



Review of spiny dogfish assessment methods: demographic model

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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 F_{msy} 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 F_{msy}
- Overview of model
 - Tribuzio and Kruse 2011

CSIRO PUBLISHING

Marine and Freshwater Research, 2011, **62**, 1395–1406
<http://dx.doi.org/10.1071/MF11062>

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
 - $T=\ln R_0/\ln \lambda$ =Generation time
 - μ_1 =Mean age of parents of cohort
 - $t_{x2}=\ln(2)/r$ =Population doubling time
 - Stable age/stage distributions
 - Reproductive value
 - Elasticities

$$\mathbf{N}_{t+1} = \mathbf{M}\mathbf{N}_t$$

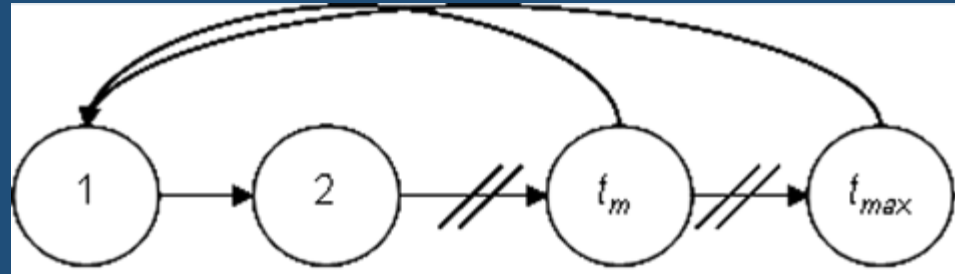
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$$N_{t+1} = \mathbf{M}N_t$$

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

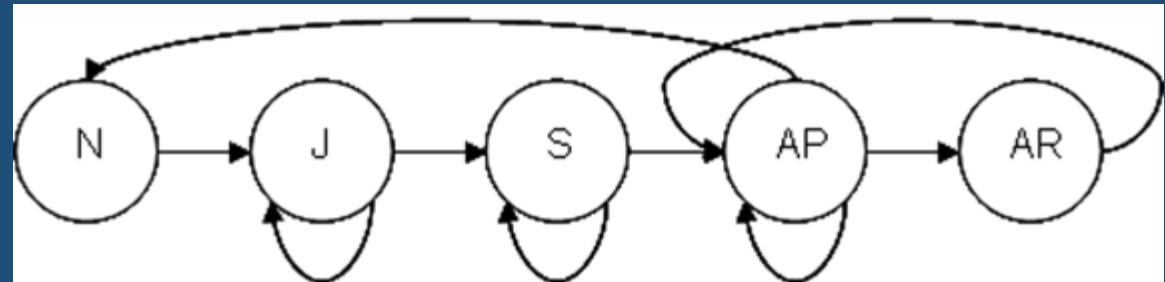
- Non-mature, recruited to large schools
 - Age range and duration variable

- 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

- $G_x = \sigma_x \gamma_x$
 - $\sigma_x = e^{-\lambda x}$ = 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 its 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

