CAN MPAs CONTRIBUTE TO ECOSYSTEM PROTECTION GOALS OF THE MBNMS?

Chris Harrold, PhD
Research Representative to the SAC

12/13/07

ADVICE FROM THE SAC: Should marine protected areas, including marine reserves, be established in federal waters of the MBNMS?

- Perspectives:
  - Scientific
  - Socioeconomic
  - Spiritual
  - Societal Values
  - Enforcement
  - Cost
  - Regulatory

How Can Science Inform this Decision?

- What are the ecosystem protection goals of the NMSA, as they relate to the MBNMS, in measurable terms?
- What is the scientific evidence that marine protected areas can contribute to achieving those measurable goals?

Ecosystem Protection Goals of the NMSA

- Maintain the natural biological communities in the national marine sanctuaries, and to protect, and, where appropriate, restore and enhance natural habitats, populations, and ecological processes.[4]
- Problems:
  - What is a “natural biological community?” Pre-human? Pre-European immigrant? Pre-industrialized fishing? Pre-1992?
  - What did one look like?
  - Restore or enhance to what target?

Ecosystem Research Goals of the NMSA

- Support, promote, and coordinate scientific research on, and long-term monitoring of, the resources of these marine areas[4]
- Problem:
  - To what end?

Measurable Ecosystem Protection and Research Goals

- Protect and maintain the ecosystem services of marine ecosystems of the MBNMS
- Prevent the loss of species biodiversity in the marine ecosystems of the MBNMS
- Improve our understanding of marine ecosystem structure, function and change in order to:
  - Disentangle natural from human effects;
  - Predict the outcomes of natural and human disturbances to the marine ecosystems of the MBNMS;
  - Monitor effectiveness of resource management strategies

Is There Evidence to Support Idea that MPAs Contribute to Ecosystem Protection?

- Biological Effects Within No-Take Marine Reserves: A Global Synthesis (Lester et al, in review[1])
  - Builds on previous review by Halpern 2003[2]
  - Reviewed 149 peer-reviewed publications 1977-2006
  - 124 no-take marine reserves in 29 countries

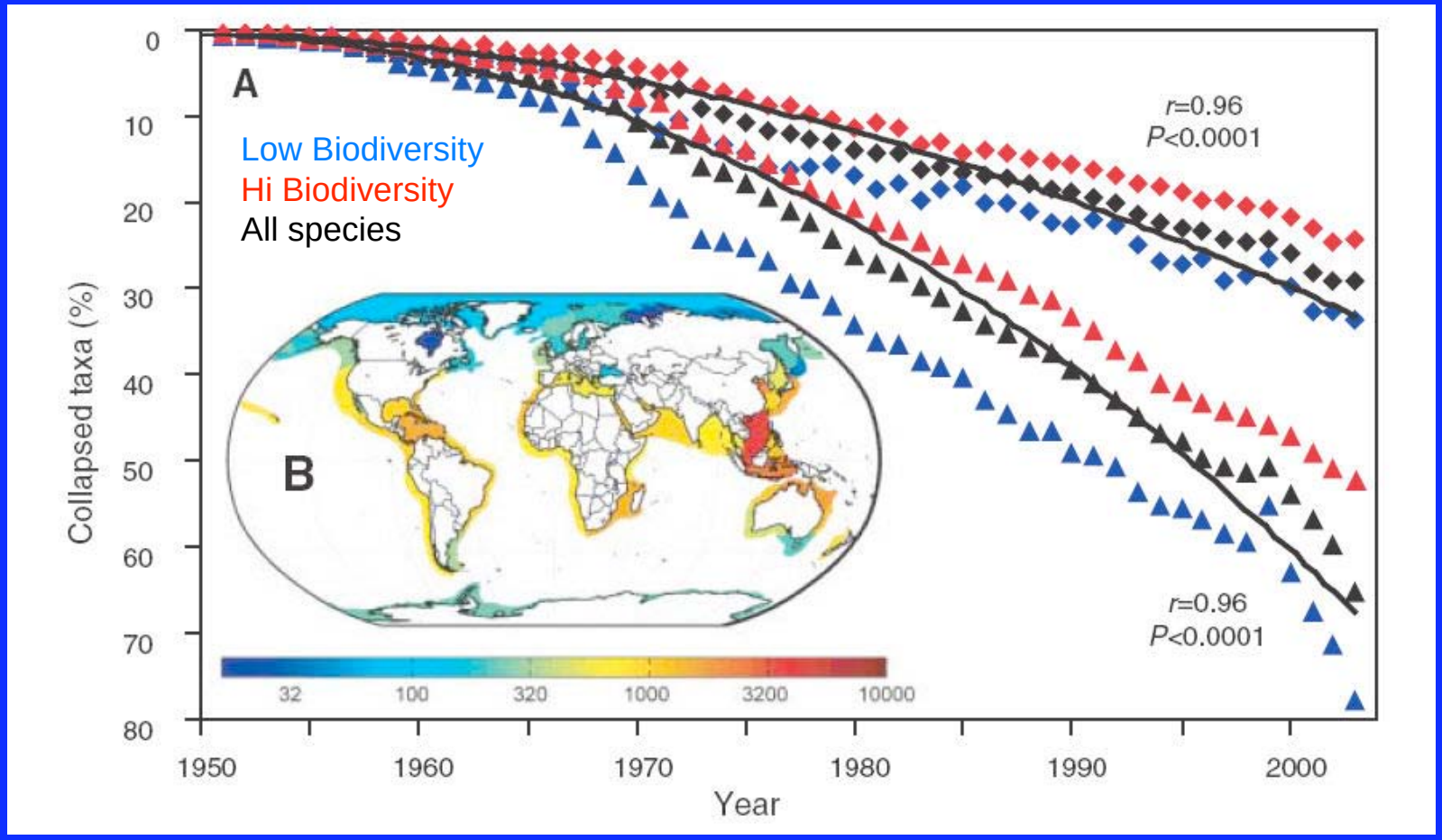
Lester et al, in review[1] (con't)

- Results:
  - Reserve protection results in statistically significant increases in all 4 attributes studied:
    - Density
    - Biomass
    - Organism size
    - Species richness
  - Magnitude of response varied greatly, some variables decreased with reserve protection
  - Reserves in temperate environments showed effects as large or larger than reserves in tropics

Marine Biodiversity, Marine Ecosystem Services and Marine Reserves (Worm et al, 2006[3)])

