TIEE

ISSUES - Frontiers to Teach Ecology

Long Term Changes in Marine Fisheries

ARTICLE

M Barange. 2003. Ecosystem science and the sustainable management of marine resources: from Rio to Johannesburg. *Frontiers in Ecology and the Environment* 4(1): 190-196.

"National Oceanic and Atmospheric Administration/Department of Commerce" (see http://www.photolib.noaa.gov/aboutimages.html)

ECOLOGICAL CONTENT

long-term change, species change, sustainability, fisheries, ecosystems management

TEACHING FOCUS

Students often have little appreciation of large interannual and longer-term changes in species composition and abundance. Less experienced ecology students may in fact think that such change is "bad." In ecology texts, species abundance shifts over time (e.g., lynx and hare cycles) are usually discussed in the population ecology chapters. In this article Barange discusses long-term (inter-decadal and longer) patterns of change in marine species in the context of over-exploitation of marine fisheries. Barange's emphasis is use of ecosystem-based management practice to move us towards sustainable fisheries. However, he questions whether we know enough about patterns and causes of long term change in marine ecosystems to develop such practices.

OVERVIEW

Barange begins this article by describing how the 1992 United Nations (UN) Conference on Environment and Development in Rio de Janeiro, Brazil, highlighted the need for ecosystem level management of marine resources. He then outlines the legal and institutional efforts since the 1992 Rio conference. These include the UN Convention on the Law of the Sea, the Food and Agriculture Organization (FAO) of the UN agreements, and the Kyoto Declaration on Fisheries and Food Security of 1995.

Barange states that these new legal efforts were developed because marine fisheries are at a crossroads: "In 1999, about 50% of all marine fisheries were fully exploited, 20% were overexploited, and a further 10% were depleted (FAO 2000). In the 1990's, the annual rate of increases of marine catches decreased to almost zero, and may even be negative (Watson and Pauly 2001). This indicates that, on average, the world's oceans have reached their maximum production, estimated to be about 80-100 million metric tons (FAO 2000)."

One response to this very serious situation is the development of ecosystem-based management systems (EBMS). This article addresses the question of whether we know enough about the structure, function, and components of marine ecosystems to predict the ecological impact of current and past fishing practices.

Barange highlights three areas of scientific development over the last decade which are especially relevant to this issue:

1. Long-term patterns of change (Fig. 1)

In this section Barange describes large changes in marine species on the 100 - 1000 year scale. Figure 1 shows very large variation in anchovy abundance off the coast of California from the years 280 – 2000 based on fish scale deposits in sediments. He states that gradual anthropogenically-driven change (due to global warming, for instance), will not likely result in greater changes than those that have occurred naturally. Instead, "the perception is that the real effects of global change on marine ecosystems will be the result of **interactions** [emphasis added] between anthropogenic pressures and natural cycles of variability."

2. Interdecadal cycles (Figs. 2, 3, and 4)

Here Barange describes how the worldwide abundance of pelagic fish cycles (e.g., sardines, Pollock, mackerel) in synchrony on decadal scales. Studies of atmospheric pressure and circulation suggest that fish production may be in

part regulated by global environmental cycles (wind, in this case). This is contrary to many people's assumption that local-scale processes mostly regulate fisheries.

Photographs of catches from bottom trawlers off Alaska (Fig. 4) dramatically illustrate what Barange calls a "regime shift." Before 1977, the fishery was largely based on invertebrates; after 1977, finfish were the dominant catch. This shift appears to be related to a change in climate on a decadal scale. Warmer waters off the northeast coast lead to decreased zooplankton abundance and increases in most Alaskan salmon stocks.

3. Trophic cascades, food webs, and biodiversity (Fig. 6)

Ecologists know that pressures on both the top and bottom of food webs can cascade through all trophic levels. However, Barange notes that we do not know how resilient marine systems are to such cascading changes, or how species diversity affects these cascades. Given the interdecadal abundance cycles described above, resilience may also vary with fish production.

Barange highlights three areas of scientific development over the last decade which are especially relevant to this issue. The figures listed below are in the "Figures" section of this *Issue*.

REFERENCES

Food and Agriculture Organization of the United Nations. 2000. State of the world fisheries and aquaculture (SOFIA). Rome. http://www.fao.org/sof/sofia/index_en.htm

- Watson R. and D. Pauly. 2001. Systematic distortions in world fisheries catch trends. *Nature*. 414: 534-36.

