Fisheries Oceanography: Fisheries Management

K.E. Selph, OCN 621, Spring 2011

Theory of Fisheries Management

- Unfished, “virgin” stock

- Fished stock

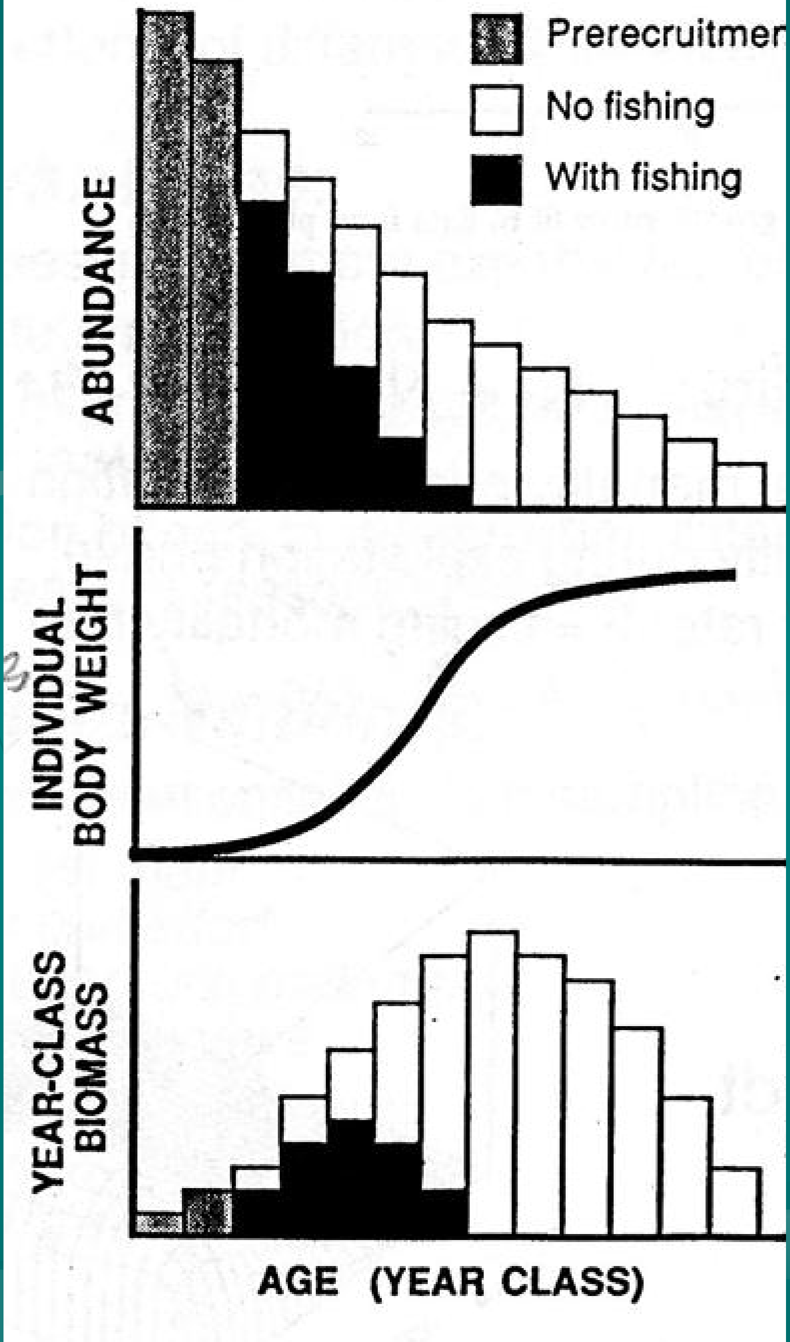
Compensating mechanisms for Fishing Mortality leading to lower Natural Mortality (Density-dependent regulation of fish stocks):

-- 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.

