Science, Service, Stewardship

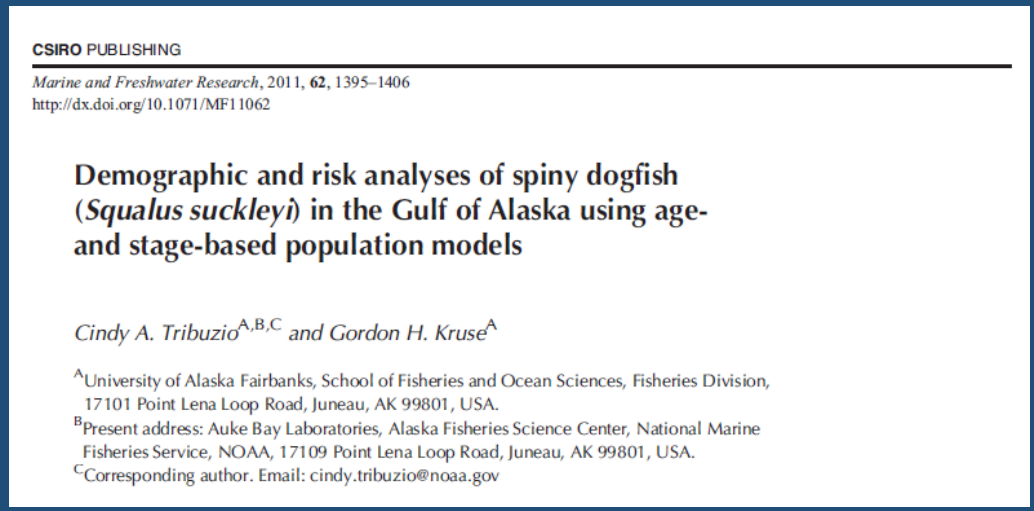
Review of spiny dogfish assessment methods: demographic model

Cindy Tribuzio, Pete Huslon, Cara Rodgveller, Katy Echave

NOAA FISHERIES SERVICE

Intro

- Spiny dogfish managed as part of shark complex
  - Tier 6*, aka Tier 5 without reliable biomass
- 2015 Nov PT:
  - Assessment authors recommended using a Fmsy instead of F=M for the tier 6* calculations
  - PT accepted author recommendations, but requested a presentation to go over the demographic model used to estimate Fmsy
- Overview of model
  - Tribuzio and Kruse 2011



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Demographic and risk analyses of spiny dogfish (*Squalus suckleyi*) in the Gulf of Alaska using age- and stage-based population models

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Basic Model

- Leslie Matrix type models
- Female only models
- Outputs included
  - r=instantaneous rates of increase
  - $\lambda=e^r$=population growth rate
  - R_0=Net reproductive rate
  - $T=lnR_0/ln\,\lambda$ =Generation time
  - $\mu 1$=Mean age of parents of cohort
  - $t_{x2}=ln(2)/r$=Population doubling time
  - Stable age/stage distributions
  - Reproductive value
  - Elasticities

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

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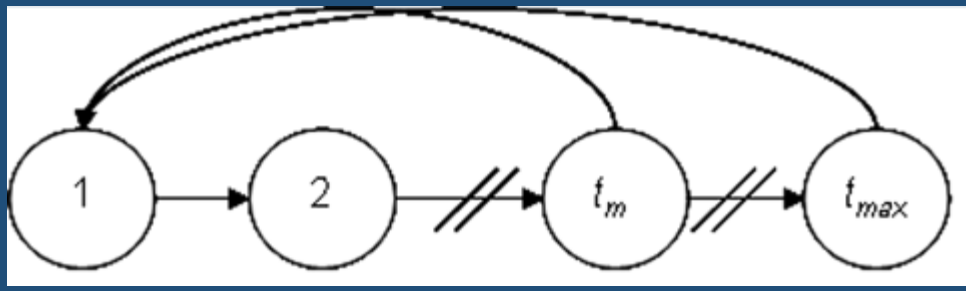
Age-based Model

