NOAA FISHERIES

AFSC, ABL

Management Strategy Evaluation:

Ideas and Application

QUEST Webinar

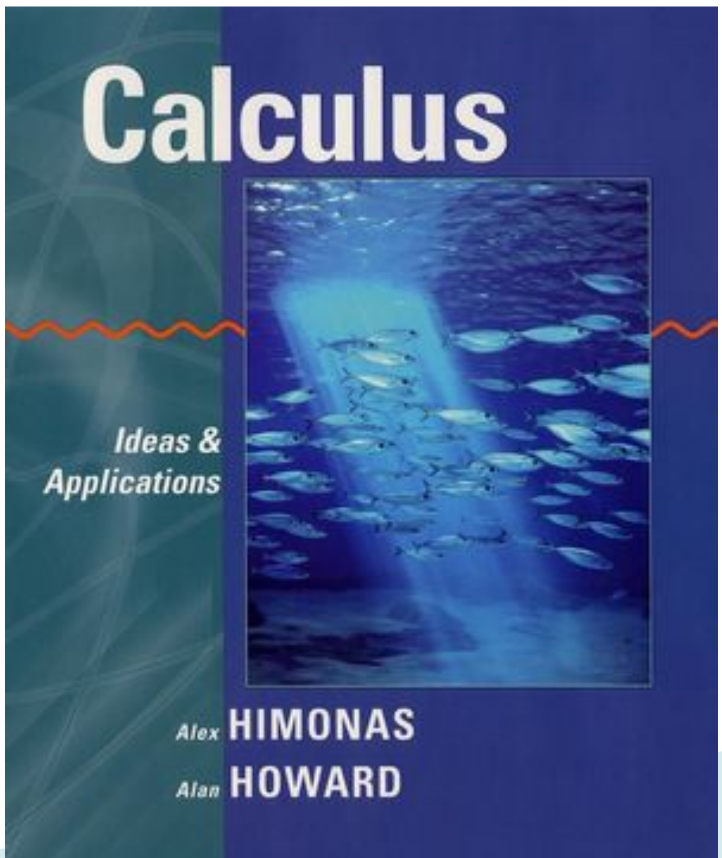
Dr. Curry Cunningham

May 10, 2017

NOAA FISHERIES
AFSC, ABL

Management Strategy Evaluation:

Ideas and Application



QUEST Webinar
Dr. Curry Cunningham

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Toward a common understanding of MSE

What, Where, When, How, and Why?

What is MSE?

FISH and FISHERIES

FISH and FISHERIES, 2016, **17**, 303–334

Management strategy evaluation: best practices

André E Punt[1,2], Doug S Butterworth[3], Carryn L de Moor[3], José A A De Oliveira[4] & Malcolm Haddon[2]

[1]School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, 98195, USA; [2]CSIRO Oceans and Atmosphere, GPO Box 1538, Hobart, TAS, 7001, Australia; [3]Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa; [4]CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK

Fish and Fisheries (2016)

- "…using simulation to compare the relative effectiveness for achieving management objectives of different combinations of data collection schemes, methods of analysis and subsequent processes leading to management actions"

What is MSE?

Opinion

Cell PRESS

Management strategy evaluation: a powerful tool for conservation?

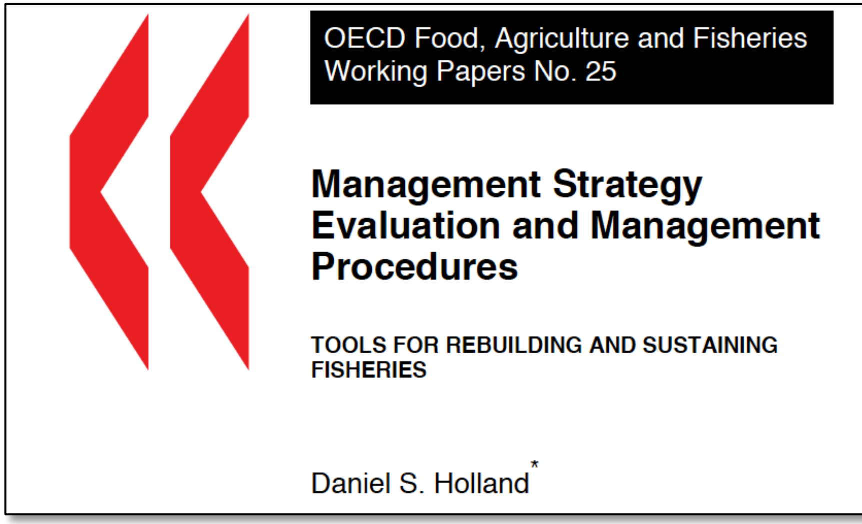
Nils Bunnefeld[1], Eriko Hoshino[1,2] and Eleanor J. Milner-Gulland[1]

[1] Department of Life Sciences, Imperial College London, Silwood Park, Buckhurst Road, Ascot, SL5 7PY, UK
[2] School of Economics and Finance, University of Tasmania, Private Bag 85, Hobart, TAS 7001, Australia

Trends in Ecology and Evol. (2011)

- "…uses simulation models within an adaptive framework that enables the comparison of alternative strategies in a virtual world under multiple (and often conflicting) objectives"

Why Conduct a MSE?


OECD Food, Agriculture and Fisheries Working Papers No. 25

Management Strategy Evaluation and Management Procedures

TOOLS FOR REBUILDING AND SUSTAINING FISHERIES

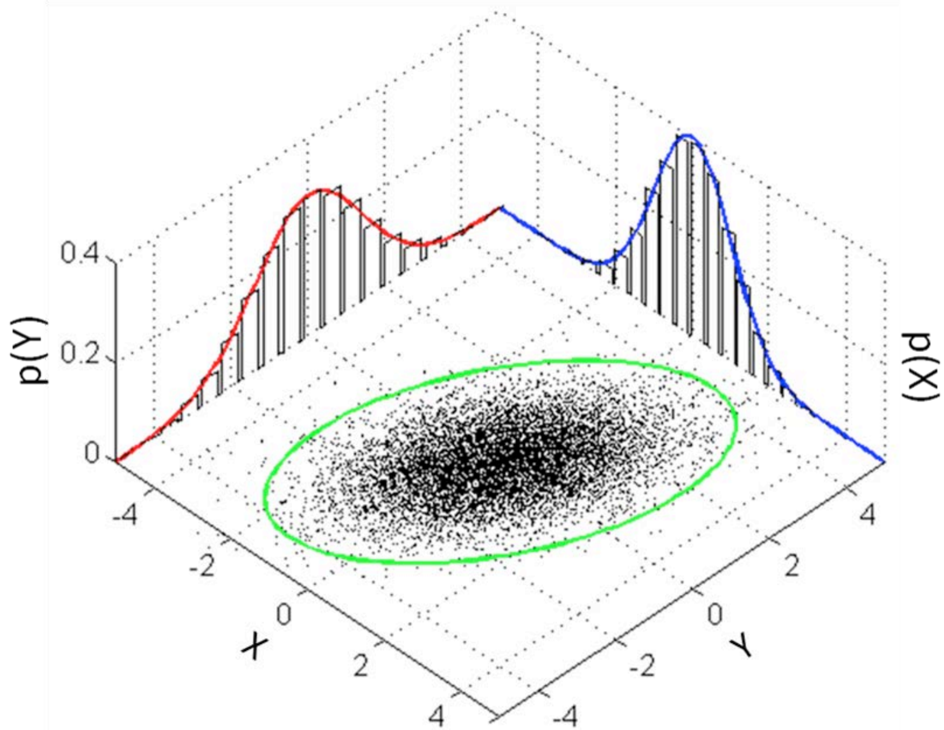
Daniel S. Holland*

OECD (2010)

- "… to identify fishery rebuilding strategies and ongoing harvest strategies that are robust to uncertainty and natural variation, and that balance biological and socioeconomic objectives"

Types of Uncertainty Confronted

- Estimation
- Model (structural)
- Process
- Sampling
- Assessment
- Implementation



Types of Uncertainty Confronted in a MSE

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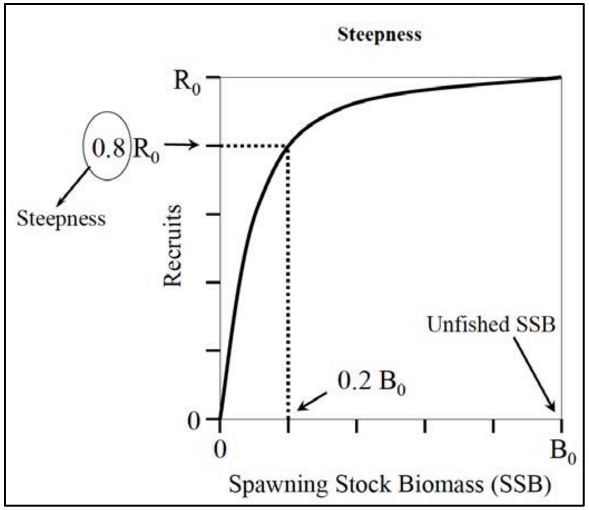

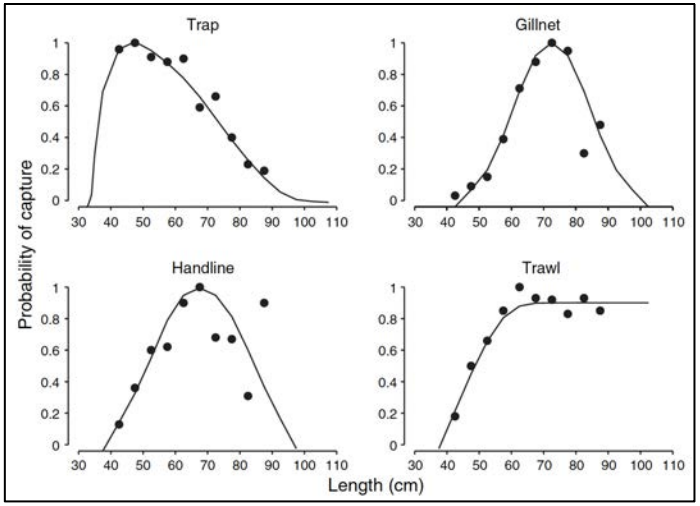

Hutchings (2009) Evo. Apps.

Types of Uncertainty Confronted in a MSE

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- **Process**
- Sampling
- Assessment
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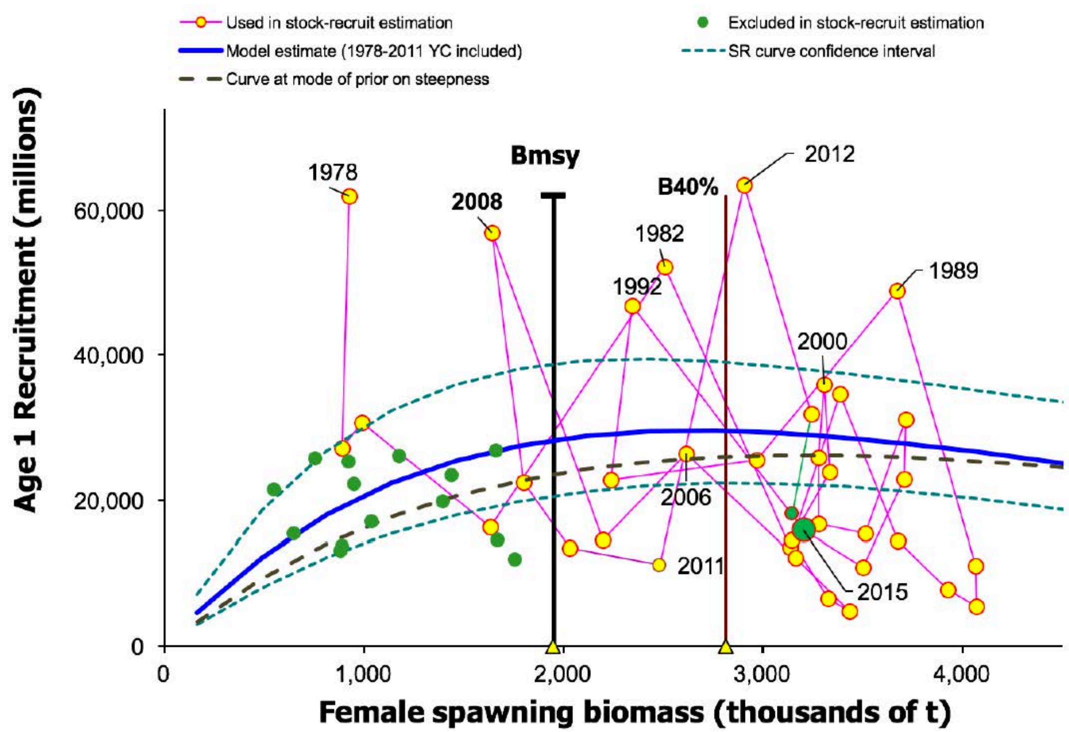