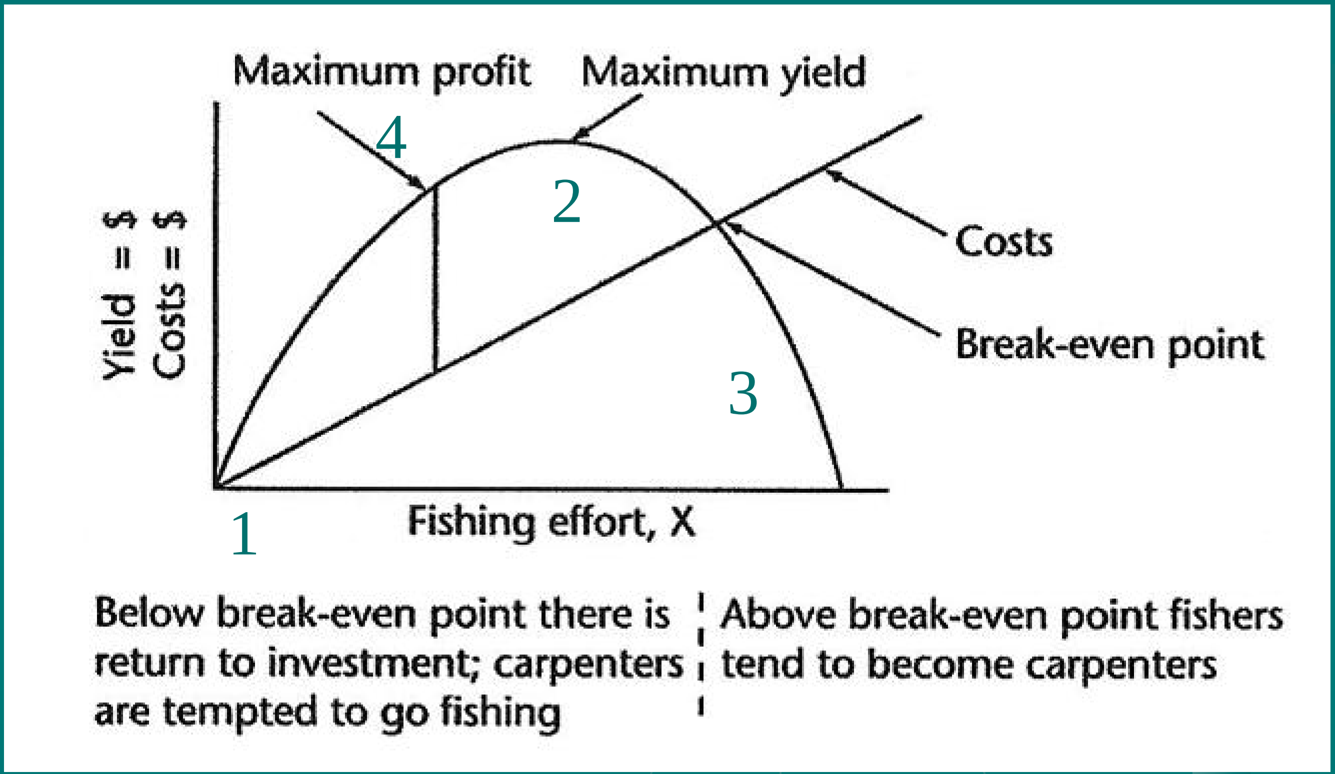


Fisheries Management Approaches

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

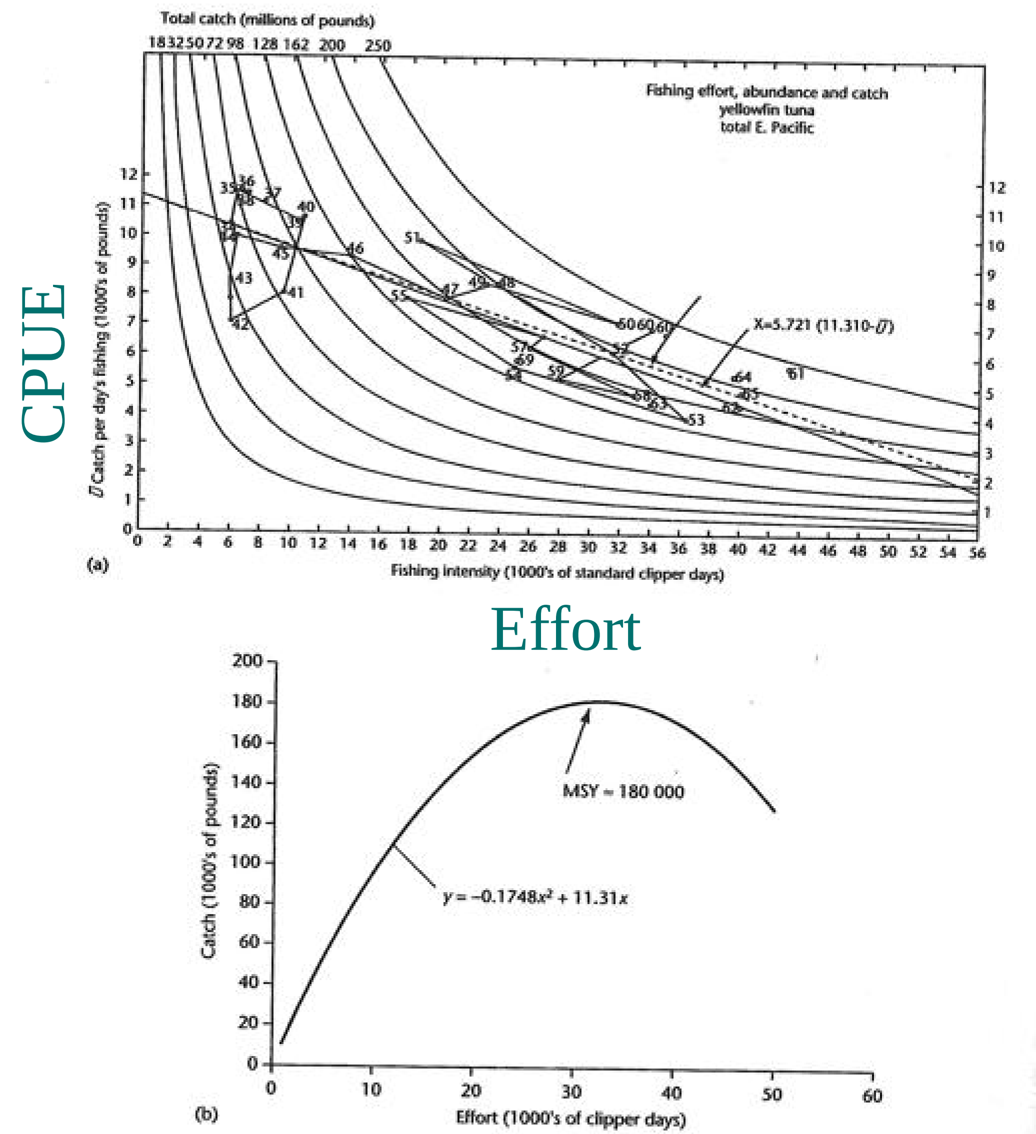


Fig. 15.7 (a) CPUE (catch per unit effort) for yellowfin tuna in the eastern tropical Pacific, 1934–1965. (b) Line in (a) converted to show catch vs. effort, a parabola. (a,b after Schaefer 1967.)

Miller 2004

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

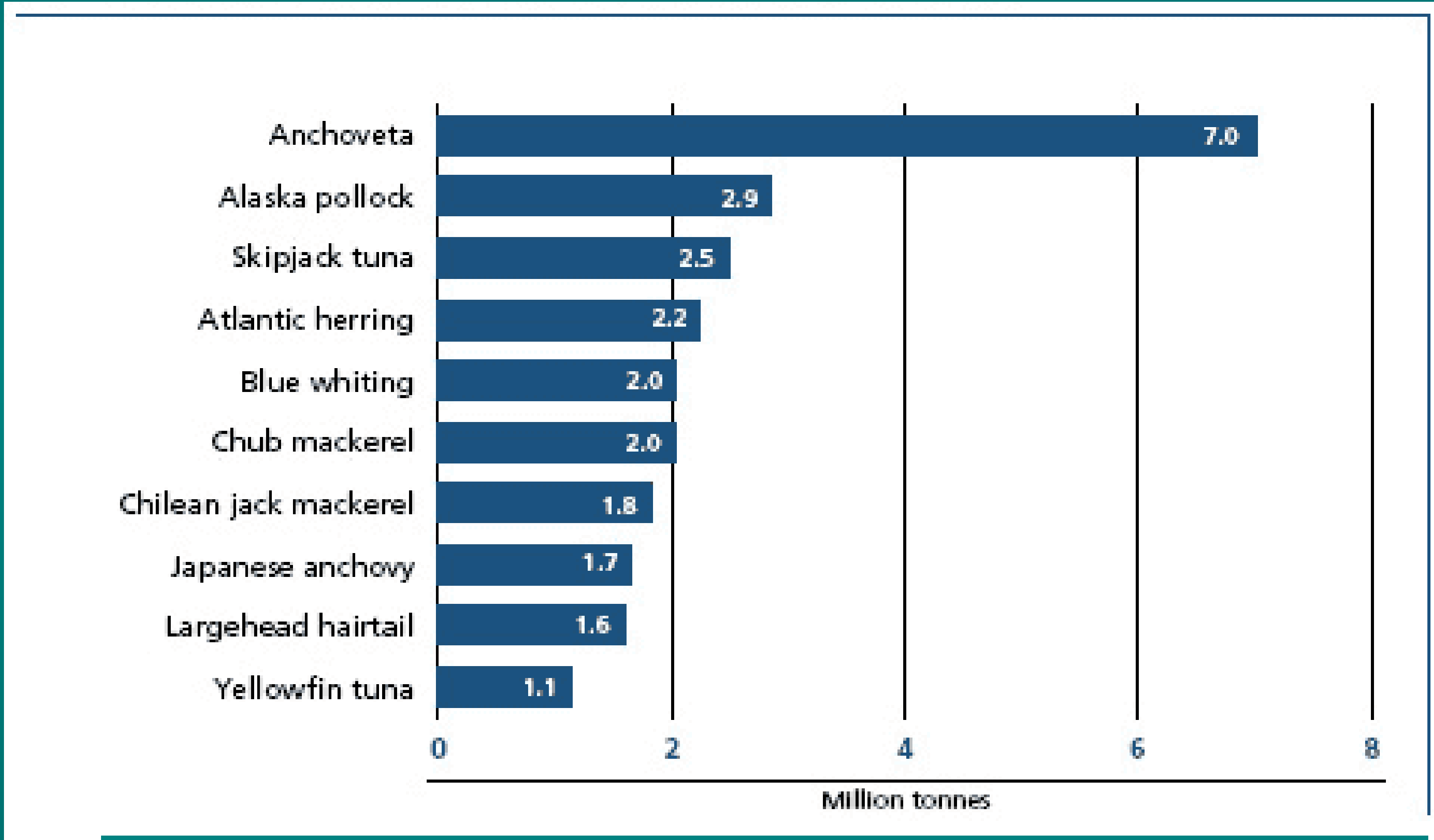
Single Species Management

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% by catch excess over shrimp and bycatch is snapper

NOAA Photo library

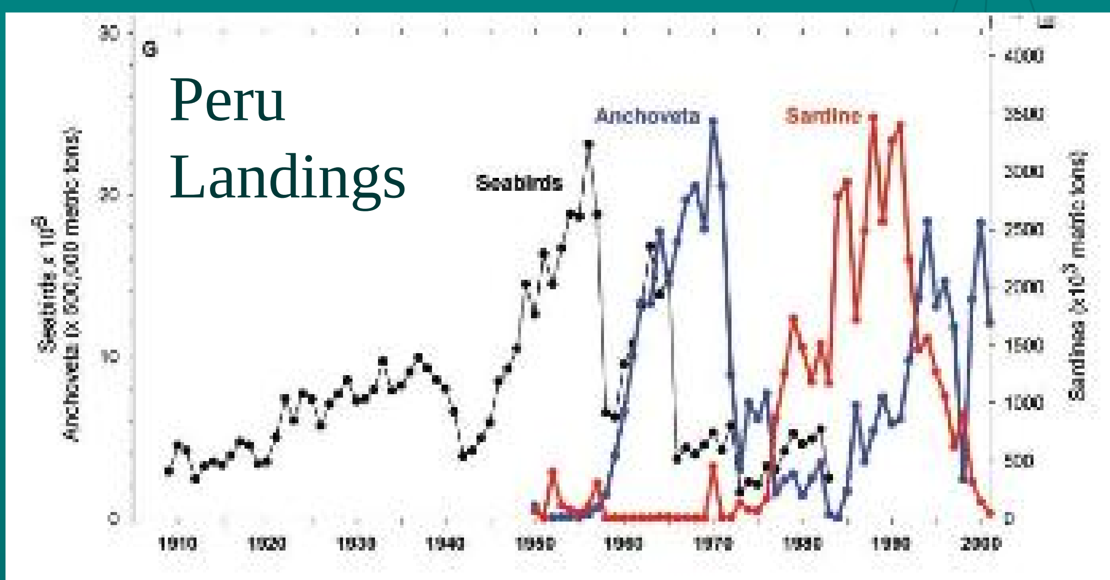
Top 10 Fish of 2006
(30% of fisheries production)



Source: FAQ Fisheries ***– The State of World Fisheries and Aquaculture, 2008 PART 1:World review of fisheries and aquaculture, p. 12***