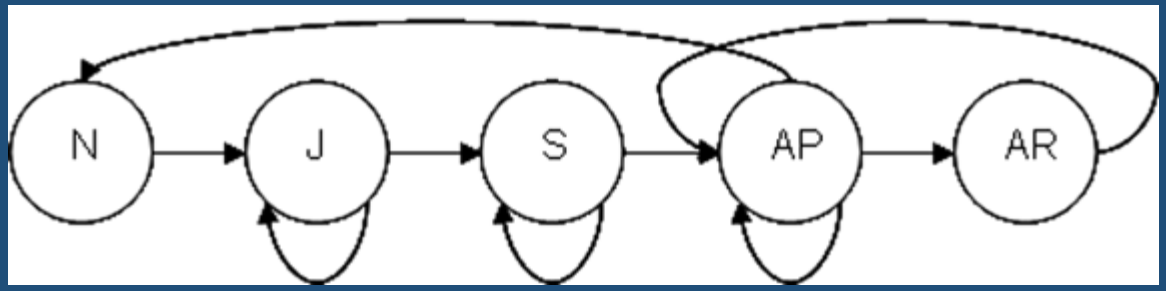


- Each animal must progress to next age class at the end of the year
- *i* is age class
  - Up to 120 ages
- *l* is age-specific survival
  - $l=e^{-M}$
- *f* is fertility
  - *m*=age specific # female pups per female per year

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

$$f_i = l_i m_i$$

Stage-based Model



- Five stages
  - N=Neonates
    - Age-0, duration=1 year
  - J=juveniles
    - Age-1+, not recruited to larger schools
    - Age range and duration variable
  - S=sub-adults
    - Non-mature, recruited to large schools
    - Age range and duration variable
  - AP=adult-pregnant
    - All mature, duration 2 years
    - May move to AR or AP
  - AR=adult-resting (not pregnant)
    - All mature, duration 1 year, must go to AP after being in AR

Stage-based Model

- $G_x=\sigma_x\gamma_x$
  - $\sigma_x = e^{-Zx}$=probability of an individual surviving that stage
  - γ_x=probability of progressing to another stage
- $P_x=\sigma_x(1-\gamma_x)$
  - probability of an individual surviving and remaining in it's current stage

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

$$\gamma_x = \frac{\left(\frac{\sigma_x}{\lambda_{init}}\right)^{t_x} - \left(\frac{\sigma_x}{\lambda_{init}}\right)^{t_x-1}}{\left(\frac{\sigma_x}{\lambda_{init}}\right)^{t_x} - 1}$$

Major assumptions

- All individuals within and age/stage class have same probability of survival
- F applied uniformly across all susceptible age/stage classes (knife edge)
- Birth-pulse, post-breeding census, with birth occurring at the end of the year
- 1:1 pup sex ratio, 2 year reproductive cycle
- Density independence
- Distinct closed population