SCIENTIFIC TEACHING AND ACTION RESEARCH

Although ecology faculty have extensive research training, most do not realize that they can do research in their own courses. This is a different kind of research than we are used to — often not controlled, without replicates, and so on. But it is still research because we can develop hypotheses, ask specific questions based on these hypotheses, and then collect and analyze data which in turn inform the questions and hypotheses. There are numerous journals dedicated to interesting research on teaching (e.g., *Journal of Research in Science Teaching*).

One type of classroom research is called "Action Research." In this type of research, faculty ask specific questions about their students or their teaching, gain information about these questions, and use this information to learn about teaching and their course in particular. A list of Action Research websites are below. Action research is an aspect of "Scientific Teaching" (Handelsman et al. 2004).

Below we describe a four-step process which you can use to conduct research on your use of the *Frontiers* article. The theoretical bases for this TIEE Scientific Teaching are three areas of research on learning (D'Avanzo 2003 a,b): *metacognition* (knowing what we know), *misconceptions* (firmly held beliefs that are incorrect) and *adult development stage theory* (stages that learners are thought to go through as their thinking about a discipline matures).

Action Research with the Barange article: Misconceptions About Change

Misconceptions: students come to class with background knowledge that may or may not be correct; when incorrect this information is called a misconception (or prior/alternative/intuitive conception). Students' misconceptions are notoriously difficult to change, and numerous studies show that students come to class – and leave – with the same content misinformation even when the content is directly dealt with in a class.

As emphasized in the "Notes to Faculty" section, **you can use this article to address a misconception shared by many ecology students: change is "bad."** That students have this misconception may surprise you – which is one of the reasons why students retain these alternative conceptions. Faculty are unaware of them!

The next section provides suggestions for assessing whether your students have this misconception, how you can use the Barange article to specifically address it, and then seeing if/how much the misconception changed as a result of your "interception":

1. Step One: Pre-test — Use questions that expose the misconception that change is a bad thing. How you do this depends in part on the size of your class. Below are several examples.

 ○ In a **small** class you can ask students to answer a short list of questions (in class – not as homework). Be clear that this is not a test, is anonymous, and has no bearing on their grade. Tell the class that it will help you better design the course for them. Students can write very short essays about questions such as "In a well known National Forest, the numbers of birds has gone up and down repeatedly over the last 15 years. Do you think that these changes in bird numbers very likely indicate some kind of environmental problem? Briefly explain why or why not." You can also use multiple-choice questions as described below.

 ○ In **larger classes**, it is harder but not impossible to ask students to write short essays. A real benefit of polling large classes is the large N. You can hand out index cards, pose the essay question described above, and simply ask students to drop the cards in a box as they leave the classroom. (Again, explain that this is not a test and is anonymous). You don't need to look at all the cards; you can randomly sample them until the answers become repetitive.

 ○ In any size class, you can also use **multiple-choice questions**. The question above could be modified with choices, such as: (a) yes, because healthy environments do not vary like that, (b) maybe, because healthy environments probably should not vary like that, (c) no, because numbers of some birds naturally change a lot, and (d) no idea.

2. Step Two: Intervention (your teaching) — Use the Barange article in a class session, being sure to clearly bring out the idea that large inter-annual and inter-decadal changes in population density can be quite normal.