Ianelli et al. (2016) SAFE

Types of Uncertainty Confronted in a MSE

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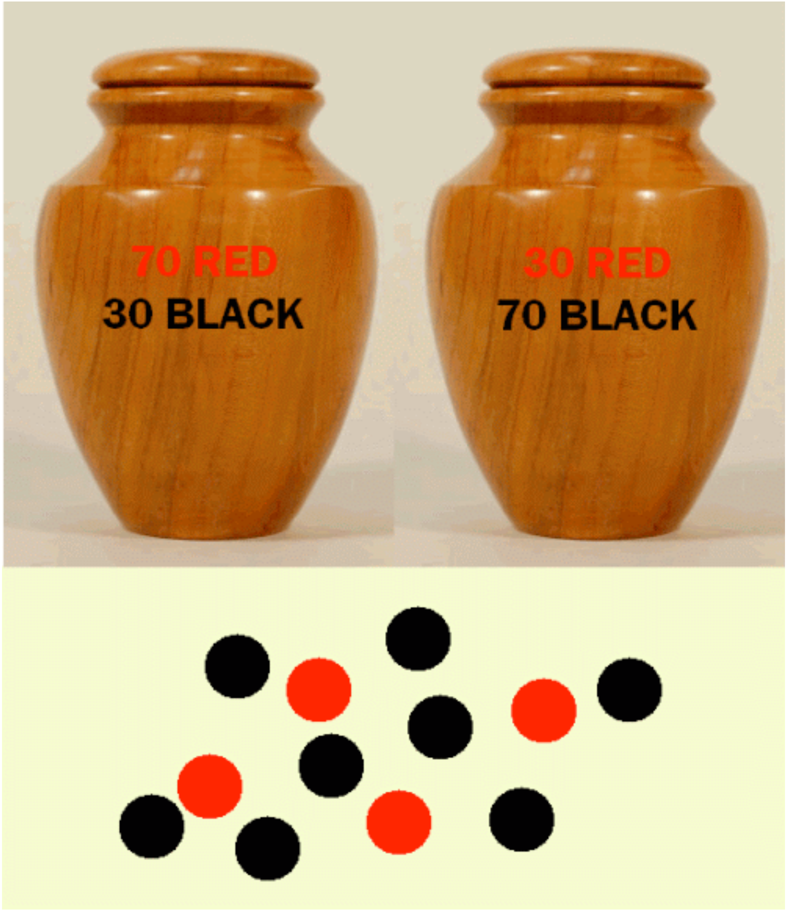

Landsberg, S.

Types of Uncertainty Confronted in a MSE

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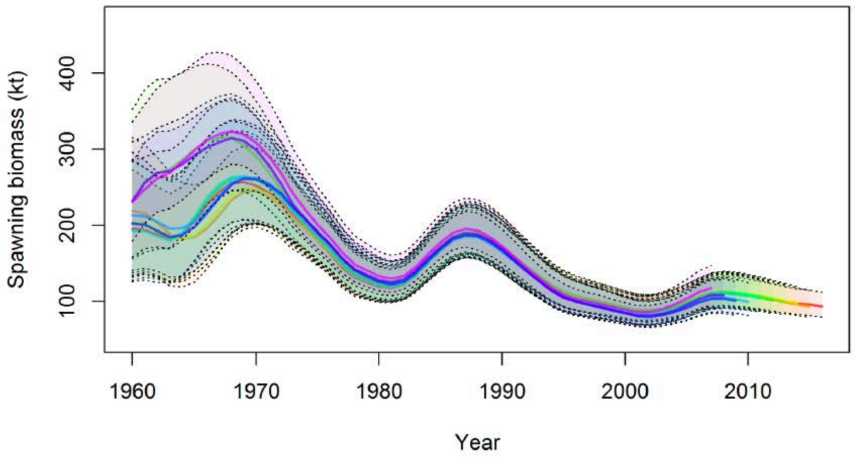

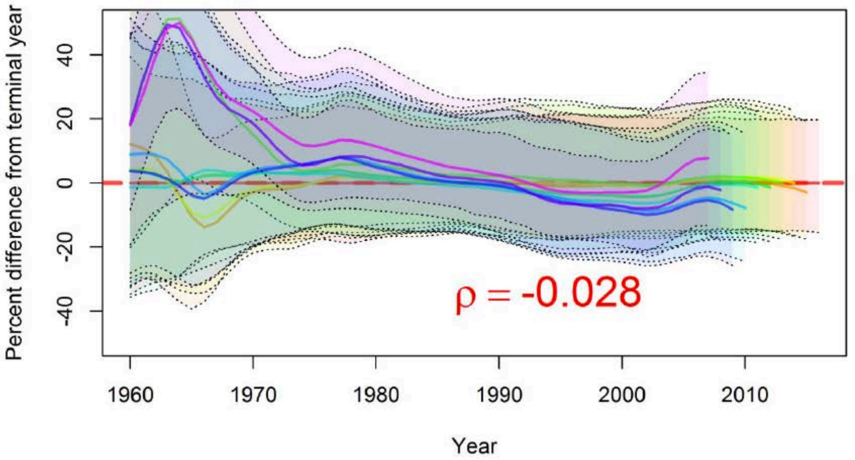

Hanselman et al. (2016) SAFE

Types of Uncertainty Confronted in a MSE

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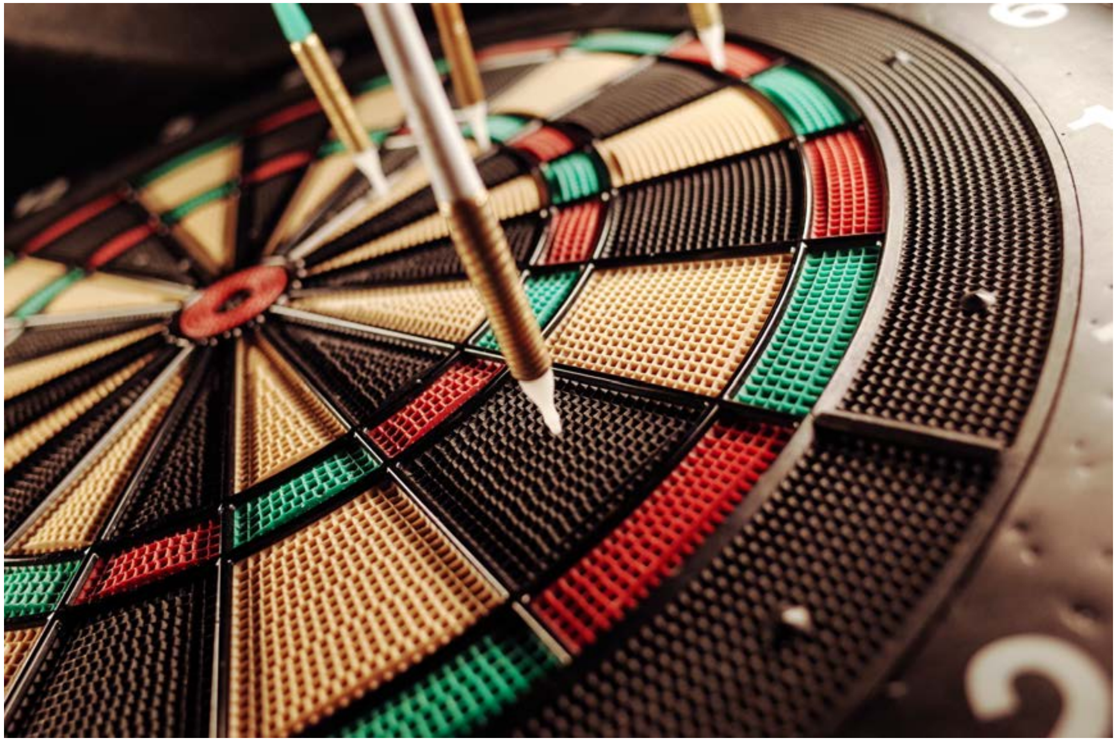

Types of Uncertainty Confronted in a MSE

- Estimation
- Model (structural)
- Process
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- Assessment
- Implementation

“Minimally, a MSE should consider…”

“Which uncertainty is most important will be case specific.”