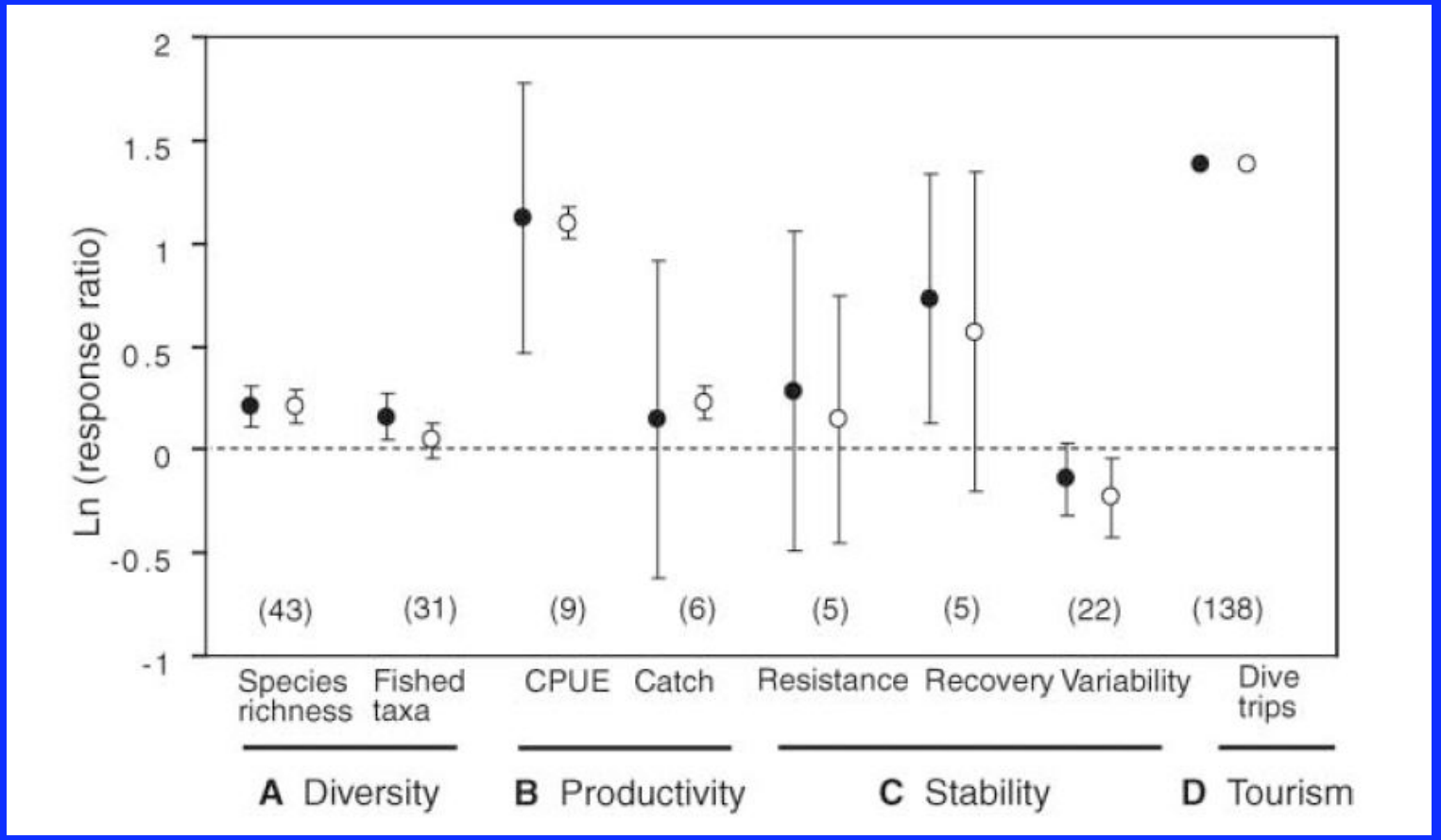
- Fish and invertebrate catches from 64 large marine ecosystems worldwide
- “Large” = ≥ 58,000 sq. mi
- From estuaries/coastal areas to seaward boundaries of continental shelves and outer margins of major current systems
- Account for 83% of global fisheries yields over past 50 years.

Marine Biodiversity Slows Collapse of Fisheries



From Worm et al, 2006[3]

Marine Reserves/Fisheries Closures Can Protect/Restore Ecosystem Services



From Worm et al, 2006[3]

Focus on Evidence Relevant to Our Situation

- West Coast of US
- Temperate marine ecosystems
- Offshore/deep-sea (>100 m)
- Ecosystem protection goals of the NMSA

Current Ecosystem Protection Regulations of the MBNMS: Prohibited Activities

- Exploring, developing, producing oil, gas or minerals
- Discharging materials
- Altering the seabed
- Disturbing marine mammals, sea turtles and birds

Prohibited Activities, con’t

- Possessing any…marine mammal, sea turtle or seabird
- Operating motorized personal watercraft
- Flying motorized aircraft below 100 ft.
- Interfering with enforcement
- Attracting white sharks

What is the Added Value of MPAs in Achieving Ecosystem Protection Goals of MBNMS?

- In practice, MPAs limit/preclude take of marine life
- Primary/sole form of take in federal waters of sanctuary is fishing
- Can MPAs protect against the ecosystem impacts of fishing?

