

An Ecological Perspective on Aquaculture Development

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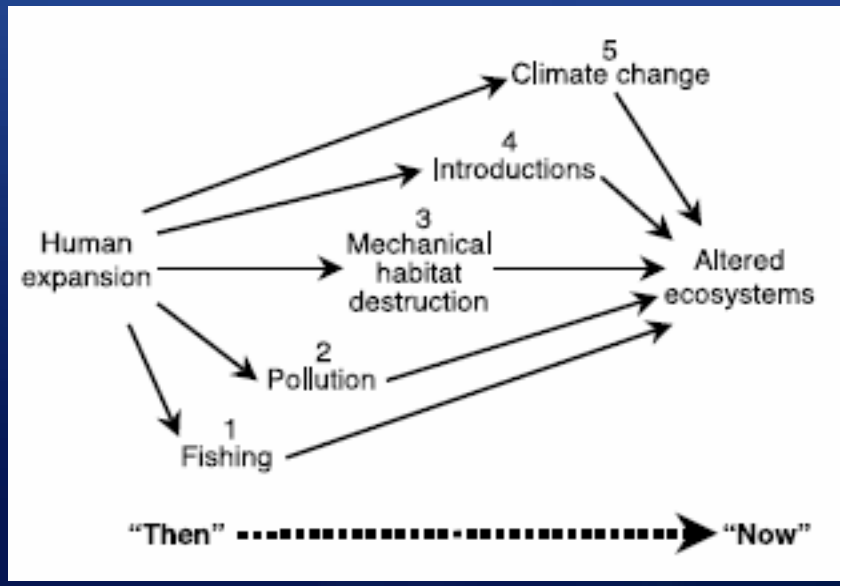
Bell Harbor Conference Center
June 20, 2005

Contribution of Ecology to Fisheries

- Historical view of ocean ecosystems
  - Jackson et al 2001
- Impacts of fishing gear on community structure
  - Watling & Norse 1998
- Population consequences of bycatch
  - Lewison and Crowder 2004