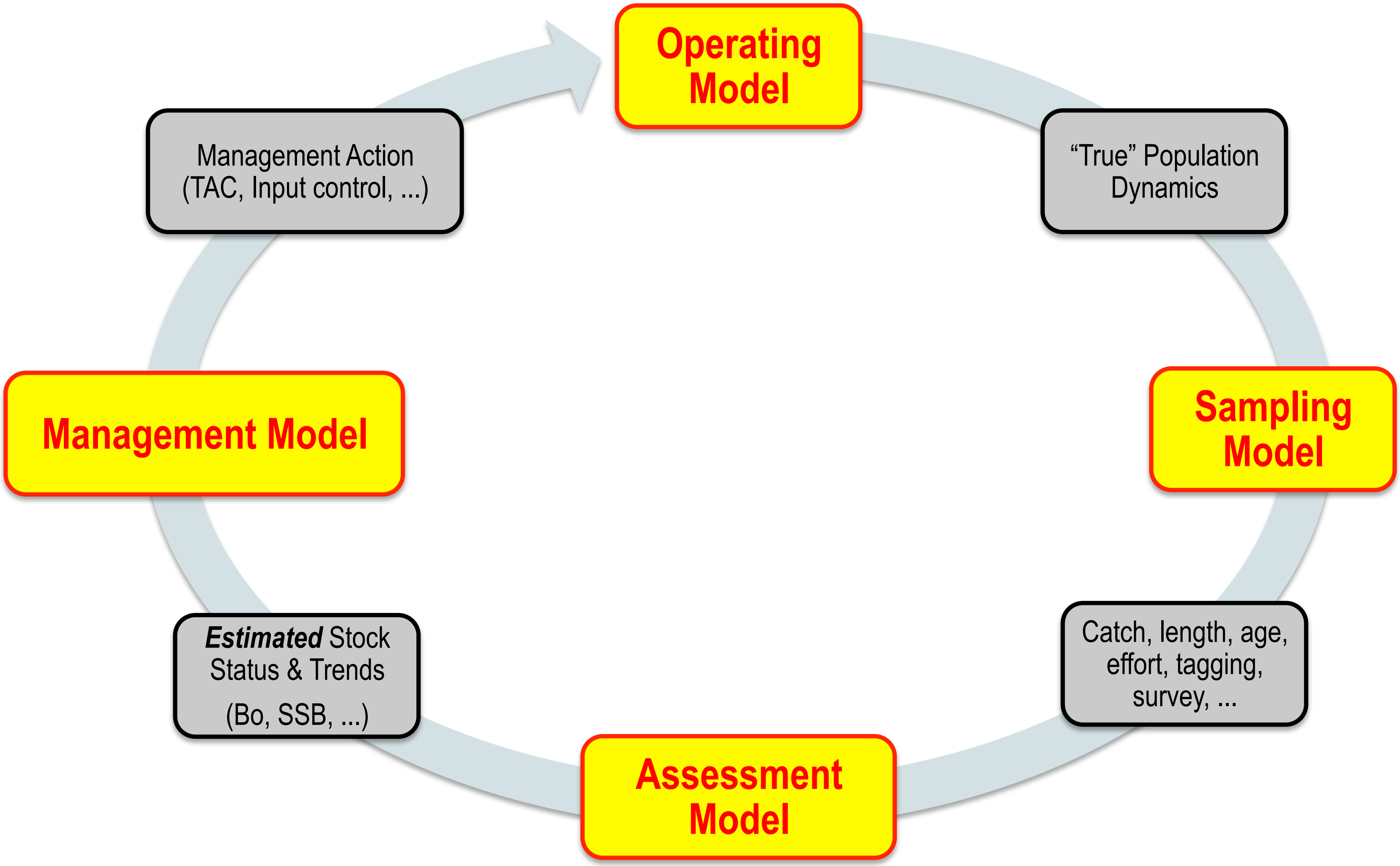
Punt et al. (2016) Fish and Fisheries

Steps in the MSE Process

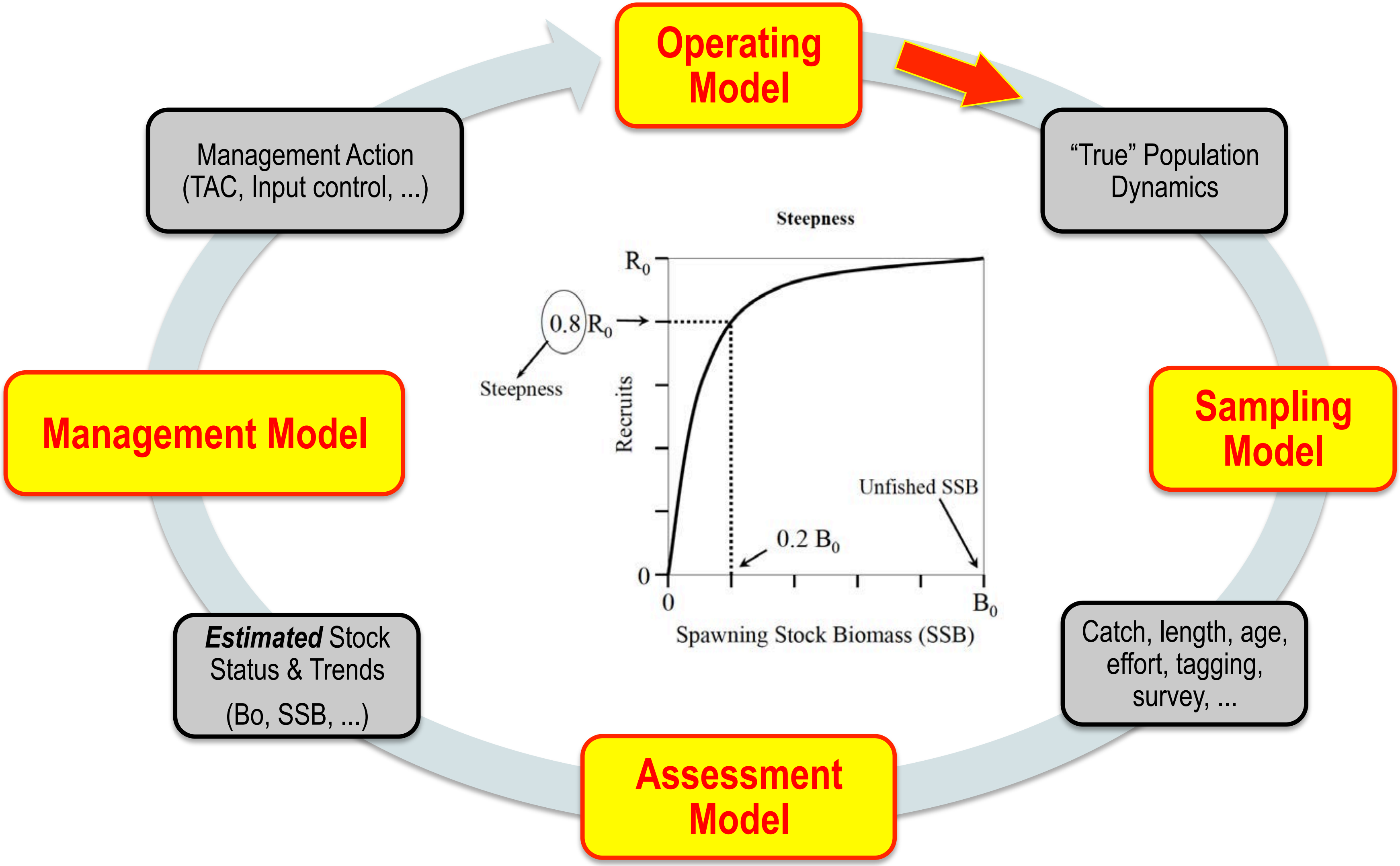
1. Identify management objectives and performance metrics*
2. Determine uncertainties to confront
3. Develop harvest strategies*
4. Build operating model
   • Conditioned on observed data
5. Simulate outcomes
6. Compare performance metrics across strategies*

* Minimum Stakeholder Involvement

MSE Framework



MSE Framework



MSE Framework

Operating Model

"True" Population Dynamics

Sampling Model

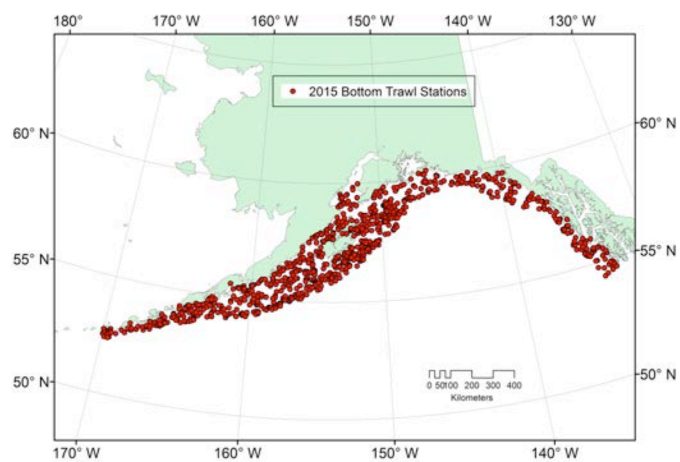
Catch, length, age, effort, tagging, survey, ...

Assessment Model

Estimated Stock Status & Trends (Bo, SSB, ...)

Management Model

Management Action (TAC, Input control, ...)



NOAA AFSC

MSE Framework

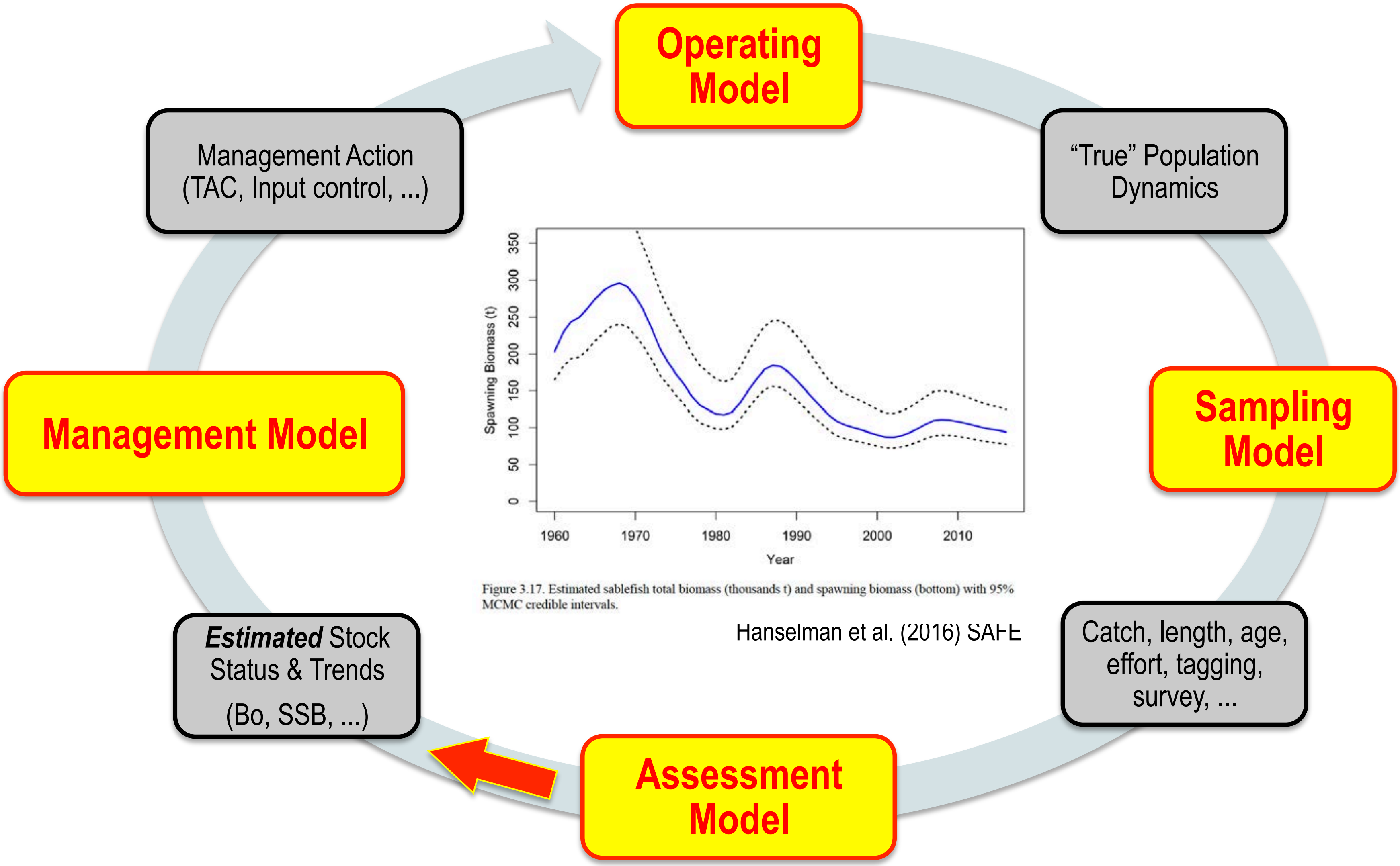
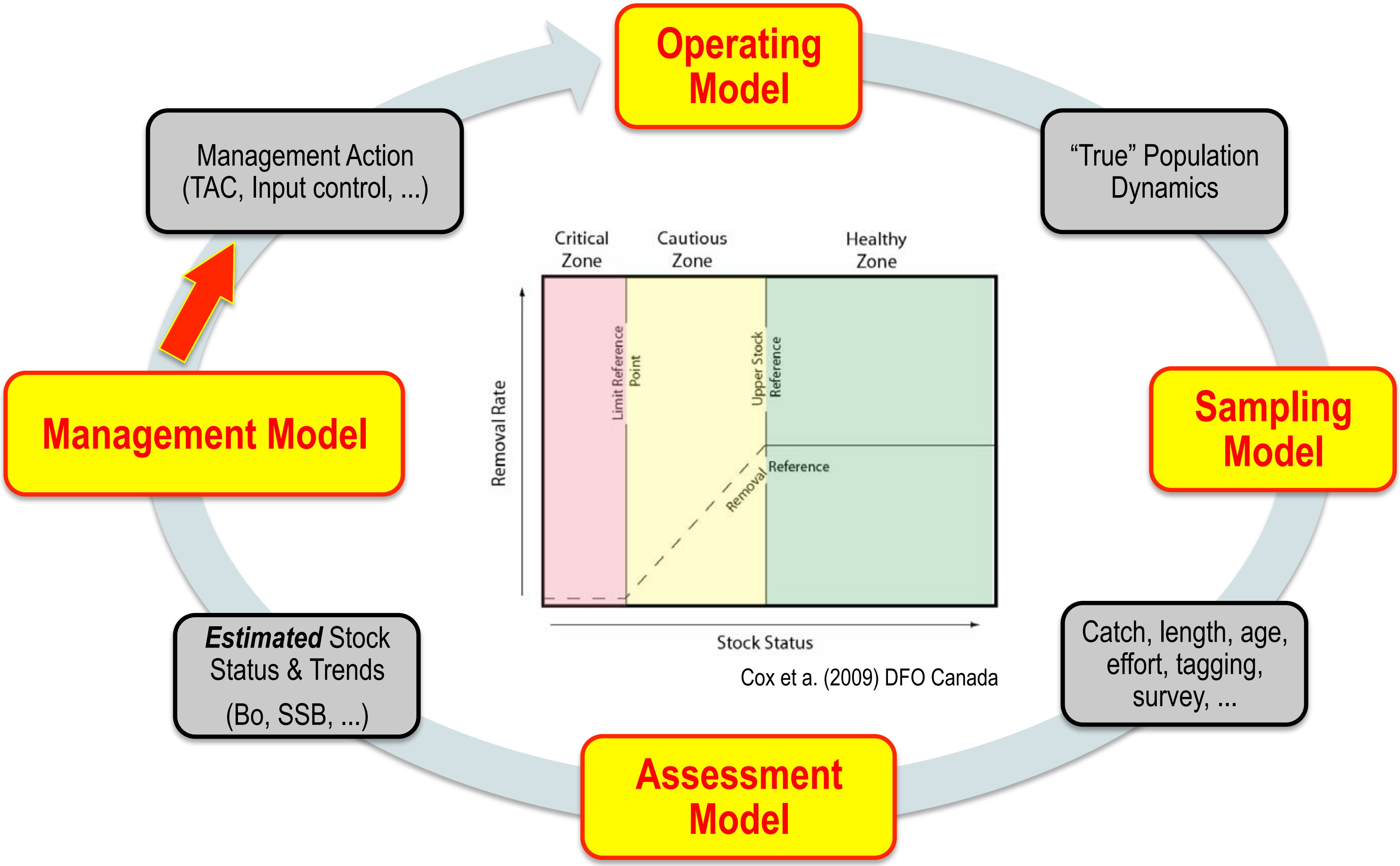


Figure 3.17. Estimated sablefish total biomass (thousands t) and spawning biomass (bottom) with 95% MCMC credible intervals.