Commercially 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

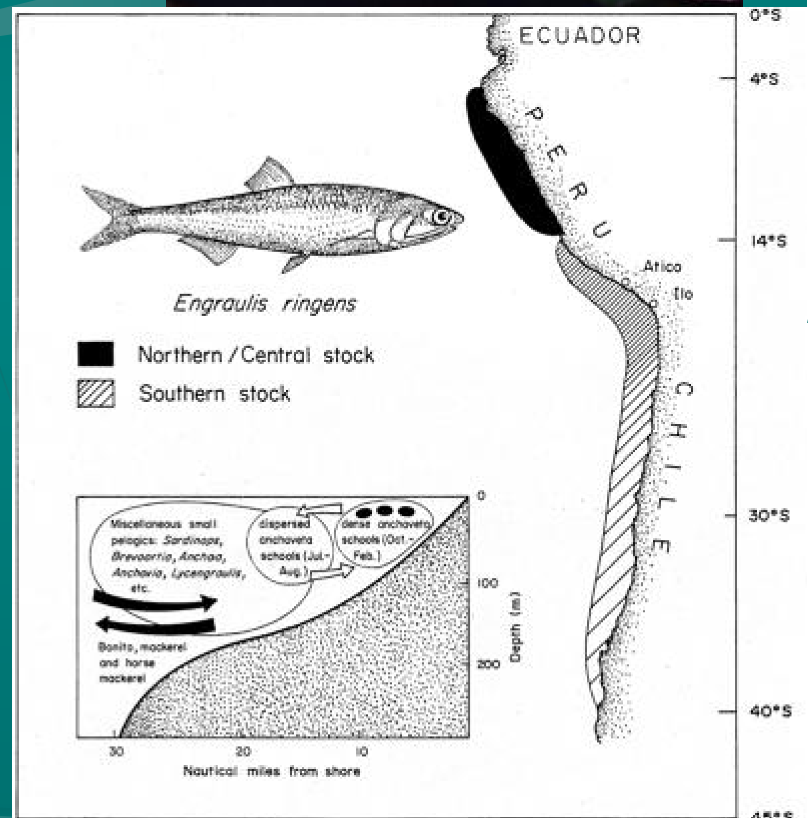


Fig. 1. Distribution of anchoveta stocks along the Eastern Coast of South America. Based on FAO (1981), Jordan (1971), Chirichigno (1974), Brandhorst (1963) and IMARPE (1973).

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)

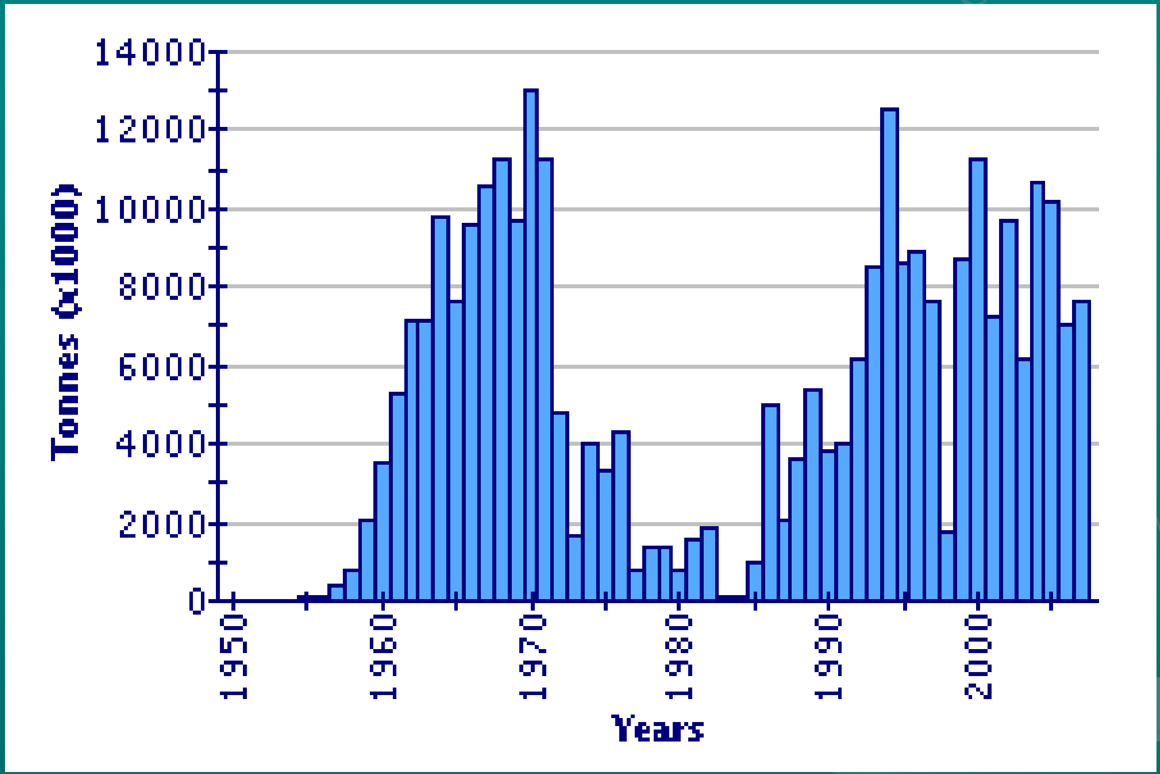
1970 Harvest 12.5 MMT; 50% greater than MSY; fishing efficient (<40 days to reach quota), ~95% of fish caught before reaching reproductive age (*overcapitalization*)

1971-2 Bad recruitment years (El Nino, too): collapse of fishery, seabirds died too

1986-96 Recovery

1997-98 El Nino collapse, recovering now

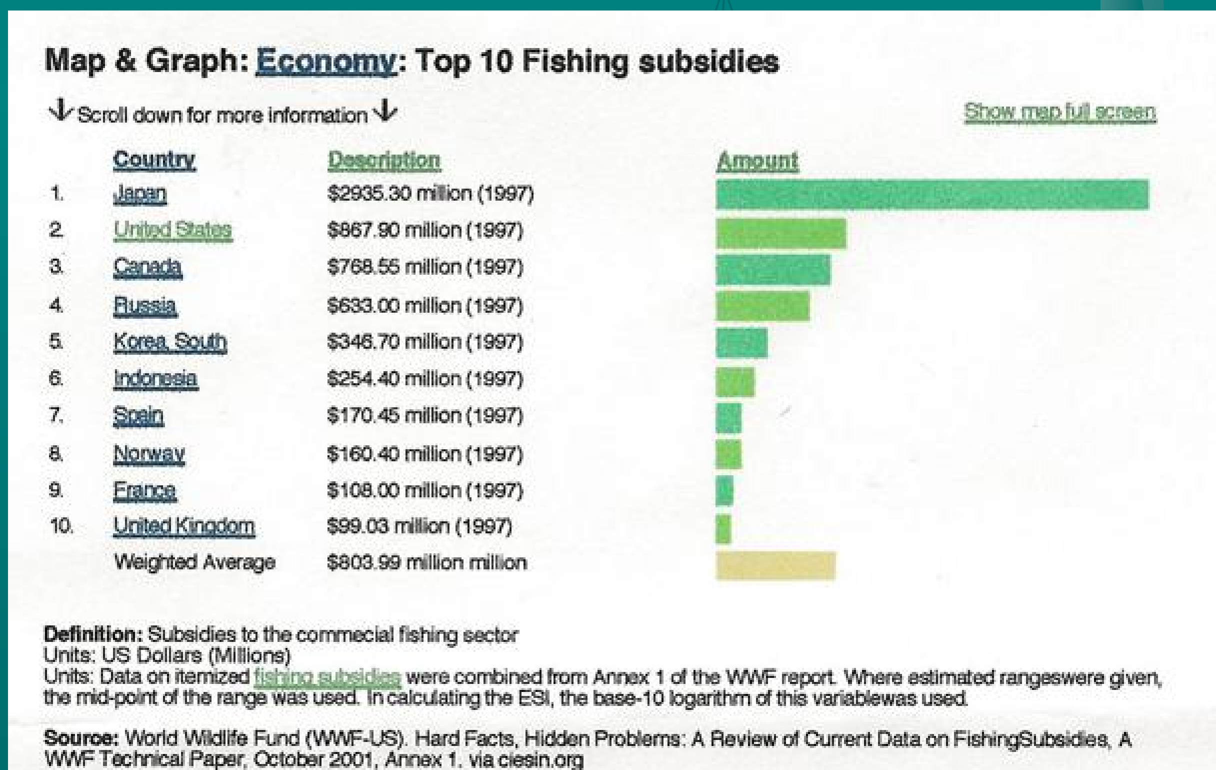
2004 10.7 MMT; 2005 10.2 MMT, 2006-201 7 MMT (FAO stats)



Overcapitalization

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

http://www.nationmaster.com



Map & Graph: Economy: Top 10 Fishing subsidies

Scroll down for more information

Show map full screen

	Country	Description	Amount
1.	Japan	$2935.30 million (1997)	
2.	United States	$867.90 million (1997)	
3.	Canada	$768.55 million (1997)	
4.	Russia	$633.00 million (1997)	
5.	Korea, South	$346.70 million (1997)	
6.	Indonesia	$254.40 million (1997)	
7.	Spain	$170.45 million (1997)	
8.	Norway	$160.40 million (1997)	
9.	France	$108.00 million (1997)	
10.	United Kingdom	$99.03 million (1997)	
	Weighted Average	$803.99 million million	

Definition: Subsidies to the commercial fishing sector
Units: US Dollars (Millions)
Units: Data on itemized fishing subsidies were combined from Annex 1 of the WWF report. Where estimated rangeswere given, the mid-point of the range was used. In calculating the ESI, the base-10 logarithm of this variablewas used.

