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

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UAF Dogfish Fishery Research

University of Alaska Fairbanks
Spiny Dogfish 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

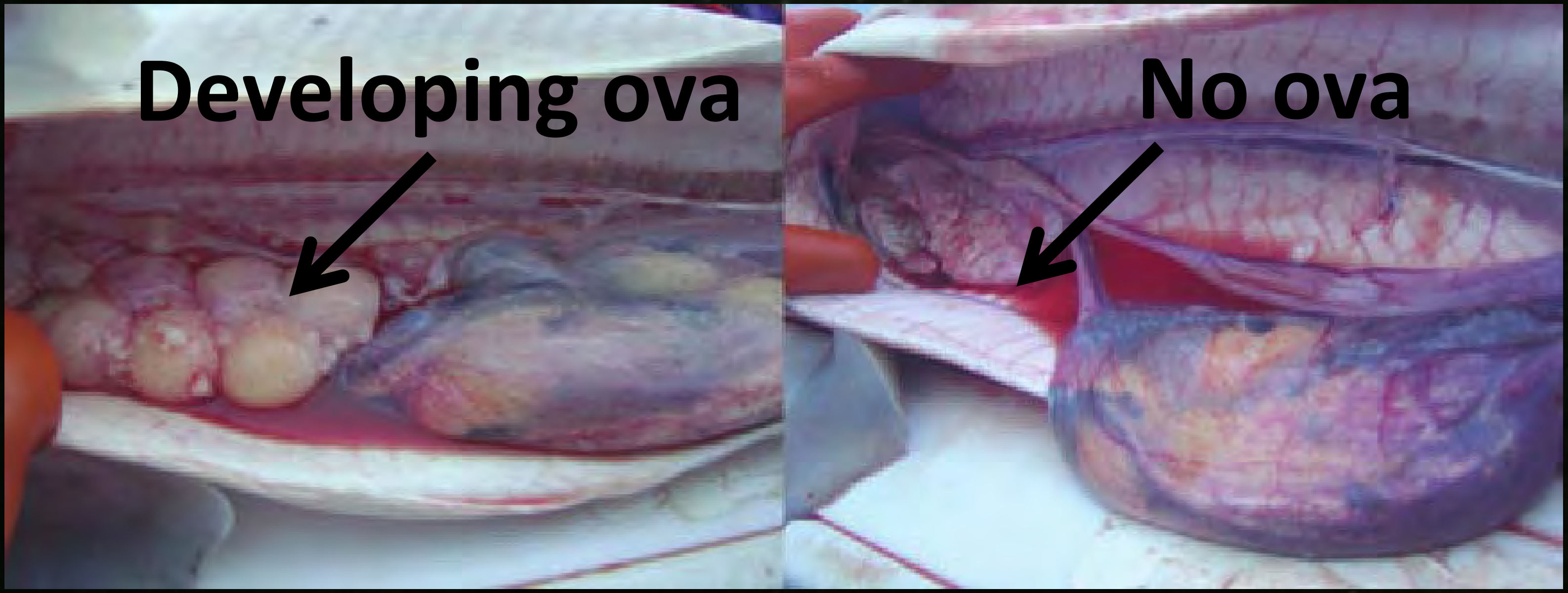
Dogfish Biology and Life History (Gulf of Alaska)

- 18-22 month gestation period
- Average of 8.5 pups per female

Photo by Rustin Director

Dogfish Biology and Life History
(Gulf of Alaska)

- 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

<u>Demographic models:</u>

- Useful in data-limited situations
- Life history requirements: fecundity, natural mortality, growth