Hanselman et al. (2016) SAFE

MSE Framework



Challenges to MSE Implementation

- High costs
  - Full MSE requires development time and computational resources
- Obtaining stakeholder buy-in
  - Will short-term sacrifice result in long-term gain?
  - Necessary to ensure political pressure to accept/follow outcomes
- Identifying objectives can be difficult
- Uncertainty about future data collection process
- Requires knowledge of the system and sources of uncertainty
- Moving beyond single-species focus

MSE Case Studies

Multispecies MSE as a Tool for EBFM

Bio-economic Modelling within a MSE Framework

Confronting Environmental Change with MSE

Simulation Study ⟷ Continuum of Complexity ⟷ **Full MSE**

Multispecies MSE as a Tool for EBFM

Vol. 523: 215–232, 2015
doi: 10.3354/meps11129
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser
Published March 16

Simulations to evaluate management trade-offs among marine mammal consumption needs, commercial fishing fleets and finfish biomass

Laurel Smith*, Robert Gamble, Sarah Gaichas, Jason Link

NOAA/Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543, USA

- Impact of alternative finfish harvest rates
  - Species interactions
  - Incidental marine mammal mortality
- Multispecies biomass dynamics model

Species Interactions within an MSE Framework

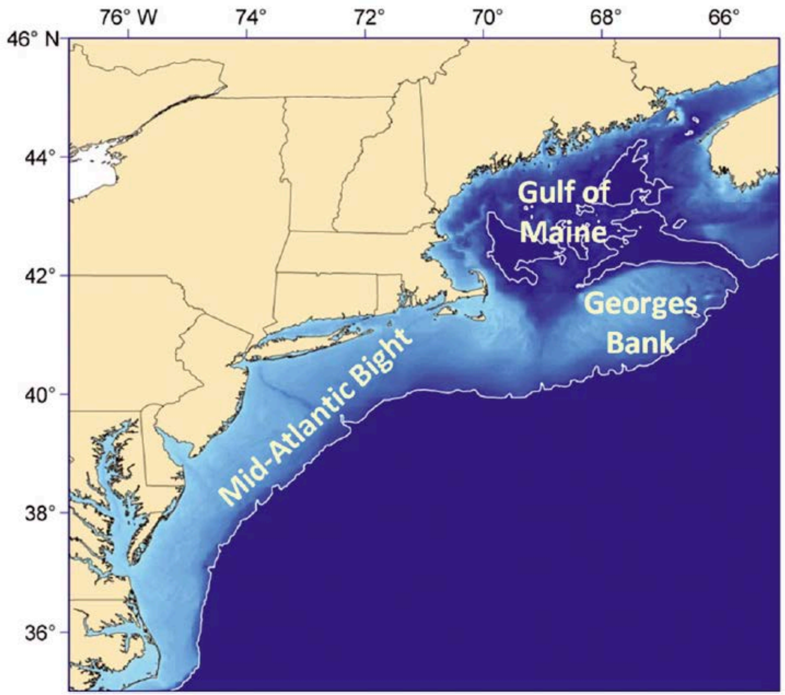


Fig. 1. Northeast US continental shelf Large Marine Ecosystem study area. White line represents the 200 m isobath

Competition Coefficient

$$B_{i,t+1} = B_{i,t} + r_i B_{i,t}\left(1 - \frac{B_{i,t}}{K_i} - \frac{\sum_j \beta_{ij} B_{j,t}}{(K_\sigma - K_i)}\right) - B_{i,t}\sum_p \alpha_{ip} B_{p,t} - H_i B_{i,t}$$

Predator-prey Interaction

Harvest Rate

12 Marine Mammals

15 Commercially Important Finfish

	Common names
Mysticetes	Fin whale, humpback whale, North Atlantic right whale, sei whale, minke whale
Odontocetes	Pilot whale, bottlenose dolphin, Atlantic white-sided dolphin, common dolphin, harbor porpoise
Pinnipeds	Gray seal, harbor seal
Small pelagic fish	Atlantic herring, river herring, saury, anchovies, Atlantic mackerel, jacks, scads
Flatfish	Yellowtail flounder, winter flounder, summer flounder, witch flounder, American plaice, Atlantic halibut, windowpane flounder
Gadids	Red hake, white hake, spotted hake, silver hake, rocklings, Atlantic cod, haddock, pollock

Smith et al. (2015) Mar. Ecol. Prog. Series

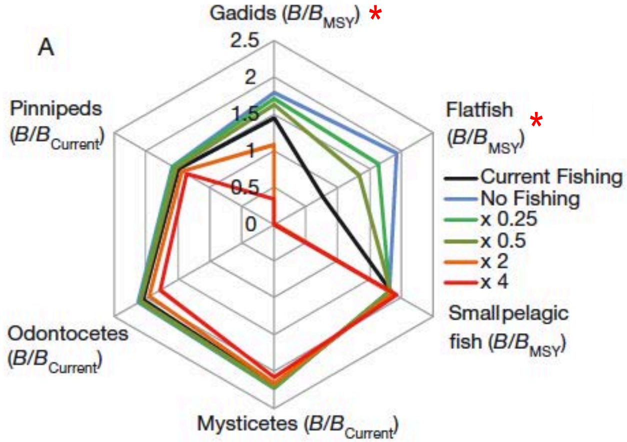
Species Interactions within an MSE Framework

Smith et al.: Management trade-offs among marine mammals, fishing fleets, and finfish 223

Reported Mar. Mammal Mortality

10x Reported Mortality

Groundfish Harvest



Pelagic Harvest

Species Interactions within an MSE Framework

Smith et al.: Management trade-offs among marine mammals, fishing fleets, and finfish 223

Reported Mar. Mammal Mortality

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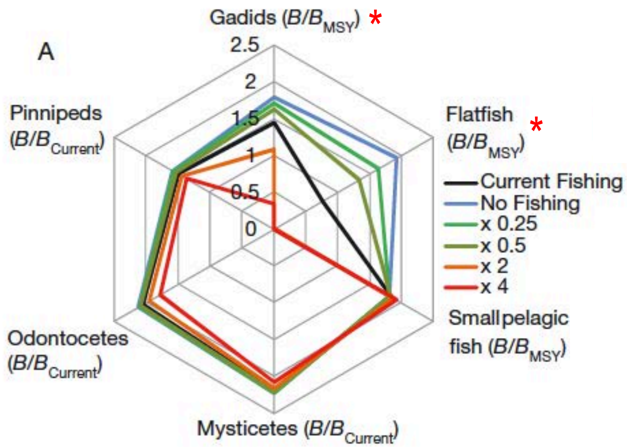
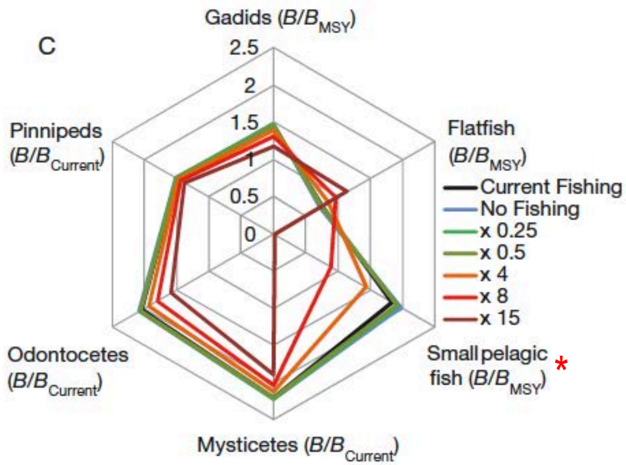
Groundfish Harvest



Pelagic Harvest



Species Interactions within an MSE Framework

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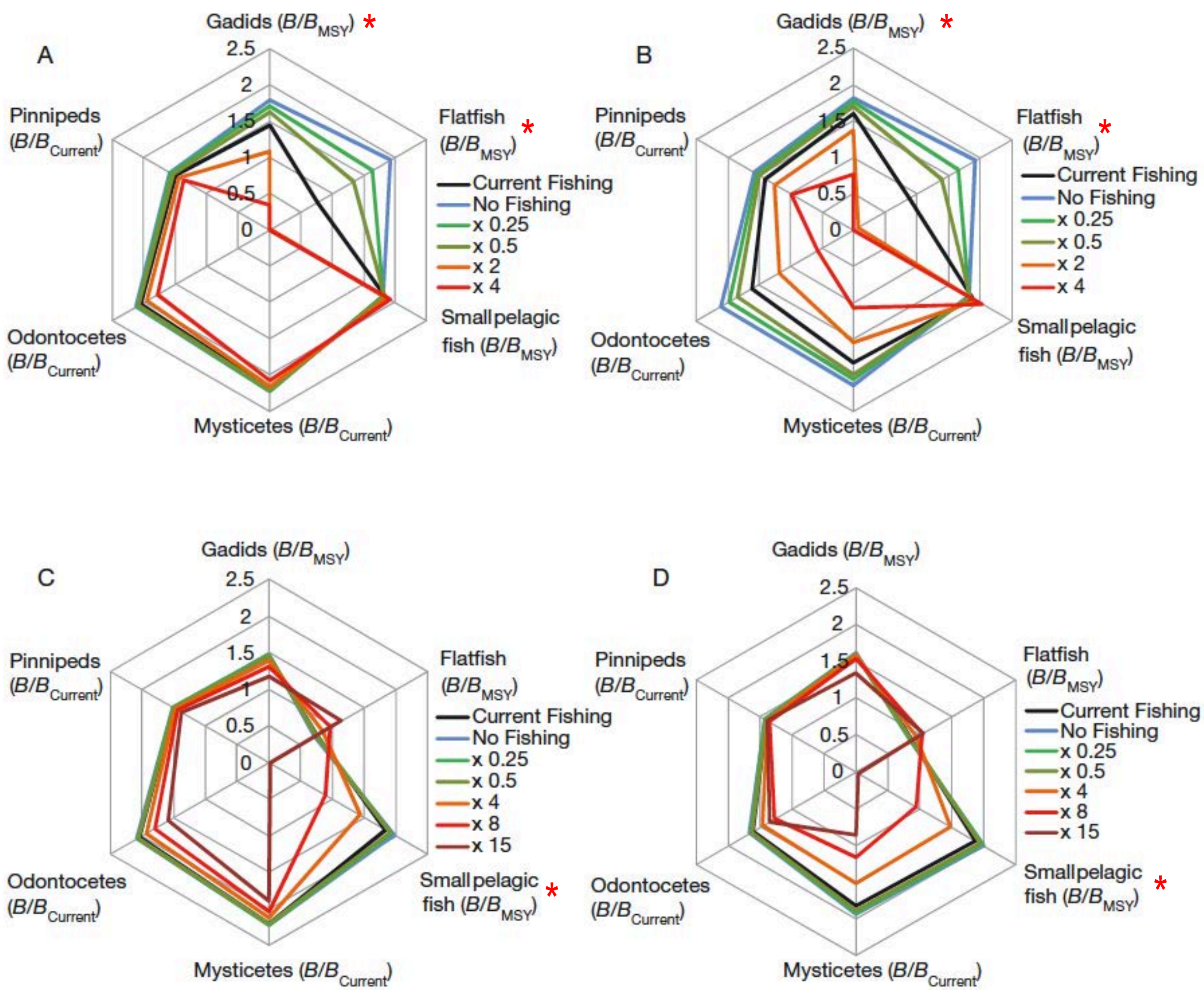


Bio-economic Modelling within a MSE Framework


Ecological Economics 99 (2014) 110–120

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

ELSEVIER

Analysis

Risk versus economic performance in a mixed fishery

S. Gourguet [a,b,*], O. Thébaud [a], C. Dichmont [a], S. Jennings [d], L.R. Little [c], S. Pascoe [a], R.A. Deng [a], L. Doyen [b]

[a] CSIRO, Marine and Atmospheric Research, 41 Boggo Road, Dutton Park, QLD 4102, Australia
[b] CNRS-MNHN, CERSP UMR 7204, CP 51, 55 rue Buffon, 75005 Paris, France
[c] CSIRO Marine and Atmospheric Research, PO Box 1538, Hobart, TAS 7001, Australia
[d] School of Economics and Finance, University of Tasmania, Hobart, TAS 7001, Australia

