Using surplus production models to study predation in age-structured populations

Kiva Oken, Timothy E. Essington
Quantitative Ecology & Resource Management
University of Washington

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Why predation?

- Variable but important in marine ecosystems

Challenging to estimate precisely
Why predation?

- Variable but important in marine ecosystems
- Part of ecosystem-based management

Natural mortality challenging to estimate precisely

Trade-offs
Why predation?

- Variable but important in marine ecosystems
- Part of ecosystem-based management
  - Trade-offs

Natural mortality is challenging to estimate precisely.
Why predation?

- Variable but important in marine ecosystems
- Part of ecosystem-based management
  - Trade-offs
  - Natural mortality
Why predation?

- Variable but important in marine ecosystems
- Part of ecosystem-based management
  - Trade-offs
  - Natural mortality
- Challenging to estimate precisely
Quantifying predation: the correlative approach

Is surplus production better?

\[
\text{Biomass}_{y+1} = \text{Biomass}_y + \text{Surplus production}_y - \text{Catch}_y
\]
Is surplus production better?

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Surplus production of age-structured populations

- Low spawning potential
- Vulnerable to predators
- Low catchability
- Large growth increment

- High spawning potential
- Less vulnerable to predators
- High catchability
- Small growth increment
Surplus production of age-structured populations

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Surplus production of age-structured populations

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Questions

What can we glean from surplus production models that account for predation?

- Quantify top-down predation effects
- Estimates of management reference points
Questions

What can we glean from surplus production models that account for predation?

▶ Quantify top-down predation effects
▶ Estimates of management reference points

Approach

▶ Operating model used to simulate data
▶ Statistical model fit to simulated data
▶ Results and conclusions
Operating model
Operating model
Operating model
Operating model

Predictation

Years

Predation

0 20

Years

0 20
Operating model

![Diagram showing the relationship between different stages and predation over time.](image-url)
Simulated data
Four different prey life histories

- **Pacific sardine**
  - Age at 50% maturity: 1.2
  - Adult natural mortality: 0.4

- **Silver hake**
  - Age at 50% maturity: 1.6
  - Adult natural mortality: 0.15

- **Atlantic menhaden**
  - Age at 50% maturity: 2.5
  - Adult natural mortality: 0.47

- **English sole**
  - Age at 50% maturity: 3.5
  - Adult natural mortality: 0.26
Deterministic dynamics

The graph shows the surplus production over time, with peaks occurring at regular intervals, indicating periodic behavior.
Deterministic dynamics

Atlantic Menhaden Biomass
Surplus production

Biomass
Deterministic dynamics

Atlantic Menhaden

Surplus production

Biomass
Deterministic dynamics

Pacific Sardine

Silver Hake

Atlantic Menhaden

English Sole

Surplus production

Biomass

Juv

Rec

Adu
Stochastic dynamics

Pacific Sardine

Silver Hake

Surplus production

Biomass
Stochastic dynamics

Pacific Sardine

Silver Hake

Atlantic Menhaden

English Sole

Surplus production

Biomass

B_{MSY} 0.5B_{MSY} B_{MSY} 1.5B_{MSY}
Top-down effects

Recruits

Predation $t$-value

Recruitment CV = 0.2

Pacific Sardine

No Obs. Error

Obs. CV = 0.2
Top-down effects

Recruits

Pacific Sardine
Silver Hake
Atlantic Menhaden
English Sole

Predation $t$-value

Recruitment CV = 0.2

Obs. CV = 0.2

No Obs. Error
Top-down effects

Recruits

Predation $t$-value

Recruitment CV = 0.2

Recruitment CV = 0.6

-20 0

-10 0

Pacific Sardine

Silver Hake

Atlantic Menhaden

English Sole

No Obs. Error

Obs. CV = 0.2
Top-down effects

Juveniles

Predation t-value

Recruitment CV = 0.2

Recruitment CV = 0.6

Pacific Sardine

Silver Hake

Atlantic Menhaden

English Sole

No Obs. Error
Obs. CV = 0.2
Top-down effects

Adults

Predation t-value

Recruitment CV = 0.2

Recruitment CV = 0.6

Pacific Sardine

Silver Hake

Atlantic Menhaden

English Sole

No Obs. Error
Obs. CV = 0.2
What if we add a second predator?
Multiple predators further degrades signal
Multiple predators further degrades signal

- Pacific Sardine
- Silver Hake
- Atlantic Menhaden

Proportion of predators detected

- Recruit
- Juvenile
Reference point estimates unreliable

- Pacific Sardine
- Silver Hake
- Atlantic Menhaden
- English Sole

Relative error

- Single species
- With predation

Graph showing relative error for different species with and without predation.
Reference point estimates unreliable

Pacific Sardine
Silver Hake
Atlantic Menhaden
English Sole

Relative error

Single species

With predation

B_{MSY}

0 1 2 3 4 5 6

MSY

0 1 2 3

Single species

With predation
Conclusions

What can we glean from surplus production models that account for predation?

- Quantify top-down predation effects:

- Estimates of management reference points:
Conclusions

What can we glean from surplus production models that account for predation?

▶ Quantify top-down predation effects:
  ▶ Easily masked by variability
  ▶ Depends on life history

▶ Estimates of management reference points:
What can we glean from surplus production models that account for predation?

- Quantify top-down predation effects:
  - Easily masked by variability
  - Depends on life history

- Estimates of management reference points:
  - Predation can improve estimates
  - Surplus production models unreliable
Thanks!

- Trevor Branch, Jason Link, Andre Punt
- Essington lab