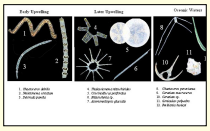
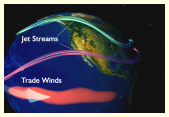




Marine Productivity and the Fishery Crisis-II

Causes, Consequences and Solutions

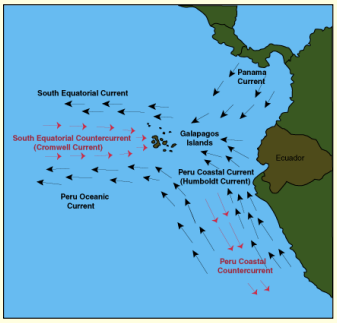
MES-ESS Winter 2011
January 20

Part-I Summary

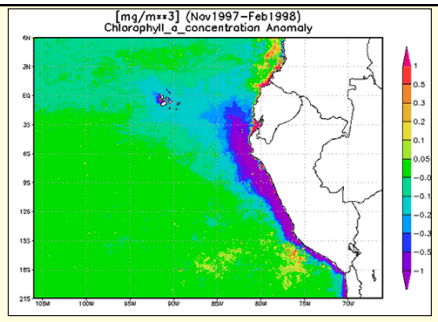
- Rate of primary production (PPR) as limit
- Marine PPR is limited by light and nutrients (N and P, Liebig's Law)
- Highest PPR is in shelf (5% of ocean), upwelling regions (.1% of ocean) and estuaries
- Shelf and upwelling regions account for nearly all the fish production (PPR, food chain length and efficiency of C-transfer)
- Fisheries in shelf and upwelling regions use 24-35% of PPR
- Peru anchoveta crash as case study for mismanagement and role of externalities

-Peruvian Anchoveta (*Engraulis ringens*)
-Filter feeder mostly on phytoplankton
-Fast growing (Up to 20 cm in 3y), spawn August
-Used primarily to produce oil and fish meal to supplement animal feed

http://www.fishbase.org/Summary/SpeciesSummary.php?id=4 and http://animaldiversity.ummz.umich.edu/site/resources/Grzimek_fish/Clupeiformes/Engraulis_ringens.jpg/badge.jpg

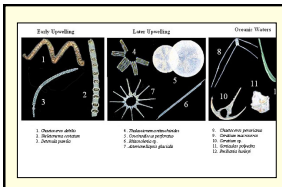


Surface circulation pattern in eastern equatorial Pacific. Cool water flowing from the south and upwelling keep the climate in this region cool. The Andes intercept the humidity traveling from the west resulting in dry conditions. From: http://www.geol.umd.edu/~jmerck/galsite/research/projects/fitz/currents.gif



Upwelling results in high concentrations of inorganic nutrients and phytoplankton productivity.

From http://daac.gsfc.nasa.gov/oceancolor/locus/images/elnino_anomaly_Nov97Feb98.gif

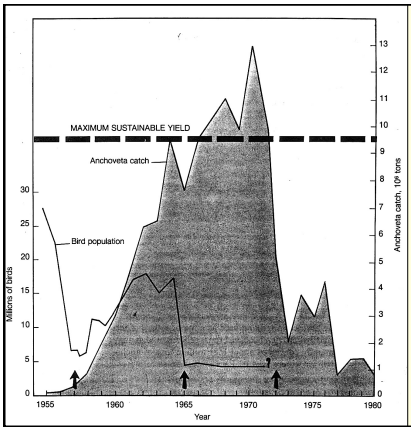


www.scielo.cl/fbpe/img/gayana/v67n2/f3tarazz.jpg
www.imarpe.gob.pe/estadistica/estardis2.html, http://www.travelblog.org/South-America/Peru/Pisco/blog-44721.html

Maximum Sustainable Yield (MSY): The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions.

