Climate Change Effects and Reef Fishes

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Warning:

This talk contains hard-boiled facts

with some

hard-boiled speculation
Overview

• Reef fishes

• Habitat and habitat loss from climate change and other factors

• Ocean acidification

• Responses to projected environmental changes

• Extinction risks

• Implications for biodiversity conservation and natural resource management

• Specific implications for the Pacific region

• Research needs
Reef Fishes

- Highly significant component of reef systems
- Important in biological and biophysical dynamics
- High diversity, endemism, specialization, but variable levels of abundance at any locality
- Important for subsistence, artisanal, and commercial fisheries, and aquaculture (food, bait and ornamental species)
- Significant problems with by-catch
- Important more recently for non-extractive benefits (also intrinsic biodiversity value)
Role of Coral Habitats for Reef Fishes

Shelter

Food

Breeding sites
Habitat Loss From Bleaching

- Reduction of architectural complexity and integrity
  - Loss of 3-D complexity
  - Loss of food sources

- Habitat phase shifts
  - Monolithic species composition or domination
  - Change from coral domination to algal domination

- Degradation
  - Formation of rubble and sand

Sheppard (2006)
Responses by Reef Fishes to Habitat Loss

Direct responses:

- Decline in species diversity and abundance
- Decline in coral specialist species
- Decline in species with ontogenetic or facultative use of corals

Indirect responses:

- Cascade effects upon predators that prey upon coral-dependent species
- Cascade effects upon omnivores and herbivores that feed upon prey or forage associated with coral structure
Ocean Acidification: Threat to Larval (and Adult) Fishes?

- Most species of reef fishes and amphidromous insular freshwater fishes have pelagic larvae

- Development of calcified structures may be impaired

- Homing abilities compromised (Munday et al. 2008)

- Recruitment failure likely

- Cascade effects upon planktivores and predators of planktivores because of loss of plankton from acidification

- (Fine print: habitat effects, too)
Extinction Risks

• Increasing annually in marine and terrestrial systems (Hughes et al., 1997; Roberts and Hawkins, Chapin et al., 2000)

• Major sources: habitat loss, over-exploitation, intrinsic factors, and indirect effects (Hilton-Taylor, 2000)

• Put another way: anthropogenic + non-anthropogenic processes can cause a lot of trouble

• Increased extinction rates range in magnitude: massive or global scales (May and Tregonning, 1998) to highly localized events (Carlton et al., 1999; Pitcher, 2001; Dulvy et al., 2003)
Extinction Susceptibility, Vulnerability and Risk

- Both wide and narrow-ranging species are vulnerable to extinction

- Life history correlates predispose many species to extinction susceptibility

- Two major kinds of factors contribute to this susceptibility:

  Intrinsic factors (life history)

  Extrinsic factors
  (anthropomorphomorphic and non-anthropomorphomorphic)
Intrinsic Factors: Life History Correlates

Individual level:
- Large body size
- Late maturity
- Long life span
- Long generation time

Population level:
- Small range size
- Rare or low abundance
- Reproductive bottlenecks
- Allee effects

(Jennings et al., 1999; Hudson, 2003; Reynolds, 2003)
Extrinsic Factors

Habitat loss and physiological/trophic disruptions

- Coral bleaching from ocean warming (Hoegh-Guldberg et al. 2007)
- Ocean acidification effects on habitats (Munday et al. 2008; this Inter-Congress)

- Coral disease and predation
- Storm, volcanic, and seismic activities
- Natural degradation (time waits for no one or nothing)
- Anthropogenic causes (pollution, sedimentation, direct physical destruction, destructive fishing, etc.)

Over-exploitation

- Subsistence, artisanal and commercial fishing of target species (food and ornamental species)
- Live Trade fisheries
- By-catch
- Ghost fishing
Interaction Between Intrinsic and Extrinsic Factors

- Extinction susceptibility = $I + E + (Interaction)$

- $I =$ sum of intrinsic factors
- $E =$ sum of extrinsic factors
- Interaction = $(I \times E)$

(Hudson, 2003; Purvis et al., 2005; Donaldson, 2007; Donaldson et al. in prep)
The Other Stuff

- Species responses to habitat loss or physiological/trophic disruptions from climate change will not occur in a “vacuum”

- Species responses will be exacerbated by existing negative impacts from anthropogenic and non-anthropogenic factors

- Exploitation (and over-exploitation) of highly favored species will continue because their value increases with rarity (overrides economic extinction)

- Effects of climate change upon fish diversity and abundance will have to be a subset of overall effects from all impacts
Response

\[ I = c + a + n + \text{(interactions of } c, a, n) \]

- \( I \) = impact
- \( c \) = climate change-induced habitat loss or physiological/structural/trophic effects from ocean acidification
- \( a \) = anthropomorphic source effects
- \( n \) = non-anthropomorphic source effects

The degree of impact will affect the probability of a localized species extinction or larger extinction event.
Consequences of impact on fishes and fish assemblages for ecosystem services to humans

- Reduction in principal fisheries regardless of level of fishery
- Shift in emphasis towards other species with corresponding declines of those species because of cumulative effects
- Increased effort in fisheries but decreased yields
- Increased effort for rare and highly-prized species
- Overall reduction in available resources
Implications for Biodiversity Conservation and Resource Management

• Loss of reef fish resources from climate change-induced habitat losses will be equivalent to massive exploitation events

• “Business as usual” makes the problem worse

• Localized extinctions occur

• Management strategies must include two components: quick fix actions in the absence of both time and knowledge, and

Research to fill data gaps but also to provide predictions of outcomes and possible mitigation actions while the clock is running
Specific Implications for the Pacific Region

• Decline or loss of intrinsic value in biodiversity coupled with phase shift effects
• Loss of keystone species
• Extinction at local and regional levels
• Long-term effects not so cheerful as primary, secondary, tertiary…. species, especially those most susceptible to extinction, decline in abundance
• Fisheries impacted negatively by declines
• Live Trade or other commercial fisheries may increase in importance over the short term by exploiting “rareness effect” of target species
• Local fishers may realize short term gains if employed in the Live Trade or other commercial fisheries but suffer long-term effects and from localized extinctions
• Socioeconomic consequences
Research Needs

• Product knowledge- know what you’re working with

• Obtain knowledge of intrinsic and extrinsic factors and their effects for any given species

• Measurement of direct and indirect responses to coral bleaching and ocean acidification in reef systems

• Application of standardized assessment methods globally

• Assemble and update database to provide fodder for analyses
Research Needs: Responses

• Conduct meta-analysis of data in order to address specific questions or make predictions regarding species responses in relation to other impacts

• Equate habitat loss/acidification impacts with massive exploitation events

• Estimate probabilities of extinction

• Develop geospatial models of the geography of extinction

• Estimate probabilities of recovery
Meanwhile: The Manager’s Conundrum

• Triage?

• Mitigation?

• Make Strange Alliances To Save What Your Can?

• Get a Bigger Ultra-Cold Freezer And Work On Your Cloning Skills?

• Cross Your Fingers and Hope For Better Days?
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