Source: World Wildlife Fund (WWF-US). Hard Facts, Hidden Problems: A Review of Current Data on FishingSubsidies, A WWF Technical Paper, October 2001, Annex 1. via ciesin.org

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

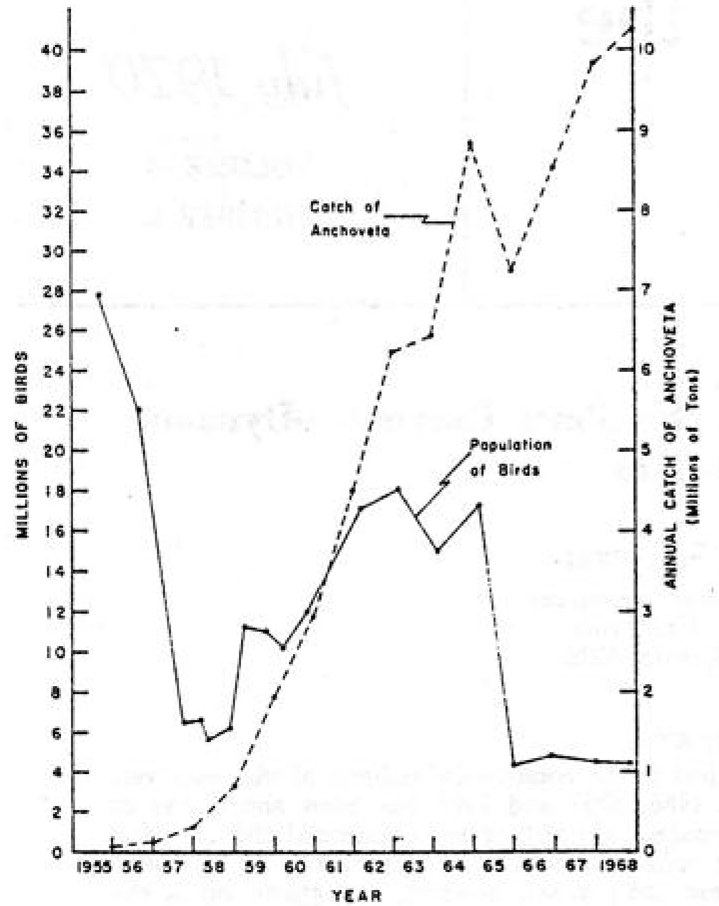


FIGURE 1.—Commercial catch of anchoveta by calendar years, and population of guano birds from censuses at indicated dates.

Schaefer 1970

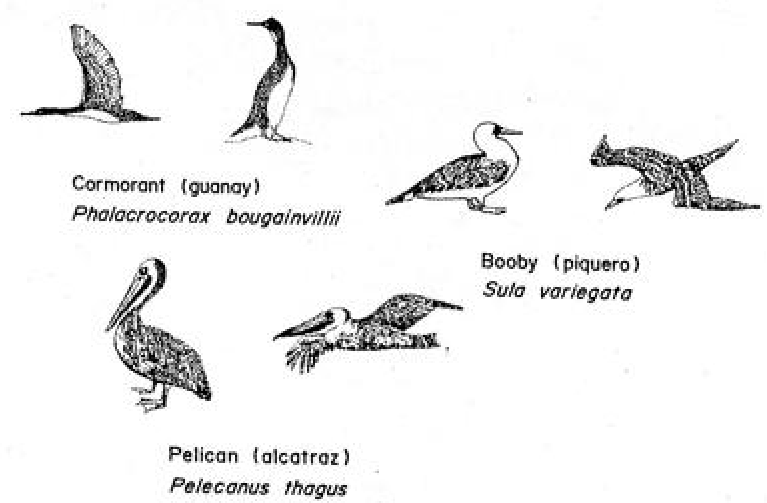
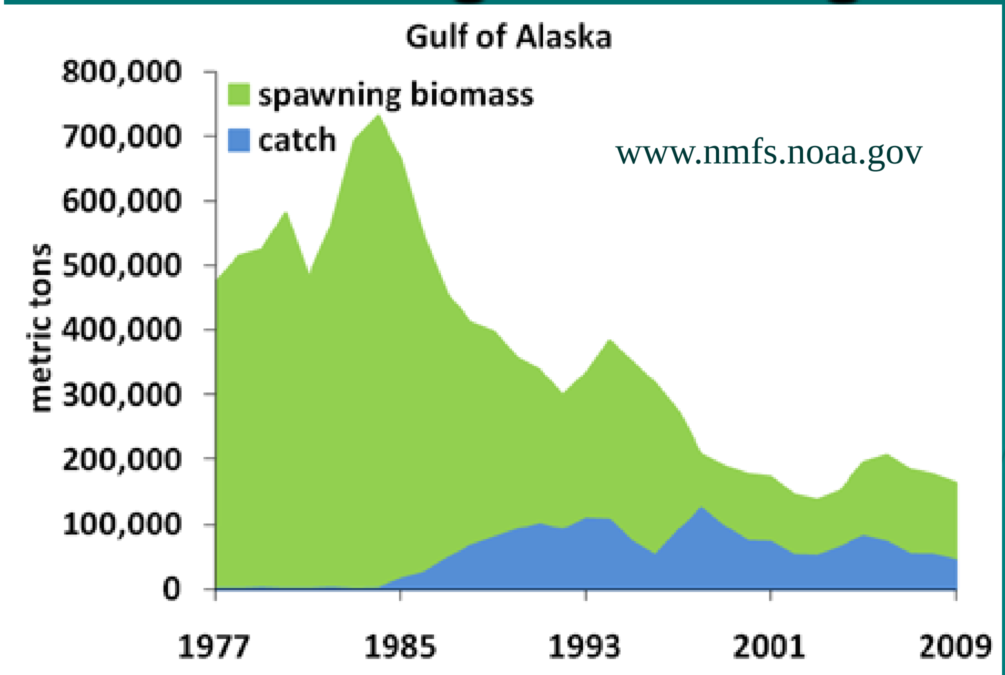
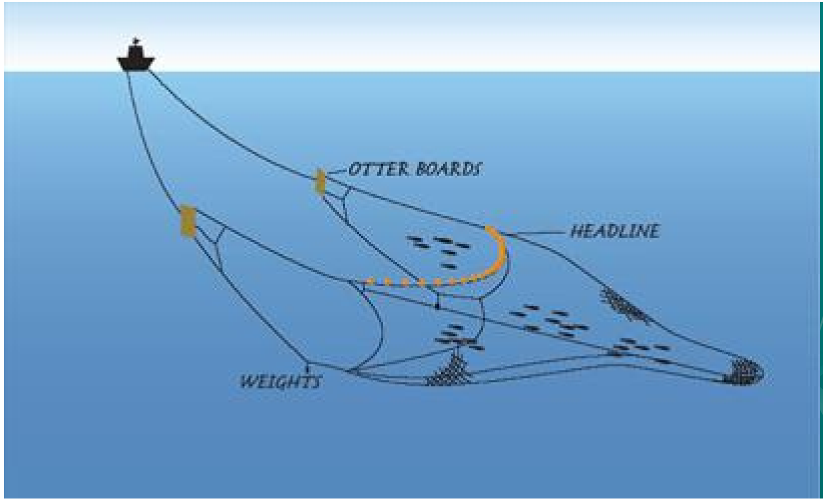


Fig. 1. The three main species of fish-eating birds of the Peruvian upwelling ecosystem (Spanish names in brackets).

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

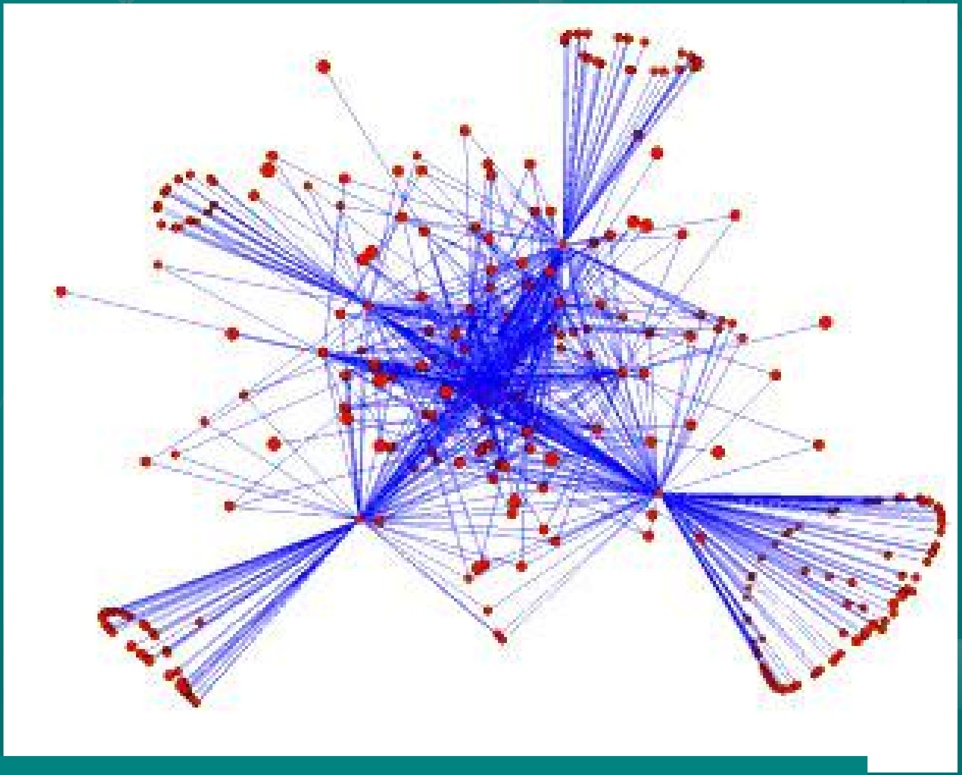
Alaska Pollock Fishery

- 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.