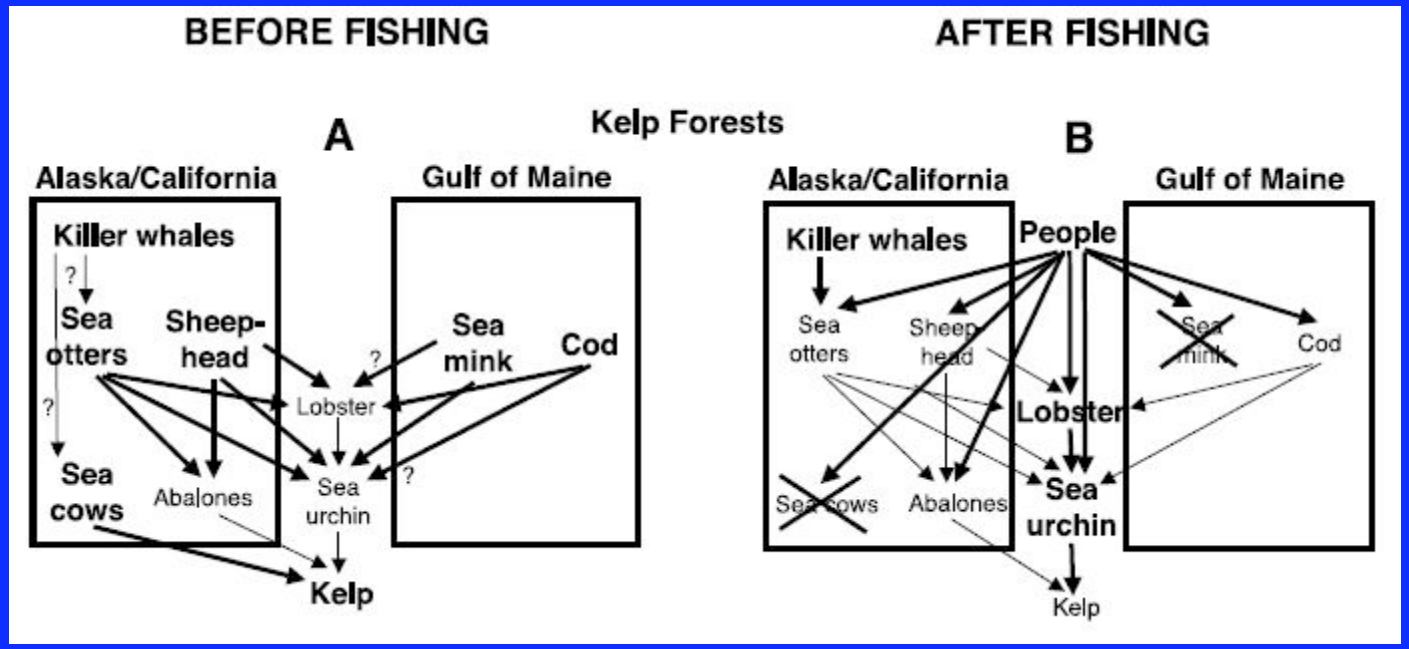
Unavoidable Ecosystem Impacts of Fishing:[5,6]

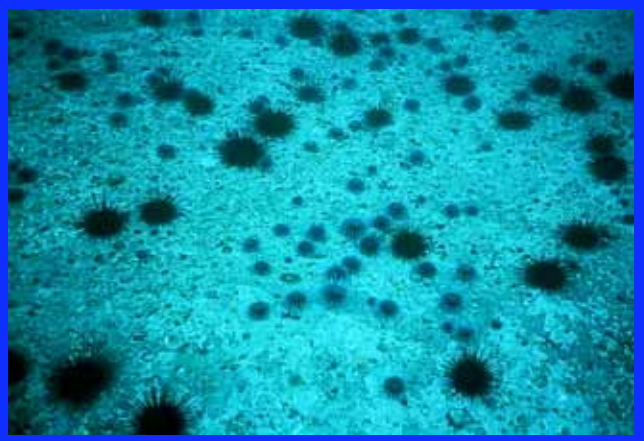
- Stock reduction, ecological cascades
- Bycatch
- Habitat destruction, esp. trawling
- Life history modification

Stock Reduction and Ecological Cascades[7]

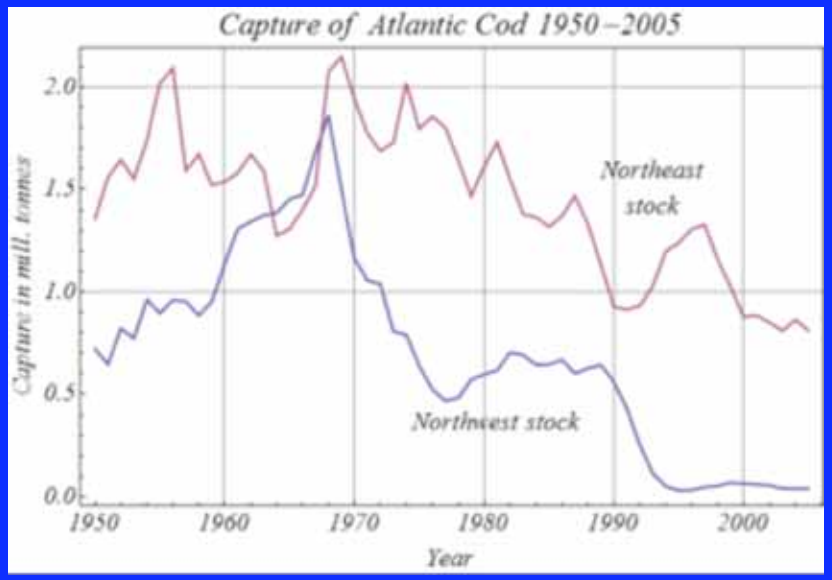
- Well-documented in nearshore waters[5]
  - Coral Reefs
  - Tropical and subtropical seagrass beds
  - Oysters and nutrient enrichment in estuaries
  - Kelp Forests

Kelp forest example:[5]



