Climate Change Effects and Reef Fishes in the Mariana Islands

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Overview

- Reef systems of the Mariana Islands
- Reef fishes
- Extinction risks
- Habitat and habitat loss
- Responses to projected environmental changes
- Research needs
- Implications for reef fish management
- Implications specific for the Mariana Islands

Reef Fishes

- Highly significant component of reef systems
- Important in biological and biophysical dynamics
- High diversity, endemism, and specialization (including microhabitat), but variable levels of abundance
- Important for subsistence, artisanal, and commericial fisheries
- Significant impacts from take as by-catch
- Important more recently for non-extractive benefits

Reef Systems of the Mariana Islands

- "Old" reef systems: Southern Mariana Islands (ca. 1,000 species of fishes)

  Older islands (35-45 myp) of limestone on volcanics with more extensive coral reef development and greater habitat complexity (Guam, Rota, Aguigan, Saipan, and Farallon de Mendinilla)

- "Young" reef systems: Northern Mariana Islands (ca. 600 species of fishes)

  Recent (1-1.5 myp) volcanic islands with limited coral development, rocky reefs, and low habitat complexity (Anatahan, Sarrigan, Guguan and Uracas)

- Both systems have low levels of known endemism but high levels of low relative abundance for many species

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 and their interaction
- 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 (life history factors)
- Extrinsic (anthropomorphic and non-anthropomorphic factors)

Intrinsic Factors: Life History Correlates

Individual level:

- Large body size
- Late maturity
- Long life span
- Long generation time
- Specialized habitat or trophic requirements

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

- Coral bleaching
- Ocean acidification
- Coral disease and predation
- Storm, volcanic, and seismic activities
- Natural degradation
- Anthropogenic causes (pollution, sedimentation, direct physical destruction, destructive fishing, etc.)

Over-exploitation

- Subsistence, artisanal and commercial fishing of target species
- Live Trade fisheries (food and ornamental)
- 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 x E)

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

Role of Habitat for Reef Fishes

Shelter

Food

Breeding sites

Habitat Loss From Climate Change Effects (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 Climate Change-Induced Habitat Loss

Direct responses:

- Decline in species diversity and abundance
- Decline in coral specialist species (obligative use)
- Decline in species with ontogenetic use of corals (facultative use)

Indirect responses:

- Cascade effects upon predators that prey upon coral-dependent species
- Similar effects upon omnivores and herbivores that feed upon prey or forage associated with coral structure

Acidification: Threat to Larval Fishes?

- Most species of reef fishes and amphidromous insular freshwater fishes have pelagic larvae
- The formation of calcified structures (i.e., bones) may be inhibited
- Recruitment failure or poor recruitment likely
- Prey also at risk

Cumulative Effects

- Species responses to habitat loss from climate change will not operate 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

$$I = Lc + La + Ln + (Lc \times La \times Ln)$$

- I = impact
- c = climate change-induced habitat loss effects
- a = anthropomorphic source effects
- n = non-anthropomorphic source effects

- The degree of impact will affect probability of localized extinction

Donaldson in review

Research Needs

- Product knowledge- know what you're working with
- Intrinsic and extrinsic factors

- Measurement of direct and indirect responses
- Application of assessment methods

- Equating habitat loss impacts with massive exploitation events
- Geospatial models of the geography of extinction

- Estimating probabilities of recovery
- Addressing the worst case scenario

Implications for Reef Fish Management

- Loss of reef fish resources from climate change-induced habitat losses will be equivalent to a massive exploitation event
- Business as usual makes the problem worse
- Localized extinctions

- 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

Implications Specific for the Mariana Islands

- Fisheries will be affected negatively by declines in abundance and diversity
- Certain local fisheries may increase in importance over the short term by exploiting "rareness effect" of target species
- Long-term effects include the decline in the abundance of species most susceptible to extinction
- Tourism impacted (scuba diving and snorkeling, recreational fishing, hotel-restaurant services)
- Decline or loss of intrinsic value in biodiversity coupled with phase shift effects from loss of species

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