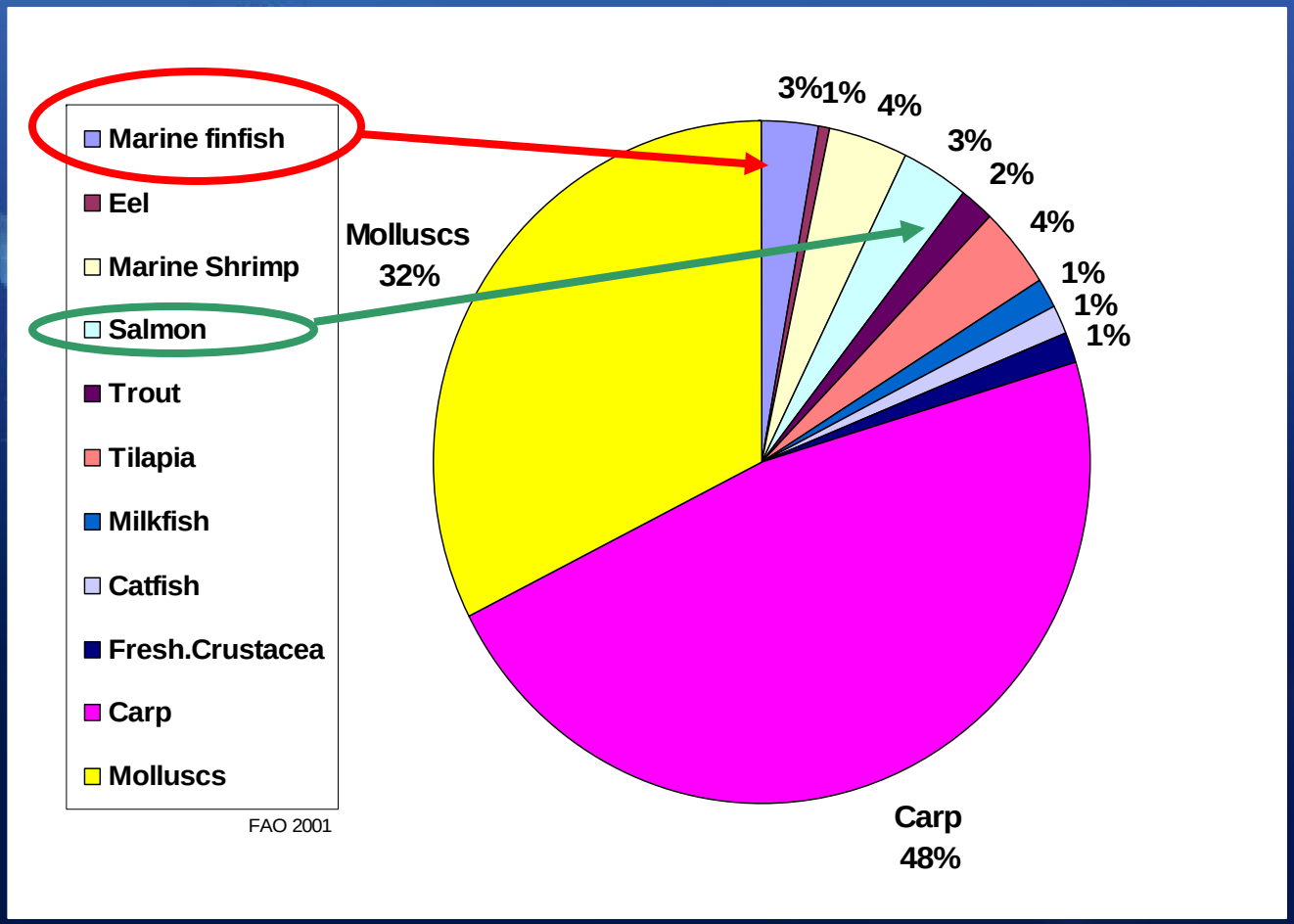


Ecology as a Framework for Aquaculture

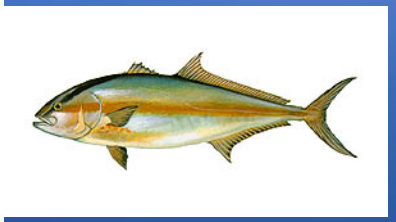
- Ecology: Study of structure and function of ecosystems
- Sustainable aquaculture development requires a connection between aquaculture production and affected ecosystems
- Goal: Minimize ecological risks while contributing to economic and social welfare

World Aquaculture is Diverse: 262 Species

World Production of Farmed Fish: FAO 2001

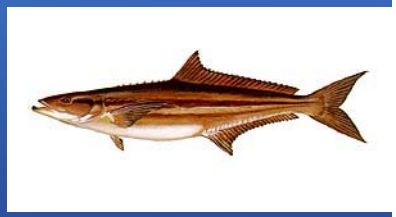


Growth in Marine Aquaculture Will Likely Involve Carnivores in Open Systems


Amberjack


Red Snapper


Red Drum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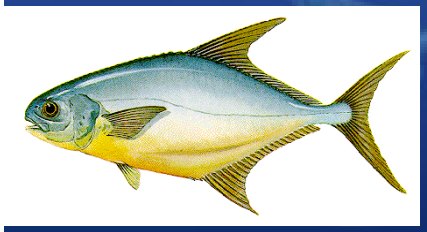