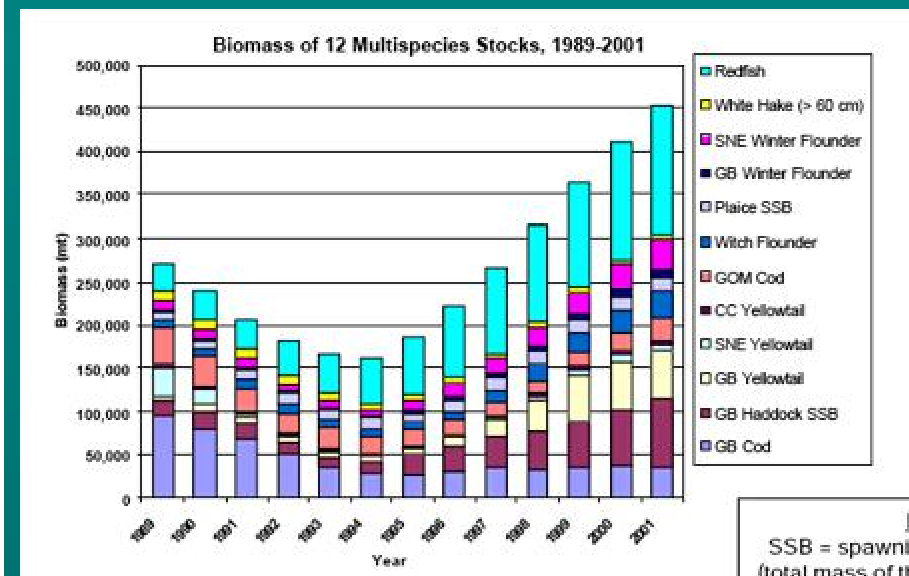


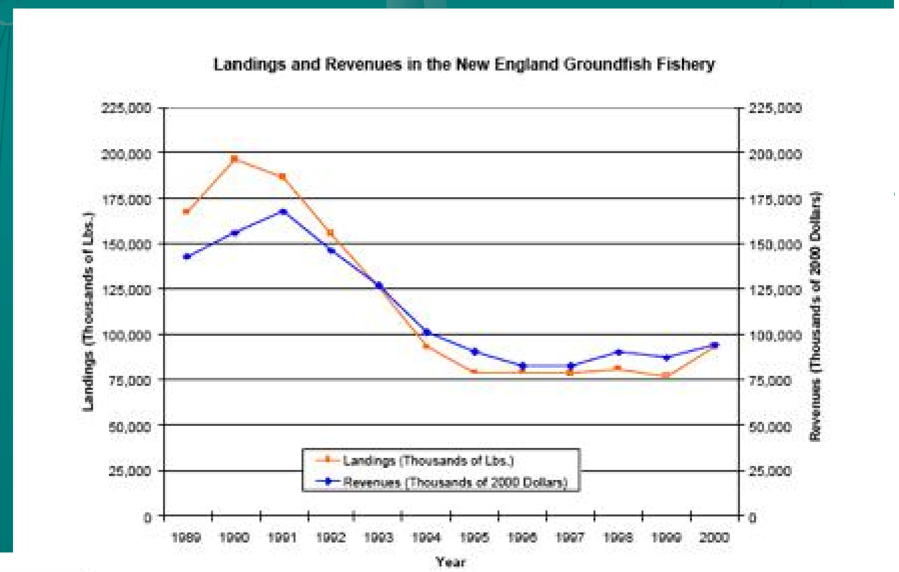
S. Gaichas, NOAA, www.afsc.noaa.gov

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





Key:
SSB = spawning stock biomass (total mass of the stock capable of spawning)
GB = Georges Bank
GOM = Gulf of Maine
SNE = Southern New England
CC = Cape Cod

www.nefmc.org

Application to Anchovy Fishery

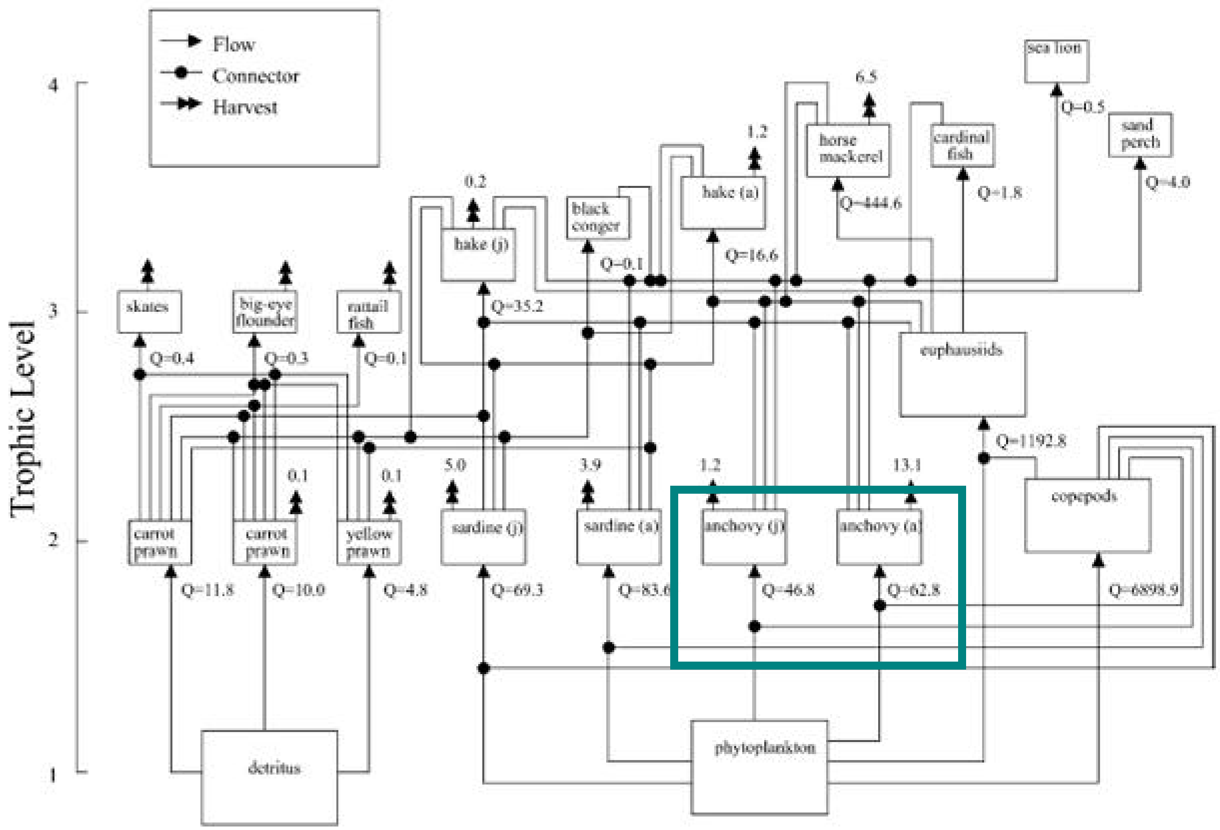
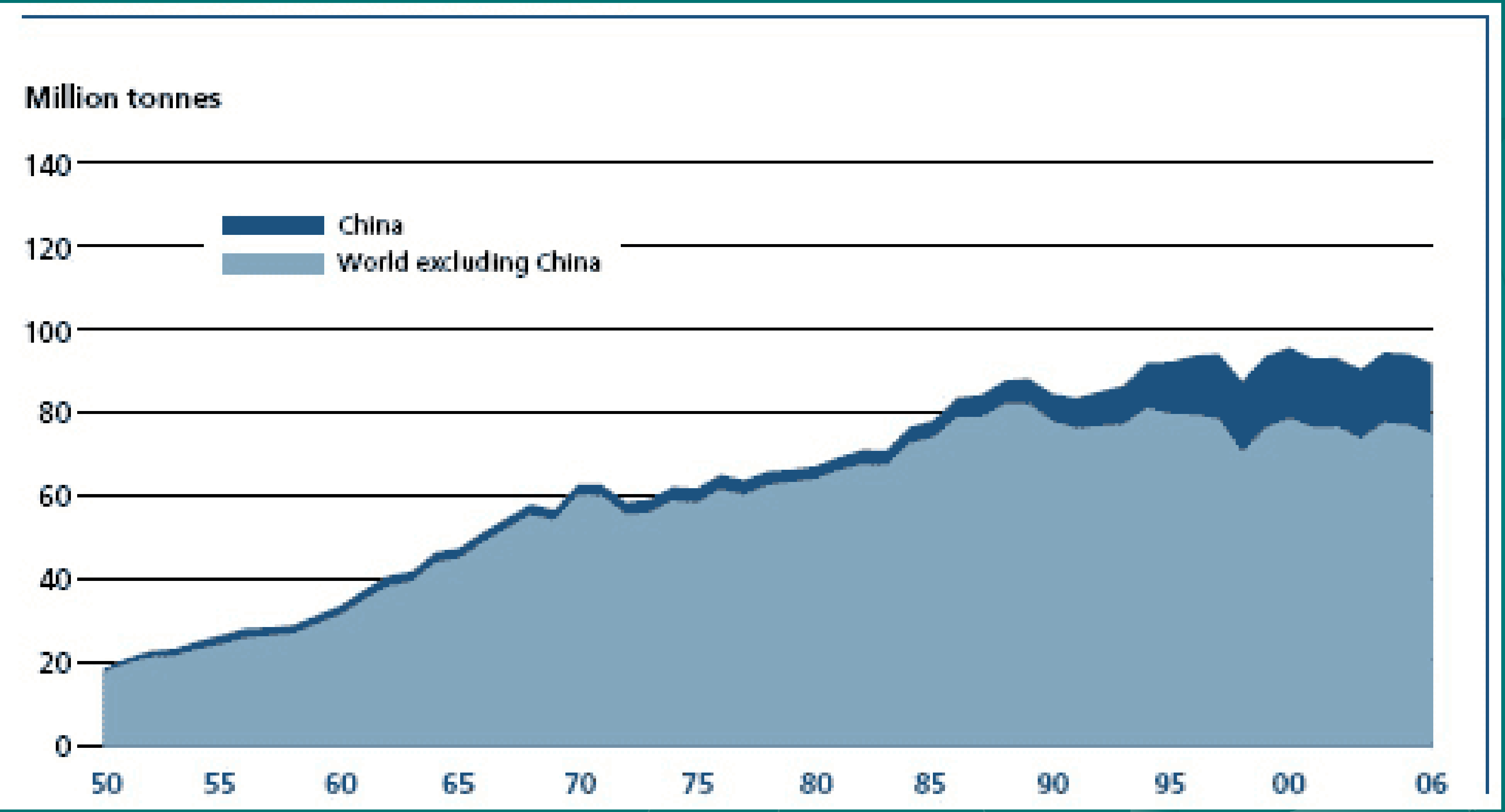