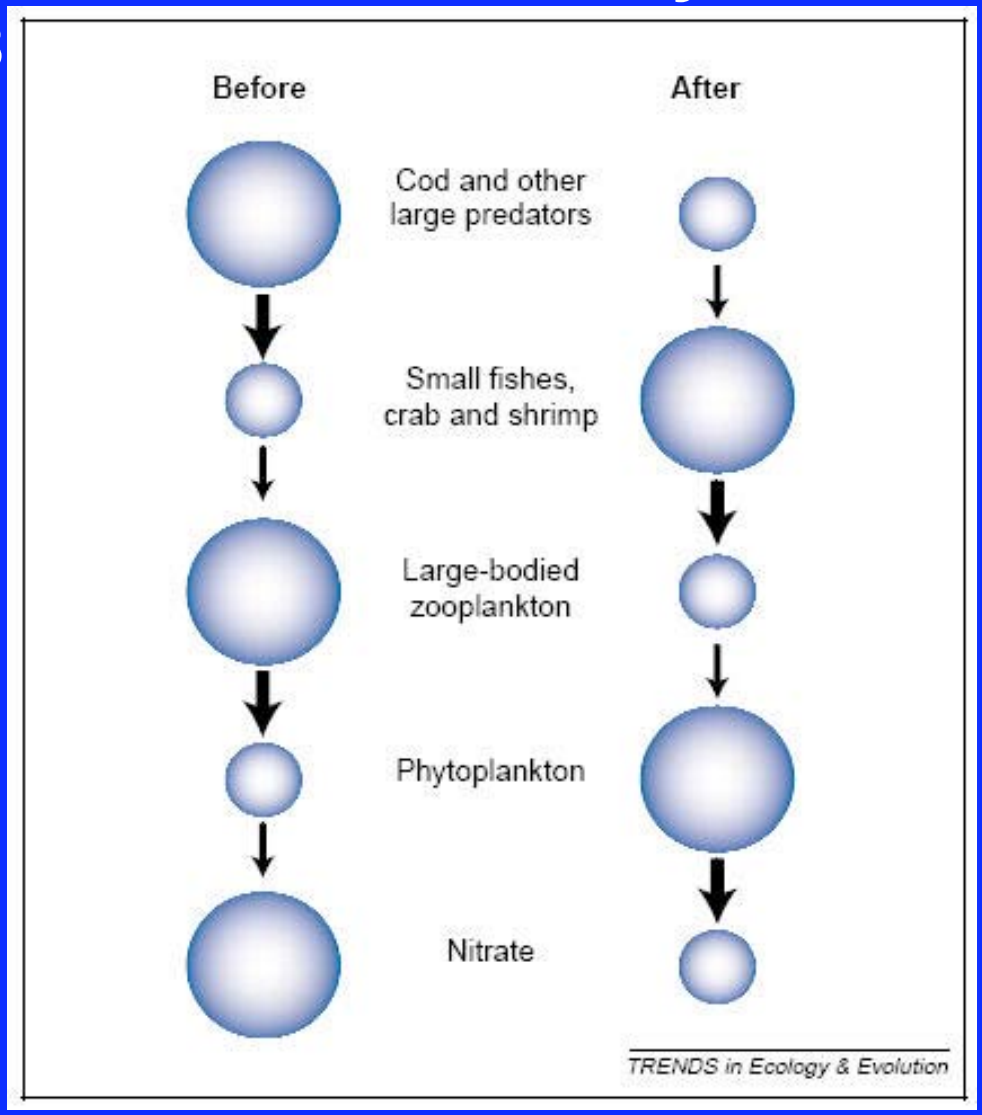


Ecological cascade in open ocean systems has been less clear[8]



From FAO Fishery Statistics

Trophic Cascade in Formerly Cod-Dominated Open Ocean Ecosystem in Off Nova Scotia[7,8]



From Frank et al., 2005[8]

How can MPAs Protect Against Unintended Trophic Cascades?

- Preserving areas where all species are protected
- Most effective for species with limited dispersal and adult ranges

Bycatch

- “That part of the capture that is discarded at sea, dead (or injured to an extent that death is the result).”

Hall, 1996[9]

From the cover of Kelleher, 2005[10]

Bycatch: Impacts

- Living resources are wasted (growing human population, declining fisheries[11]
- Populations of rare/endangered species are threatened
- Heavily exploited stocks are further impacted
- Ecosystem structure & function change due to trophic cascades

West Coast Bycatch in 2002-2003 (Harrington et al., 2005[12])

Fishery	Targeted Landings (tons)	Discards (tons)	Ratio	Discarded Species Groups
West coast groundfish	25,000	23,000	.880	Flatfish, skates, halibut, whiting, sharks
Pacific halibut	26,000	21,000	.800	Rockfish, spiny dogfish, skates, sharks, sablefish
Pacific coastal pelagics	123,000	2,600	.020	Flatfish, skates, halibut
Pacific whiting	142,000	600	.004	Rockfish, salmon
Regional Total	316,200	47,400	.150	
National Total	3,717,000	1,058,000	.280	
Global Total[11]	78,400,000	6,800,000	.080	

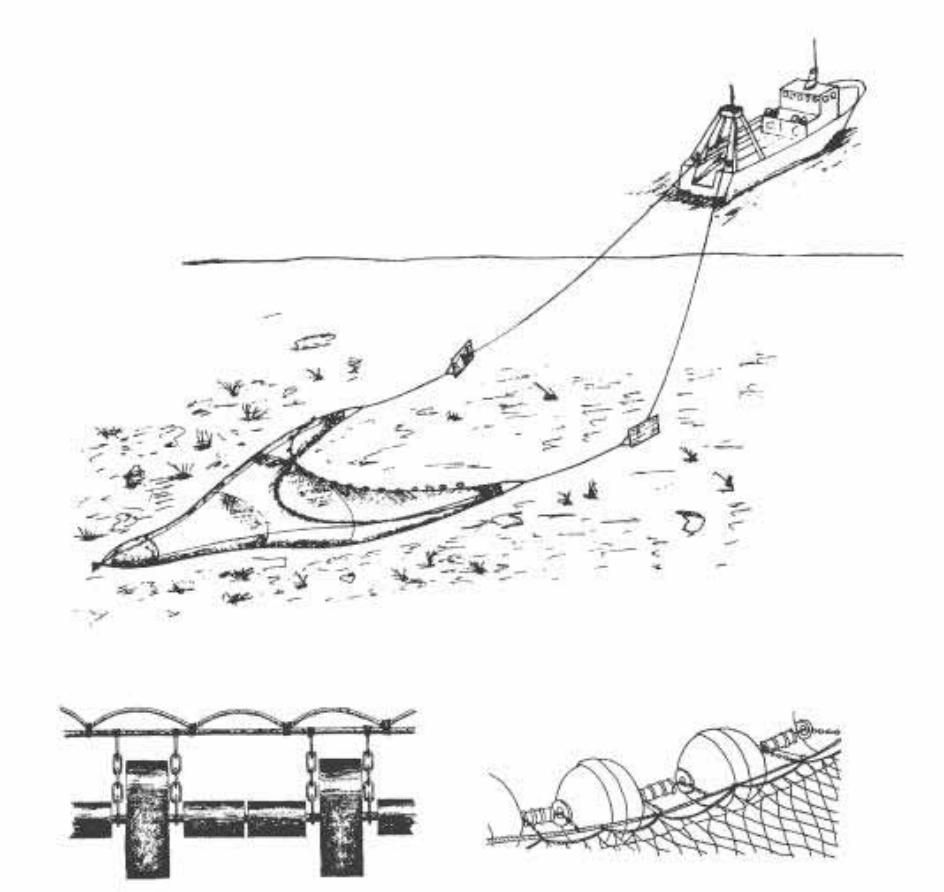
Amendment 18 (Bycatch Mitigation Program) to Pacific Coast Groundfish Fishery Management Plan, 2005

- Standardized report methods
- Observers/electronic monitoring
- Full retention program (keep all fish caught)
- Total catch limits
- Catch allocation to low-bycatch gear types
- Recreational catch-and-release
- Gear type restrictions & prohibitions
- Time-area closures, including MPAs
- Controls on fishing capacity

