Fisheries Oceanography: Fisheries Management

K.E. Selph, OCN 621, Spring 2011
Compensating mechanisms for Fishing Mortality leading to lower Natural Mortality (Density-dependent regulation of fish stocks):
-- growth increases (less competition for resources)
-- recruitment increases (less competition, more survivorship, less predation)
Fisheries as Predation

- From a fisherman’s perspective, natural mortality is “wasted.”
- Fisheries compete with natural losses by catching fish before they are eaten or die of old age.
- Fishing changes the size and age structure of the stocks, thereby reducing the “resiliency” of stock to environmental fluctuations.
Fisheries Management Approaches

- Goals to Balance:
  - Socio-economic -- maximize "benefit" to society, i.e., optimize physical yield without jeopardizing ability of stock to reproduce
  - Biological -- protect genetic diversity, population integrity, habitat
  - Economic -- optimize economic gain; efficiency
What is a suitable (sustainable) amount of Fishing Mortality?

MSY = Maximum Sustainable Yield

Zone 1: under-fished (catch good, cost low, profits high)
Zone 2: MSY (catch more, costs more, profit good)
Zone 3: over-fished (catch less, costs high, profit negative)
Zone 4: optimum yield (catch vs. cost best, max. profit)
CPUE

Catch Per Unit Effort

- We would like to know how many fish are out there, but all we know is Catch/Fishing Effort
- This model assumes that the system is in *equilibrium*

- If this ratio is declining, we are over-fishing
- World CPUE in decline since 1980s

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Fig. 15.7 (a) CPUE (catch per unit effort) for yellowfin tuna in the eastern tropical Pacific, 1934–1965. (b) Line is converted to show catch vs. effort, a parabola. (a,b after Schaefer 1967.)
Equilibrium Assumption

- Equilibrium (=steady state) assumption:
  if true, then it reflects excess fish stock that can be removed (surplus production) and not affect the underlying population dynamics

- Big problem: catch can increase for other reasons
  1) if gear used is more efficient or
  2) range fished is bigger or
  3) fish population changes its distribution/behavior

If this is the case, then the steady state assumption violated
Single Species Management

Usual method, but, too narrowly focused, as fishing for one species can affect other exploited fish

- Discards/bycatch usually discarded dead
  - dead mammals, reptiles, etc. in gill nets
  - example: Shrimp trawling: 125 - 830% bycatch excess over shrimp and bycatch is snapper
Top 10 Fish of 2006 (30% of fisheries production)

- Anchoveta: 7.0 million tonnes
- Alaska pollock: 2.9 million tonnes
- Skipjack tuna: 2.5 million tonnes
- Atlantic herring: 2.2 million tonnes
- Blue whiting: 2.0 million tonnes
- Chub mackerel: 2.0 million tonnes
- Chilean jack mackerel: 1.8 million tonnes
- Japanese anchovy: 1.7 million tonnes
- Largehead hairtail: 1.6 million tonnes
- Yellowfin tuna: 1.1 million tonnes

Commmercially harvested marine fish

- Anchovy, herring and sardines: all small pelagic fish, represent by far the largest fisheries in the world
- Live in highly productive areas (upwelling regions & off Japan & Argentina)
- Unstable populations (time scale of 10 - 30 yrs):
  - collapse of fisheries is a function of over-fishing & natural environmental change

Chavez et al. 2003 (Science, 299:217): theory on regime shift in the Pacific, favoring sardines or anchovies, alternately – has to do with large scale changes in ocean temperatures (25 year cycle)
Peruvian anchoveta: #1
*Engraulis ringens*

- **Vital statistics**
  - Max size: 20 cm
  - Max reported age: 4 years; time to maturity: 1 year
  - Depth range found: 3 - 80 m
  - Recruits: ~5 months old+ (mainly used in fishmeal)
  - Ecosystem role: eats phytoplankton & zooplankton, preyed upon by man and seabirds
  - Spawn near shore; Behavior enabling high success of fishery? Schooling

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Fig. 1. Distribution of anchoveta stocks along the Eastern Coast of South America. Based on FAO (1981), Itohka (1971), Chirichigno (1974), Brandt (1963) and MARPE (1973).
History

mid-1950  Fishery begins and rapidly expands (fish meal for livestock)
1964  Catch = 8.7 MMT (17% of world catch); Schaefer (FAO study) estimates MSY at 9.5 MMT, but guano birds and other predators took 2 MMT leaving 7.5 MMT for man
1965  El Nino - low reproductive success, schools dispersed, bird predators gone (Cormorants)
1970  Harvest 12.5 MMT; 50% greater than MSY; fishing efficient (<40 days to reach quota), ~95% of fish caught before reaching reproductive age (overcapitalization)
1971-2  Bad recruitment years (El Nino, too): collapse of fishery, seabirds died too
1986-96 Recovery
1997-98 El Nino collapse, recovering now
2004 10.7 MMT; 2005 10.2 MMT, 2006-2017 MMT (FAO stats)
Overcapitalization

- When fishing is good, more boats are built, people employed
- When yield declines, it is hard to cut back
- Subsidies are paid to fishermen
- Fishing continues, even though not commercially viable
- Exacerbates over-fishing problems, but not a surprising consequence of economic pressures

Map & Graph: **Economy**: Top 10 Fishing subsidies

<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
<th>Amount</th>
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<tbody>
<tr>
<td>Japan</td>
<td>$2935.30 million</td>
<td>(1997)</td>
</tr>
<tr>
<td>United States</td>
<td>$667.90 million</td>
<td>(1997)</td>
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<tr>
<td>Canada</td>
<td>$768.55 million</td>
<td>(1997)</td>
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<td>Russia</td>
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<td>Spain</td>
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<td>(1997)</td>
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<tr>
<td>Norway</td>
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<td>(1997)</td>
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<tr>
<td>France</td>
<td>$108.00 million</td>
<td>(1997)</td>
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<tr>
<td>United Kingdom</td>
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<td>(1997)</td>
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<tr>
<td>Weighted Average</td>
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**Definition:** Subsidies to the commercial fishing sector

**Units:** US Dollars (Millions)

Notes: Data on itemized fishing subsidies were combined from Annex 1 of the WWF report. Where estimated ranges were given, the mid-point of the range was used. In calculating the ESI, the base-10 logarithm of this variable was used.