3. Step Three: Post-test — Decide on a way to assess your students' learning in regard to the misconception. This could be through a brief essay or multiple-choice question similar to the ones described above but specifically concerning information from the Barange article. Another way is to give students a new figure to analyze, such as the one below.
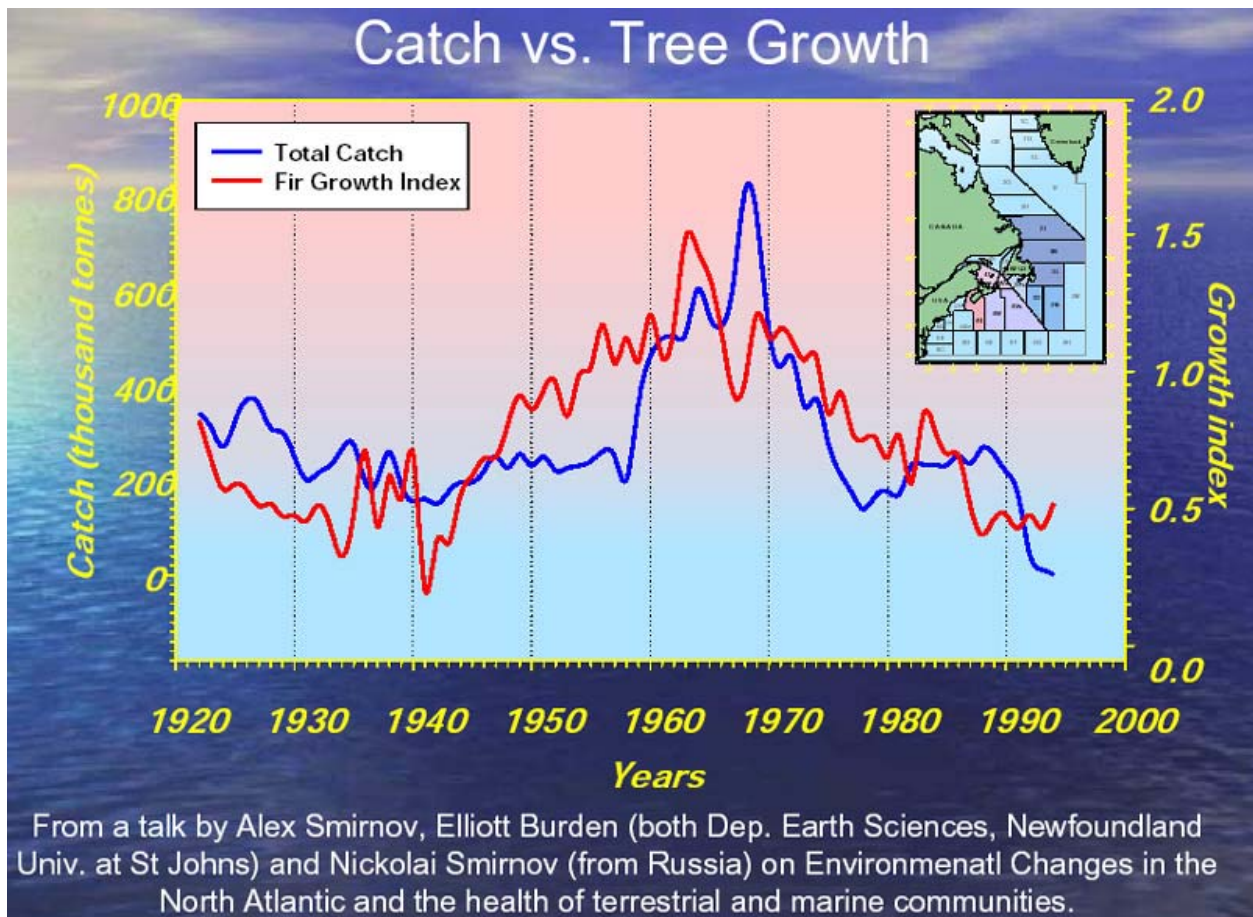

Figure by Smirnov et al. titled "Environmental Changes in the
North Atlantic and Health of Terrestrial and Marine
Communities"
(http://www.pml.ac.uk/globec/Publications/Presentations/CEF
AS_2002.pdf)

For this essay, students are asked to respond to a comment about this figure supposedly written by another student. The idea is to compare their response to an ecology expert's (e.g., you).

For homework give students this figure plus the paragraph below written by "a student" and ask them to write a one-page (300 words or so) analysis of the student's commentary. Along with your written description of the homework assignment, give a little background of the figure (such as the location, what a fir is, and that Growth Index indicates rate of tree growth). You may also need to explain a double-y type plot if students have not seen one before.

In the essays, you are looking for the kinds of comments you would expect from an ecologist, e.g., that the "student" 1) describes some of the patterns evident in the figure but misses others (and gives examples), 2) rightly observes the similar patterns in the fish and tree data, but does not suggest a likely reason (that they both are responding to some environmental factor such as weather), and 3) comments that given the large variation in both trees and fish over this time period, the statement that the decline from 1960 on "doesn't look so good" is unwarranted. Only excellent students would clearly describe each of these points.

If you have a large class, you can skim these essays — or look at a sample subset. You don't need to grade these, but give students a point or two for doing the work.

Student comment about Catch vs. Tree Growth Fig. (Smirnov et al.)