Role of MPAs in Addressing Bycatch

- MPAs can reduce bycatch by reducing overall catch (effort reduction)
- Other bycatch reduction strategies are more effective:[13]
  - Gear modification (e.g., turtle-excluder devices)
  - Deployment, retrieval changes (e.g., “back-down” in tuna purse-seining)
  - Training (recognition of bycatch potential, techniques, technology)
  - Management actions (e.g., time-area closures, individual vessel by-catch limits)

Habitat Alteration: Trawling

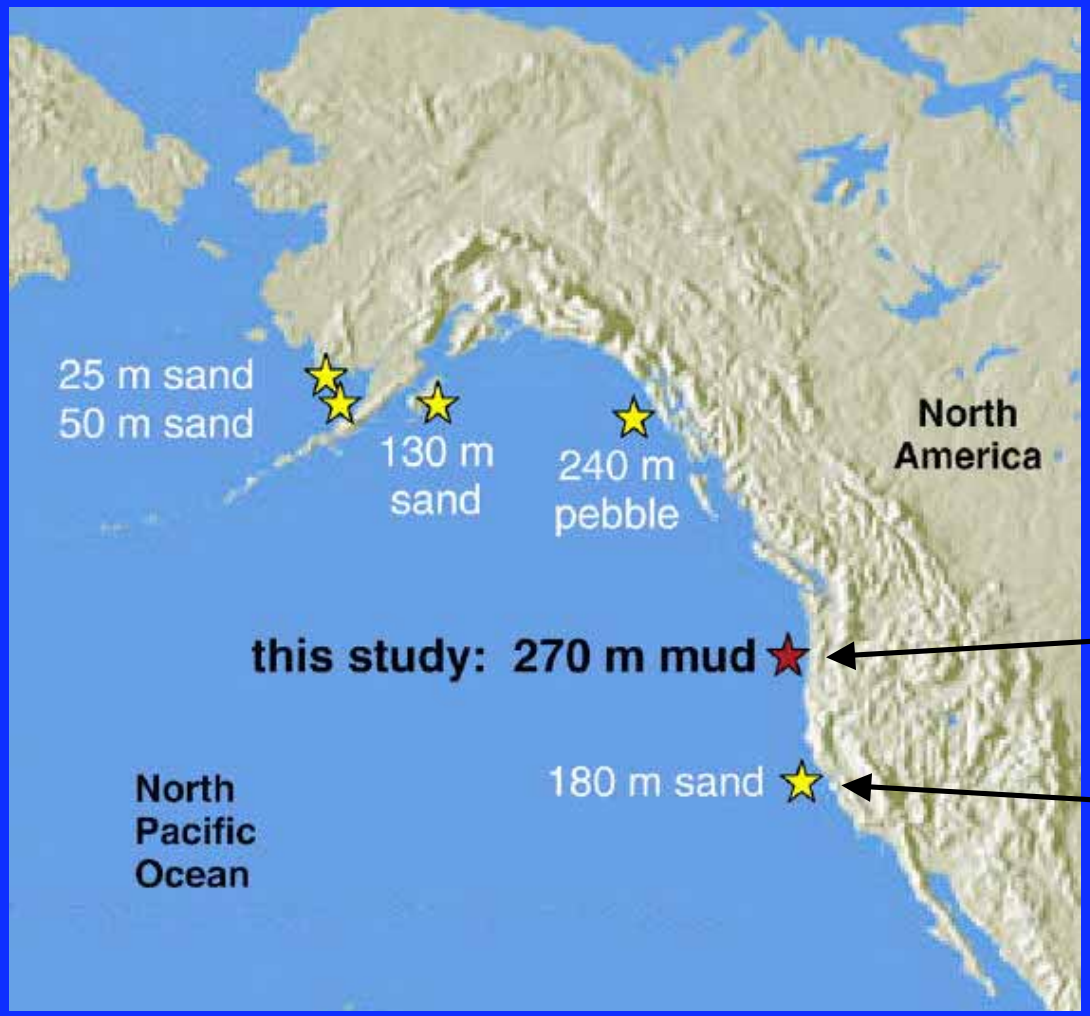


From Watling & Norse, 1998[15]

Impacts of Bottom Trawling:[14]

- Reduces habitat complexity
- Alters benthic communities
- Reduces benthic productivity
- Soft-bodied, erect, sessile organisms in low-disturbance regimes most susceptible.