Peruvian Anchovy

- Effects of El Niño
  - anchovy feeds on phytoplankton/zooplankton
  - during El Nino, no upwelling, fewer phytoplankton, fewer zooplankton, fewer fish

- Other ecosystem effects of fishing
  - Depleting anchovy stocks results in reduced populations of fish-eating sea birds

**Figure 1.**—Commercial catch of anchoveta by calendar years, and population of guano birds from censuses at indicated dates.

Schaefer 1970
Alaska Pollock
*Theragra chalcogramma*

- max size/age: ~3 feet/17 yrs,
- **Age at 1st maturity:** 3 - 5.5 yr
- benthopelagic, brackish/marine waters, usually found from ~300 - 1000 m depth
- Feeds on fish and crustaceans (esp. krill), *TL* = 2.8+
- Prey for Stellar Sea Lion (Alaska) & other marine mammals, seabirds, bigger fish
- Fished with midwater trawl nets having little by-catch
Alaska Pollock Fishery

- Currently well managed, but not managed as a multispecies fishery
- Efforts are going into ecosystem modeling, including physical forcing, to better predict all fisheries in region

GOA Ecosystem
Each species is a node (dots) and each predator-prey interaction is a link (line).

Four hubs are cod, pollock, halibut and arrowtooth flounder.

S. Gaichas, NOAA, www.afsc.noaa.gov
Multispecies Management

Example: New England Groundfish Fisheries
15 species managed
implemented in 1986, but did not include catch or fishing effort restrictions
1994: Amended management plan to address these problems
Application to Anchovy Fishery

Fig. 4. Flow diagram of the Central Chile marine ecosystem (33°–38°S), 1992. Q: consumption. Flows are expressed in t km⁻² per year.

World Capture Fisheries Production

Source: FAO Fisheries – The State of World Fisheries and Aquaculture, 2008 PART 1: World review of fisheries and aquaculture, p. 6
Most recent data (released March 2, 2009): World Capture and Aquaculture Production

Source: FAO Fisheries – The State of World Fisheries and Aquaculture, 2008 PART 1: World review of fisheries and aquaculture, p. 4
Aqua and Mariculture: Promise and Threat

Promises:
- Potential new fisheries – rapidly growing sector of many economies (especially in Asia)
- Relieve pressure on “wild” fish stocks
- Not as dependent on environmental fluctuations as “wild” stocks

Threats:
- Use of other fish as food for aquacultured species (fish meal)
- Habitat degradation
- Genetic “dilution” and disease outbreaks
~50% of world stocks fully exploited
Previously over-exploited, depleted or recovering stocks have been stable for 10-15 years
Fish Catch: what does it include?

**Catches**: Fish caught by the fisher, as well as BY-CATCH

**By-catch**: Fish caught unintentionally (because of fishing gear) -- most usually discarded (not legal size, not valuable for selling/eating)

**Landings**: Fish that are caught and brought ashore (= capture stats)
Global MSY: Maximum Sustainable Yield

- Best estimate = 100-135 MMT (all species, all oceans)
- Most recent compilation of world fisheries:
  - 92 MMT (Present Harvest)
  - + Discards (by-catch), ~30% of total catch
  - + IUU (Illegal, unreported or unregulated catch),

  All together, ~130 MMT

- So, Global MSY reached already
• Because top, or higher, trophic levels vanishing due to over-fishing, fishermen are exploiting lower trophic levels

• Note that dip in marine curve in 60’s was due to extremely large catches of Peruvian anchoveteta with low trophic level of 2.2 (TL = 2 is that of primary herbivores)

The mean trophic level of the species groups reported in Food and Agricultural Organization global fisheries statistics declined from 1950 to 1994. This reflects a gradual transition in landings from long-lived, high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish. This effect, also found to be occurring in inland fisheries, is most pronounced in the Northern Hemisphere. Fishing down food webs (that is, at lower trophic levels) leads at first to increasing catches, then to a phase transition associated with stagnating or declining catches. These results indicate that present exploitation patterns are unsustainable.
Fishing down the food web

**Figure 17. Fishing down: what it actually means.**
Fishing down marine food webs means that the fisheries (blue arrow), having at first removed the larger fishes at the top of various food chains, must target fishes lower and lower down, and end up targeting very small fishes and plankton, including jellyfish.
Fishing down the food web?

Branch et al., 2010, Nature 468: 431-435

- Idea recently challenged:

  Concluded that we are really overfishing at all levels in most places, not just at the top level (see web page handout)
One step in the right direction: Marine Protected Areas (MPA)

- Can “seed” fished areas
- Success dependant upon mobility of fish and size of MPA
- Wouldn’t help wide-roaming fish like tuna or other pelagic fish, but would help coastal-based fisheries
  (unless they stop at “oases” in the open ocean and these are included)
- Also preserves habitat in case of destructive fishing (i.e., trawling which destroys bottom populations)
- Currently, 1300 marine reserves globally, but only 0.01% of world’s ocean areas are closed to fishing: need to have significantly more protection to make a global difference
Also...

- Also handed out “Box 15.1” from Miller’s Biological Oceanography textbook – which goes through the calculation of expected Fisheries Production based on Primary Production.