Basic Model

$$N_{t+1} = \mathbf{M} N_t$$

- 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

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

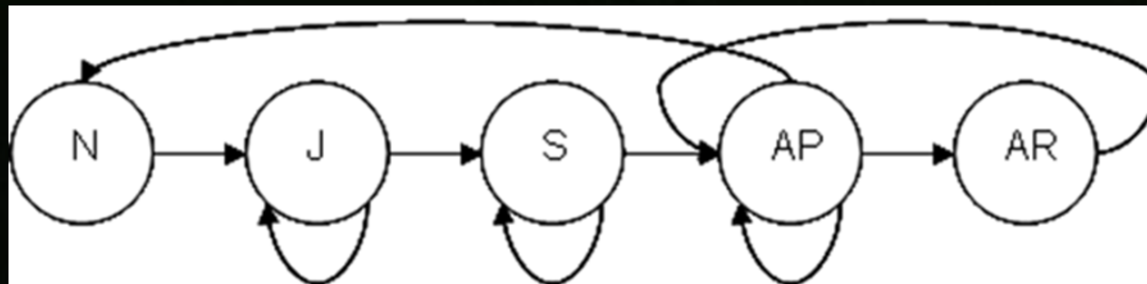
- where:
  - l_x are the age-specific survivorship at age x
  - f_x is the age-specific per capita fecundity rate (fertility) at age x