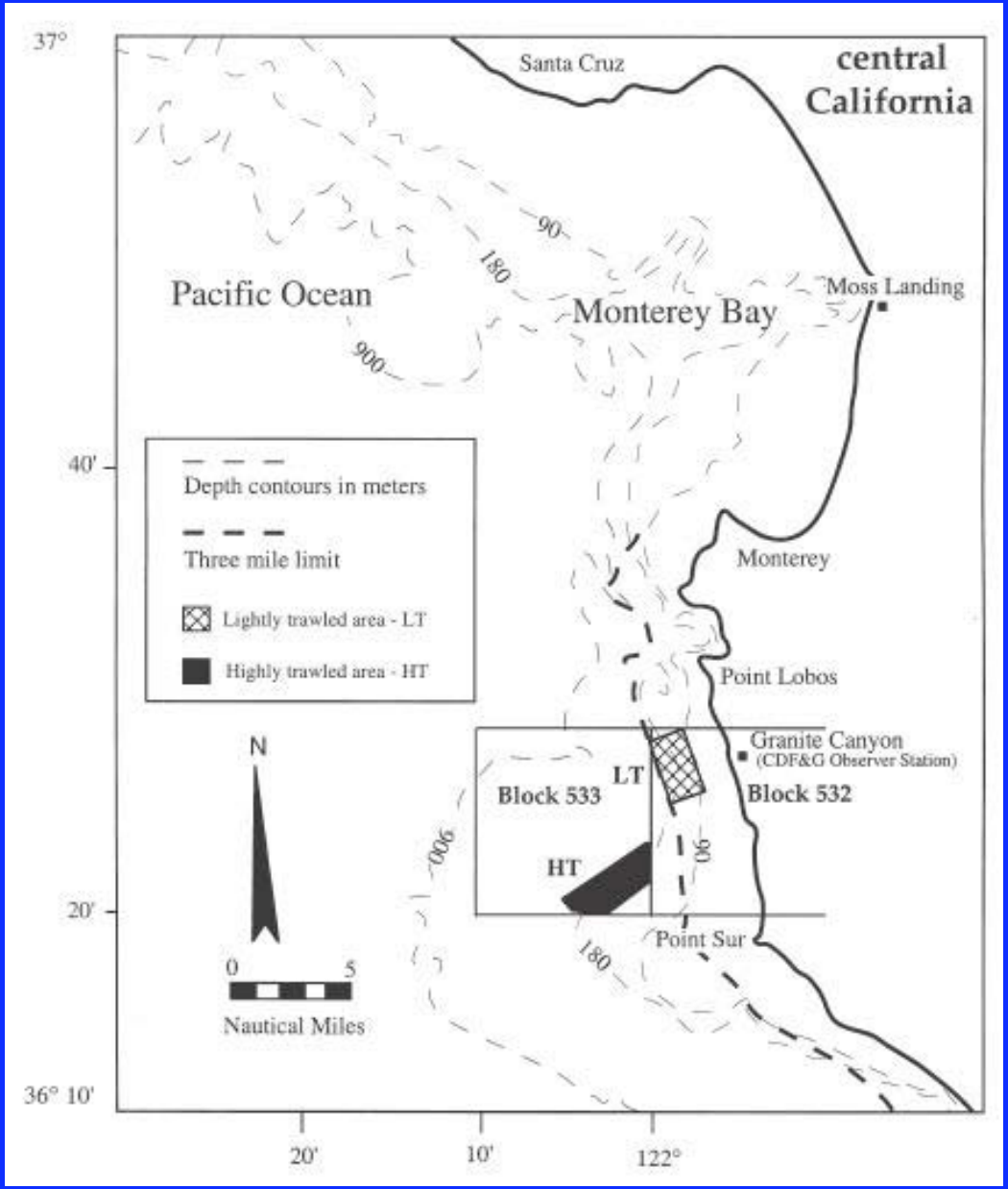
West Coast Studies of Trawling Impacts



Hixon & Tissot, 2007[16]

Engel & Kvitek, 1998[17]

From Hixon & Tissot, 2007[16]



From Engel & Kvitek, 1998[17]

Engel, J., & R. Kvitek. 1998. Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary, *Conservation Biology* 12:1204-1214.[17]

Engel & Kvitek, 1998[17]

Data:

- Stills, video from manned submersible
- Grab samples
- Fish guts

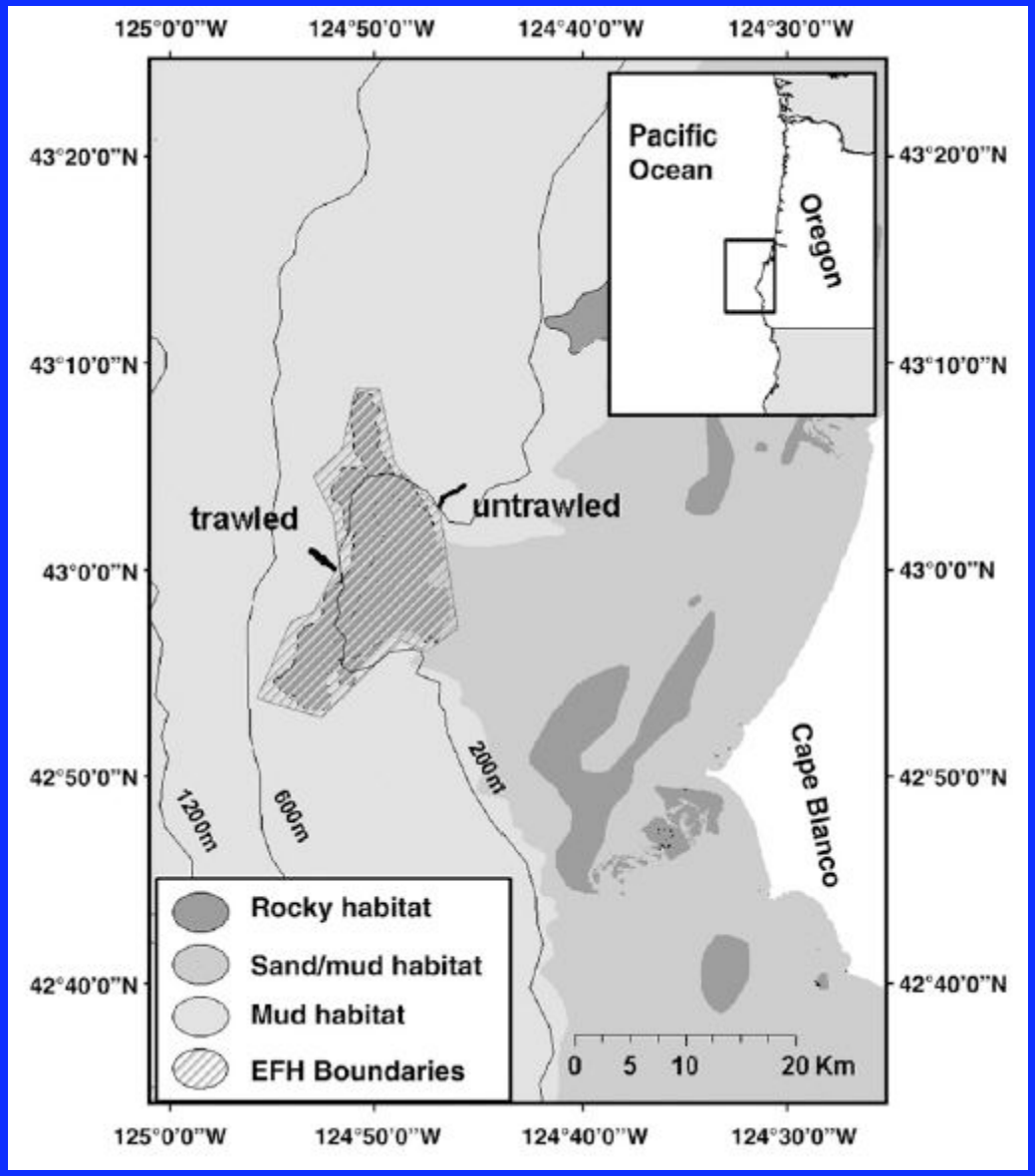
Results:

Epifaunal invertebrates	All species counted more abundant in low trawl, esp. long-lived spp.
Polychaete infauna	More abundant, more diverse in low trawl
Infaunal crustaceans	No difference
Oligochaetes & nematodes	More abundant in high trawl
Brittle stars	No difference
*Chloeia pinnata*i polychaete	More abundant in high trawl
Mounds, rocks vertical relieve	More abundance in low trawl
Trawl tracks, crushed shell debris	More abundant in high trawl

Engel & Kvitek, 1998[17]

Conclusions:

- High density trawling increased density of opportunistic infauna and prey of commercial fish species
- High density trawling reduced habitat complexity and biodiversity, which may degrade habitat for juveniles
- Use marine reserves to experimentally determine optimal level of trawling for preserving fish stocks as well as biodiversity.



