A Meta-Analysis of Rates of Depletion and Recovery of Overfished Stocks

ICES CM P:18
Theme Session: Reversing the Burden of Proof

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Questions: Do depleted fish stocks increase when F is reduced substantially and F reduction is sustained? If so, how do rates of rebuilding and depletion compare?

Criteria For Selecting Case Studies: (1) ≥50% decline in SSB, (2) ≥25% sustained cut in F, (3) adequate stock assessment.

Methodology: compute the instantaneous annual rate of biomass change from \( B_t = B_0 \times e^{r_R t} \) where:

\[ r_D = \text{rate of decline}, \quad r_R = \text{rate of recovery} \]

Recovery Math:

\[ B_t = B_0 \times e^{r_R t} \]

\( \ln(B_t/B_0) = r_R t \)

\( T = \frac{\ln(RF)}{r_R} \)

Species/Stock | Decline | Recovery |
---|---|---|
Atlantic Cod | 0.12 | 0.57 | 0.90/07, 0.07/06 | Mayo et al. 2008
Atlantic Cod - JUSL | -1.39 | 0.41 | 0.47/07, 0.51/06 | Koo et al. 2009
Atlantic Cod - 4T | 0.28 | 0.17 | 0.50 | Oosting et al. 2009
Northeast Arctic Cod | -0.18 | 0.01 | 0.08 | Pitcher et al. 2007
Haddock | -0.17 | 0.02 | 0.06 | Pitcher et al. 2007
Haddock | 0.27 | 0.13 | 0.29 | Pitcher et al. 2007
Herring | -0.27 | 0.16 | 0.24 | CIES 2009
Herring | -0.18 | 0.02 | 0.05 | CIES 2009
Herring - North Sea | -0.17 | 0.02 | 0.05 | CIES 2009
Herring - St. John's | -0.18 | 0.02 | 0.05 | CIES 2009
Plaice - North Sea | -0.10 | 0.06 | 0.13 | CIES 2009
English Sole | -0.05 | 0.00 | 0.16 | CIES 2009
Summer Flounder | -0.09 | 0.00 | 0.16 | CIES 2009
Sea Scallop - US | -0.27 | 0.01 | 0.05 | CIES 2009
Bristol Bay Red King Crab | -0.13 | 0.01 | 0.05 | CIES 2009
Acadian Redfish | -0.16 | 0.01 | 0.05 | CIES 2009
Bacalao | -0.98 | 0.06 | 0.15 | Pitcher et al. 2007
Coryn Rockfish | -0.08 | 0.09 | 0.08 | CIES 2009
Chesapeake Rockfish | -0.05 | 0.08 | 0.15 | CIES 2009
Pacific Ocean Perch | -0.05 | 0.09 | 0.14 | CIES 2009
Pacific Cod | N/A | 0.00 | 0.07 | CIES 2009
Kelp | 0.03 | 0.01 | 0.01 | CIES 2009
Striped Bass | N/A | 0.00 | 0.05 | CIES 2009
Northeast Atlantic Swordfish | 0.05 | 0.07 | 0.03 | CIES 2009

Mean | 0.21 | 0.93 | 13.2 y | Median | 0.14 | 0.95 | 12 y

Rate of Recovery (\( r_D \)) | 2x | 3x | 5x | 10x | 100x
---|---|---|---|---|---|
0.05 | 13.9 | 22.0 | 32.1 | 46.1 | 92.1
0.10 | 6.9 | 11.0 | 16.1 | 23.0 | 46.1
0.15 | 4.6 | 7.3 | 10.7 | 15.4 | 30.7
0.20 | 3.5 | 5.5 | 8.0 | 11.5 | 23.0
0.25 | 2.8 | 4.4 | 6.4 | 9.2 | 18.4
0.30 | 2.3 | 3.7 | 5.4 | 7.7 | 15.4
0.35 | 2.0 | 3.1 | 4.6 | 6.6 | 13.2
0.40 | 1.7 | 2.7 | 4.0 | 5.8 | 11.5
0.50 | 1.4 | 2.2 | 3.2 | 4.6 | 9.2

Conclusions:

1. Very little empirical evidence for depensation affecting rebuilding rates (e.g., negative residuals from log abundance plots over time)
2. With a few exceptions (1 analyzed), stocks having sustained reductions in F recovered by factors ranging from 1.4x (swordfish) to 1.221x (Pacific sardine)
3. Complex interactions among degree of depletion, life history, recruitment variation, and degree of F reduction complicates inferences of rebuilding trajectories for recovery planning