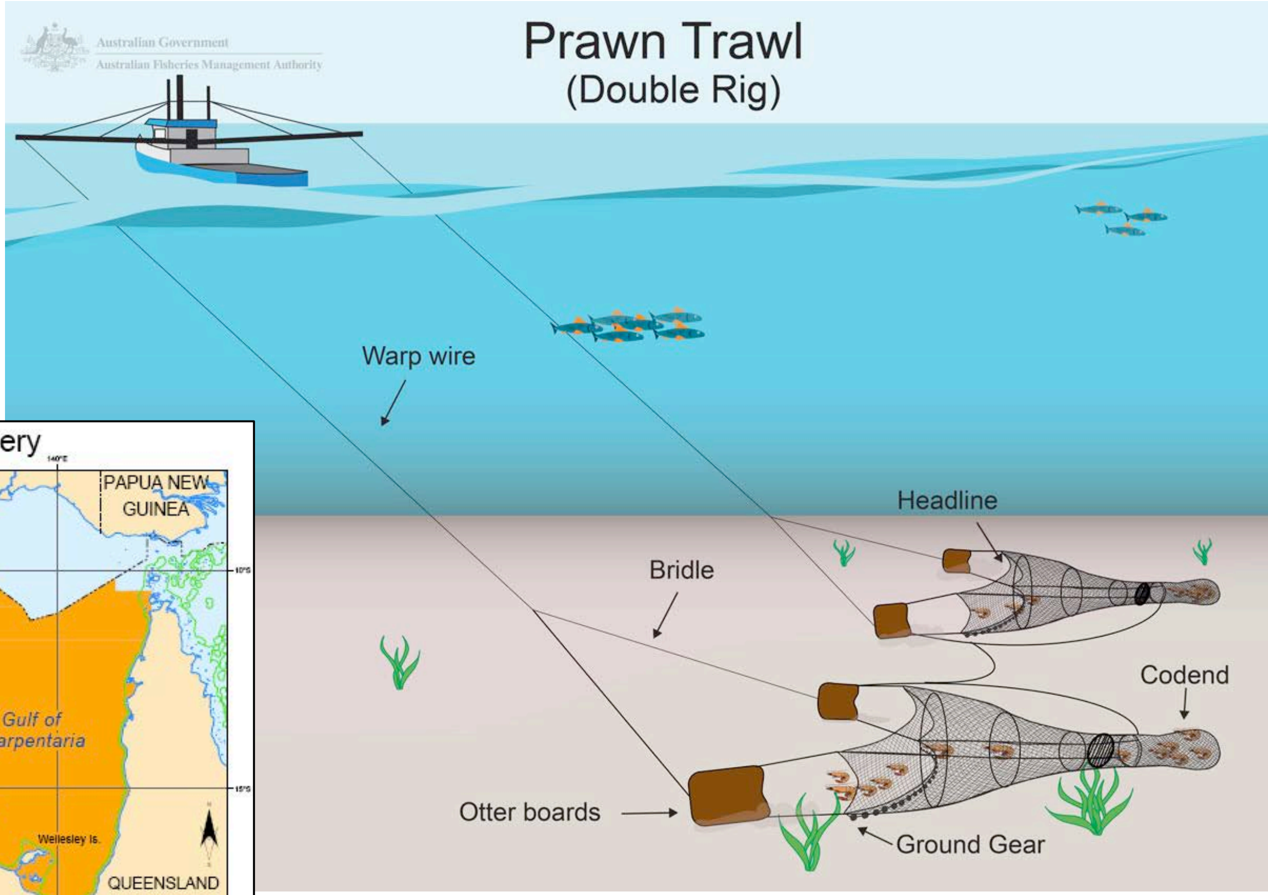
Laird (2015), NPF Industry Pty Ltd

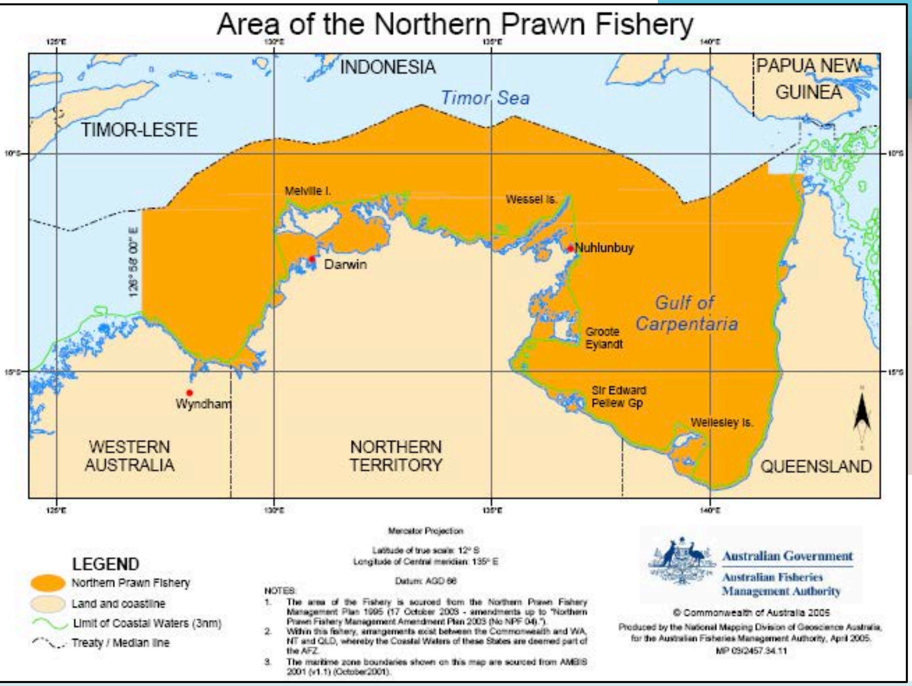
- Evaluate economic outcomes of
  - Effort allocation among target species
  - Changes in fleet size
- Stochastic multispecies bio-economic model

Laird (2015), NPF Industry Pty Ltd

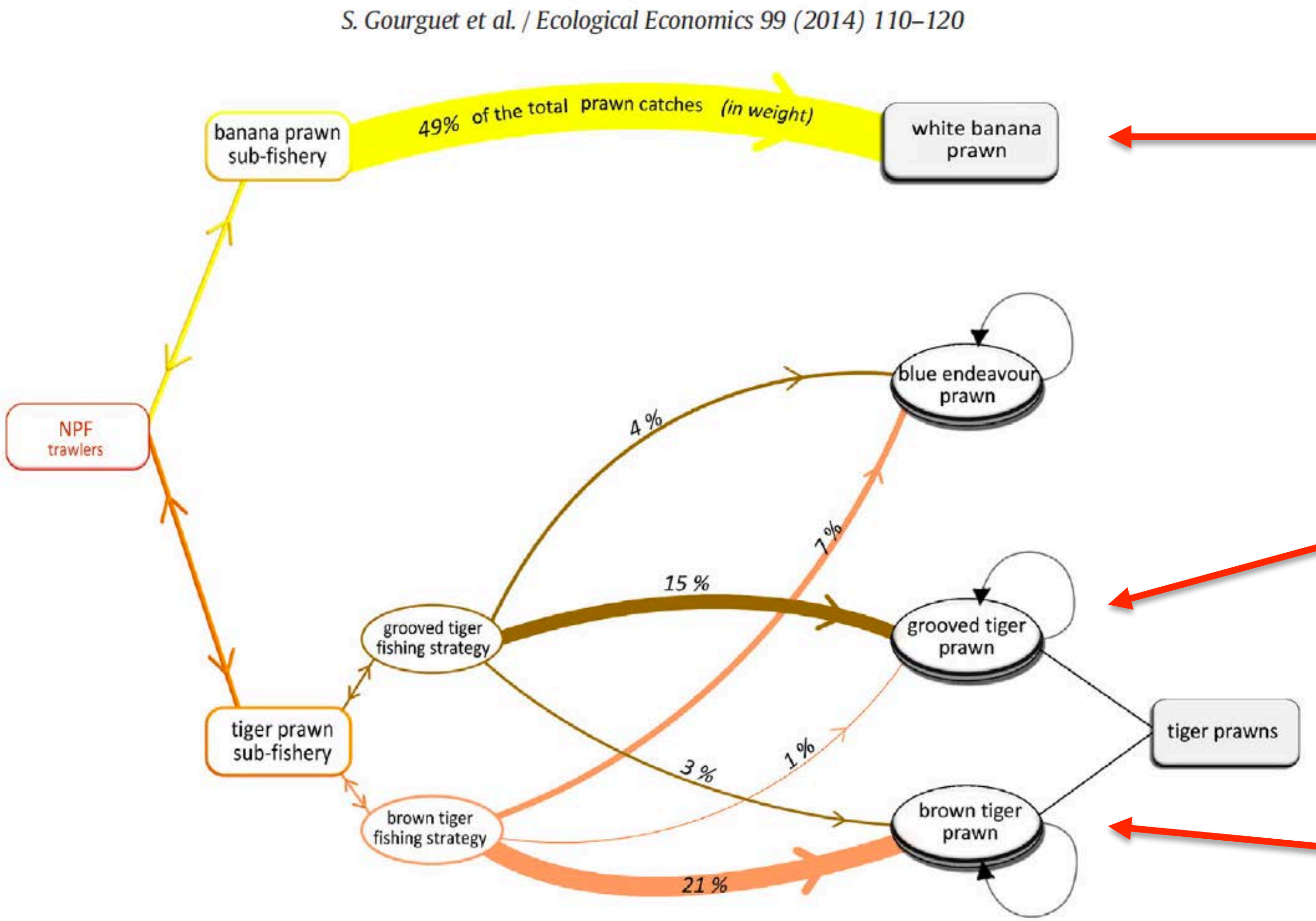
Economic MSE: Australian Northern Prawn Fishery

