- Uneven impacts on production systems
  - Ratio of capture to aquaculture in production
- Existing governance, socioeconomic and market conditions
  - Ability of producers to pass on costs to consumer
  - Dependency of community and adaptive capacity
  - Impacts along value chain

Issues related to broadened scope of impact valuation to other ecosystem services

	USE VALUE		NON-USE VALUE	
TV categories	**Direct use value** Consumptive, non consumptive	**Indirect use value**	**Option and quasi-option** Bequest value	**Existence**
Example Fisheries ecosystem services	•Capture/Recreational/Aquarium fishing (food, income) •Ornamental resources •Medicinal resources •Tourism/Recreation •Culture/heritage/spiritual •Science and Education	•Habitats and biological regulation •Employment/livelihoods •Food chain/global life support •Transportation •Local/National/Int'l relations	•Preservation for future uses •Stewardship •Precautionary or risk/uncertainty reduction •Future knowledge potentials	•Intrinsic preservation •Biodiversity •Social Identity •Religious and cultural identities

So, what can we do?

In addition to cutting CO_2 emissions, that is….

Adaptation of aquatic systems to acidification

Organism responses:

- Organism acclimatisation as OA will be gradual shifts as opposed to sudden changes in most experimental designs
  - Transgenerational coping abilities
  - Selection and genetic adaptation
- Species already living at extremes

Adaptation of aquatic systems to acidification

Human responses:

- Reduce land-based pollution and other pressures (e.g. over and destructive fishing) on vulnerable aquatic systems
- Marine spatial planning to preservie refugia areas (e.g. kelp forest systems)
- Phytoremediation - seagrass meadow, macroalgae on coral reefs, kelp forests
  - Encourage these habitats near sensitive areas, short-term buffers

Adaptation of fisheries systems to acidification

CCRF and ecosystem approach, including:

- Encourage good governance and adaptive management (e.g. stable but flexible access)
- Encourage monitoring and sharing of information by all stakeholders including researchers, industry, communities
- Undertake OA adaptive capacity assessments for fisheries socio-ecological systems and reduce food and livelihood vulnerability via diversification, insurance schemes, DRM, etc

Adaptation of aquaculture systems to acidification

In addition to EAA, some technical adaptations:

- Species selection (higher tolerance, etc.)
- Shift hatcheries to less impacted areas (if possible)
- Monitor and work around chemical changes
  - e.g. Whiskey Creek hatchery times oyster spawning with pumping higher pH water
- Regulate seawater chemistry
  - e.g. seeding mud flats with calcium carbonate (crushed shell) (Green et al. 2009)

Some acidification questions

Impact pathways (ecological processes potentially at risk and interactions with human-social systems).

- Direct and indirect impacts on commercial species?
- Impacts on relative composition of species in a given system?
- Impacts on overall system productivity (substitutes in habitats and species?; changes along food webs?)
- Relative impacts of acidification among multiple drivers (additive/cumulative effects) and where and in what processes might it be a more important driver of change?
- What are the predicted social and economic effects?
    - What do we risk losing? Yields/production, costs, profits, access to food, income, social values, security nets, etc? Will substitutes suffice?
    - Market impacts - global price changes versus local prices?

Some acidification questions

- Capture fisheries and aquaculture
- Time scales
- Small-scale versus large scale
- Estuaries, coastal, out to open ocean and high seas
- Fishers/farmers, processers, or traders, global markets
- Gender, age, marginalized groups

- Vulnerabilities? - mappings to identify social-ecological systems especially exposed to and sensitive to acidification or with low adaptive capacities - Again, looking at different scales and groups
- Adaptation options? – social, economic, technical, governance (who and how?)
  - anything specific to acidification in capture fisheries? What is good in general is good for acidification?
  - aquaculture examples?
    - Farmers, traders, government
    - Insurance schemes (risk management)
    - Technological change, etc
  - What costs to adaptation? To whom?

Some final, broader acidification questions

- How to improve the science to policy bridge, esp. under uncertainty?
- How can we support the transition to durable and resilient FI&AQ facing acidification?
- What changes will acidification require of decision-making and information processes?
- What changes will acidification require in FI&AQ management and ocean governance?
- How to communicate and advocate to decision-makers and other stakeholders?

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