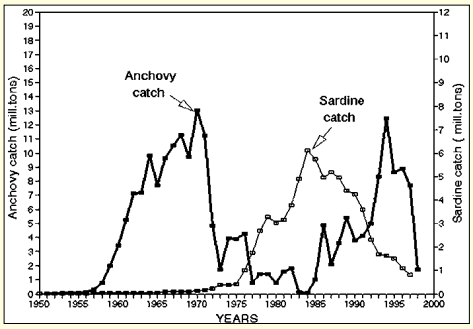
For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others.

Also called: maximum equilibrium catch or sustainable catch (www.nefsc.noaa.gov)



Peruvian Anchovy Catches, Bird Populations, MSY and El Niño.

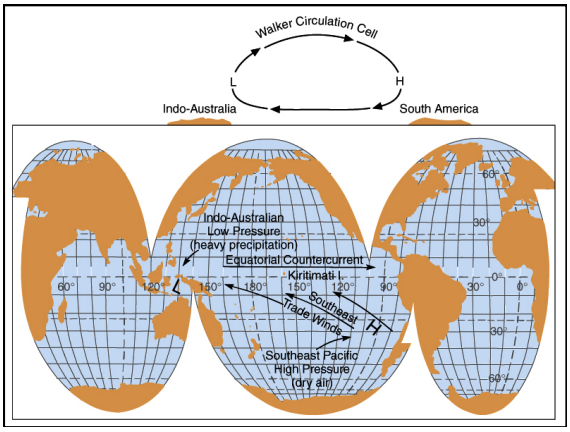
-Rapid growth of fishery in 60s
-MSY = 9.5 MT
-Overshoot due to overcapitalization of fishery, new technology and dependency of Peru on Fishery (1/3 of economy)
-In 1971 catches = 22% of world catch
-Bird populations declines as fishery grows and El Niño events occur
-**El Niño events + overfish = collapse**

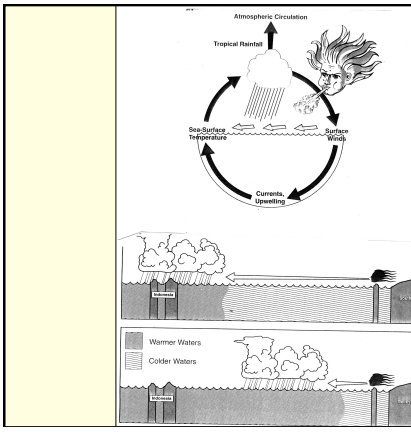


Collapse and recovery of Peruvian anchoveta. Why do sardine catches increase when anchovy catches are low?
From : http://www.fao.org/docrep/005/y2787e/y2787e3b.gif

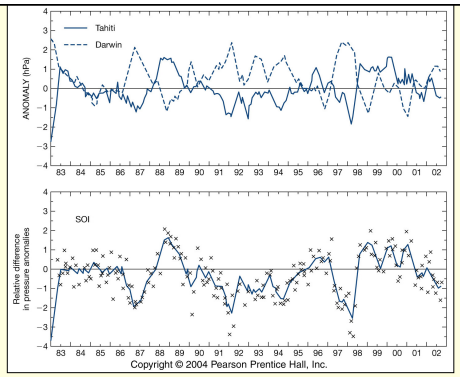
El Niño off the coast of Peru

- Annual occurrence starting in Dec and lasting ~ 3 months. Frequency of severe events is ~ 5-7 y and events may last 2 y.
- Weakening of coastal winds and upwelling
- Low concentrations of inorganic nutrients
- Low primary production
- Warming of sea surface
- Decline of native fishes and birds and appearance of tropical species
- Torrential rains