Florida Pompano


Atlantic Salmon


Summer Flounder


Mutton Snapper


Halibut


Pacific Threadfin


Atlantic Cod


Haddock

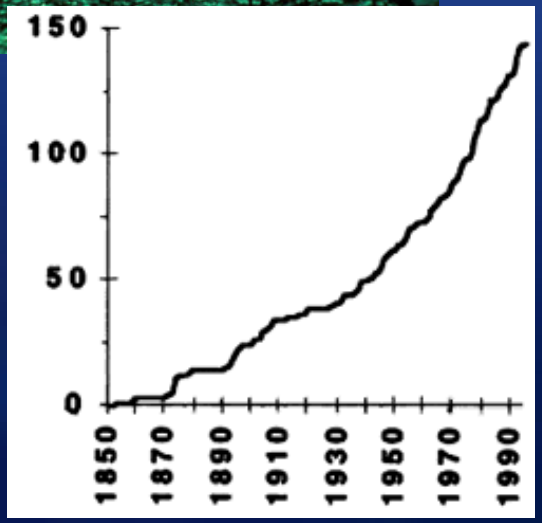
Ecological Issues of Concern

- Risk of Escapes
- Risk of Disease Transfer
- Wastes & Pollution
- Fish meal and Fish oil in Feeds

- Important because they are examples of broader threats to ecological integrity ocean ecosystems

Risk of Escapes

- Invasive species is a CRITICAL conservation issue
  - 2nd to habitat destruction as biggest threat to biodiversity (UNEP 2002)
  - Kudzu – 1876; now 7 million acres
  - San Francisco Bay – 212 species invaded since 1850's (Cohen and Carlton 1995)
  - "Invasion Meltdown" – Simberloff and Von Holle 1999



SF Bay invasions over time

Risk of Escapes

- Aquaculture is both a victim of AND cause of escapes
  - *Victim* – Green crab impacts on shellfish farming (DFO 2003)
  - *Cause* – Japanese oyster established throughout Northern hemisphere (Shatkin et al. 1997)
  - *Cause* – salmon farming (Whoriskey 2003; Naylor et al. 2005)

Altered Genetics: Whole-river Experiment

Srahrevagh River
(Burrishoole system)

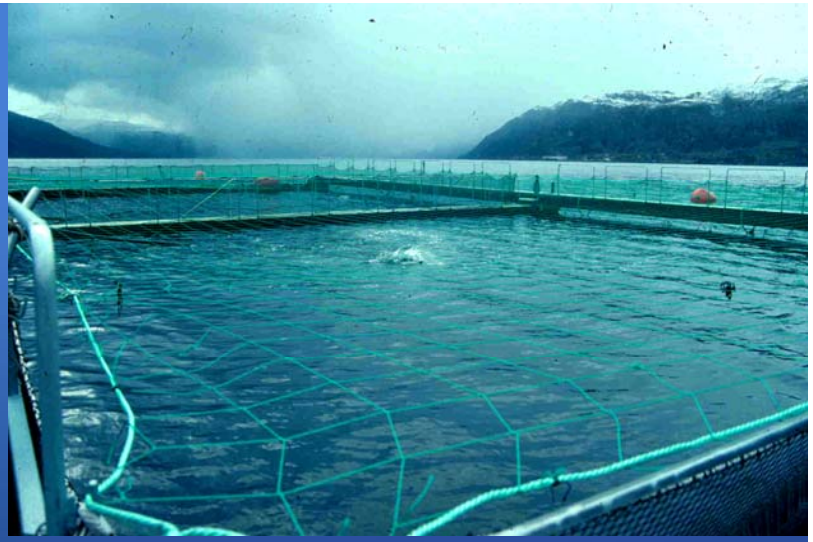
- 7 types of crosses (wild, farm, 5 types of hybrids)
- outplanted eggs in the river
- sampled fish at various life stages to adulthood

Outbreeding Depression

- Lifetime success of hybrids 27- 89% of wild cousins
- Depression population fitness

McGinnity et al. 1997, 2003

Going Forward: Risk of Escapes



Function of:

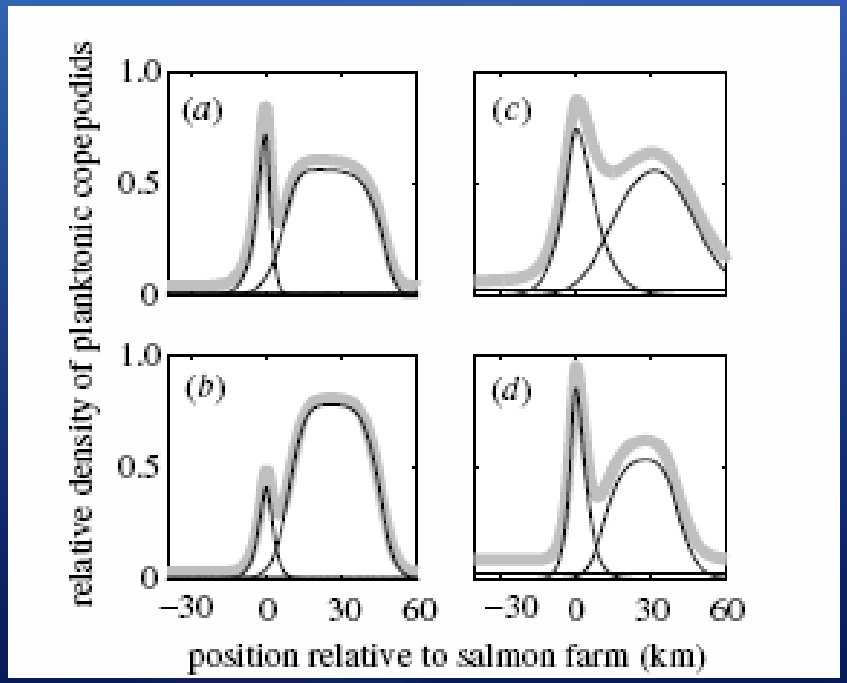
- Probability of escapes
- Magnitude of each escape
- Frequency of occurrence
- Impact on wild populations & ecosystems

- Insights from evolutionary theory and invasive species biology must be brought to bear
- “Expect the unexpected”: Lack of demonstrated effect *currently* should be little cause for comfort

Risk of Disease Transfer

- Disease is a normal part of natural ecosystems, agriculture and aquaculture
- Disease begins in the wild but amplification and re-transmission under high densities (which is not common naturally) is the key issue
- Density-dependent disease amplification is common process (e.g. bovine tuberculosis in brushtail possums; Caley and Hone 2004)

Transfer of Sea Lice



Krkosek et al (2005): Infection pressure more than 4 orders of magnitude above ambient at salmon farm

Nutrient Input

Gulf of Mexico: 2003

- Global nutrient budgets are dominated by human activities (Vitousek et al 1997)
- Coastal waters becoming more eutrophic (Boesch et al. 2003)
- Results:
  - 146 dead zones (2x increase since 1960)
  - Increased incidences of HAB's
  - Red tide in New England – MA state of emergency declared

Noctiluca scintillians: Gilbert & Pitcher 2001

Nutrient Input

- All farming operations produce waste
- Relative contribution of aquaculture to marine systems is small but open pens can have local impacts (Gowen and Bradbury 1987; Beveridge 1996)
- Contribution from aquaculture will certainly grow with offshore expansion