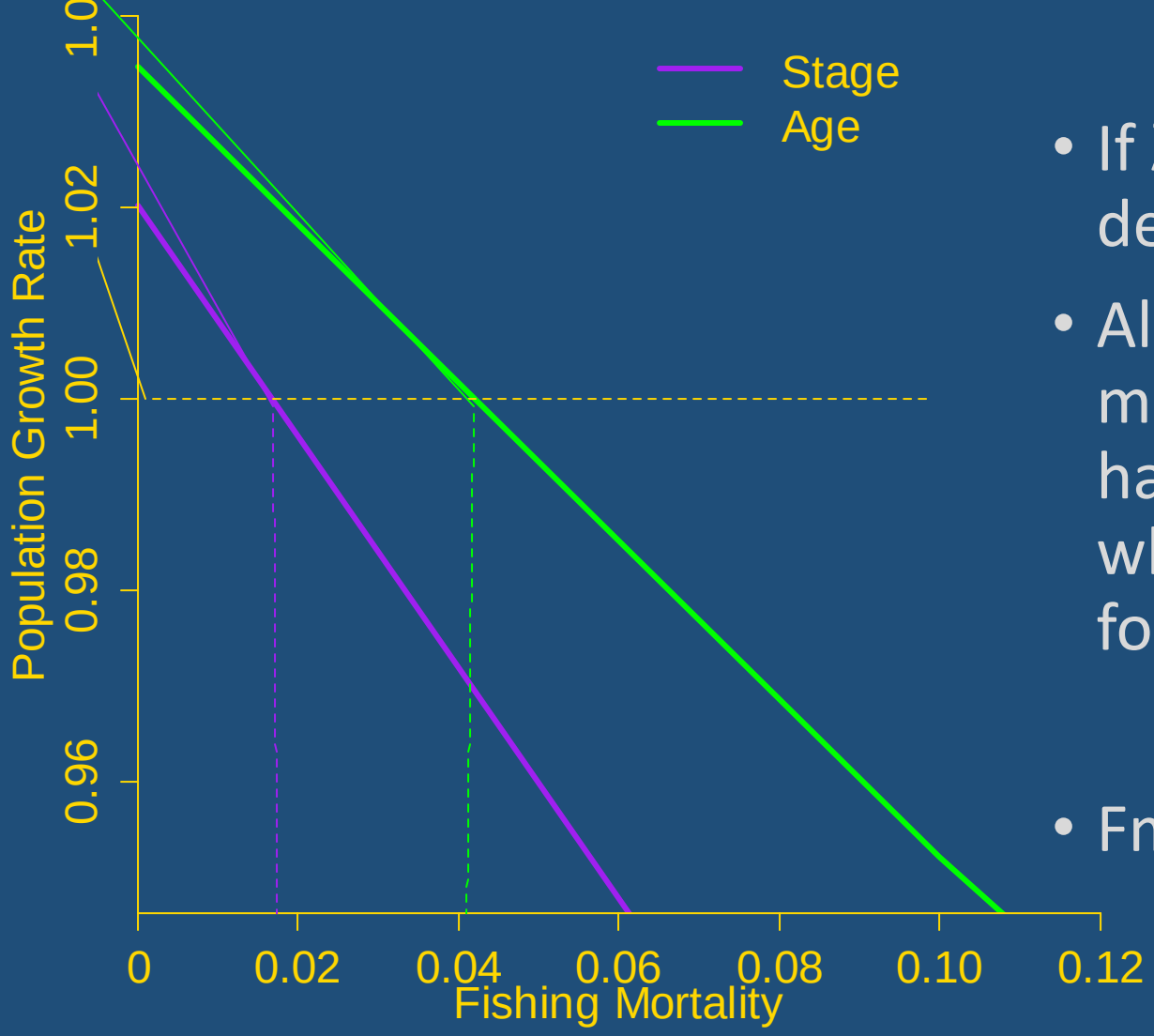
Stochasticity

- Probability density and mass functions defined for input parameters
  - Incorporates uncertainty into input parameters, such as age at 50% maturity, fecundity and natural mortality
- 10K Monte Carlo simulations run for each study situation (i.e. with and without fishing)

Stochasticity

- Natural Mortality (M)
  - Triangular pdf, min=0.011, max=0.101, peak=0.097
- Age at first capture (t_c)
  - Uniform pdf, 0-60 years
- Stage at first capture (S_c)
  - Fixed at sub-adult stage, but duration of juvenile/subadult stages based on age-at-50% maturity
- Age-at-50% maturity (t_m)
  - Normally distributed, mean=34 years, st dev=7 years
- Fecundity (b)
  - Normally distributed, mean=4.9 pups, st dev=1.7 pups
- Fecundity-at-age (m)
  - Normally distributed, with age specific mean and st dev

