Why Do Fisheries Fail?
(Other than the fact that we’re greedy and we eat them all)

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Lecture notes, Fisheries Science

The Life and Death of a Fishery

Focus of Lecture
• The life and death of a Fishery
• Density dependence and the misleading myth of surplus production
• Causes of declines and failures: the picture worldwide
• Case study: collapse of the Peruvian anchoveta fishery

The Big Lie

Catch = Abundance*Catchability*Effort

C = NqE

Problem: q is not constant for all N
Density-Dependence in Fish Populations

- Also termed **compensation** or **depensation**, depending on relation between mortality and abundance
- Difficult to measure
- Probably a principal reason why fisheries fail
- Why is it so elusive?

Compensation and Surplus Production

- Quantification of compensatory responses usually relies on stock-recruitment (S-R) modeling
- Key characteristics of S-R models
- Progeny in excess of replacement = **surplus production**

Surplus Production

- Introduced into fisheries management lexicon over 60 years ago
- Premise: “excess” or “wastage” there for the taking by harvesters, power plants, etc.
- Baranov’s principle
Model mis-specification (essentially, a poor description of the fishery situation at hand) is a common problem and can result from poor understanding of the biology and ecology, as well as excessive reliance on standard models.

Some Ugly Rumors

- S-R Relationships are two dimensional (stocks and recruits tightly coupled)
Some Other Ugly Rumors

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- Nature works on averages
- Nature wastes
Some Other Ugly Rumors

- S/R Relationships are two dimensional
- Nature works on averages
- Nature wastes
- Anthropogenic mortality behaves like natural mortality

Some Ugly Truths

- S-R Relationships are not two dimensional
- Nature does not work on averages
- Nature does not waste
- Anthropogenic sources of mortality do not behave like natural mortality

Cushing (1977) defined **overfishing** as reducing the production potential of a fish population. He said this could occur in two ways:

a) **Growth overfishing**: excessive harvesting of younger individuals in a population, resulting in a lower mean sizes of caught fish, and hence lower biomass harvested. This would be an outcome detectable in the Yield-per-Recruit (YPR) model.

b) **Recruitment overfishing**: excessive harvesting of the reproductive spawning stock, such that reproduction and recruitment decline. This would not be detectable in a YPR approach, because YPR does not consider the relationship between the fishable stock and recruitment.
The global outlook today

World fisheries production has increased at an exponential pace over the last century or so, but most of us have not been aware of this. Here are some enlightening statistics.

- Global fisheries catches in the 19th century = 2 x 10^6 metric tons (MT) (McGoodwin 1990)
- Today the reported production is around 100 x 10^6 MT – 50-fold higher than in the mid 1800’s, and five-fold higher than in 1950
- World capture (wild) fisheries seem to be leveling off at around 90-95 x 10^6 MT
Thus, it appears we are at, or above, the maximum harvest level NOW…

- Big increase in *developing countries’* share of world catch:
  - 1960 – 35%
  - 1994 – 70%

- *Marine fisheries* have increased > 4-fold between 1950-2000’s, from $18.5 \times 10^6$ to around $75 \times 10^6$ MT

- *Bycatch* is increasing and its estimates are imprecise: for example in 1992 bycatch was estimated as $17.9—39.5 \times 10^6$ MT

  → Bycatch isn’t landed, so it has to be added to the world landings statistics. Doing so, we see that world catches are at least 130 million MT.

- *Food fish production* is increasing, particularly through aquaculture (esp. in China). Today nearly 1/3 of world food fish production is via aquaculture.

Some trends in food fish production (source: FAO):

- **1988**
  - *Japan* 27.0 T (39%)
  - *China* 15.8 T (23%)

- **1995**
  - *Japan* 27.0 T (34%)
  - *Tonga* 13.2 T (19%)

- **2000**
  - *Japan* 12.0 T (22%)
  - *Korea* 17.2 T (34%)

*Deutsch et al. 2004 (ms).*
Causes:

The Food and Agricultural Organization of the UN (FAO) reported in 1994 that 22% of the world’s fished stocks were overexploited or depleted (mild word for “collapsed”).