> *"Well one thing for sure is that the fish catch changes a lot from 1920 to 1990 — I mean just look at the numbers — it's all over the place and goes from 0 way up to more than 800 thousand tonnes. The tree growth changes an awful lot too, although I am not sure what growth index means. The fact that the fish and tree numbers seem to go up and down together may be just a coincidence, I don't know. Overall two things make we wonder about the health of the fish and the trees. The first is that the numbers for both go up and down so much. The second is that there is pretty much a steady decline in both from 1960 on — that doesn't look so good."*

4.Step Four: Reflection and Response — This is probably the hardest part of the whole process — once you have your "data," what you do with it.

- This kind of evaluation is a way for you to think more deeply about your students' learning — what you really want them to learn and what inhibits them from achieving this goal. When done well, classroom research like this can help make students' thinking more transparent — so that you can better design on ways to "get through" to them. The idea is to reflect on their learning as opposed to your teaching.

- Discussing your findings with a trusted and knowledgeable colleague may be the best thing to do, if you have such a colleague. You could also email one of the TIEE editors or post a question on Ecolog (ECOLOG-L@LISTSERV.UMD.EDU), a discussion forum used by ecology faculty).

- What you do in the class of course depends on what you have learned and also the time you can spend on follow-up. At a minimum, in the next class session you should report back to the students and give an overview of their writings — good points and ones many missed — and use this as a way to again discuss how ecologists think about change.

- If students made good progress between the pre and post-tests, say so and praise them. Don't expect a big change; modest growth as a result of one class session is a real achievement.

REFERENCES

D'Avanzo, C. 2003a. Application of research on learning to college teaching: ecological examples. *BioScience* 53: 1121-1128.

- D'Avanzo, C. 2003b. Research on learning: Potential for improving college science teaching. *Frontiers for Ecology and the Environment* 1: 533-540.

- Handelsman, J. et al. 2004. Scientific Teaching. *Science* 304: 521-522.

RESOURCES

General

Handelsman, J., D. Ebert-May, R. Beichner, P. Bruns, A. Chang, R. DeHaan, J. Gentile, S. Lauffer, J. Stewart, S. M. Tilghman, and W. B. Wood. 2004. Scientific Teaching, Science. 304: 521-522.

Action Research

Good overview and history of Action Research (http://www.infed.org/research/b-actres.htm)

- Overview with focus on curriculum development (http://informationr.net/ir/1-1/paper2.html)

- San Jose State University; brief overview and ideas for how to start (http://www.accessexcellence.org/21st/TL/AR/)

- University of Colorado site; has many articles
  (http://carbon.cudenver.edu/~mryder/itc/act_res.html)

Misconceptions

Five misconceptions about evolution
  (http://www.talkorigins.org/faqs/faq-misconceptions.html)

- Articles about biology misconceptions
  (http://tortoise.oise.utoronto.ca/~science/biomisc.htm)

- "Bioliteracy and teaching efficacy: what biologists can learn from physicists";
  from Cell Biology Education Journal, good overview that contains many links
  (http://www.cellbioed.org/articles/vol2no3/article.cfm?articleID=67)

NOTES TO FACULTY

The emphasis in TIEE Issues is use of figures and tables for discussion and other types of student-active teaching and learning. These notes will give you ideas about using the figures in this paper in your ecology class. The Student-Active Teaching table will introduce you to a variety of approaches you can use in your class to actively engage your students. To see an essay on leading good discussions, go to Guided Class Discussions.

Tips on How to Use This Issue

Focus on some aspect of this Issue (inter-decadal changes) and select a figure or discussion question dealing with this point. Then select a teaching approach. The table of Student-Active Approaches includes suggestions for **all class sizes**.

Although population change on different time scales, from interannual to interdecadal and longer, is an important aspect of ecology, it is often difficult to interest students in this topic. Barange discusses such variations in marine species in the context of sustainable fisheries. This practical focus may be an effective way to engage students in discussion about long term scale population shifts and their possible causes.

Barange presents remarkable data on temporal changes in marine species composition. Fig. 1 on anchovy abundance from the years 280-2000 off California shows very dramatic changes with time. One of the questions below prompts discussion about the nature of this evidence: why is it available and how do scientists collect it. One problem with this figure for students is that calculation of "abundance index" is not described (see note below).

Fig. 2 shows catch of some major commercial fisheries in the 20th century, again demonstrating dramatic (in this case inter-decadal) species shifts. Students may assume that over-fishing causes fluctuations like these; the idea that changes in atmospheric circulation (wind) can also result in large population shifts will bring home the idea that informed management of fisheries requires much better understanding of natural cycles.