Laird (2015), NPF Industry Pty Ltd





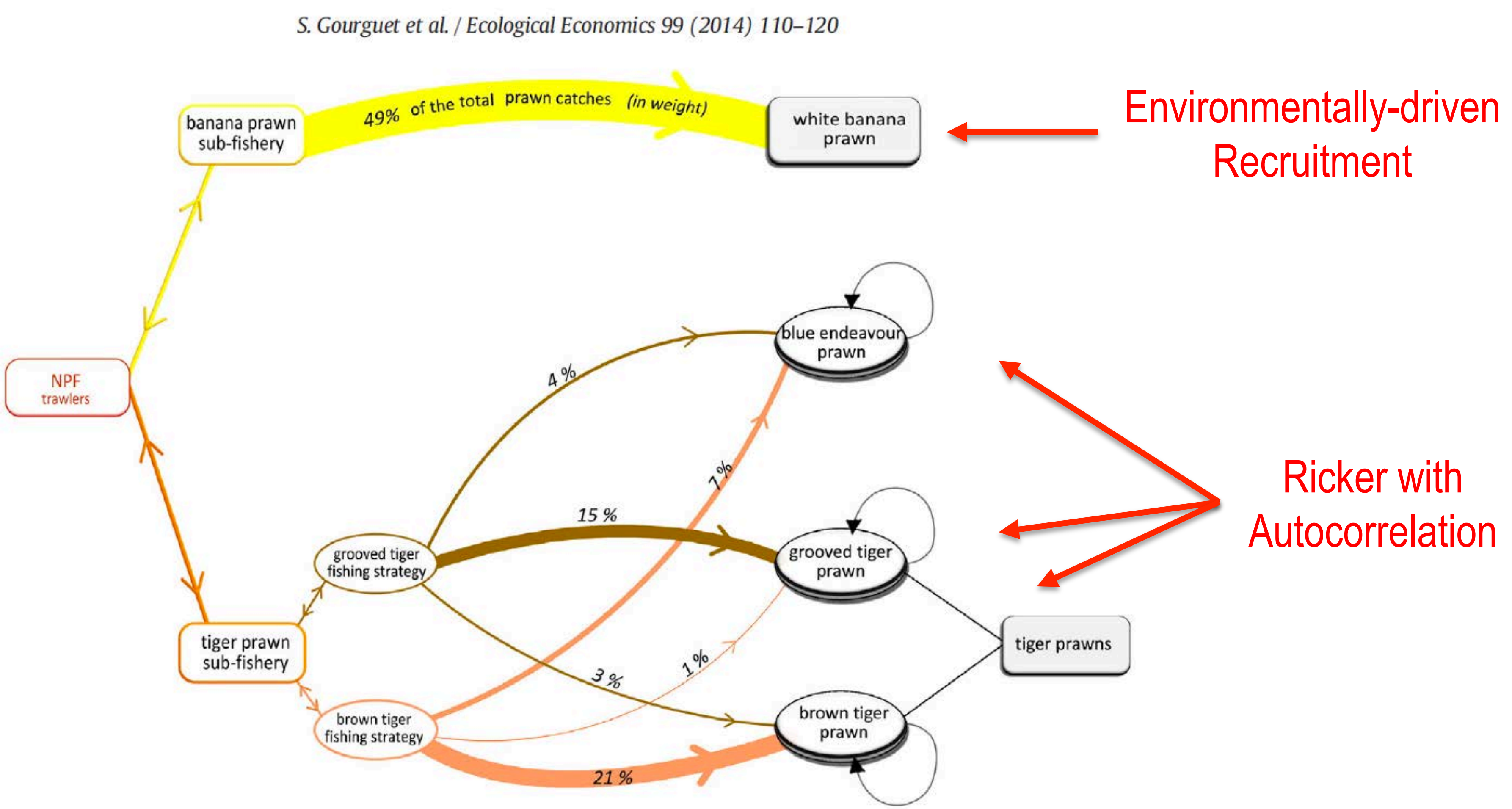
Northern Prawn Fishery Schematic



NPF Industry Pty Ltd

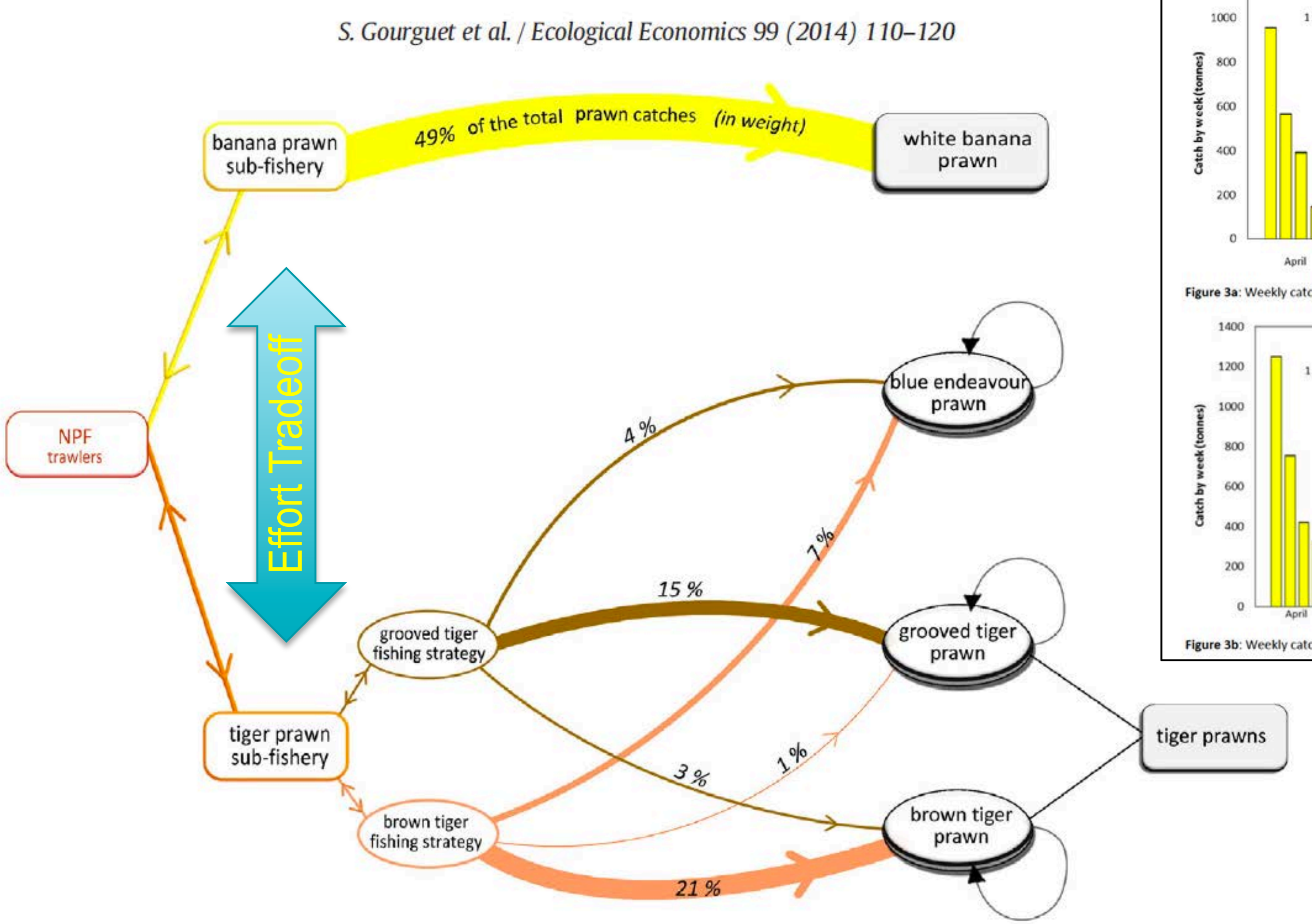
Gourguet et al. (2014) Ecological Economics

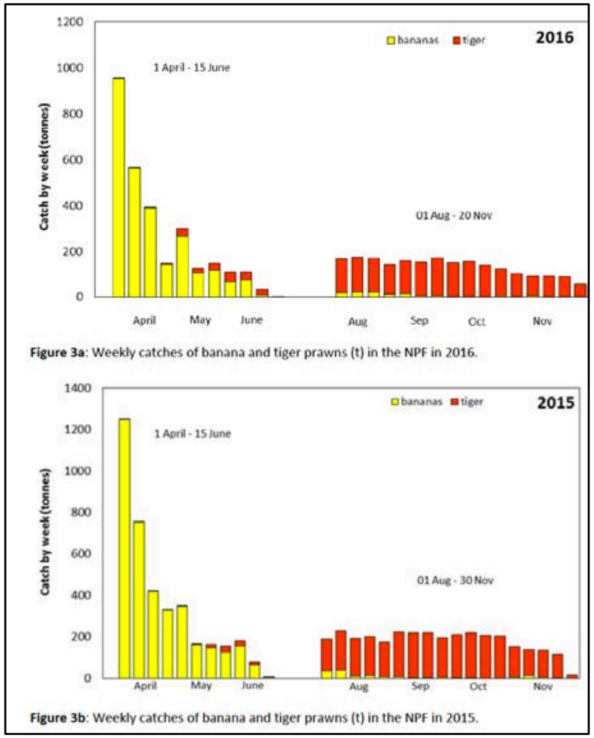
Northern Prawn Fishery Schematic



Gourguet et al. (2014) Ecological Economics

Northern Prawn Fishery Schematic



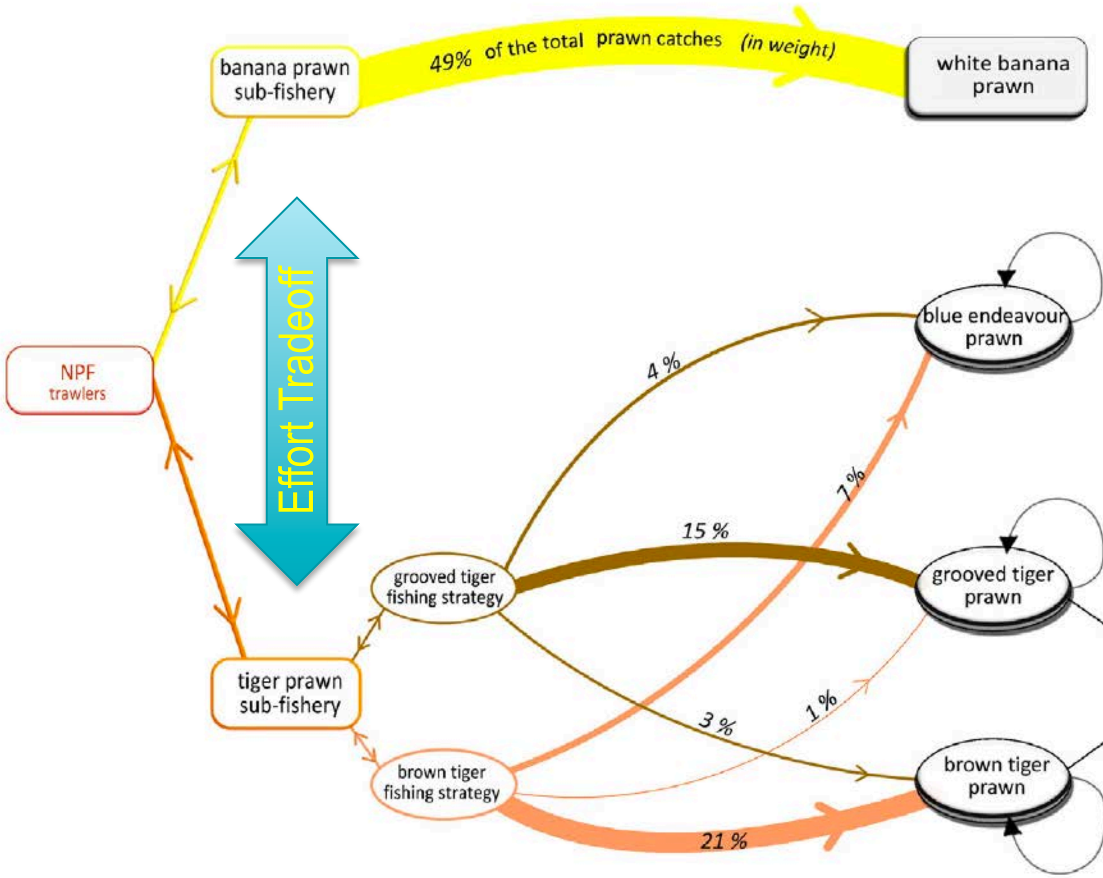


Laird (2017), NPF Industry Pty Ltd

Gourguet et al. (2014) Ecological Economics

Economic MSE: N. Australian Prawn Fisheries

S. Gourguet et al. / Ecological Economics 99 (2014) 110–120



Effort Allocation

Effort combinations	Description
T_0	$\propto_{tig} = 0\ \%$.
T_{10}	$\propto_{tig} = 10\ \%$.
T_{50}	$\propto_{tig} = 50\ \%$.
T_{adapt}	See Eq. (10).
T_{90}	$\propto_{tig} = 90\ \%$.
T_{100}	$\propto_{tig} = 100\ \%$.