Nutrient Input

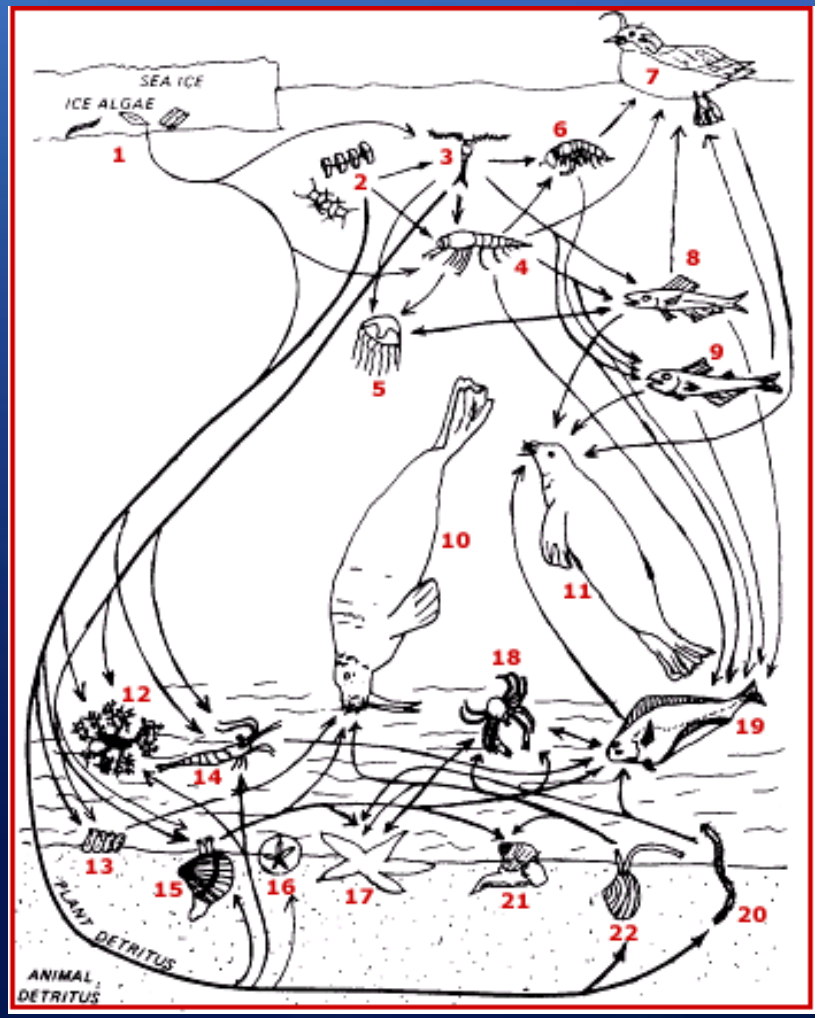
An underwater view of the submerged sea cage with divers. -Oceanic Institute photo

- As expected, available data show little to no impact from experimental open ocean cages (e.g. Bybee et al. 2003)

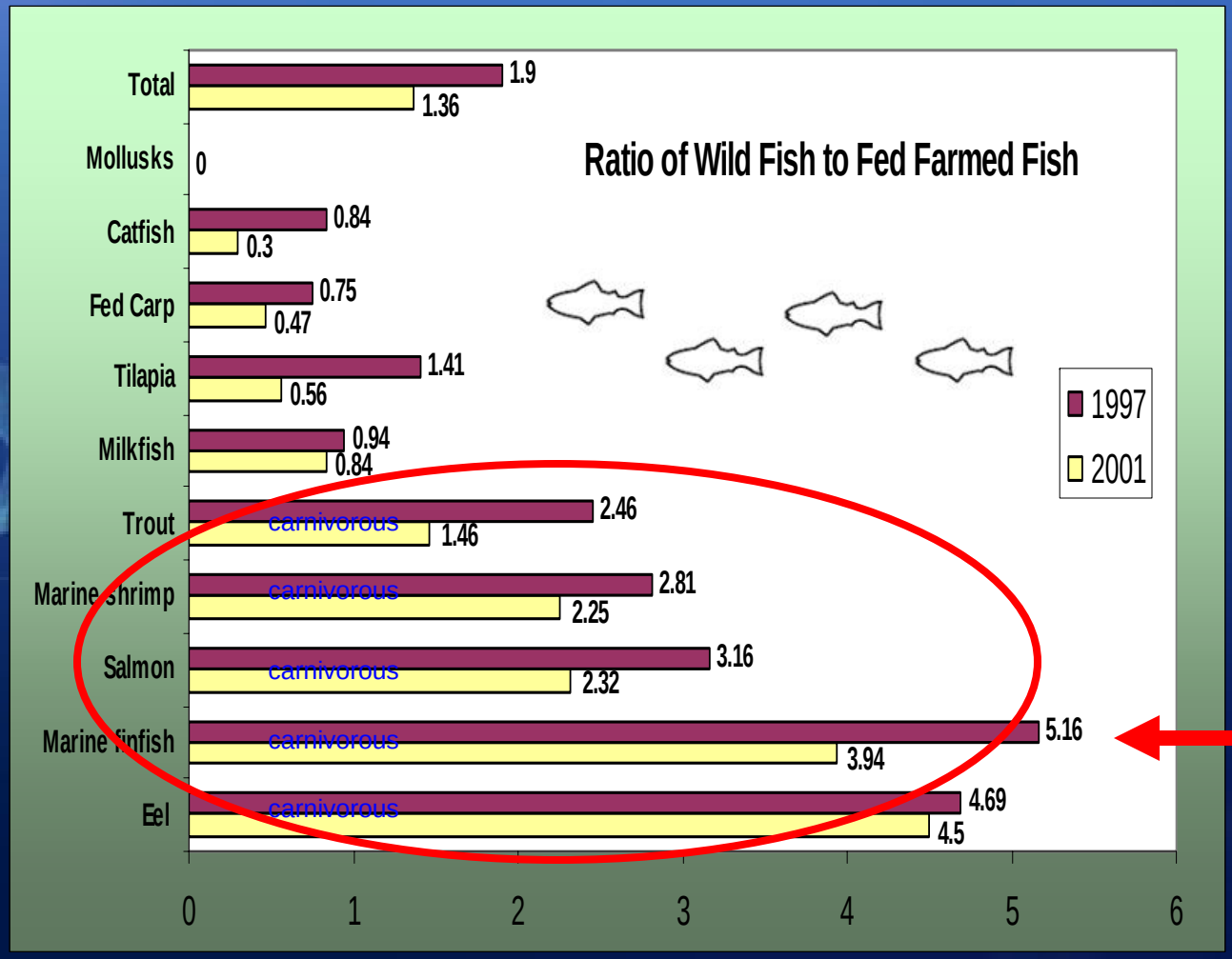
- But ecosystem modeling is needed to guide industry expansion:
  - "Dilution is the solution" is not appropriate unless assimilative capacity of ecosystem is understood and cumulative ("scaling up") impacts are anticipated

