CAN MPAs CONTRIBUTE TO ECOSYSTEM PROTECTION GOALS OF THE MBNMS?

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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 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

• 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)

- 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, 2006³
Marine Reserves/Fisheries Closures Can Protect/Restore Ecosystem Services

From Worm et al, 2006
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

• Well-documented in nearshore waters – Coral Reefs
– Tropical and subtropical seagrass beds
– Oysters and nutrient enrichment in estuaries
– Kelp Forests
Kelp forest example:

Before fishing:

A. Kelp Forests
- Alaska/California
- Killer whales
- Sea otters
- Sheephead
- Abalones
- Lobster
- Sea urchin
- Kelp

B. Kelp Forests
- Gulf of Maine
- Sea mink
- Cod
- Killer whales
- Sea otters
- Sheephead
- Abalones
- Sea urchin
- Kelp

After fishing:

- People
- Lobster
- Sea urchin
- Abalones
- Sea otters
- Sheephead
- Sea mink
- Cod
- Killer whales

Images of kelp forest tissue and bottom.
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\textsuperscript{7,8}

From Frank et al., 2005\textsuperscript{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

From the cover of Kelleher, 2005
Bycatch: Impacts

• Living resources are wasted (growing human population, declining fisheries\textsuperscript{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)

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

Impacts of Bottom Trawling:\textsuperscript{14}

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

From Watling & Norse, 1998\textsuperscript{15}
West Coast Studies of Trawling Impacts

From Hixon & Tissot, 2007

Hixon & Tissot, 2007

Engel & Kvitek, 1998

From Hixon & Tissot, 2007

From Engel & Kvitek, 199817
Engel & Kvitek, 1998¹⁷

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

Results:

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epifaunal invertebrates</td>
<td>All species counted more abundant in low trawl, esp. long-lived spp.</td>
</tr>
<tr>
<td>Polychaete infauna</td>
<td>More abundant, more diverse in low trawl</td>
</tr>
<tr>
<td>Infaunal crustaceans</td>
<td>No difference</td>
</tr>
<tr>
<td>Oligochaetes &amp; nematodes</td>
<td>More abundant in high trawl</td>
</tr>
<tr>
<td>Brittle stars</td>
<td>No difference</td>
</tr>
<tr>
<td><em>Chloeia pinnata</em> polychaete</td>
<td>More abundant in high trawl</td>
</tr>
<tr>
<td>Mounds, rocks vertical relieve</td>
<td>More abundance in low trawl</td>
</tr>
<tr>
<td>Trawl tracks, crushed shell debris</td>
<td>More abundant in high trawl</td>
</tr>
</tbody>
</table>
Engel & Kvitek, 1998

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
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
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\textsuperscript{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\textsuperscript{21}
West Coast Examples of Fishery-induced life history modification

From Hsieh et al, 2006\textsuperscript{18}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{doversole.png}
\caption{Dover sole}
\end{figure}

\begin{align*}
r &= -0.774 \\
P &< 0.001
\end{align*}
West Coast Examples of Fishery-induced life history modification

From Hsieh et al, 2006
Life History Modification: Consequences

- Fewer eggs produced (smaller females)
- Eggs/larvae are lower quality in younger/smaller reproducers,\(^2\) 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
• Model results from Berkeley, 2006

- 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.\textsuperscript{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.

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

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

*Not overfished

- Current strategy: control fishing effort to maintain spawning output at or above 40% of unfished population. No effort to control size taken.
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*)
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\textsuperscript{25}

• Discern fisheries-related impacts from non-fisheries impacts on ecosystem change
  – Use MPAs to set up paired treatments\textsuperscript{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?