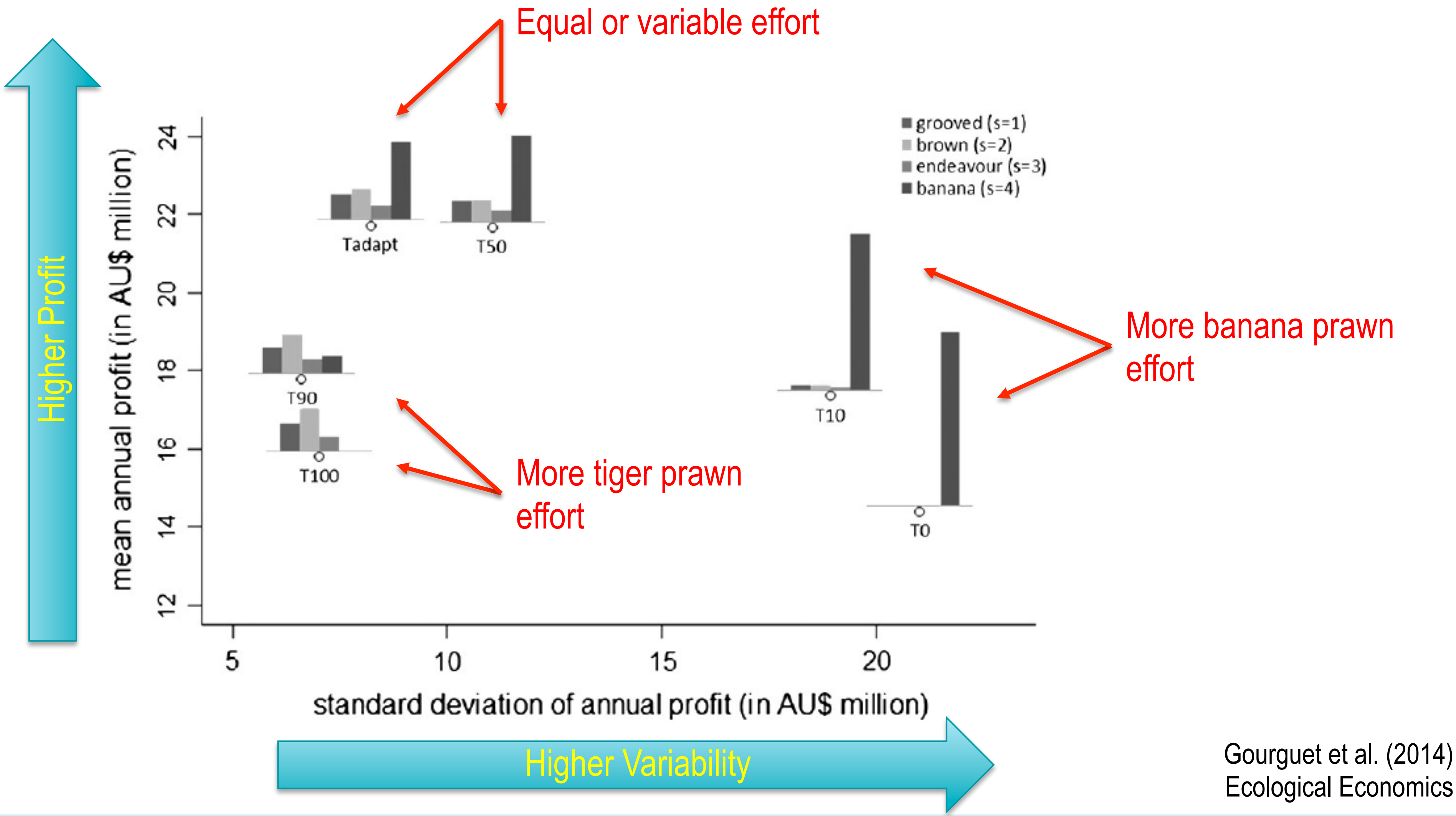
More Banana

More Tiger

Vessel Participation

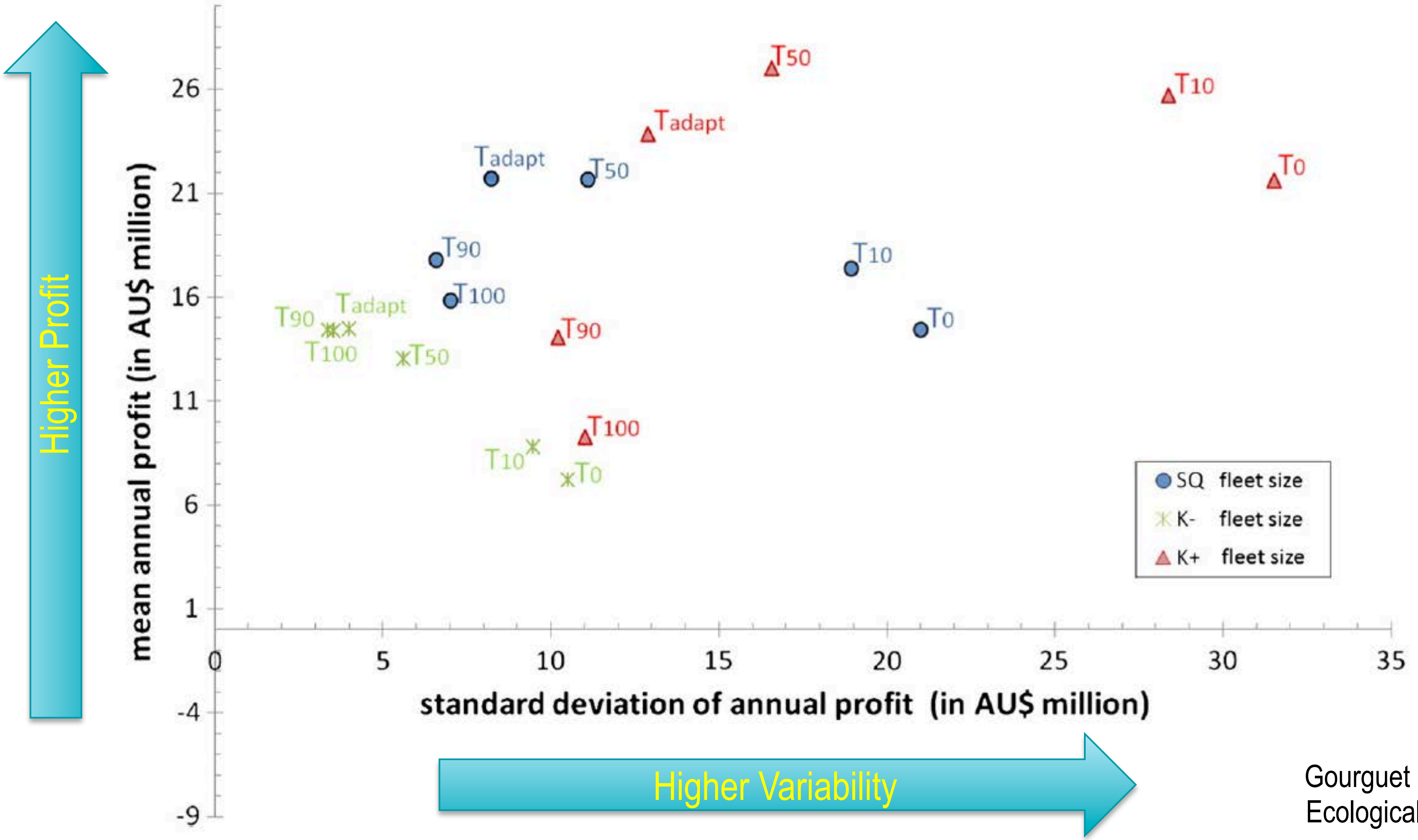
- SQ fleet size
- K- fleet size
- K+ fleet size

Economic MSE: N. Australian Prawn Fisheries



Gourguet et al. (2014)
Ecological Economics

Economic MSE: N. Australian Prawn Fisheries



Gourguet et al. (2014)
Ecological Economics

Confronting Environmental Change with MSE

ICES Journal of Marine Science (2011), 68(6), 1297–1304. doi:10.1093/icesjms/fsr010

Evaluating management strategies for eastern Bering Sea walleye pollock (*Theragra chalcogramma*) in a changing environment

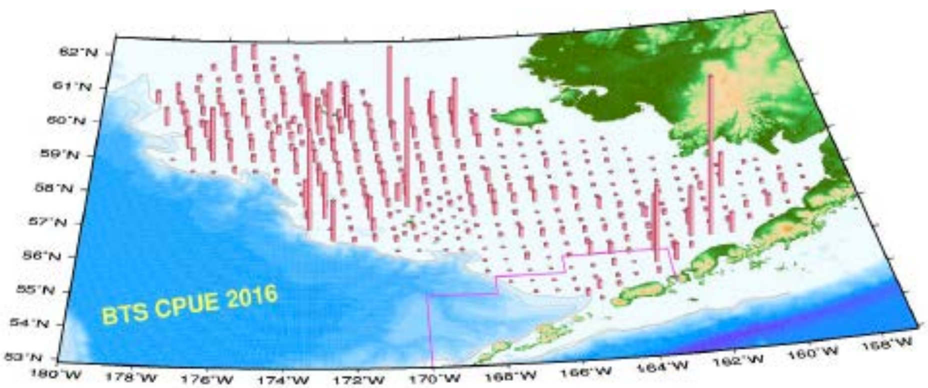
James N. Ianelli[1]*, Anne B. Hollowed[1], Alan C. Haynie[1], Franz J. Mueter[2], and Nicholas A. Bond[3]

[1]*Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle, WA 98115, USA*
[2]*School of Fisheries and Ocean Sciences, 315 Lena Point, 17101 Pt. Lena Loop Rd, Juneau, AK 99801, USA*
[3]*Joint Institute for the Study of Atmosphere and Ocean, University of Washington, Box 354925, Seattle, WA 98195, USA*

**Corresponding Author: tel: +1 206 526 6510; fax: +1 206 526 6723; e-mail: jim.ianelli@noaa.gov.*

Ianelli, J. N., Hollowed, A. B., Haynie, A. C., Mueter, F. J., and Bond, N. A. 2011. Evaluating management strategies for eastern Bering Sea walleye pollock (*Theragra chalcogramma*) in a changing environment. – ICES Journal of Marine Science, 68: 1297–1304.

Received 19 July 2010; accepted 6 January 2011; advance access publication 11 April 2011.