Fig. 4 is even more dramatic. The species composition of catches in bottom trawls off the Alaskan coast shifted from largely invertebrates in the 1970s to finfish (salmon) in the 1980s. Barange calls this a "regime shift" and attributes it to inter-decadal changes in water temperature. Again, it is clear that we cannot manage our fisheries unless we better understand these ecosystem-level interactions.

The focus of Fig. 6 is overfishing. It is intriguing that both the Gulf of Thailand and Georges Bank show the same pattern: fish diversity increases during early years of the fishery and then dramatically decreases several decades later. Students from

the northeast may be familiar with the crash of the cod (and other) fisheries off the coasts of Maine, Nova Scotia, and Newfoundland. (However, as a marine ecologist I am surprised how few students know anything about the cod crash, which is on the scale of the buffalo decimation in the American west). Barange also makes the point that the Gulf of Thailand and Georges Bank has not returned to prior high diversity values, despite lower catches in the early 1990s.

Discussion questions:

1. Barange's main point is that development of sustainable fishing practices requires a better understanding of the causes for long-term scale changes in marine species. However, it appears to be quite difficult for people involved in fisheries (both fishermen and managers) to think about fisheries over the long term. What are some reasons for this?

2. Figure 1 shows changes in anchovy abundance off the coast of California from the years 280-2000. Recent fisheries data are from reported fish catches; that is clearly not the case here. What is the basis for the data in Figure 1? How are these data collected? How reliable would you think these data are? How might you assess their reliability?

3. Both Figures 2 and 4 show dramatic changes in fisheries catches over the scale of decades throughout the world. The author of this paper cites evidence that these marine population shifts are due to changes in atmospheric circulation (wind) and consequently in coastal water temperature. What does this mean in regard to our ability to effectively regulate marine fisheries?

4. In Figure 6, fish diversity in very different places in the world (the Gulf of Thailand and Georges Bank off the northeast U.S. coast) responded similarly to over-fishing. In both cases, fish diversity increased during early years of the fishery and then dramatically decreased several decades later (H is an index of diversity). Why might the diversity of fish caught at first increase as more fish were caught in the 1960s-1970s? Why did the diversity of caught fish then decrease?

5. The diversity data in Figure 6 are evidence of a phenomenon called "fishing down the food chain." Explain.

Additional activities:

As homework assignment students could figure out what "Abundance Index" means by finding and reading the referenced article by Baumgartner et al.

This would help them recognize the value of references and learn that they can work through uncertainties like this on their own.

- Students could go to a local seafood market, get lists of fish for sale, and investigate where they were likely caught and their trophic status. In locations with local fisheries, students could investigate the fishery directly. Both activities would make more real the idea of trophic levels.

RESOURCES

http://www.habitatmedia.org/EOEN/index.html
(Habitat Media: includes 2 minute trailer for the video "Empty Oceans, Empty Nets.")

- http://oceanworld.tamu.edu/students/fisheries/salmon_weather/Annsdoc.html
(Paper by Ann Gargett, Institute of Ocean Sciences, BC, called "Why would salmon care about the weather?" Includes 7 high quality figures you can use in class.)

- http://msnbc.msn.com/id/3077415/
(Review of Aug. 14, 2003 *Science* article documenting long term human effects on coral reefs.)

- http://www.fisheries.ubc.ca/members/dpauly/
(Includes downloads of articles on overfishing by D. Pauly.)

