Assessment of the trophic impacts of fishing in the central Pacific Ocean

Steve Martell\textsuperscript{1}
Sean Cox\textsuperscript{2}

\textsuperscript{1} Center for Limnology, 680 North Park Street, Madison, WI, 53706, U.S.A.
\textsuperscript{2} School of Resource and Environmental Management, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6
CNP Fishing Fleets

- Pole and line
- Longline
- Driftnet
- Purse seine
1. Can an ecosystem-model (Ecosim) reproduce dynamics of apex predators as predicted by the single-species approach?

2. Have apex predator dynamics affected recruitment of tunas?
Direct harvest tradeoffs among fleets are better analyzed from a single-species perspective.

Indirect harvest tradeoffs owing to predator/prey interactions cannot be addressed using single-species approach.

3. So, where do the main effects of fishing appear in the CNP ecosystem?

4. Does the ecosystem model imply indirect harvest trade-offs?
Biomass next year = Growth/survival of biomass this year + Biomass of new recruits

\[ \text{Stochastic variation in juvenile survival} \]

\[ B_{t+1} = g_t B_t + R_t \exp(v_t) \]

\[ g_t = S[1-\exp(qE_t)][\frac{\alpha}{m_t} + \rho] \]

• We used a delay-difference model, with full age structured accounting for juveniles
Multi-species production model (Ecosim)

\[ B_{t+1} = g_t B_t + R_t \exp(v_t) \]

- Biomass next year
- Growth/survival of biomass this year
- Biomass of new recruits
- Deterministic variation due to predation, feeding, & growth

\[ g_t = S[1-\exp(qE_t)][\alpha/m_t+\rho] \]
Biomass trends: Apex Predators

Blue Marlin

Biomass (kg km⁻²)

1950 1970 1990

Blue Shark

Biomass (kg km⁻²)

1950 1970 1990

Swordfish

Biomass (kg km⁻²)

1950 1970 1990

Other Billfish

Biomass (kg km⁻²)

1950 1970 1990

Other Sharks

Biomass (kg km⁻²)

1950 1970 1990

CPE data are scaled to Ecosim fits for trend comparison.
Biomass trends: Albacore Tuna

Large Albacore

Small Albacore

CPE data

Ecosim

Single-species
Biomass trends: Bigeye Tuna

Large bigeye
- CPE data
- Ecosim
- Single-species

Small bigeye
- CPE data
- Ecosim
- Single-species

Biomass (kg·km\(^2\))

Biomass trends: Yellowfin Tuna

Large yellowfin
- CPE data
- Ecosim
- Single-species

Small yellowfin
- CPE data
- Ecosim
- Single-species
Biomass trends: Skipjack tuna

Skipjack biomass

- CPE data
- Ecosim
- Single-species
1. Can an ecosystem-model (Ecosim) reproduce dynamics of apex predators as predicted by single-species approach?

- Apex Predators: captures declining trends
- Albacore: matches decadal trends
- Bigeye tuna: not so well
- Yellowfin tuna: surprisingly good for juveniles
- Skipjack tuna: almost identical
Mortality Components

Small yellowfin mortality

Skipjack mortality

- Billfish
- Sharks
- Tuna
- Fishing

Mortality rate (yr⁻¹)


0.0 0.3 0.6 0.9 1.2 1.5
2. Have apex predator dynamics affected recruitment of tunas?

- **Bigeye**: an effect on recruitment causes large discrepancies from single-species. **Unlikely**
- **Yellowfin**: predicted apex predator declines cause similar juvenile dynamics as single-species. **Possible**
- **Skipjack**: fishing appears to be main factor, not apex predators. **Unlikely**
3. So, where do the main effects of fishing appear in the CNP ecosystem? Small scombrids

- But, such data do not exist... of course!
4. Does the ecosystem model imply indirect harvest trade-offs?

- Suppose a miracle device is developed to reduce or eliminate by-catch of apex predators in longline fisheries.
- Simulation: this device only reduces $F$ on apex predators and $F$ on all remaining species remains constant at present rates.
Question 4: By-catch reduction

- Would a single-species model make this prediction?
Conclusions

- Ecosystem models require same tenuous assumptions as single-species.
- “Fish gotta eat somethin”. Beyond that, ecosystem models contain multiple layers of uncertainty that we have yet to evaluate quantitatively.
- Evaluating indirect harvest trade-offs or environmental forcing must consider how effects propagate through food webs.