Population growth rate (λ)



- If $\lambda < 1$, population is decreasing
- Also, indicates maximum sustainable harvest rate, Fmax, which can be a proxy for Fmsy
- Fmax <= 0.02 or 0.04

Changes to Assessment Methods F Rate

- Status quo is $F_{OFL} = F_{MSY} = M = 0.097$
- Demographic analyses: $F_{MSY} = F_{max} = 0.04$
  - Presented in 2010 and 2011 assessments
  - Sustainable F results in $\lambda >= 1$
  - $\lambda < 1$ at $F > 0.04$ (age)
  - $\lambda < 1$ at $F > 0.02$ (stage)

ABC and OFL results

	Tier 6*	(aka Tier 5)		
	Biomass	M	Frate	Tons
Standard Tier 6* ABC	56181.2	0.097	0.073	4087
Standard Tier 6* OFL	56181.2	0.097	0.097	5450
Demo. Tier 6* ABC	56181.2		0.03	1685
Demo. Tier 6* OFL	56181.2		0.04	2247
WC Tier 6* ABC	56181.2		0.003975	
WC Tier 6* OFL	56181.2		0.0053	

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Total complex ABC = 2,113, OFL = 2817

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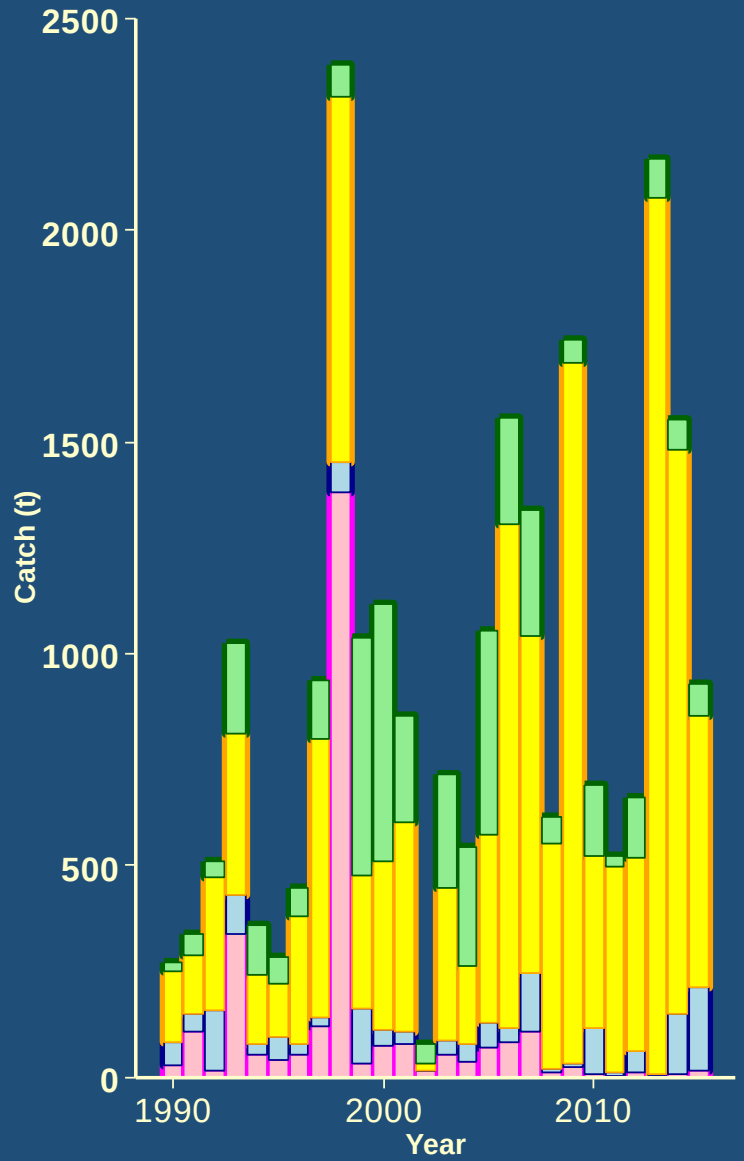