Stage-based Model

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

- 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

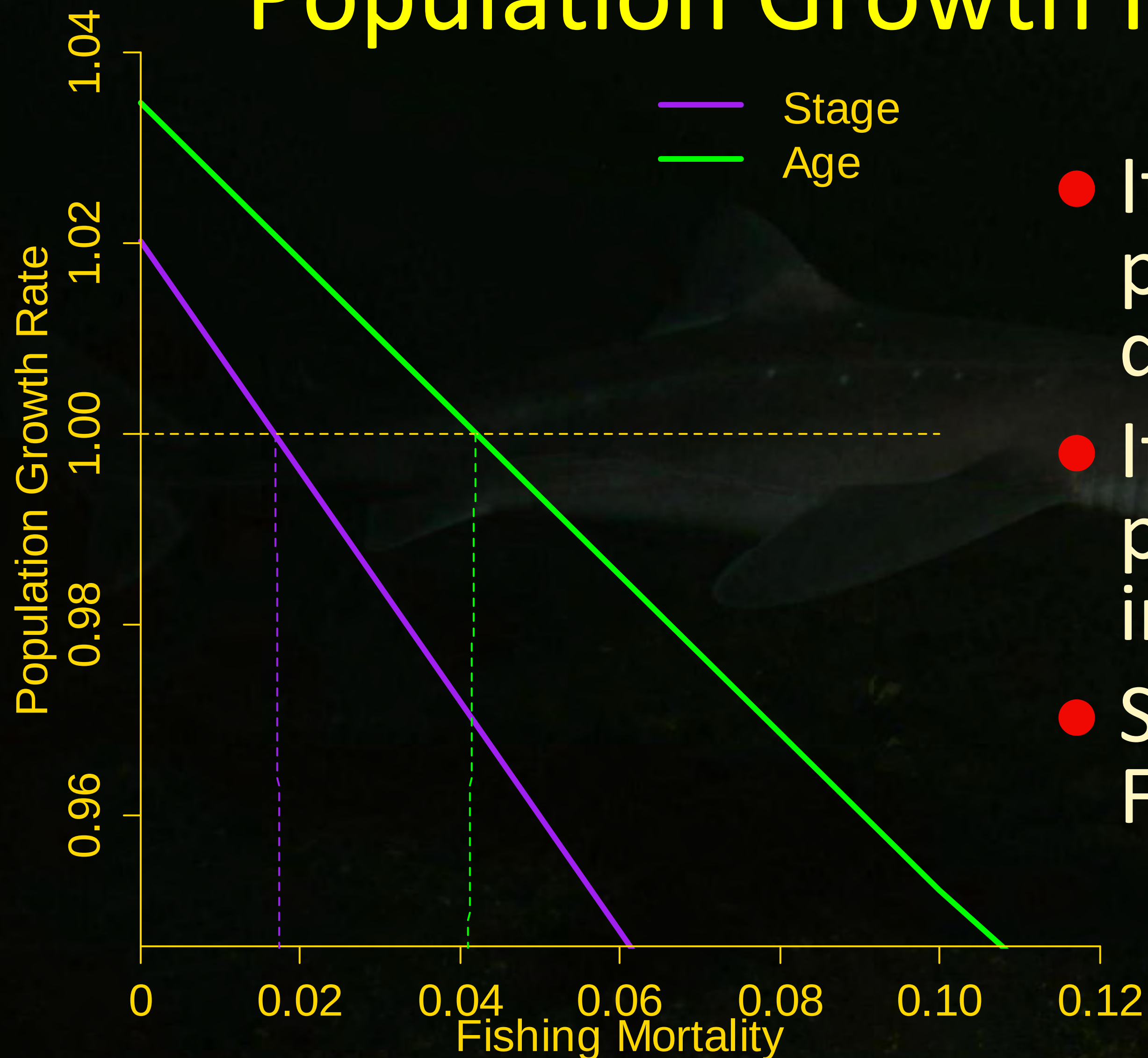


- Stages:
  - N = Neonate (young of year)
  - J = Juvenile (inshore waters, not susceptible to fishing)
  - S = Subadult (mixes with adults, susceptible to fishing)
  - AP = Adult, pregnant
  - AR = Adult, resting