From Hixon & Tissot, 2007[16]

Hixon, M.A., & B.N. Tissot. 2007. Comparison of trawled vs. untrawled mud seafloor assemblages of fishes and macroinvertebrates at Coquille Bank, Oregon. *J. Exp. Mar. Biol. Ecol.* 344:23-34[16]

Hixon & Tissot 2007[16]

Data:

- Visual transects from manned submersible
- Stills, video from manned submersible

Results:

- 34% more fish, and more species of fish, over untrawled versus trawled
- Epibenthic invertebrates 6 times more abundant, but fewer taxa, on untrawled versus trawled.

Untrawled Species Assemblage:

- Sea pens
- Spotted ratfish
- Sablefish
- Ronquil
- Slender sole
- Poacher

Trawled Species Assemblage:

- Red seastars
- Sunstars
- Hermit crabs
- Bigfin eelpout
- Dover sole
- Hagfish
- Shortspine thornyhead

Hixon & Tissot 2007[16]

Conclusions:

- Observed differences were due to trawling *per se*
- Results consistent with those from other areas of the world
- Trawling impacts can occur on mud as well as rocky bottom habitats

Role of MPAs in addressing impacts of bottom trawling

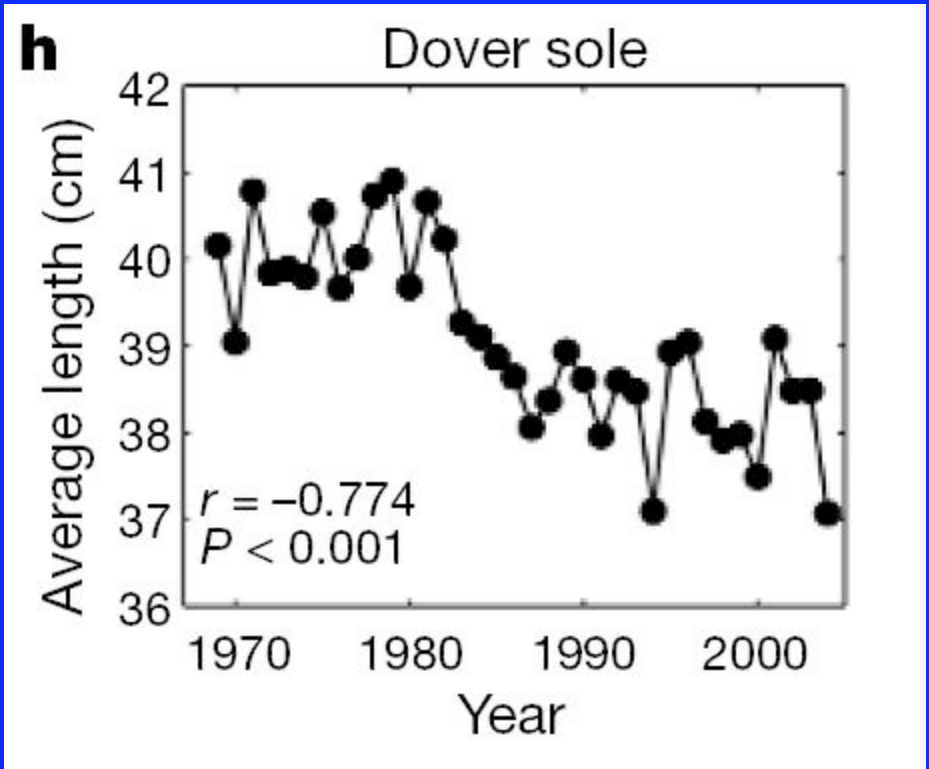
- Use marine reserves to experimentally assess the impact of trawling, devise optimum trawling strategy
- Use marine reserves to restore and preserve benthic habitats

Fishery Impacts on Age and Size in Target Stocks

Fishing leads to shift toward maturation at smaller size/younger age[18,19,20]

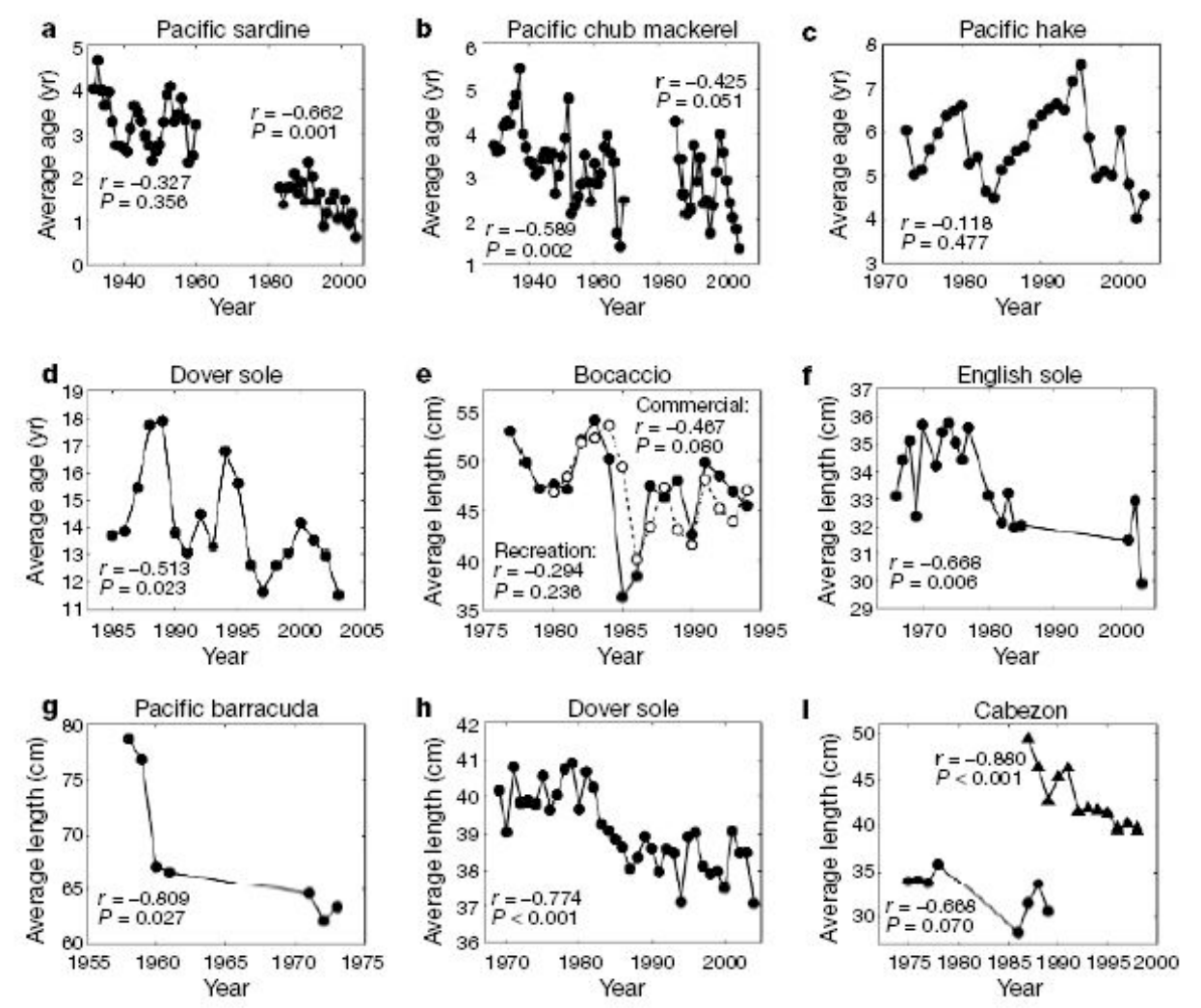
- Gear types and regulations encourage capture of largest & oldest fish
- Selects against fish that breed at older ages, larger sizes
- Selects for fish that breed at earlier ages, smaller size
- Fisheries-induced evolution toward smaller/younger age classes[21]