Presentations and PDFs by Manuel Barange

http://www.pml.ac.uk/globec/Publications/Presentations/presentation.htm

- Climate Change and Long Term Fish Fluctuations

Figure 1

Index of anchovy abundance from fish scales in sediment cores in the Santa Barbara Basin, California. Barange, M. 2003. *Frontiers in Ecology and the Environment* 4(1): 190-196
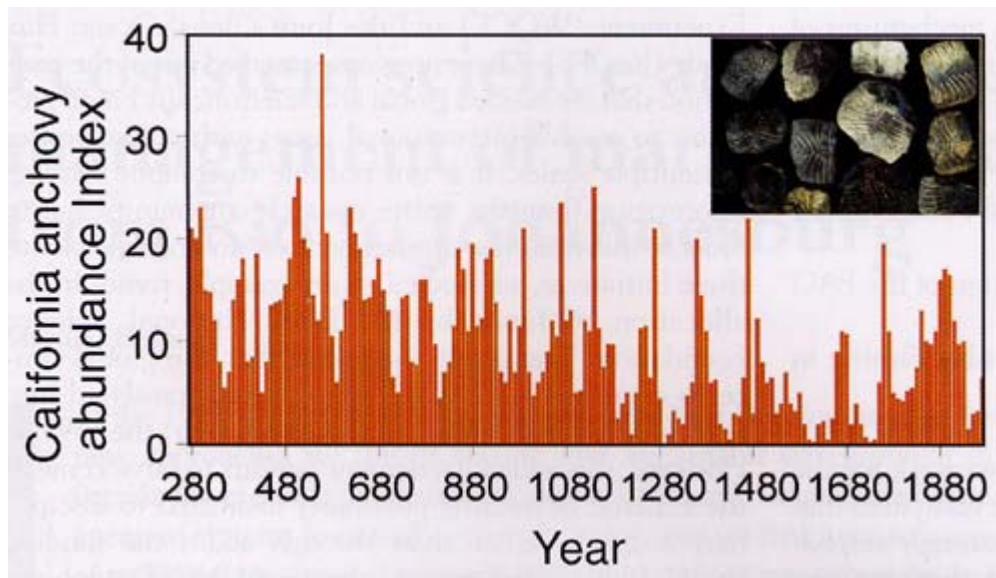
Figure 2

Catch trends in several major commercial species and dynamics of the zonal
Atmospheric Index (ACI), a measure of hemispheric air mass transport. Barange, M.
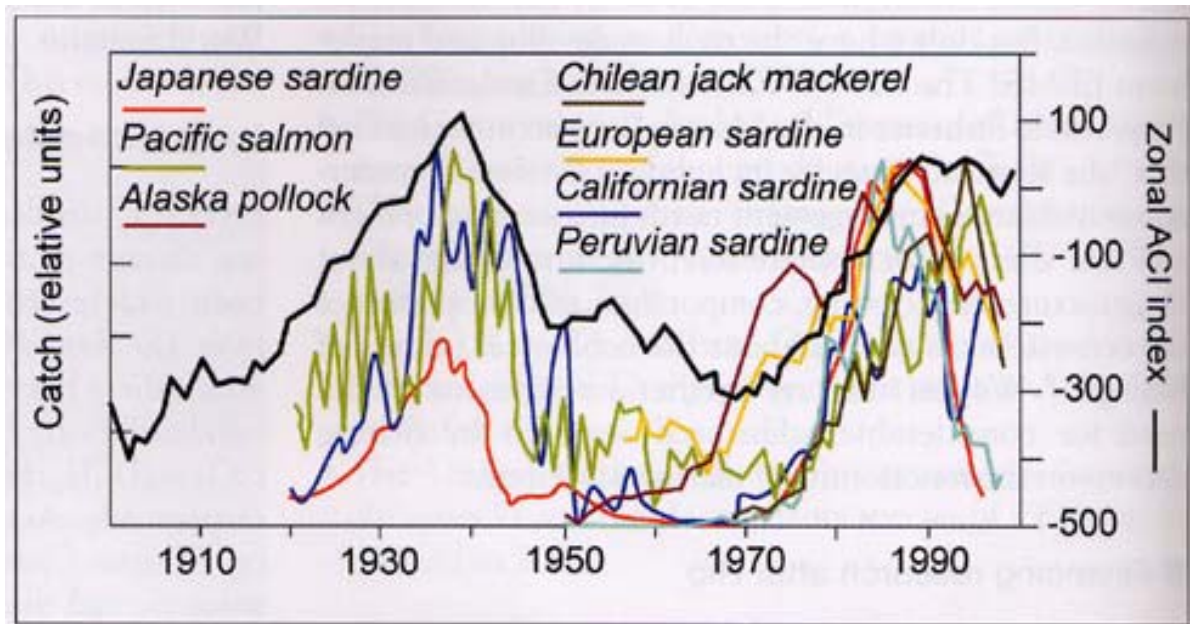2003. *Frontiers in Ecology and the Environment* 4(1): 190-196

Figure 4

Catches in species composition of catches in a small-mesh bottom trawl in Pavlof Bay, Alaska, through the regime shift of the mid-1970s. Barange, M. 2003. *Frontiers in Ecology and the Environment* 4(1): 190-196