Another 44% are considered to be “max’ed out”

Source: FAO statistics, re-drawn in Botsford et al. 1997

The current picture:


Percentage of world capture fisheries that are lightly or moderately exploited

Percentage = -0.5802(year) + 1185.2

R² = 0.895

Based on SoFIA reports

Figure 16. Trend over time in biomass (thick, dark lines) and fishing effort (thin lines) from assessments of major resource species in the North Atlantic, including many of the commercially important, high trophic-level species that are the focus of this study. The horizontal axis spans the second half of the 20th Century. The general trend of decreasing biomass and increasing fishing effort is in line with the findings reported here. Based on data from the database assembled by R. Myers (http://fish.dal.ca/~myers/webome.html).
Not only are there problems in statistical estimation, which by now we are all aware of, but the gathering of primary data can be flawed as well. Causes:

- Inaccurate estimates of catch by observers
- False reporting by fishers
- Failure to include accurate data in estimates (leads to Type II statistical error)
- Failure to recognize uncertainties

(MSY requires deliberate over-fishing to establish $F_{MSY}$…doesn’t account for other factors that can render it invalid)

A recent attempt to estimate what really happened in the North Atlantic…part of the “Sea Around Us” Project

http://www.seaaroundus.org/flash/NorthAtlanticTrends.htm

Daniel Pauly →
Other drivers of overfishing:

1. Overcapitalization of fleets
   In the 1960s, ‘70s, and ‘80s, many nations invested heavily in building up their fishing fleet capacity. This included not only subsidies in the form of loans to fishers, but also other economic incentives to allow fishers to purchase equipment.
   But in order to pay off the loans they took out, fishers were forced to keep on fishing, even during times of low fish abundance.
   Overcapacity and subsidies tend to be perpetuated:
   Globally, the cost of fishing > income from harvest
   …therefore governments *must* subsidize the industry

2. Policy and politics
   • Policies can be set to stimulate particular fisheries
   • Very difficult to cut back (“ratchet effect”)
   • Political forces can be very strong, e.g., fishers’ lobbies or associations. Can be a strong voice at public hearings that set quotas. Can lobby individual legislators (just like anyone else!).

3. Economic drivers:
   • The perceived need to keep an economy growing, or to pull stagnant economies out of stagnation
   • Costs of fishing: purchasing equipment, fuel, paying off interest on loans…getting into debt…

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Has Fisheries Management Failed Us ??

- More failures than successes in both marine and freshwater fisheries.
- Many fisheries have "collapsed" from overexploitation.
- Little consideration of "risk" in communication and decision-making.
- Failure to utilize better precautionary management.
- Fishery collapses can be "invisible", hence are often only recognized *after* they have occurred: Scientists "burden of proof"
- Conflicting values between user groups: recreational vs. commercial interests.
- Biological and ecological risks difficult to quantify vs. economic risks.
- Few fishery recovery plans exist.
- Management objectives are often poorly defined.
- Failure to take multi-species, ecosystem approaches to management.
- Scientific methods are sometimes flawed.
- Disconnect between scientists, assessment biologists, and the public.
- Science vs. assessment: Conflicting management needs.
- Lack of data integration.
- Political/economic decisions can often outweigh scientific data.
4. Case study:
Collapse of the Peruvian anchoveta fishery

A fishery for the Peruvian anchoveta, *Engraulis ringens*, sprang up in the 1950s. These anchovies were used to produce fish meal, and the market had opened up after a collapse of the California sardine industry.

The fishery prospered for about a dozen years, reaching over $12 \times 10^6$ MT/year (recall that this is around 10% of what we think is the global production limits to fishing – all in one fishery).

El Niño effects – cause production to $\downarrow$
In the mid-1960s an El Niño event caused a dip in catches and biologists became concerned.

Later on in the ’60s, government fisheries scientists were sufficiently worried to call in international experts for a stock assessment, to see what the MSY might be.

“As usual, the experts could not agree, and produced numerous estimates of sustainable yield ranging from 7 million to 10 million tons per year.”

- Hilborn and Walters (1992)

Meanwhile, Peru was becoming ever more dependent on the fishery for its national income.

By the time of the fisheries collapse in 1972, it was earning Peru one-third of its foreign exchange.

With such economic pressures,

“…the fishery continued to catch more than what all but the most optimistic of biologists felt was sustainable.” (H & W ’92)

The next major El Niño event occurred in 1972-73 - caused two things that precipitated the dramatic collapse of the fishery:

1. Warm waters concentrated stocks inshore → made them highly vulnerable to fishery (fishermen thought it was just a great year)

2. Poor production → juveniles starved → poor year-class formation

Although the stock began to recover in the late 1970s, a third El Niño hit in 1982-83, causing the fishery to “bottom out.”
MSY management failed because of the interaction of climate, fishing pressure, and the lack of understanding of the stock variability.

References.

Peruvian Anchoveta Fishery, 1950-2005

Data source: FAO Fisheries Statistics