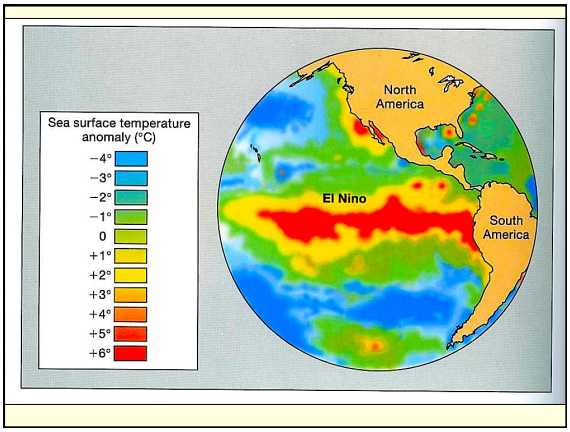


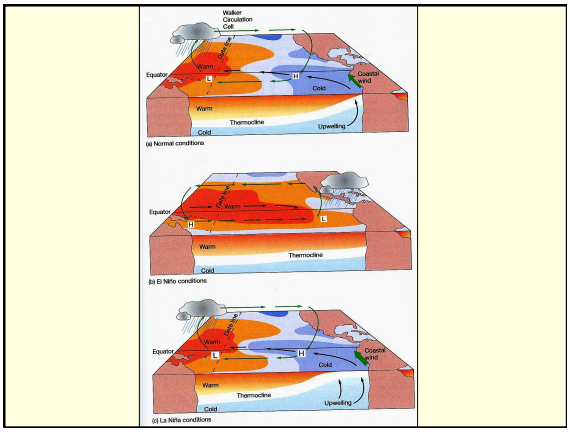


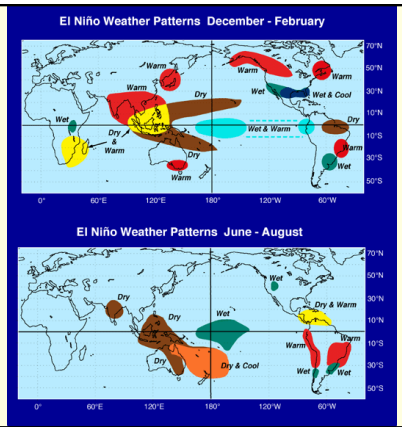
Southern Oscillation Index (SOI)



The Southern Oscillation Index (SIO) compares the atmospheric pressure anomalies (deviations from an average value) between Tahiti (150˚W) and Darwin, Australia (130 ˚E)







http://www.pmel.noaa.gov/tao/proj_over/diagrams/gif/weatherpat.gif

El Niño / Southern Oscillation (ENSO)

-Interannual climate disturbance characterized by warming of the equatorial Pacific. This is caused by oscillations in the atmospheric pressure systems in the Southern Hemisphere which results in:

-Weakening of southwest trades wind leading to weak upwelling off the coast of Peru. This leads to warmer seawater, reversal of local climate, low primary production and low production of anchovies/seabirds

-Warming of the Equatorial Pacific and disruption of global weather

-ENSO illustrates the feeback loops between the ocean and the atmosphere. Because ocean and atmosphere respond to each other, it difficult to determine what triggers an ENSO event.

-Due to the short food chains in upwelling zones. The biological impacts of ENSO event are experienced rapidly by all levels of the ecosystem. These climate events need to be considered in fisheries management.

"A marine biologist with no understanding of meteorology or currents is just whistling in the dark"

-R.T. Barber

FACTORS TO CONSIDER IN THE MANAGEMENT OF FISHERIES

Biological: life history, age structure, survival of larvae, recruitment, migratory paths, predation

Ecological: Primary production, food web efficiency, nutrient availability

Oceanographic/Climate: upwelling, local and global wind and current patterns, coastline shape, bathymetry, inter-annual variation in climate

Technological: Efficiency of detection and capture devices

Socio-politico-economic: Ownership of resources, international boundaries, local and world markets

Fisheries-II

- Food from the Sea
  - Current Fisheries Trends
- Fisheries Crisis
  - Causes
  - Consequences
- Solutions
- Lessons