Fig. 4. Flow diagram of the Central Chile marine ecosystem (33°–39°S), 1992. Q: consumption. Flows are expressed in t km^{-2} per year.

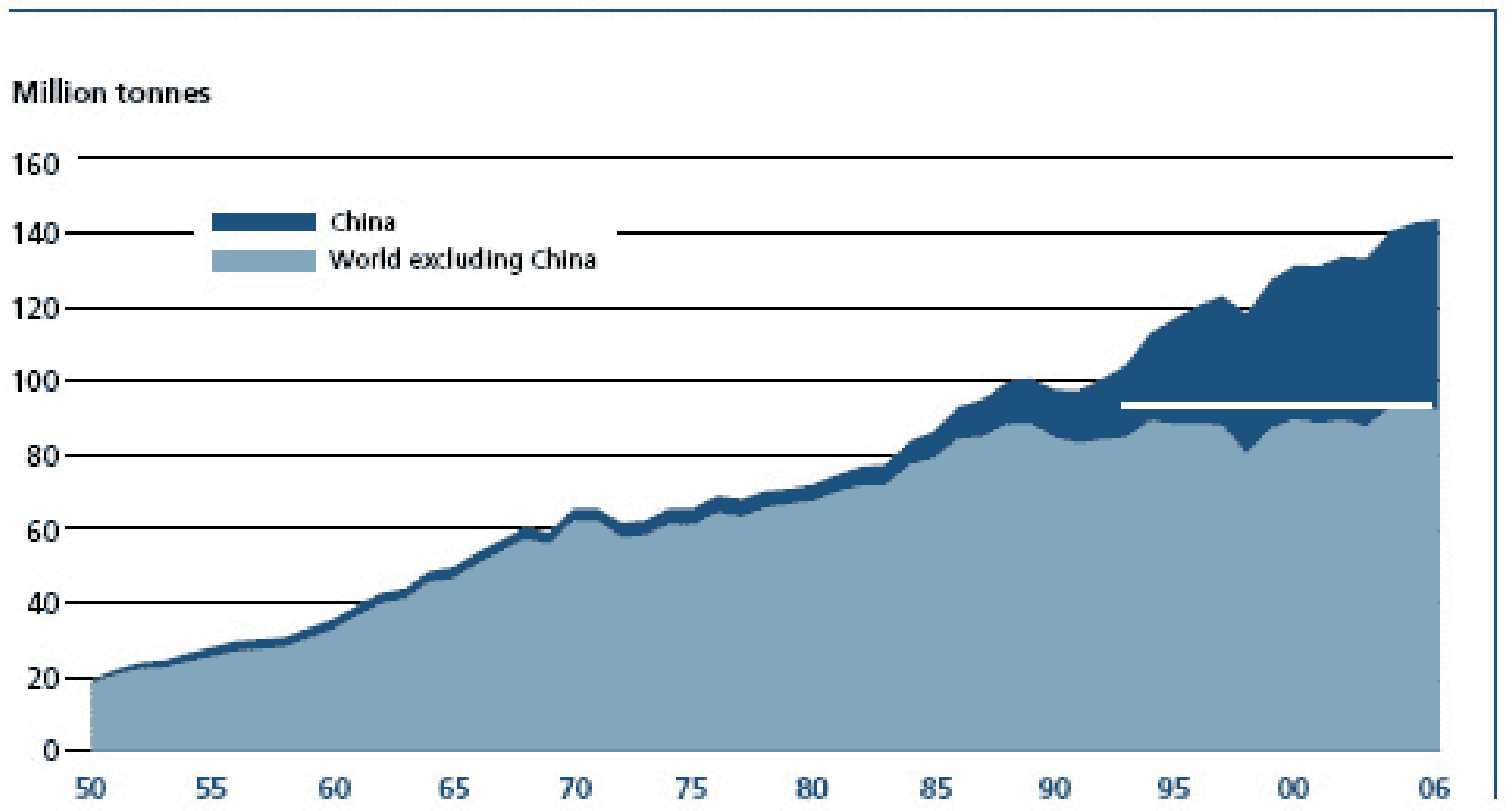
Niera et al. 2004. Comparative analysis of trophic structure of commercial fishery species off Central Chile in 1992 and 1998. Ecol. Model. 172:233-248

