Evidence for Ecosystem Overfishing in North Pacific Ecosystems

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Basic tenet of renewable natural resource mgt

\[ R_{\text{removal}} \leq R_{\text{renewal}} \]
Stock Overfishing

C↓, E↑, CPUE ↓, repeat...
(Graham's Law of Overfishing)

\[ F_{\text{max}} \rightarrow \begin{cases} N, B, Y, B/B_{\text{MSY}} \\ r, \text{size}_{\text{mat}}, \text{age}_{\text{mat}}, \uparrow \\ \text{wt}_{a}, \text{len}, g \end{cases} \rightarrow \begin{cases} E \\ \text{Area}_{\text{fished}} \\ F/F_{\text{MSY}} \end{cases} \]
Ecosystem Overfishing

\[ C_1 \downarrow, E_1 \uparrow, \ldots \text{CPUE}_1 \to \text{min}; \to E_2 \uparrow, C_2 \uparrow, \text{CPUE}_2 \uparrow, C_2 \downarrow, E_2 \downarrow, \ldots \text{CPUE}_2 \to \text{min}; \to \]

(Law of Sequential Depletion)

\[ F_{\text{system}} \to \max \quad \text{yields} \quad \begin{cases} \sum N, \sum B, \sum Y, B_{\text{apex}} \\ \bar{l}, \text{cum}B_{\text{infl}}, \text{cum}P \quad \uparrow \\ L_{\text{index}}, \text{TST}, A, R, TL_{\mu} \end{cases} \quad \begin{cases} E, \beta \\ \text{Area}_{\text{fished}} \end{cases} \quad \frac{F_{\text{system}}}{F_{\text{System MSY}}}
\]
Stock Overfishing

Ecosystem Overfishing

A

B

time
Bottom Line: cumulative trophic curve big “S” and shrinking hockey sticks are everywhere, respond consistently to perturbation, and can inform marine ecosystem overfishing

What’s the Point:
- Every marine ecosystem exhibits these emergent patterns (>120 cases) of cumB-TL, cumB-cumP
- The “S” and hockey stick curves always stretch, shrink and move toward origin under perturbation
- Tracking curve parameters follows dynamics of an ecosystem and indicates degree of recovery/perturbation
- Globally, empirical and modeled thresholds emerge when tracking perturbation wrt 1st & 2nd derivative (i.e. slope & inflection point) on “S” curve
  - cumB_{infl pt} $\sim$ 33%
  - TL_{infl pt} $T$ $\sim$ 3.38
  - Steep $\sim$ 0.5

Read more (since we don’t have lots of time now):
Link et al. 2015, TREE v.30- main description
Libralato et al. 2019, Ecol. Ind. v. 103- thresholds
Pranovi et al. in press, Glob. Change Biol.- decadal patterns for all LMEs
Bottom Line: There are real limits to how much fish any ecosystem can produce, can be caught, and there are associated thresholds that can delineate EOF

What’s the Point:

- Trophic transfer calculations, modeling, and global observations, show limits to fisheries production, as set by PP
- Total Oceanic Primary Production is on the order of 40-50 G ton C yr⁻¹
- Total Marine Capture Fishery Yield is on the order of 0.1 G ton yr⁻¹ and has been for 30+ years
- From these, we can calculate thresholds used to delineate Ecosystem Overfishing (EOF)
  - Ryther index ~ 1 (to a high of 3) t km⁻² yr⁻¹
  - Fogarty index ~ 1‰
  - Friedland index ~1
- These thresholds suggest that ~50% of the worlds LMEs are experiencing EOF

Read more (since we don’t have lots of time now):
Link and Watson, Science Adv. v.5- main description
Stock et al. 2017, PNAS v. 114- relating PP to fish production
Fogarty et al. 2016, Environ. Dev. v. 17- fishery production potential
Friedland et al. 2012, PLoS One v. 7- relating PP and chl a to fish production
H₀: PP $\rightarrow$ B_{targeted, protected spp, ecosystem} $\leftrightarrow$ L↑_{targeted spp, bycatch} $\rightarrow$ jobs, economic revenue

c.f. Link and Marshak 2019, RFBF v.29
Examples of early detection signal

Show up in:

- Abundance
- Mean size
- CPUE (Catch Per Unit Effort)
- Biomass
- T/L (Trend/Long-term)
- F/F
- B/B
- E/E
- Effort
- Landings
- Others

Almost always 5-10 yrs earlier in EOE indicators

Show up in Sea of Japan/East Sea

Doesn't matter if a set of single stocks, aggregate groups, guilds, entire TL, etc.

Often with signs of sequential depletion, expanded area, etc.

From Sea Around Us
www.seaaroundus.org
Examples of early detection signal

From Sea Around Us

www.seaaroundus.org

Sea of Okhotsk

Shows up in:

- Abundance
- CPUE
- Biomasses
- Landings
- Mean size
- Effort
- Mean TL

Almost always 5-10 yrs earlier in EOF indicators

Doesn’t matter if a set of single stocks, aggregate groups, guilds, entire TL, etc.

Often with signs of sequential depletion, expanded area, etc.

Note: The data we present (reconstructed data) combine official reported data and reconstructed estimates of unreported data (including major discards), with reference to individual EEZs. Official reported data are mainly extracted from the Food and Agriculture Organization of the United Nations (FAO) FishStat database. The ‘Reported catch’ line overlaid on the catch graph represent all catches deemed reported (including foreign) and allocated to this spatial entity. For background information on the reconstruction data, download the .pdf file for the specific EEZ(s) and also examine our methods for data and spatial allocation.
Examples of early detection signal

From SWFSC
Harvey et al. 2018
Conclusions

• Many (>6 out of 10) N. Pacific marine ecosystems exhibit signs of Ecosystem-Overfishing (EOF)

• Some N. Pacific marine ecosystems exhibit signs of ecosystem recovery or have experienced minimal Ecosystem-Overfishing (EOF)

• At least 3 N. Pacific marine ecosystems continue to experience significant Ecosystem-Overfishing

• EOF was detectable at least half a decade prior to major stock or stock group collapses in many of these LMEs

• Even if EOF was not detected, EOF indicators provided early warning signals at least half a decade prior to other observable changes in the ecosystem

• Detecting and acting on the ecosystem-level information can prevent both continued EOF and sequential stock OF, as well as save money
What’s Next?

• How do we operationalize this in real world fisheries mgt?
• How do we robustly translate EOF into economics & value?
  • Ecosystem Overfishing
  • Ecosystem Underfishing
• Can we use this approach to make predictions/projections, in time & space, of potential ecosystem catch levels?
  • wrt models of changing PP
  • wrt models of changing fish distributions
• Anybody wanna help with this effort?