

Patterns and drivers of resilience in over-fished populations

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...background...

Fisheries ecologist & modeler @ Dragonfly Science, Wellington, New Zealand

Research interest in the ecology of exploited marine populations and ecosystems

Bayesian methods in ecology and fisheries



- 1. Of Stock declines...
- 2. ...and recoveries
- 3. Patterns and drivers of resilience
- 4. (Some) Limits of resilience
- 5. Resilient fisheries

Of stock declines...



Some places were intensely fished by the early 1800s

- the North Sea
- Mediterranean
- New England

By the late 19th/early 20th century, some stocks were already quite heavily exploited:

- North Sea herring
- Atlantic Halibut & Cod















Costello et al. 2012 - Science

Where are we today?

Around 2/3 of global (assessed) fisheries are below target biomass levels¹



An estimated 15% of assessed fished stocks are collapsed²

Fishing mortality (F) is declining in many parts of the world, but often still too high

¹ Worm et al 2009 – Science
² <0.2x Target Biomass (@MSY)

Trends



...and recoveries

Stocks can recover

Many well known depletions and subsequent recoveries: e.g., North Sea Herring



ICES advice 2013

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Depletions and recoveries...

Elsewhere - depletions and subsequent recoveries: Western Hoki in New Zealand







Biomass, B

...but some stocks defy simple models

A notorious depletions without recovery: North West Atlantic Cod







...too simplistic?

Hutchings 2000 – Nature Hutchings 2001 – J.Fish.Bio

What could be missing?

Allee effects/depensation



Cultivation/Depensation





Walters & Kitchell 2001 - CJFAS

A) Atlantic cod



Predator trap



Swain & Benoit 2015 – MEPS

What could be missing?

Impacts beyond just reduction in abundance

Selective fishing alters the age and size structure of fished populations

Fishing exerts selective pressure & reduces genetic diversity – a Darwinian debt?^{1,2}



Biomass, B

Resilience: Ability of populations to recover from low biomass

How resilient are fish stocks to over-fishing?

or

How predictable are recoveries?

Data

RAM Legacy Stock Assessment Database: over 360 stock assessments from around the globe

Ricard et al. 2012 - Fish & Fisheries

Data

RAM Legacy Stock Assessment Database: over 360 stock assessments from around the globe

153 stocks that had been depleted at least once to below 0.5x target (MSY)

Survival analysis of overfished stocks: Does overfishing reduce population resilience?

Overfished stocks as sick patients

Bayesian **survival-analysis** regression model of **time-torecovery**:

Assumes that biomass dynamics follow a stochastic process

$$dB_t = \varphi_t B_t dt + \sigma B_t dW_t$$

Which leads to in inverse-Gaussian model for recovery times

$$f_{IG}(t) = \frac{c'}{\sigma\sqrt{2\pi}} t^{-3/2} \exp\left[-\frac{(c' - \nu't)^2}{2\sigma^2 t}\right]$$
$$c' = f(B_{\min}, ...)$$
$$\nu' = f(F/F_{msy},)$$

Overfished stocks as sick patients

Bayesian **survival-analysis** regression model of **time-torecovery**.

Survival analysis: Will the patient (stock) survive the illness (collapse), how long will he take to heal (recover) and why?

Overfished stocks as sick patients

Bayesian **survival-analysis** regression model of **time-torecovery**

Survival analysis: Will the patient (stock) survive the illness (collapse), how long will he take to heal (recover) and why?

Includes covariates for management, life-history and exploitation history

Allowed us to estimate the effect of covariates on median recovery times and the probability of recovery within a given timeframe

Patterns and drivers of resilience

Drivers of resilience

Responsible and responsive management is key to building resilience and recovering overfished populations

Adapted from Neubauer et al. 2013 Science

Examples

Drivers of resilience

Recovery is accelerated for moderately high historical fishing regimes

Negative impacts of fishing only for very long and intense fishing regimes

Adapted from Neubauer et al. 2013 Science

Explanations?

Phenotypic plasticity and fishery induced evolution can increase the productivity of fished populations

Adapted from Eikeset et al. 2013 – PNAS,

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(Some) Limits of resilience

Importance of age/size structure

Shelton et al. 2010 - CJFAS

Adverse environments

Over-fished stocks can fall into the *environmental trap*

Vert-Pre et al. 2013 – PNAS

Limits of resilience

Increases in productivity could lead to unstable (nonlinear) population dynamics

Anderson et al 2008 - Nature

Resilient Fisheries

Building resilience

Precautionary fishing mortality rates limit ecosystem wide risks of over-fishing

Building resilience

Precautionary fishing mortality rates limit ecosystem wide risks of over-fishing

Adapted from Worm et al. 2009 – Science

Building resilience

Precautionary fishing mortality rates limit ecosystem wide risks of over-fishing

Maintaining age/size structure to maintain reproductive and adaptive potential

Acknowledging environmentally/climate driven variability in demographic rates, adjust management advice accordingly

Marsden Questions

How resilient are ecosystems to over-fishing?

How does fishing alter ecosystem responses and resilience to climate change?

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