Major Commercial Species

- Fishes (Bony+cartilageneous fishes)
  - Clupeoid. Herrings, sardines, anchovies. Small, pelagic, feed on low trophic levels.
  - Gadoids. Cod, haddock, pollock, hake. Bottom dwelling (demersal)
  - Scombroid. Mackerel, and tunas. Temperate and tropical waters.
  - Redfishes. Rockfishes, sea basses. Demersal.
  - Flatfishes. (halibut, sole, plaice, flounder)
  - Sharks
  - Salmonids.
- Crustaceans: shrimp, crabs, lobsters.
- Mollusks: squid, oysters, clams.
- Mammals: whales, seals, sea lions.
- Algae

Table 17.2 Examples of Commercially Important Fishes Around the World

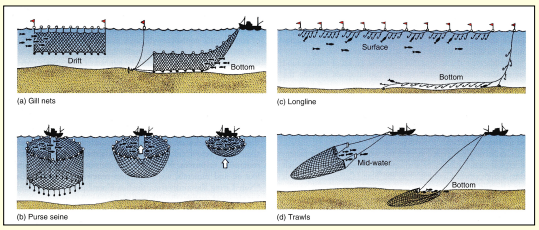
Species	Distribution and Habits	Species	Distribution and Habits
Herrings (*Clupea*)	North Atlantic and Pacific; schooling, plankton feeders; 38 cm (15 in)	Hakes and whiting (*Merluccius*)	Temperate worldwide; demersal, feed on bottom invertebrates and fishes; 1 m (3 ft)
Sardines, or pilchards (*Sardinops, Sardinella, Sardina*)	Mostly temperate worldwide; schooling, plankton feeders; 30 cm (12 in)	Flatfishes: flounders, halibuts, soles, and others (*Platichthys, Hippoglossus*, etc.)	Mostly temperate worldwide; demersal, feed on bottom invertebrates and fishes; 2 m (6.5 ft) in some halibuts
Anchovies (*Engraulis*)	Worldwide; schooling, plankton feeders; 20 cm (8 in)		
Menhadens (*Brevoortia*)	Temperate and subtropical Atlantic; schooling, plankton feeders; 38 cm (15 in)	Tunas (*Thunnus, Katsuwonus*, etc.)	Tropical and temperate; schooling, carnivores; 4.3 m (14 ft) in the bluefin tuna
Cods (*Gadus*)	North Atlantic and Pacific; demersal, feed on bottom invertebrates and fishes; 1.5 m (5 ft) in the Atlantic cod (no longer this large)	Mackerels (*Scomber, Scomberomorus*)	Tropical and temperate worldwide; schooling, carnivores; 2.4 m (8 ft)
Alaska, or walleye, pollock (*Theragra chalcogramma*)	Temperate North and Central Pacific; demersal, feeds mostly on bottom invertebrates and fishes; 90 cm (35 in)	Salmon (*Oncorhynchus, Salmo*)	North Pacific and Atlantic; open ocean and rivers, carnivores; 1 m (3 ft)
Haddock (*Melanogrammus aeglefinus*)	North Atlantic; demersal, feeds mostly on bottom invertebrates; 90 cm (35 in)		

Note: Fishes are not drawn to scale. The measurements given are the approximate maximum length.

Table 17.1 World Commercial Catches of Selected Fishes, Molluscs, and Crustaceans in Millions of Metric Tons