Some Estimated Parameters

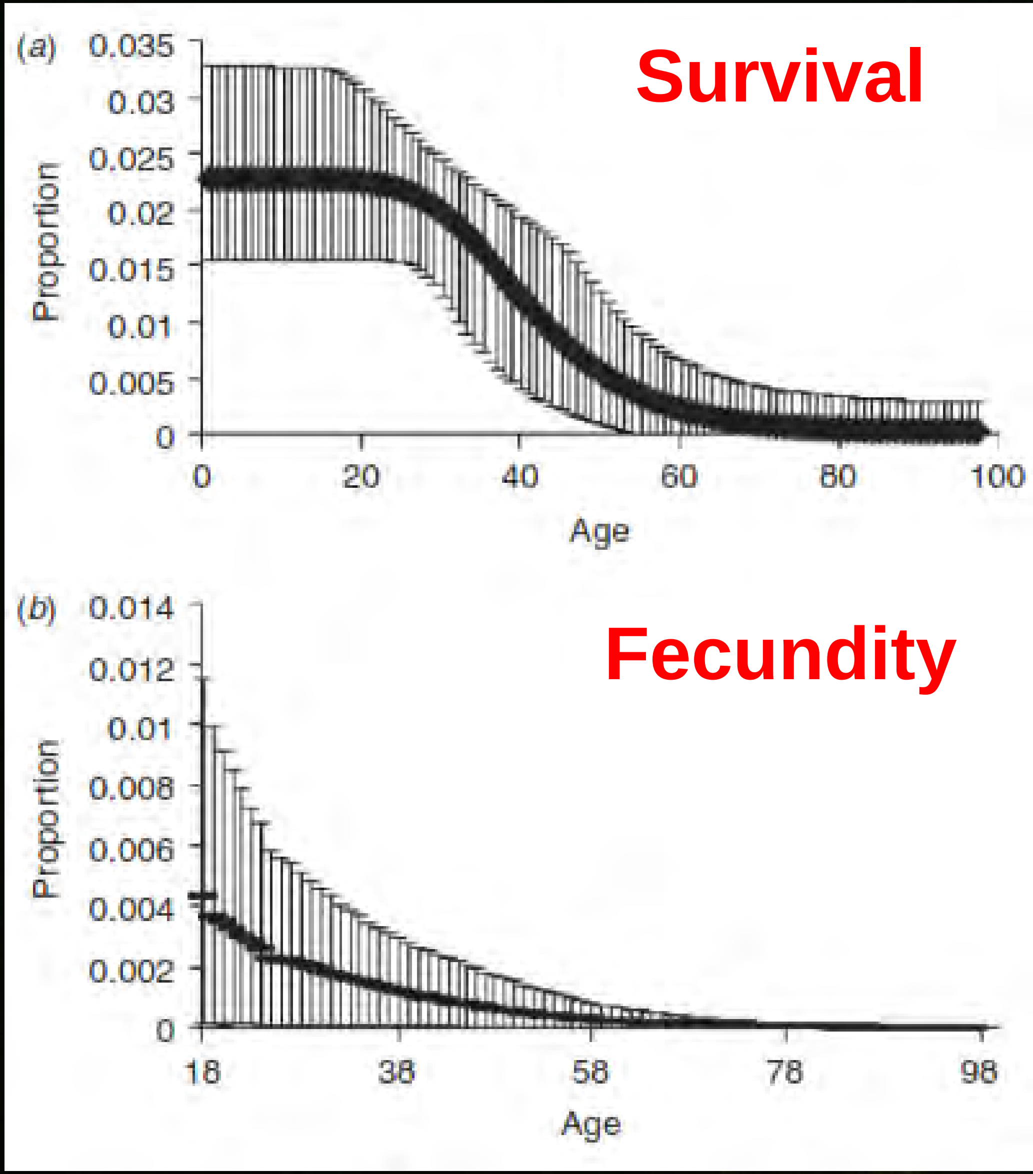
- *r* = instantaneous rate of increase (rebound potential)
- *λ* = population growth rate (e^r)
- R_o = net reproductive rate per generation (female offspring per ind.)
- *T* = mean generation time
- e_{kj} = elasticities to examine how *r* is affected by changes in individual survival and fecundity