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

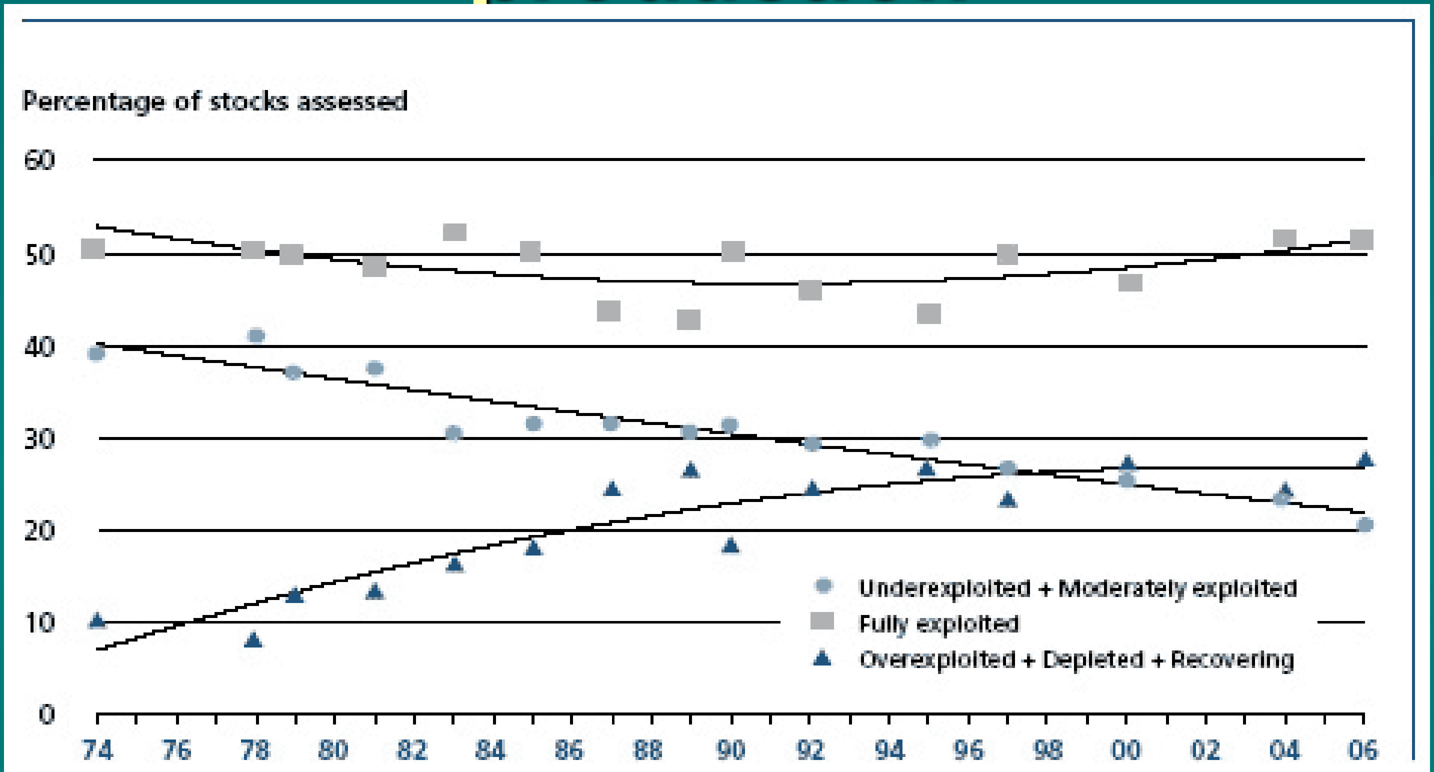


Source: FAO Fisheries ***– The State of World Fisheries and Aquaculture, 2008 PART 1:World review of fisheries and aquaculture, p. 4***

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

Current state of world fisheries production



Source: FAO Fisheries ***– The State of World Fisheries and Aquaculture, 2008***
PART 1:World review of fisheries and aquaculture, p. 33

~50% of world stocks fully exploited
Previously over-exploited, depleted or recovering stocks have been stable for 10-15 years

Global Fish Catch

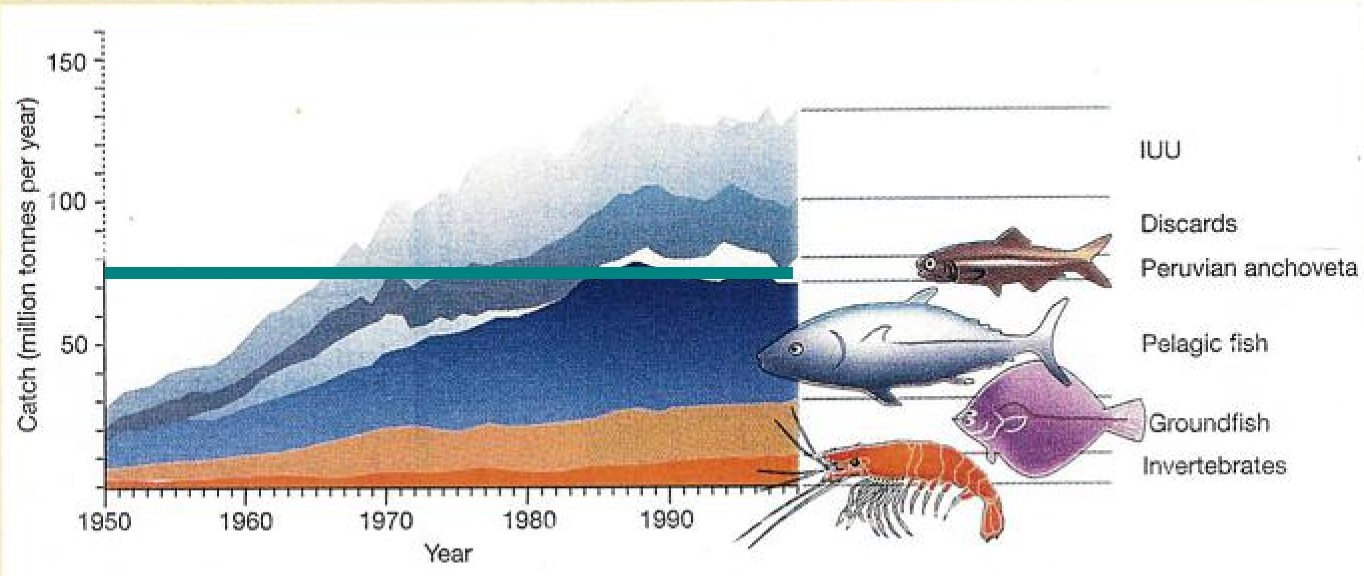


Figure 1 Estimated global fish landings 1950–1999. Figures for invertebrates, groundfish, pelagic fish and Peruvian anchoveta are from FAO catch statistics, with adjustment for over-reporting from China[26]. Fish caught but then discarded were not included in the FAO landings; data relate to the early 1990s[83] were made proportional to the FAO landings for other periods. Other illegal, unreported or unregulated (IUU) catches[65] were estimated by identifying, for each 5-year block, the dominant jurisdiction and gear use (and hence incentive for IUU)[84]; reported catches were then raised by the percentage of IUU in major fisheries for each 5-year block. The resulting estimates of IUU are very tentative (note dotted *y*-axis), and we consider that complementing landings statistics with more reliable estimates of discards and IUU is crucial for a transition to ecosystem-based management.

Pauly et al. 2002

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 anchovetta with low trophic level of 2.2 (TL = 2 is that of primary herbivores)

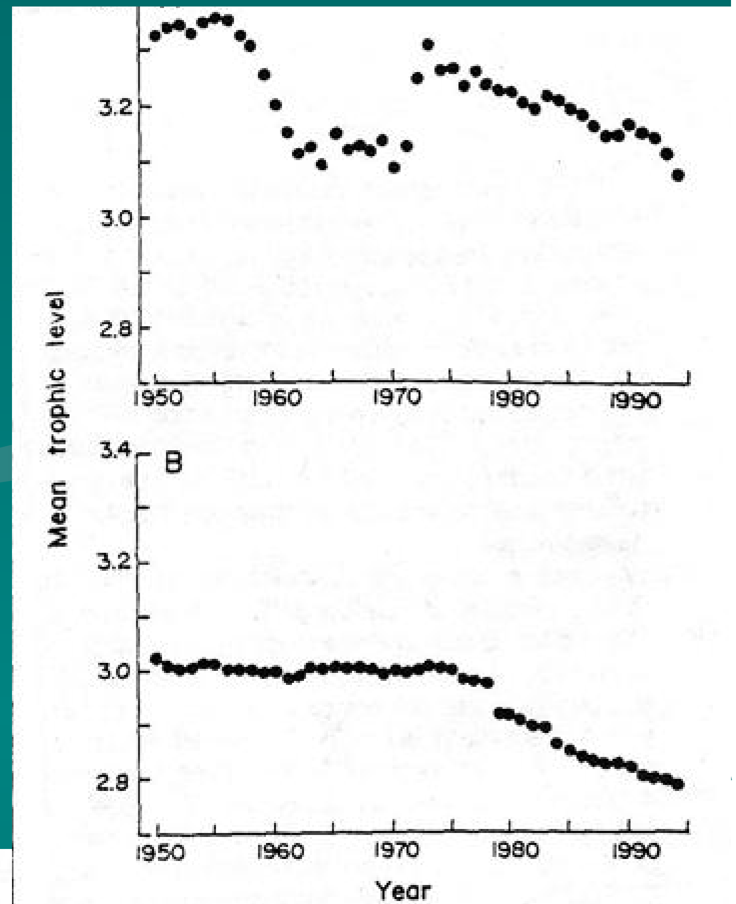


Fig. 1. Global trends of mean trophic level of fisheries landings, 1950 to 1994. (**A**) Marine areas; (**B**) inland areas.

1998

Fishing Down Marine Food Webs

Daniel Pauly,* Villy Christensen, Johanne Dalsgaard
Rainer Froese, Francisco Torres Jr.