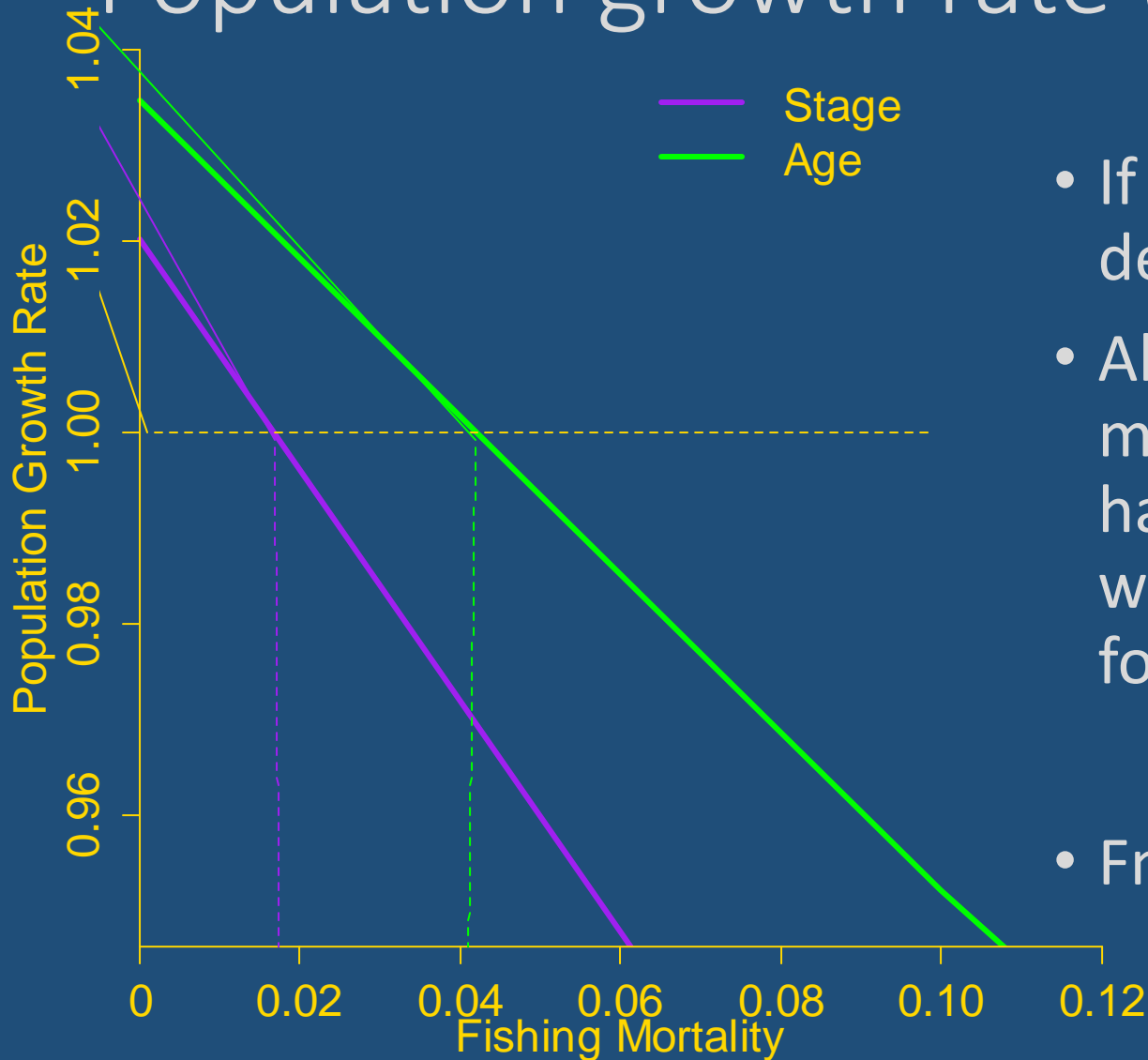
Stochasticity

- 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, F_{max} , which can be a proxy for F_{msy}
- $F_{max} \leq 0.02$ 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 $\lambda \geq 1$
 - $\lambda < 1$ 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	