Population Growth Rate (λ)



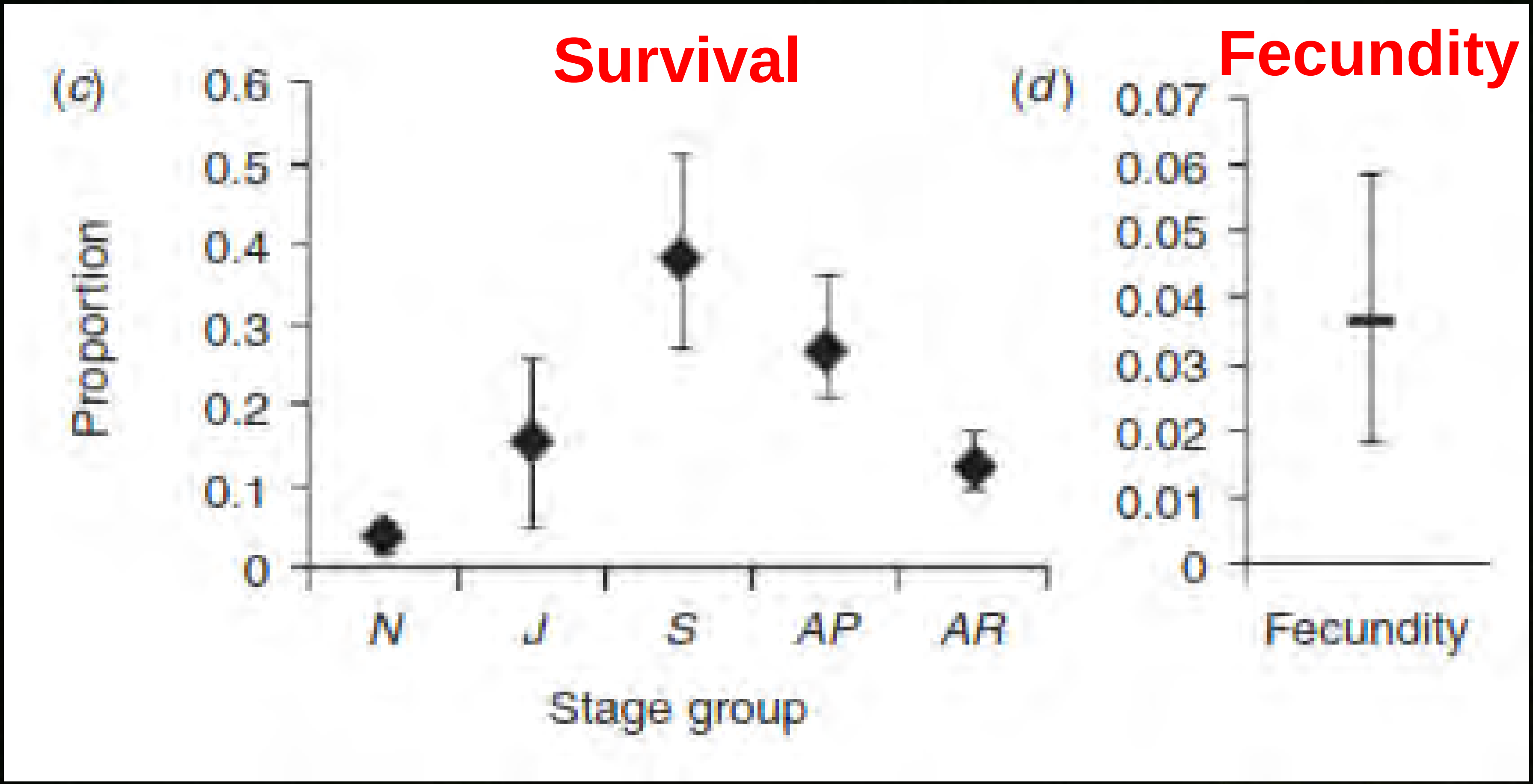
- If λ < 1, population is decreasing
- If λ > 1, population is increasing
- Sustainable F<0.02 or 0.04