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

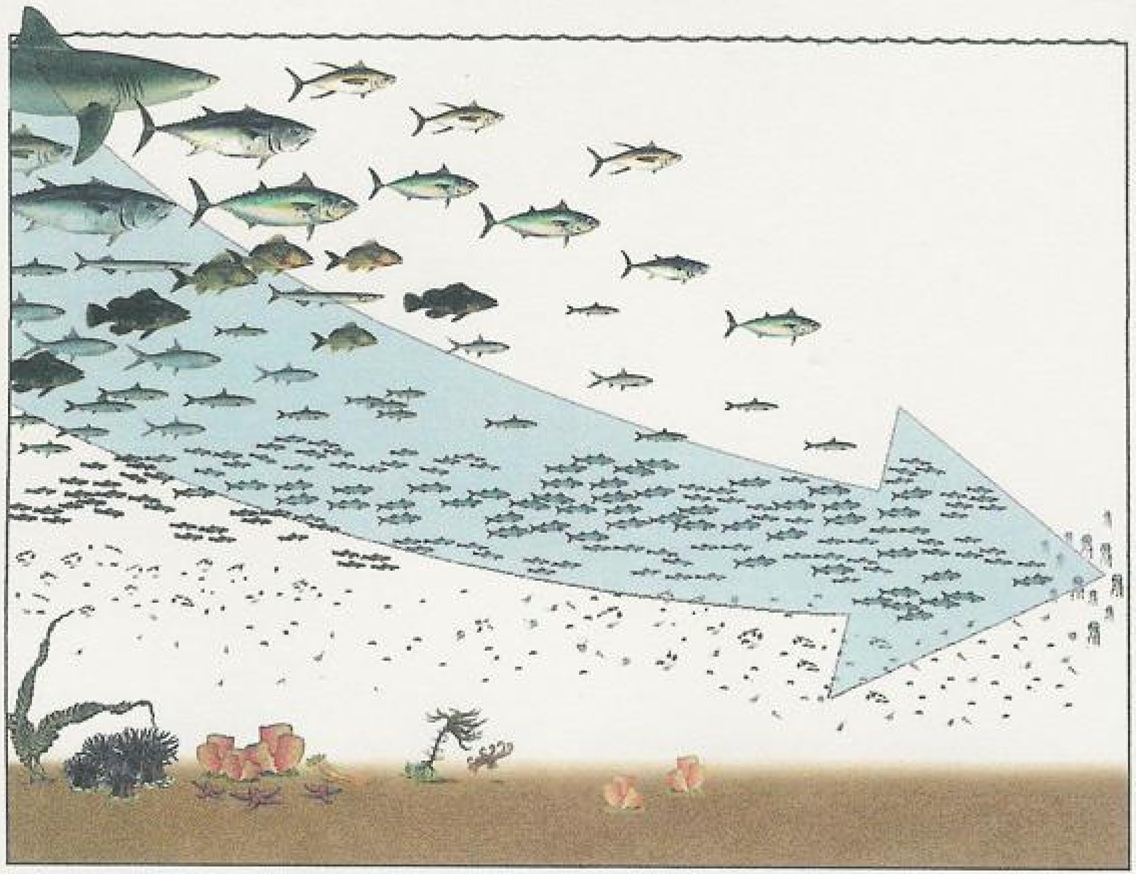
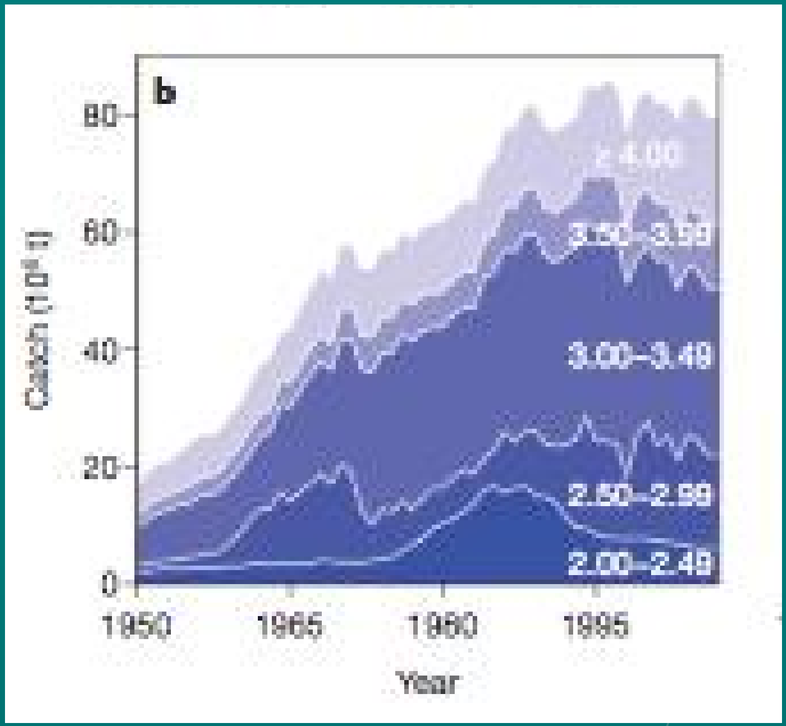


FIGURE 17. FISHING DOWN: WHAT IT ACTUALLY MEANS.
Fishing down marine food webs means that the fisheries (blue arrow), having at first removed the larger fishes at the top of various food chains, must target fishes lower and lower down, and end up targeting very small fishes and plankton, including jellyfish.

Pauly & Maclean 2003

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)

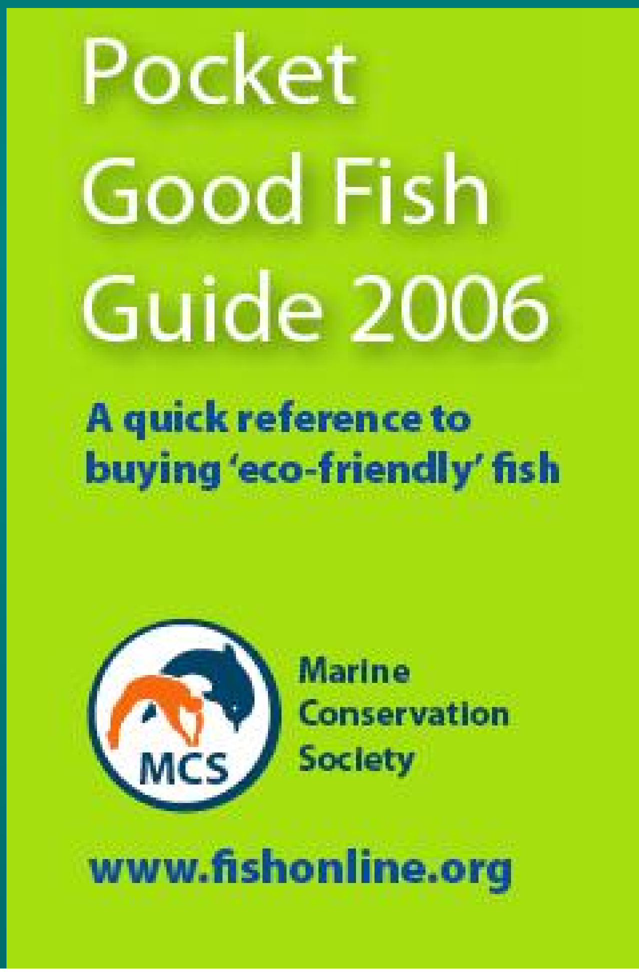
One step in the right direction: Marine Protected Areas (MPA)

- 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

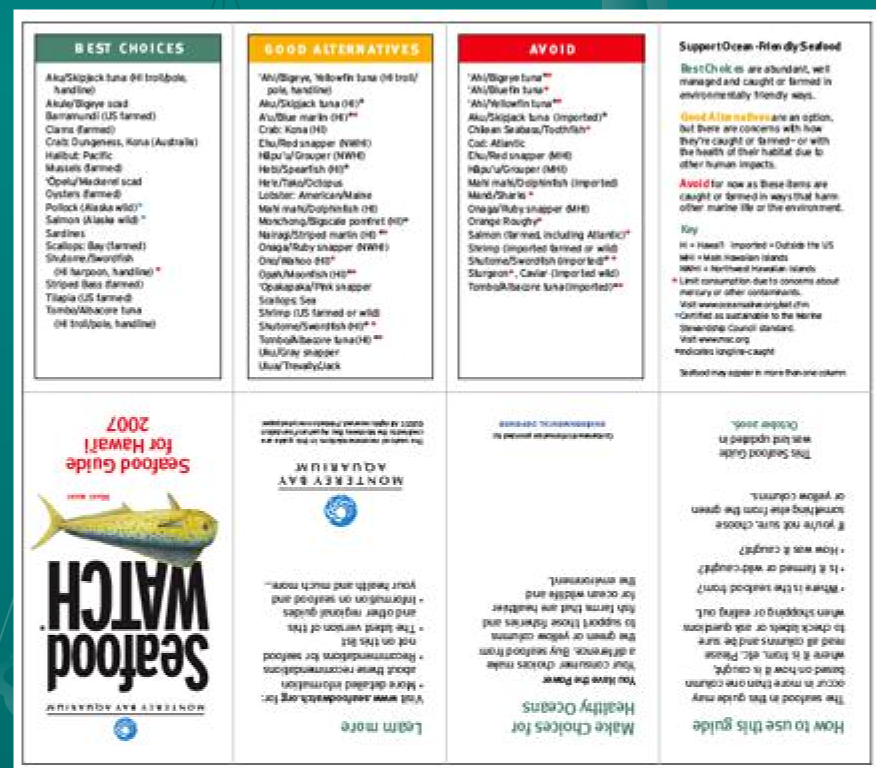
(unless they stop at "oases" in the open ocean and these are included)

- 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

http://www.fishbase.org
http://www.fishonline.org/
http://www.mbayaq.org/cr/cr_seafoodwatch
blueocean.org & edf.org



To download onto mobile phone:
mobile.seafoodwatch.org



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.