Catch	1975	1980	1985	1990	1995	2000	2003
Herrings, sardines, etc.	13.43	16.14	21.10	22.32	22.01	24.90	18.94
Miscellaneous pelagic fishes	not listed	not listed	not listed	not listed	13.93	10.64	11.50
Cods, haddocks, hakes, pollocks	11.85	10.75	12.46	11.58	10.74	8.68	9.31
Tunas, bonitos, billfishes	2.06	2.55	3.18	4.43	4.89	5.82	6.31
Salmon, smelts	0.55	0.80	1.17	1.51	1.15	0.80	0.96
Flounders and other flatfishes	1.16	1.08	1.35	1.23	0.92	1.01	0.92
Sharks, rays	0.59	0.60	0.62	0.69	0.76	0.87	0.86
Total marine fishes	**51.93**	**55.73**	**64.40**	**69.36**	**72.00**	**71.84**	**67.25**
Freshwater fishes	5.96	6.17	8.74	12.23	5.80	6.80	7.60
Anadromous and catadromous fishes (other than salmon)	1.53	1.82	2.57	3.24	1.83	1.77	1.57
Squids, octopuses	1.18	1.53	1.79	2.36	2.94	3.66	3.51
Clams, cockles	0.94	1.20	1.51	1.53	0.96	0.80	0.94
Scallops	0.29	0.37	0.60	0.87	0.54	0.66	0.80
Oysters	0.85	0.97	1.09	1.00	0.19	0.25	0.20
Mussels	0.53	0.62	0.97	1.34	0.24	0.26	0.19
Total marine molluscs	**4.03**	**4.91**	**6.18**	**7.73**	**6.38**	**7.25**	**6.70**
Shrimps	1.33	1.70	2.12	2.63	2.44	3.08	3.52
Crabs	0.75	0.82	0.89	0.89	0.95	1.09	1.32
Lobsters	0.10	0.10	0.20	0.21	0.22	0.23	0.22
Krill	0.04	0.48	0.19	0.37	0.12	0.11	0.12
Total marine crustaceans	**2.35**	**3.20**	**3.42**	**4.50**	**4.77**	**5.91**	**5.57**
World total (all groups, marine and freshwater)	**66.13**	**72.38**	**86.26**	**97.97**	**91.37**	**95.47**	**90.22**

Note: Catches tabulated in groups defined by the Food and Agriculture Organization of the United Nations; only selected groups are listed, and, when added, may not equal totals.



Examples of Fishing Methods
From Castro&Huber (2004) Marine Biology

Fisheries Contribution to Global Food Supply

Fisheries account for 6% total food production, but 17% of protein production. In some developing countries fish protein = 45 % of animal protein intake (Source = FAO).

UTILIZATION OF FISHERY HARVEST (2002) in MT

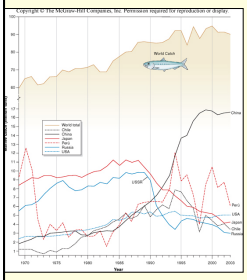
TOTAL = 95 (122 – discarded bycatch (27))

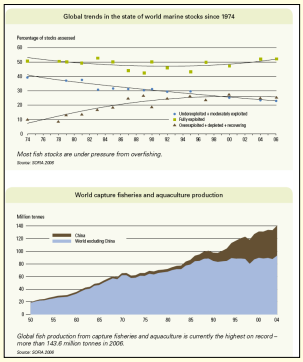
Fish eaten whole= 65 (2 of scraps used for feed)

Fish for aquaculture=10 (Gross yield*=29, net=19)

Fish for animal feed = 20+2 (25% efficiency 22->5.5)

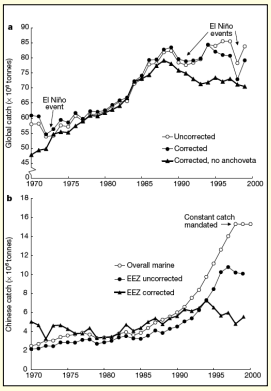
*Latest FAO report (09) states that aquaculture now provides nearly half of all fish consumed





What is the evidence that the oceans are over-fished?

52% marine fisheries=fished to max and 28% depleted. From www.fao.org



From Watson&Pauly 2001

Evidence of under-reporting by Chinese Fisheries

-Chinese catches do not match expected catches based on linear model. Model predicts catches elsewhere.

-Global catches corrected for under-reporting reflect decline since late 80s.