West Coast Examples of Fishery-induced life history modification



From Hsieh et al, 2006[18]

West Coast Examples of Fishery-induced life history modification



From Hsieh et al, 2006[18]

Life History Modification: Consequences

- Fewer eggs produced (smaller females)
- Eggs/larvae are lower quality in younger/smaller reproducers,[22] leading to poor recruitment
- Remove proven survivors and their egg production, recruitment capacity and offspring (large, old individuals have survived previous episodes of poor environmental conditions
- Remove “bet-hedgers:” Age-related variation in timing, location of spawning spreads effort across variable environments
- Reduce yield of target stocks
- Increased population variability and risk of collapse
- Stock may not recover (e.g., northern cod[19])

Can MPAs Protect Stocks from Fisheries Impacts on Age and Size?

- Model results from Baskett et al, 2005 [23]
- Model results from Berkeley, 2006[24]

Baskett, Levin, Gaines & Dushoff, 2005. Marine reserve design and the evolution of size at maturation in harvested fish. *Ecological Applications* 15:882-901.[23]

- Mathematical model to assess impact of conventional fisheries management (harvest rates, maximum size limit) vs. MPA networks on:
  - Size at maturation
  - Population size
  - Size distribution of population
  - Biomass yield
- Used biological parameters of bocaccio (*Sebastes paucispinis*) and yelloweye rockfish (*S. ruberrimus*)

Baskett et al, 2005.[23]

- Conclusions:
  - Traditional management = marine reserves for age-at-maturation
  - Traditional management ≥ marine reserves for long-term biomass yield
  - Marine reserves are more robust to environmental uncertainty, scientific and management uncertainty, and enforcement uncertainty.

Berkeley, S.A. 2006. Pacific rockfish management: are we circling the wagons around the wrong paradigm? *Bulletin of Marine Science* 78:655-668.[24]

- Focus on management strategies for west coast rockfishes
- Groundfish Fisheries Management Plan covers 63 species, 7 of which are declared overfished:

Species	Maximum age	Age at 50% maturity	Spawning biomass (as % of B_0)	Recovery time (yr) with no fishing
Black,[a] *Sebastes melanops*	50	7	49	NA
Bocaccio, *S. paucispinis*	50	?	7	18
Canary, *S. pinniger*	84	8	8	54
Cowcod, *S. levis*	55	11	7	59
Darkblotched, *S. crameri*	105	8	14–17	8
Pacific Ocean perch, *S. alutus*	100	8	25	15
Widow, *S. entomelas*	60	6	22	23
Yelloweye, *S. ruberrimus*	118	19	24	21

[a]Not overfished

- Current strategy: control fishing effort to maintain spawning output at or above 40% of unfished population. No effort to control size taken.

Berkeley, 2006[24]: The model

- Mathematical model that accounts for influence of maternal age on larval survival.
- Compare impacts of 4 different management strategies:
  - Status quo
  - Slot limits
  - Marine reserves
  - Reduced fishing mortality
- On 4 fishery attributes:
  - Population age structure
  - Fishery yield
  - Larval output
  - Recruitment
- Used biological parameters of black rockfish (*Sebastes melanops*)

Berkeley, 2006[24]: Conclusions

- Marine reserves increase recruitment, with no loss or modest increase in yield over the long-run.
- Effort reduction gives same recruitment, slightly higher yield, but effort reduction (35%) likely unacceptable in short term.
- Additional advantages of marine reserves:
  - Protect bycatch species
  - Maintain species diversity
  - Maintain resilience of targeted populations by protecting all age classes
  - Eliminate fishing gear impacts

MPAs as Research Tools

- How do ecosystems change with minimal human impacts?
  - Use MPAs to protect undisturbed, baseline control sites[25]
- Discern fisheries-related impacts from non-fisheries impacts on ecosystem change
  - Use MPAs to set up paired treatments[16]
  - Replicate treatments for robust statistical design

Conclusions

- Globally, MPAs can protect and restore marine ecosystem biodiversity and ecosystem services.
- Fishing activity is impacting the marine ecosystem in federal waters of MBNMS
- MPAs, plus sound fishery management, can improve and protect marine ecosystem services.

Conclusions, con’t

- Multiple stressors impact marine ecosystems in federal waters of MBNMS (e.g., pollution, climate change, oceanographic regime shifts)
- MPAs, esp. marine reserves, are the only way to disentangle human from non-human impacts, esp. fishery-related from non-fishery related impacts.
- Established MPAs, especially marine reserves, attract research funding and research initiatives.

Questions?