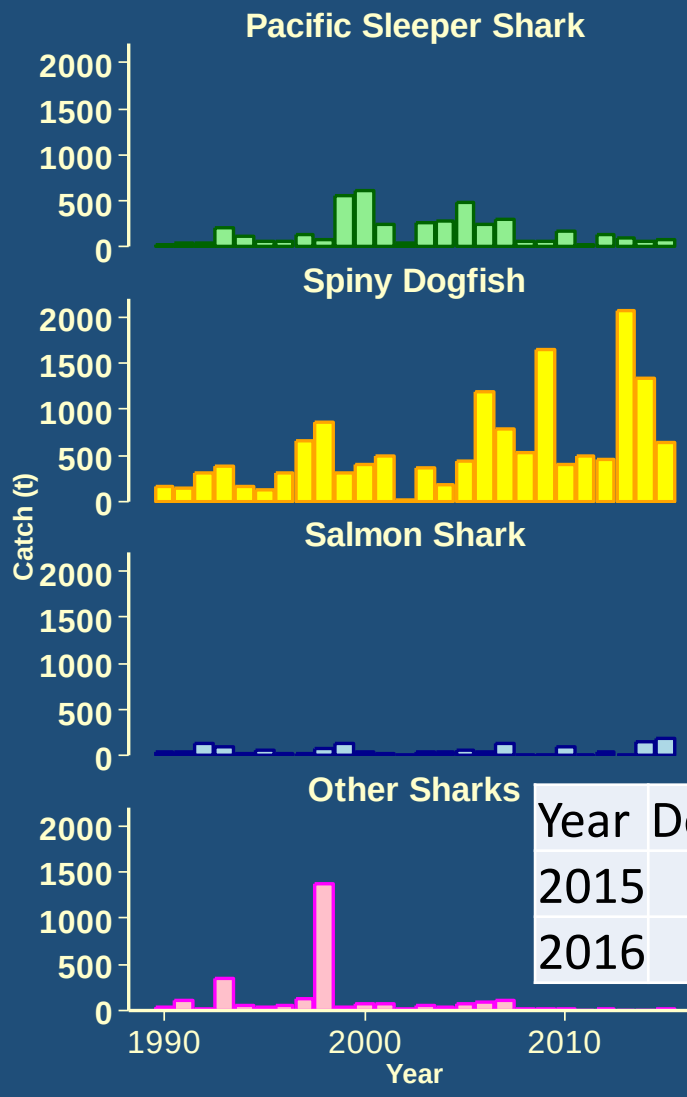

Year	Dogfish	Complex
2015	955	1414
2016	1138	1170

Tier 4, just for fun!

	Tier 4			
	Biomass	F	Frate	Tons
Standard Tier 4 ABC	56181.2	Fmsy=F40	0.025	1405
Standard Tier 4 OFL	56181.2	F35	0.029	1629
Rice MSY ABC	56181.2	Fmsy=F63	0.012	
Rice MSY OFL	56181.2	F58	0.015	
WC MSY ABC	56181.2	Fmsy=F79	0.006	
WC MSY OFL	56181.2	F74	0.008	

Future plan

- This is not the end for spiny dogfish
- Still working to improve biomass estimates
- Exploring models
  - Expand demographic model to incorporate density dependence and open the population (i.e., coast wide movement?)
  - Time series of length frequencies from IPHC and AFSC LL surveys
  - Need to get more length frequency data from fishery
  - Incorporating tag data estimates of availability into biomass estimates
- 2017 Assessment
  - Consider the demographic model as “Base Model”
  - Use Fmax from demographic model in Tier 6* estimate
  - Report any improvements to biomass estimates in Sept

Questions?