-Note role of El Niño in affecting anchoveta and global catches

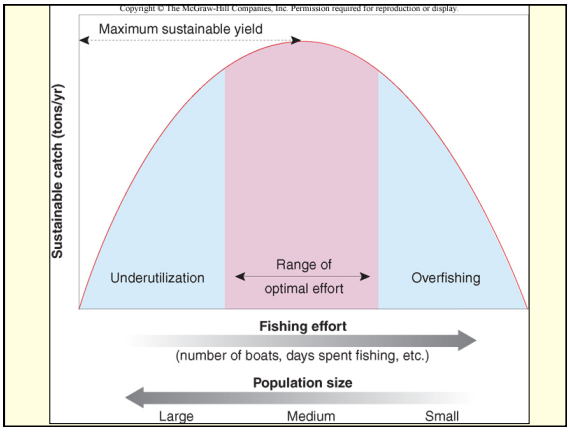
-Accurate catch data is essential for management

Over Fishing Causes

- Tragedy of the Commons: Open access to wild resource
- Technological advances: find, catch and preserve
- Fishing models inadequate to develop sustainable policies
  - Scientific uncertainty: biology, ecology, climate for MSY
  - Baseline may be based on already diminished stocks
- *Market failures:*
  - *Humans cannot control production of wild habitat*
  - *Low catches = low supply=high price=more pressure*
  - *Not consider true cost of fishery (habitat degradation, ecological consequences, etc.)*
  - *Subsidies to support fishing fleet*
  - *Over-capitalized industry: More people and boats employed than the fishery can support*
- *Political factors: lack of consensus over management of resource*

Maximum Sustainable Yield (MSY). Maximum tonnage of organisms that can be taken from a harvested population each year without eventually destroying the population.

- Biological Data: population dynamics, reproductive age, efficiency of trophic transfers and natural predation. Ecological interactions.
- Chemical Data: nutrient concentrations fueling primary production
- Physical Data: ocean circulation and its impacts on migration, feeding and recruitment
- Fishery Data: Models of equilibrium levels between biological productivity, fishing effort and mortality
- Meteorological Data: interannual variations in climate (ENSO)



Over Fishing Consequences

- As fishing effort increases, large fishes are removed
- Large numbers of smaller fish are then caught to compensate for the loss of large fish
- Fish are caught before reaching reproductive age
- Reduced harvest of individual species
  - Masked by substitutions and technological improvement in gear
- Switch to fishery to lesser value fish (e.g. 80s, 30%catch = 6%value)
  - Lesser value fish used for aquaculture and poultry/pig feeds
- Fishing down the food chain. Fishing targets smaller fishes down the food chain

Over Fishing Consequences-continued

- Shifts in species composition. Top predators decrease, prey of target species increase. Results are simplified food webs and other ecosystem wide impacts
  - "Fishing Down the Food Chain" removes large predators. Fisheries then catch prey fish in lower trophic levels. Result is short food chains dominated by invertebrates
  - increased vulnerability to climate change, pollution, invasive species, eutrophication, habitat destruction
  - Incidental catches (by-catch) and ghost fishing (lost gear)
- Inefficient fishing effort - less fishing would improve yields
- More people employed than the fishery can support
- More boats than needed to harvest the available fish (Over-capitalized industry)