Fish Meal and Fish Oil

- Key issue: impact on affected ecosystems
- Small pelagics play key trophic role
- Fisheries models don't incorporate this role
- Knock on effects can occur (e.g. sand eels; Furness 2002)
  - Competition between fishing and kittiwakes for prey



World Fish Supplies: Producer or Net Consumer?



Naylor and Burke (2005)

Status: Use of Marine Resources

- By 2010, aquaculture is anticipated to use 50% of meal and 97% of oil (IFFO 2001)
- Feed efficiency for some species is improving, but aggregate use of marine resources by aquaculture is rising steadily
- Greater quantities and more species of carnivorous (fishmeal dependent) marine fish are being farmed
- Feed conversion for new species is worse than salmon
  - -Tuna: Estimates as high as 20:1

Use of Marine Resources

- Growth of aquaculture industry will certainly put added pressure on reduction fisheries and pelagic ecosystems
- If marine aquaculture begins to supplant capture fisheries, impetus may be to shift from managing the oceans for fisheries to managing them for aquaculture production
- Economically rational but ecologically irrational

Summary: Ecological Issues of Concern

- Risk of Escapes
- Risk of Disease Transfer
- Wastes & Pollution
- Fish meal and Fish oil in Feeds

- Important because these are examples of broader threats to integrity of ocean ecosystems. Must be addressed as industry expands
- Ecosystem-based management is the future of fishery management
- Same approach can help ensure the sustainable development of aquaculture

An Ecological View of Sustainable Aquaculture

MONTEREY BAY AQUARIUM®
Seafood WATCH

- Escapes: No risk of deleterious effects on wild fish and ecosystems
- Disease: No risk of deleterious effects through amplification, transmission or introduction of disease/parasites
- Waste: Treat and reduce discharge to ensure no adverse impacts to surrounding ecosystem
- Feed: A net producer rather than consumer of edible fish protein
- Management: Utilizes a precautionary approach for daily operations and industry expansion