Figure 6

Anthropogenic changes in marine ecosystem structure (top), trends in the Shannon-Wiener diversity index in the Gulf of Thailand and Georges Bank, and (bottom) mean trophic level versus catch in the Northwest Atlantic, 1950-1994. Barange, M. 2003. *Frontiers in Ecology and the Environment* 4(1): 190-196
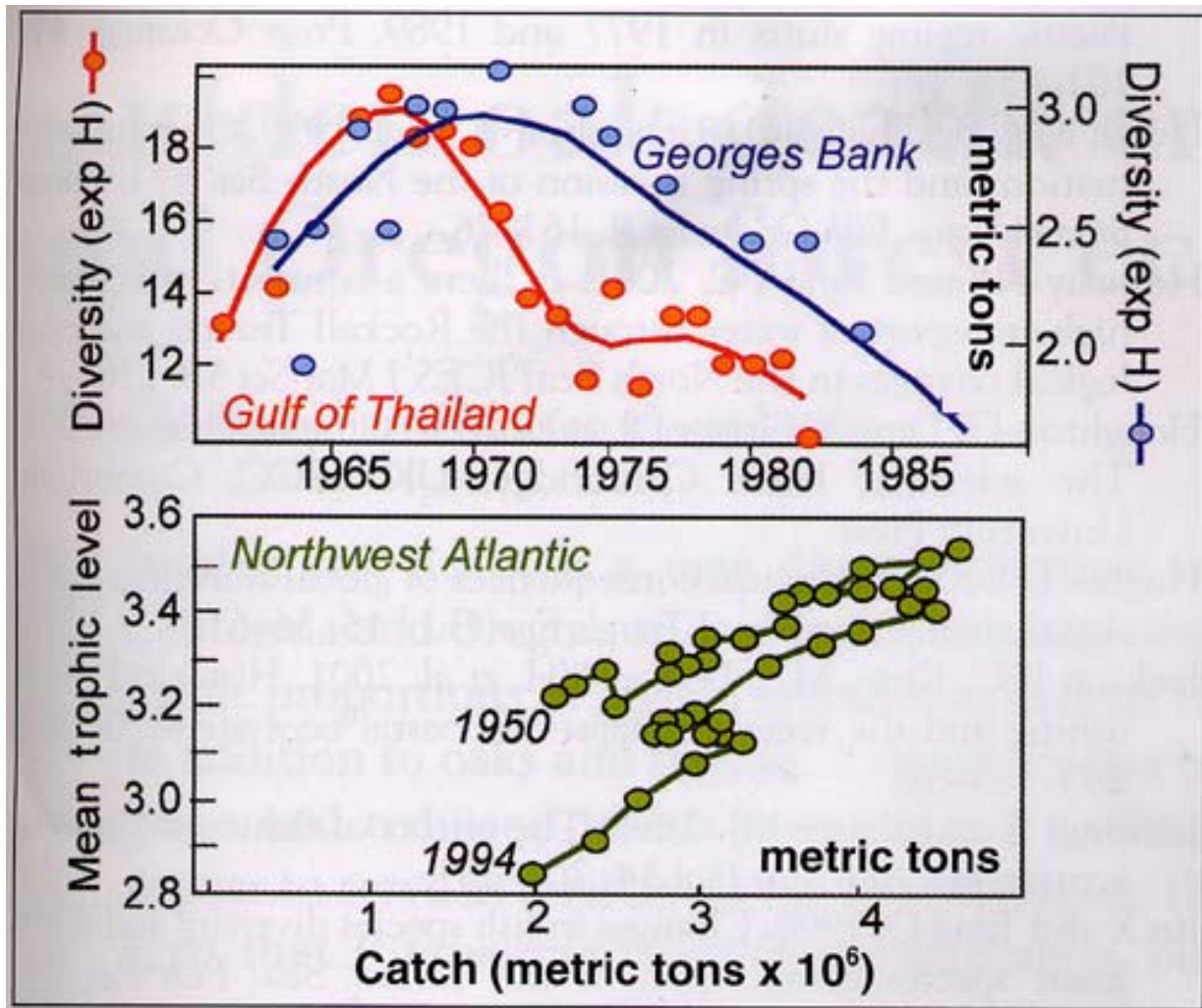
CREDITS AND DISCLAIMERS

CREDITS FOR THIS EXPERIMENT:

This submission was greatly improved by comments from anonymous reviewers.

GENERIC DISCLAIMER:

Lastly, we request that you return your students' and your comments on this activity to Susan Musante (tieesubmissions@esa.org), Managing Editor for TIEE, for posting at this site.