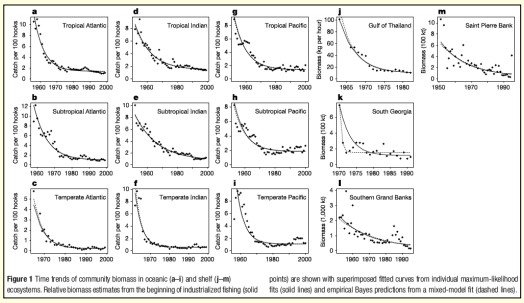
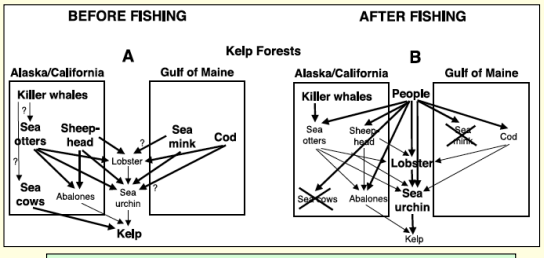
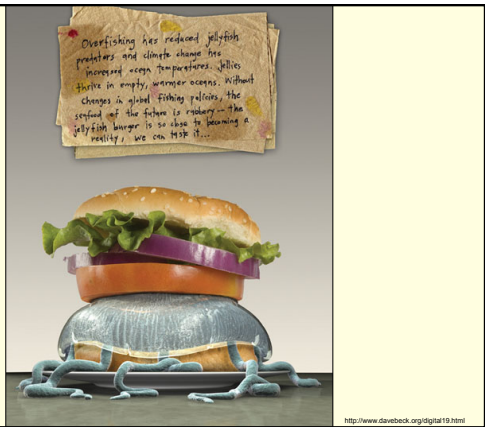


Figure 1 Time trends of community biomass in oceanic (a–i) and shelf (j–m) ecosystems. Relative biomass estimates from the beginning of industrialized fishing (solid points) are shown with superimposed fitted curves from individual maximum-likelihood fits (solid lines) and empirical Bayes predictions from a mixed-model fit (dashed lines).

Evidence for rapid disappearance of large predatory fishes
(From Myers&Worm (2003))

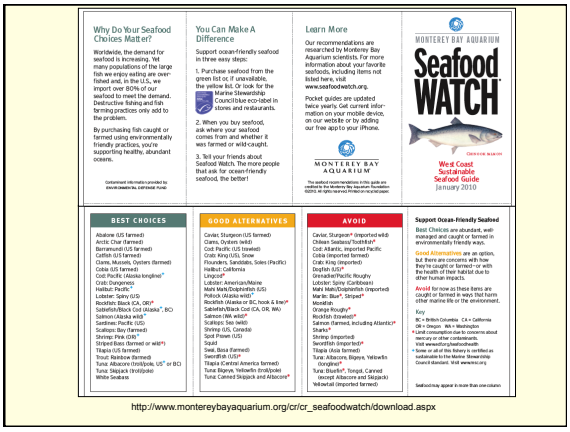


Example of models showing feeding relationships among dominant organisms before and after fishing. Current practices has resulted in depleted fish stocks and other ecological consequences (e.g. changes in food web composition and structure). Figure from: Jackson et al. (2001)



Over Fishing Solutions (?)

- "Precautionary Principle." Err on side of resource in spite of economic loss.
- Ownership of resource (e.g. Keen)
- Remove subsidies
- Sustainable aquaculture
  - low trophic level fish (tilapia, milk-cat-fish Vs salmon/shrimp)
  - Reduce fish meal/oil in feeds
  - Integrated systems (polyculture)
  - Environmentally sound design
- Reduce fishing (e.g. control technology, taxes, etc.)
- Protective areas (Marine Reserves)
- Ecosystem-based management Vs single-species
- Consumer education
  - Purchase from responsibly produced herbivorous fish
  - Purchase from well-managed fisheries
- Understand role of history and culture (e.g.COD)



Why Do Your Seafood Choices Matter?

Worldwide, the demand for seafood is increasing. Yet many populations of the large fish we enjoy eating are overfished and, in the U.S., we import over 80% of our seafood to meet the demand. Destructive fishing and fish farming practices only add to the problem.

By purchasing fish caught or farmed using environmentally friendly practices, you're supporting healthy, abundant oceans.

You Can Make A Difference

Support ocean-friendly seafood in three easy steps:

1. Purchase seafood from the green list or, if unavailable, the yellow list. Or look for the Marine Stewardship Council blue eco-label in stores and restaurants.