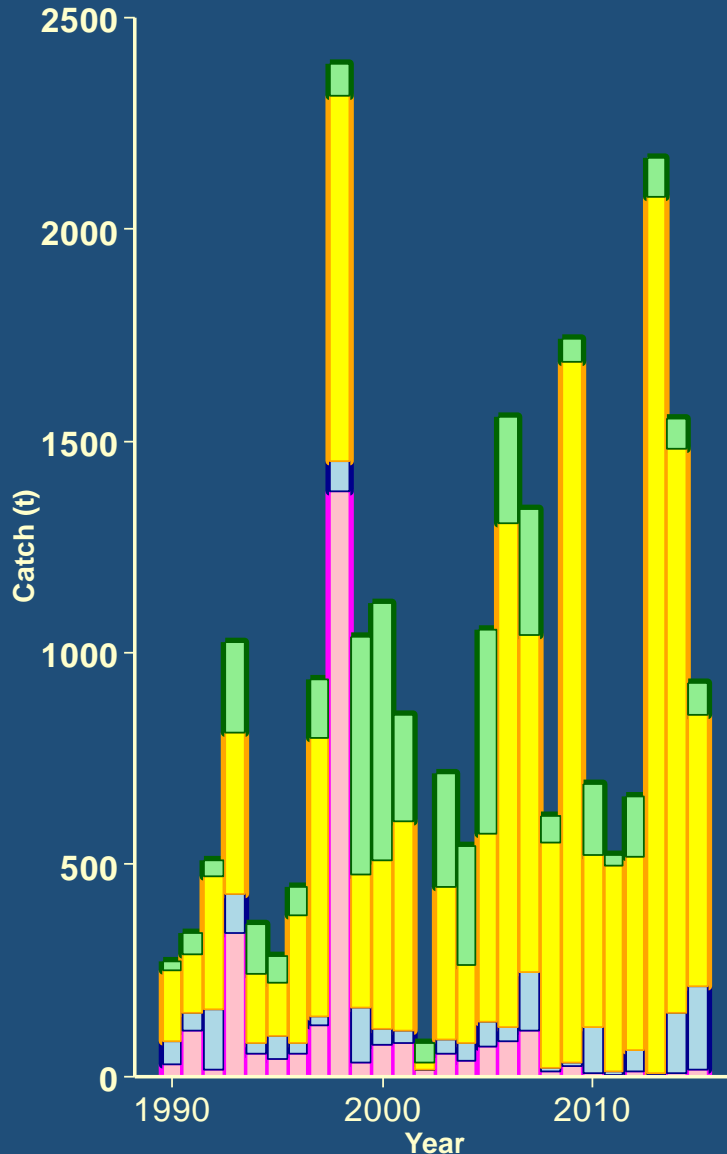
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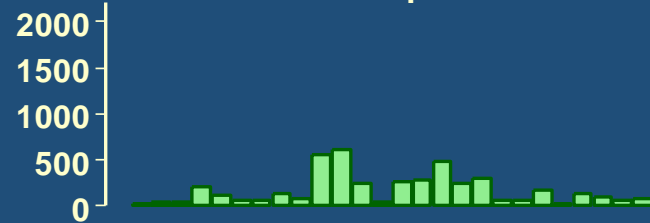
Total complex ABC = 2,113, OFL = 2817

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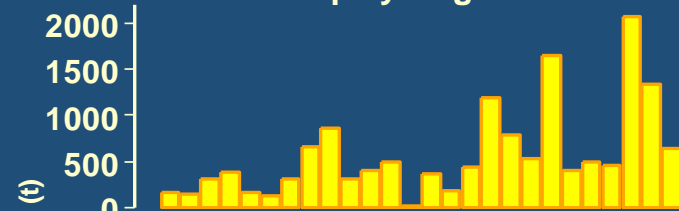
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Pacific Sleeper Shark



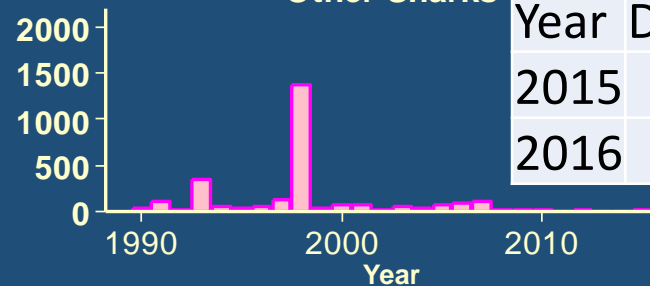
Spiny Dogfish



Salmon Shark



Other Sharks



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 F_{max} from demographic model in Tier 6* estimate
 - Report any improvements to biomass estimates in Sept

Questions?