Demographic and Risk Analyses of Spiny Dogfish in the Gulf of Alaska

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UAF Dogfish Fishery Research

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- Age and growth
- Life history
- Diet
- Demographic model

Jason Gasper
- Spatial modeling
- World market analysis
- Policy analysis
Dogfish Biology and Life History (Gulf of Alaska)

- **Age at 50% maturity:** 21 years (males), 36 years (females)
- **Length at 50% maturity:** 74.5 cm (males), 97.3 cm (females)
- **Maximum size:** 1.1 m (males), 1.3 m (females)
- **Max. age** ≈ 100 years (BC)
- **M** = 0.097
Dogfish Biology and Life History (Gulf of Alaska)

- 18-22 month gestation period
- Average of 8.5 pups per female
Some females may have an extended resting period (∼1 year) between pregnancies.

Two pregnant females at similar stage of gestation.
Dogfish Fishery Management

- Dogfish harvested in Northeast Pacific for >100 years (British Columbia, Washington)
- Only bycatch in Alaska, some retained
- Ave. commercial catch (1997-2007) = 530 t
- 93-99% discarded (1993-2011)
- Recreational harvest
- **Management concerns:**
  - Uncertainties in biomass and total fishing mortality
  - What catch is sustainable?
Demographic Population Model

Objectives to estimate:
(1) population growth rate, (2) sustainable fishing mortality, and (3) risk of stock collapse under fishing

Demographic models:
● Useful in data-limited situations
● Life history requirements: fecundity, natural mortality, growth
Basic Model

\[ N_{t+1} = MN_t \]

- Leslie matrix-type models
- Consider females only
- Assumptions: (1) no migration, (2) constant environment, and (3) no density dependence
- 10,000 replication MC approach (mean, CIs)
- Fitted both age- and stage-based models
- Equations solved with Poptools (www.poptools.org)
Age-based Model

\[
M = \begin{bmatrix}
  f_0 & f_1 & \cdots & f_{i-1} & f_i \\
  l_0 & 0 & \cdots & 0 & 0 \\
  0 & l_1 & \cdots & 0 & 0 \\
  0 & 0 & \cdots & l_{i-1} & 0 \\
\end{bmatrix},
\]

- where:
  - \( l_x \) are the age-specific survivorship at age \( x \)
  - \( f_x \) is the age-specific per capita fecundity rate (fertility) at age \( x \)
Stage-based Model

\[
M = \begin{bmatrix}
0 & 0 & 0 & f_{AP} & 0 \\
G_N & P_J & 0 & 0 & 0 \\
0 & G_J & P_S & 0 & 0 \\
0 & 0 & G_S & P_{AP} & G_{AR} \\
0 & 0 & 0 & G_{AP} & 0 \\
\end{bmatrix},
\]

- where:
  - \( G_x \) is the probability of an individual surviving and shifting to another stage
  - \( P_x \) is the probability of an individual surviving and remaining in the same stage
Stage-based Model

- Stages:
  - **N** = Neonate (young of year)
  - **J** = Juvenile (inshore waters, not susceptible to fishing)
  - **S** = Subadult (mixes with adults, susceptible to fishing)
  - **AP** = Adult, pregnant
  - **AR** = Adult, resting
Some Estimated Parameters

- $r =$ instantaneous rate of increase (rebound potential)
- $\lambda =$ population growth rate ($e^r$)
- $R_o =$ net reproductive rate per generation (female offspring per ind.)
- $T =$ mean generation time
- $e_{ki} =$ elasticities to examine how $r$ is affected by changes in individual survival and fecundity
Population Growth Rate ($\lambda$)

- If $\lambda < 1$, population is decreasing
- If $\lambda > 1$, population is increasing
- Sustainable F$<0.02$ or 0.04
Elasticities: Age-based Model

- Changes in survival at ages <24 years had the greatest impact on $r$
- Lesser effects of changes in fecundity on $r$
Elasticities: Stage-based Model

- Changes in survival of the subadult class had the greatest impact on $r$
Risk Analysis

- Starting biomass ($B_{2006}$) = 1.5 million t, $B_{MSY}$ = 0.9 million t (Rice 2007)
- Estimate the probability that population biomass declines below a threshold value after 20 years of harvest
- Thresholds were $B_{MSY}$, $B_{50\%}$ and $B_{40\%}$
Risk: Stage-based Model

Stage-based Model

\[ B_{MSY} \]
\[ B_{50\%} \]
\[ B_{40\%} \]

FS = 0  
FS = 0.02  
FS = 0.04  
FS = 0.06  
FS = 0.08  
FS = 0.1

FA = 0.1  
FA = 0.05  
FA = 0.02  
FA = 0.01  
FA = 0.00  
FA = 0.00

FJ  
FJ  
FJ  
FJ  
FJ  
FJ
Risk: Stage-based Model
**Risk: Stage-based Model**

- **Stage-based:** Increased $F_s$ causes greatest risk
- **Age-based:** Increased $F_j$ causes greatest risk
Conclusions

- Low natural mortality, old age at maturity, and low fecundity lead to a low natural population growth rate, even when $F=0$
- Rebound potential becomes negative quickly as $F$ increases
- If younger age/stage classes were to become exploited, overfishing risk would increase substantially
- Fishing mortality should be kept very low, while improved models for tactical fishery management are under development
Next Steps by NMFS

- Consideration of migration
  - Ongoing tagging studies
- Better estimates of biomass
  - Population estimation models
- Better estimates of total fishing mortality
  - Redesigned federal observer program
  - Improved catch estimates from state fisheries
For More Information:

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