2. When you buy seafood, ask where your seafood comes from and whether it was farmed or wild-caught.

3. Tell your friends about Seafood Watch. The more people that ask for ocean-friendly seafood, the better!

Learn More

Our recommendations are researched by Monterey Bay Aquarium scientists. For more information about your favorite seafoods, including items not listed here, visit www.seafoodwatch.org.

Pocket guides are updated twice yearly. Get current information on your mobile device, on our website or by adding our free app to your iPhone.

MONTEREY BAY AQUARIUM

MONTEREY BAY AQUARIUM
Seafood WATCH
West Coast Sustainable Seafood Guide
January 2010

BEST CHOICES

Abalone (US farmed)
Arctic Char (farmed)
Barramundi (US farmed)
Catfish (US farmed)
Clams, Mussels, Oysters (farmed)
Cobia (US farmed)
Cod: Pacific (Alaska longline)*
Crab: Dungeness*
Halibut: Pacific*
Lobster: Spiny (US)
Rockfish: Black (CA, OR)*
Sablefish/Black Cod (Alaska*, BC)
Salmon (Alaska wild)*
Sardines: Pacific (US)
Scallops: Bay (farmed)
Shrimp: Pink (OR)*
Striped Bass (farmed or wild*)
Tilapia (US farmed)
Trout: Rainbow (farmed)
Tuna: Albacore (troll/pole, US* or BC)
Tuna: Skipjack (troll/pole)
White Seabass

GOOD ALTERNATIVES

Caviar, Sturgeon (US farmed)
Clams, Oysters (wild)
Cod: Pacific (US trawled)
Crab: King (US), Snow
Flounders, Sandabs, Soles (Pacific)
Halibut: California
Lobster: American/Maine
Mahi Mahi/Dolphinfish (US)
Pollock (Alaska wild)*
Rockfish (Alaska or BC, hook & line)*
Sablefish/Black Cod (CA, OR, WA)
Salmon (WA wild)*
Scallops: Sea (wild)
Shrimp (US, Canada)
Spot Prawn (US)
Squid
Swai, Basa (farmed)
Swordfish (US)*
Tilapia (Central America farmed)
Tuna: Bigeye, Yellowfin (troll/pole)
Tuna: Canned Skipjack and Albacore*

AVOID

Caviar, Sturgeon* (imported wild)
Chilean Seabass/Toothfish*
Cod: Atlantic, Imported Pacific
Cobia (imported farmed)
Crab: King (imported)
Dogfish (US)*
Halibut: Atlantic, Pacific Roughy
Lobster: Spiny (Caribbean)
Mahi Mahi/Dolphinfish (imported)
Marlin: Blue*, Striped*
Monkfish
Orange Roughy*
Rockfish (Sopwell)*
Salmon (farmed, including Atlantic)*
Sharks*
Shrimp (imported)
Swordfish (imported)*
Tilapia (Asia farmed)
Tuna: Albacore, Bigeye, Yellowfin (longline)*
Tuna: Bluefin*, Tongol, Canned (except Albacore and Skipjack)
Yellowtail (imported farmed)

Support Ocean-Friendly Seafood

Best Choices are abundant, well-managed and caught or farmed in environmentally friendly ways.

Good Alternatives are an option, but there are concerns with how they're caught or farmed—or with the health of their habitat due to other human impacts.

Avoid for now as these items are caught or farmed in ways that harm other marine life or the environment.

Key

BC = British Columbia CA = California OR = Oregon WA = Washington

* Limit consumption due to concerns about mercury. For more information, visit www.seafoodwatch.org/seafoodhealth.

+ Some or all of this fishery is certified as sustainable to the Marine Stewardship Council standard. Visit www.msc.org.

Seafood may appear in more than one column.

http://www.montereybayaquarium.org/cr/cr_seafoodwatch/download.aspx

General Lessons from Natural Resource Exploitation History

- Tragedy of the Commons
- Inadequate knowledge of the system
  - Exogeneous factors
- Market failures
- Resistance to change (policy, history, culture, etc.).