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

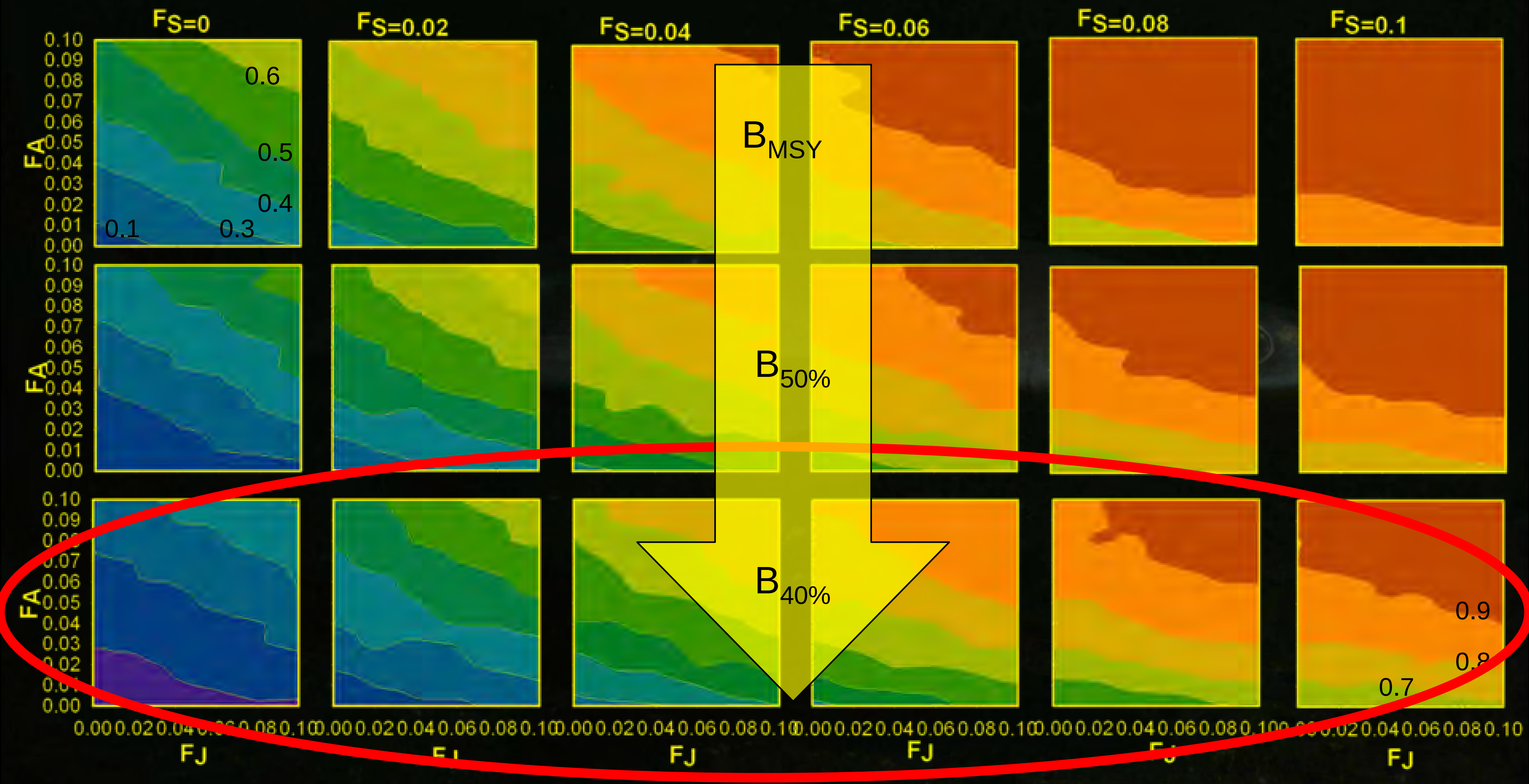


- Changes in survival of the subadult class had the greatest impact on *r*

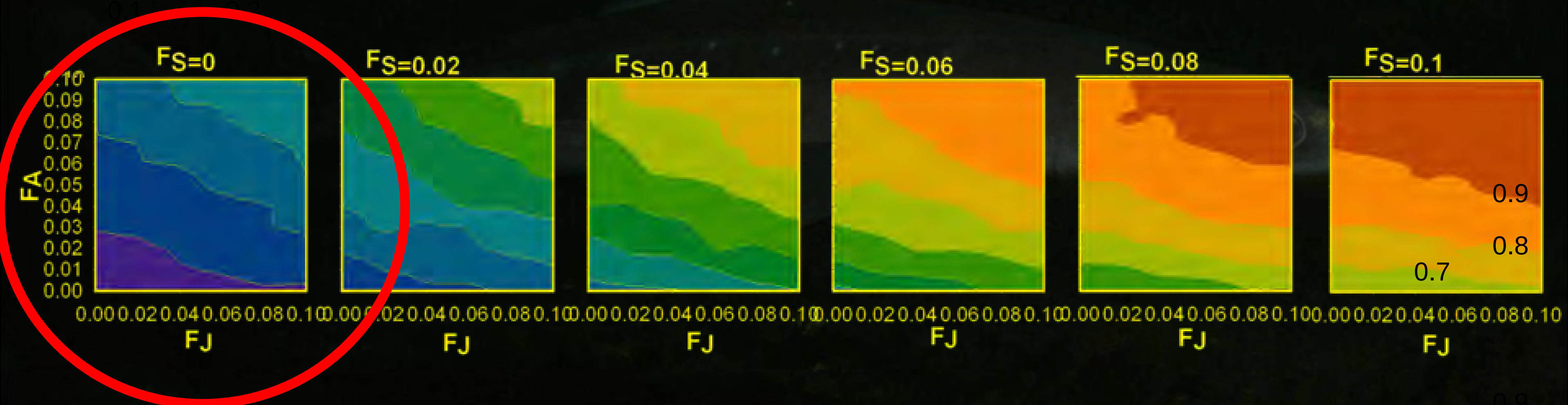
Risk Analysis

- 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

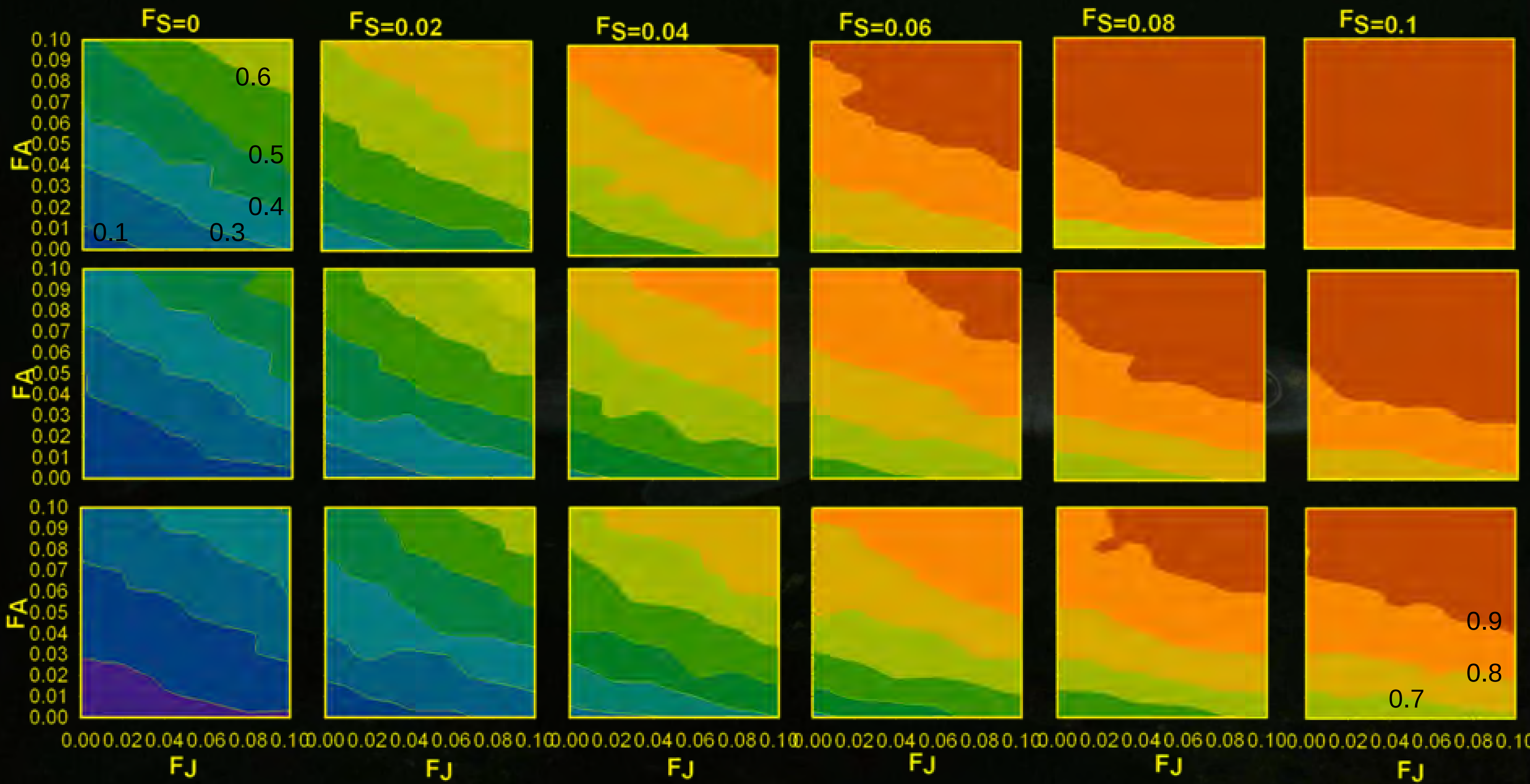


Risk: Stage-based Model



F_S=0
F_S=0.02
F_S=0.04
F_S=0.06
F_S=0.08
F_S=0.1
FA
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.00 0.02 0.04 0.06 0.08 0.10
FJ
0.9
0.8
0.7
F_S=0
0.3
0.2
0.1

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:

Tribuzio, C.A., and G.H. Kruse. 2012. Demographic and risk analyses of spiny dogfish *(Squalus suckleyi)* in the Gulf of Alaska using age- and stage-based population models. Marine and Freshwater Research 62:1395-1406.

Funding:

North Pacific Research Board, Alaska Fisheries Science Center Population Dynamics Fellowship, UAF Rasmuson Fisheries Research Center Fellowship