Ianelli et al. (2016) SAFE

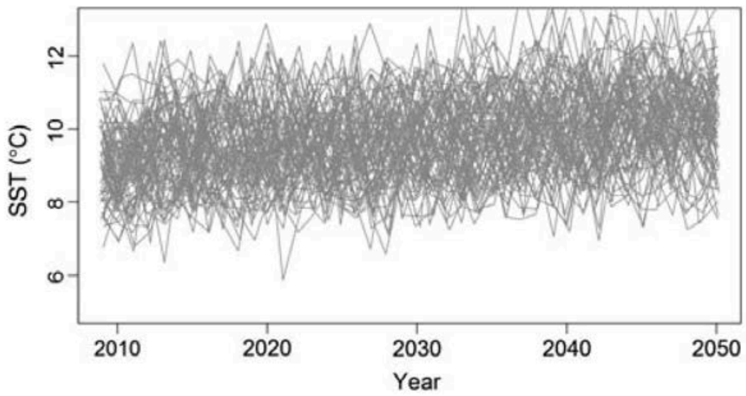
David Csepp NOAA/NMFS ABL

Mechanistic vs. Empirical Approach

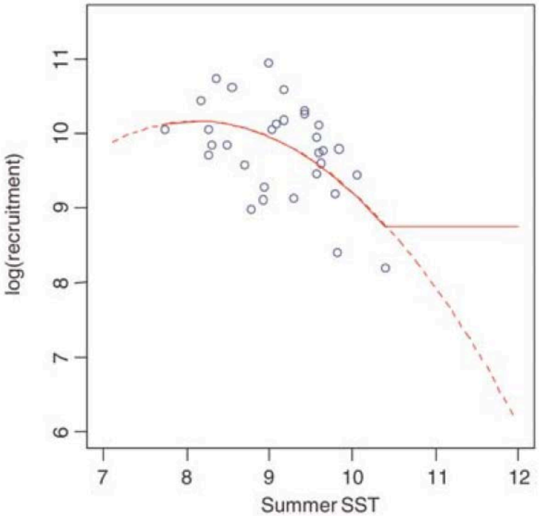
Punt et al. (2014) ICES JMS

Simulating Future Recruitment

1) 82 IPCC Climate Models

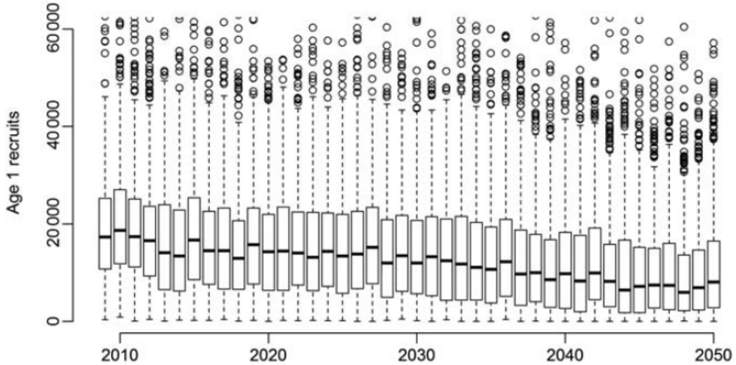


2) Recruitment ~ SST

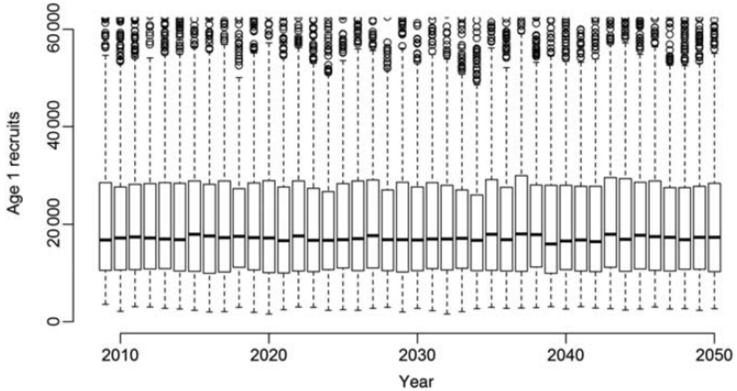


3) Simulated Future Recruitment

Under Climate Change

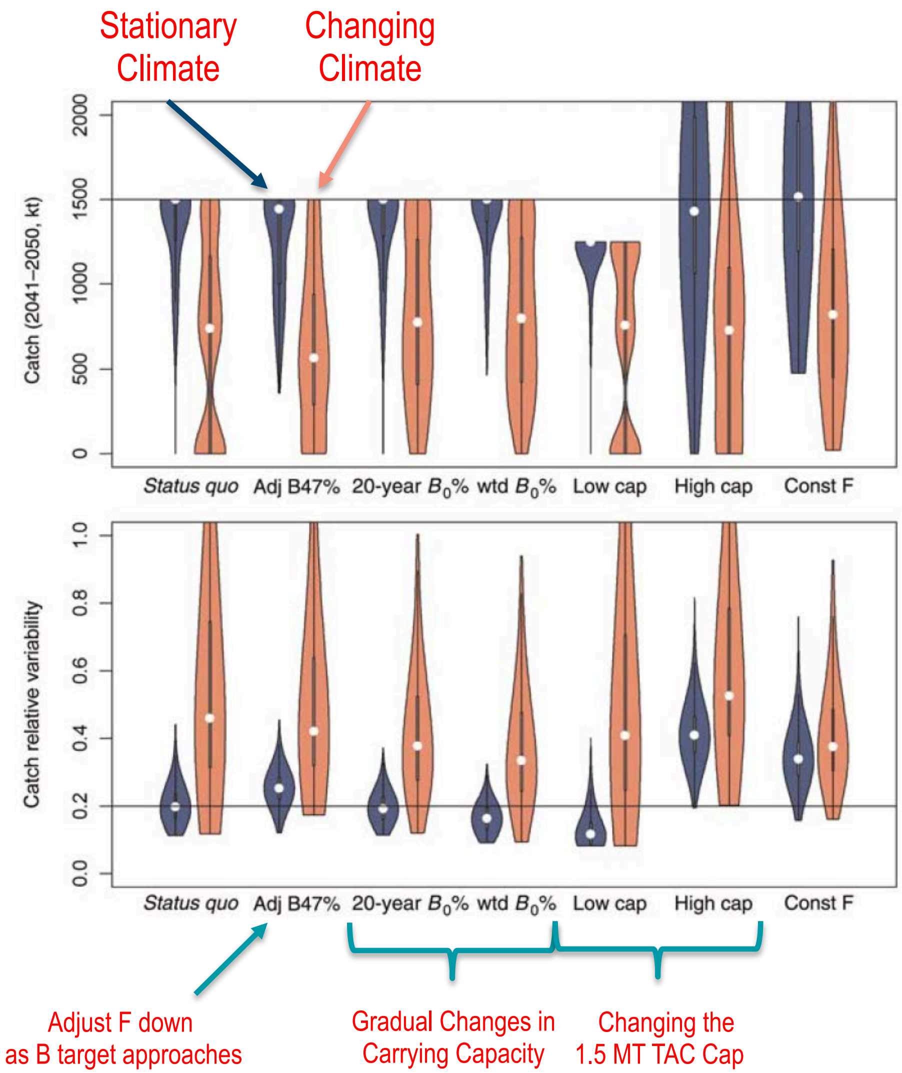


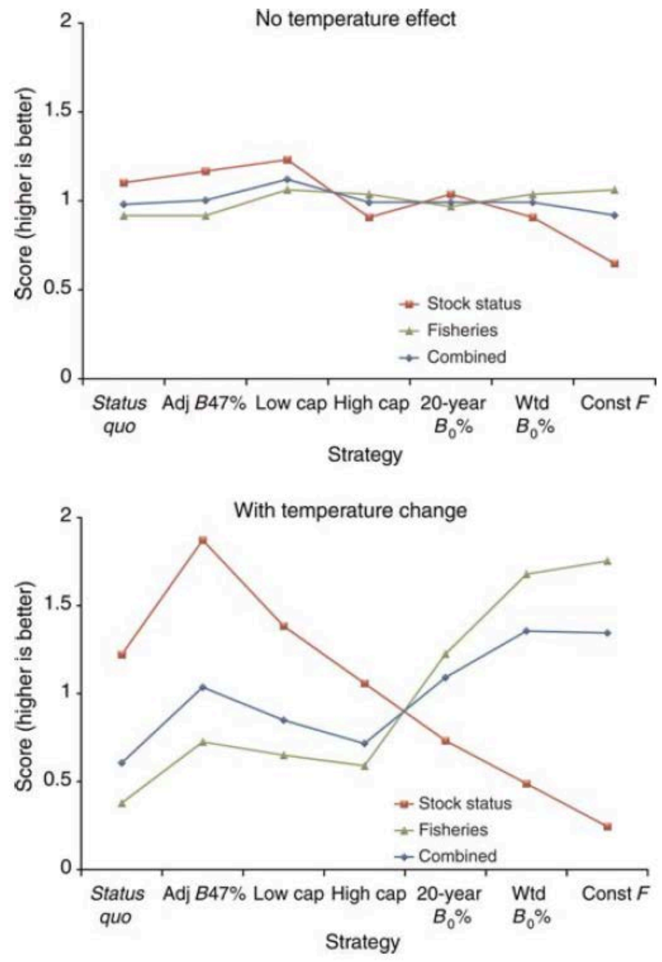
Stationary Recruitment



Ianelli et al. (2011) ICES JMS

Alternative Management in a Changing Climate





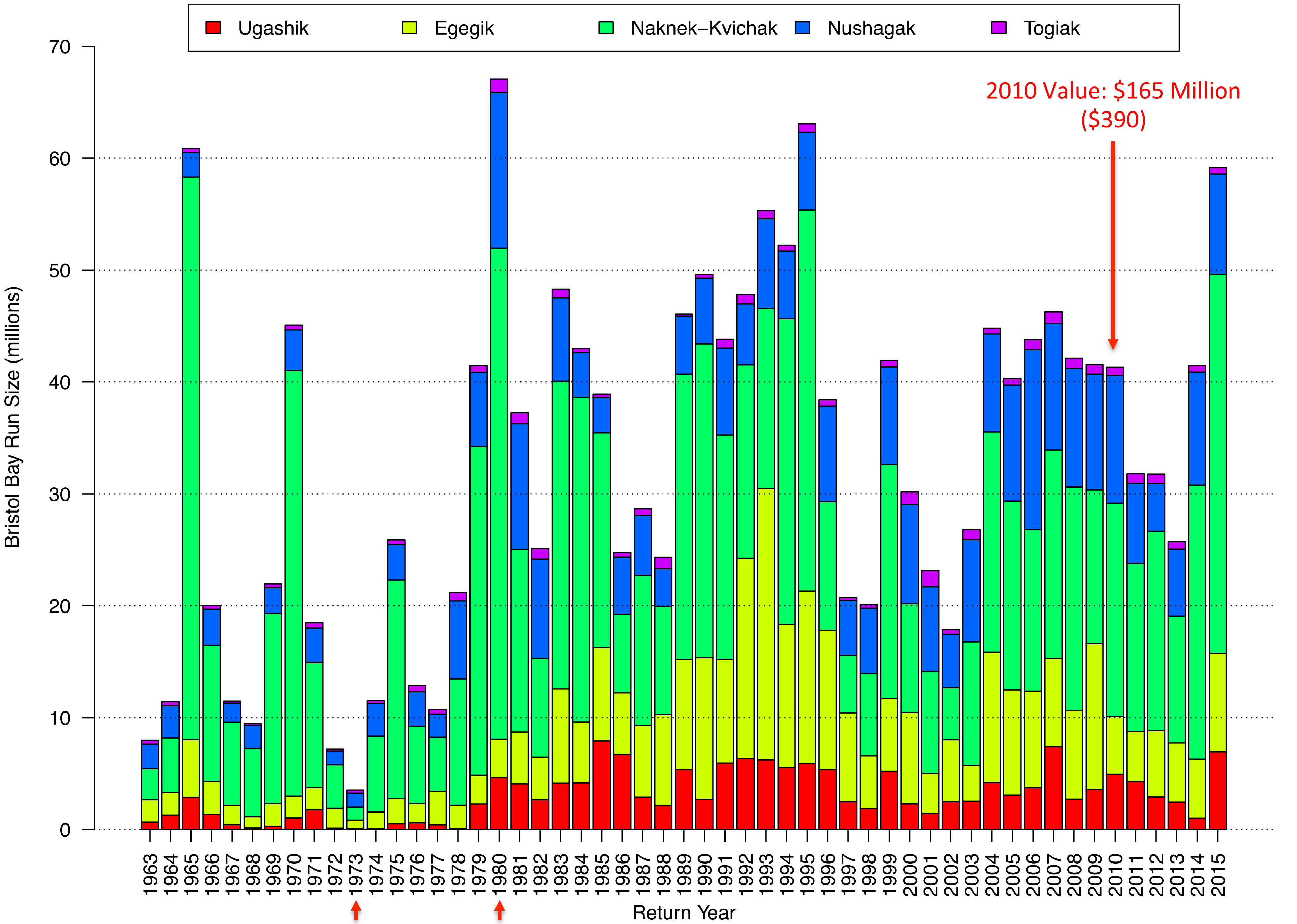
Ianelli et al. (2011) ICES JMS

MSE of the Sockeye Salmon Fishery in Bristol Bay, Alaska

Collaborators:
Ray Hilborn
Chris Anderson
Jocelyn Wang
Michael Link

***NOTE: This does not represent NOAA/NMFS research.**

Funding provided by the Bristol Bay Science and Research Institute, and the Bristol Bay Regional Seafood Development Association



Ugashik
Egegik
Naknek–Kvichak
Nushagak
Togiak
2010 Value: $165 Million
($390)
Bristol Bay Run Size (millions)
0
10
20
30
40
50
60
70
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
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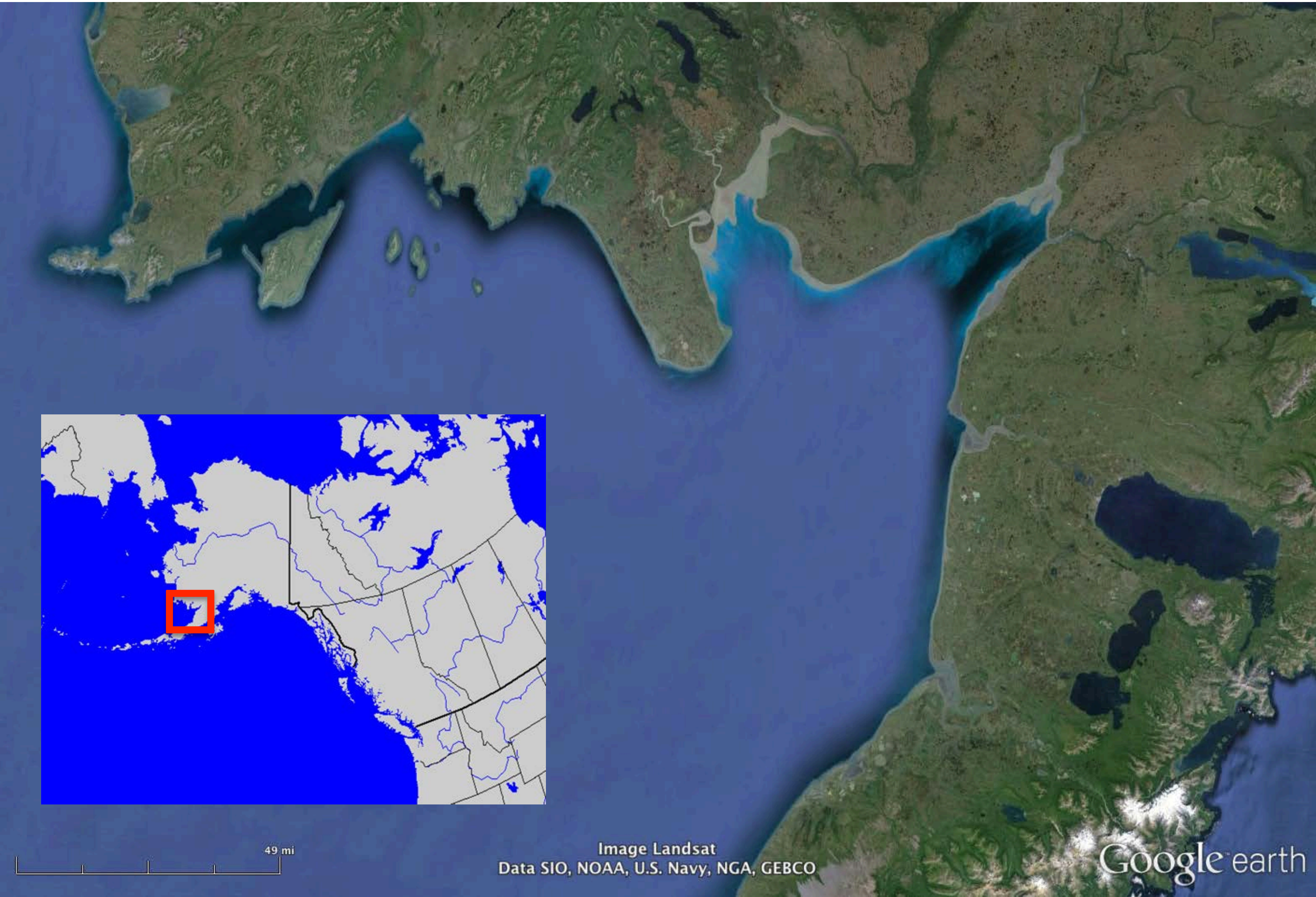
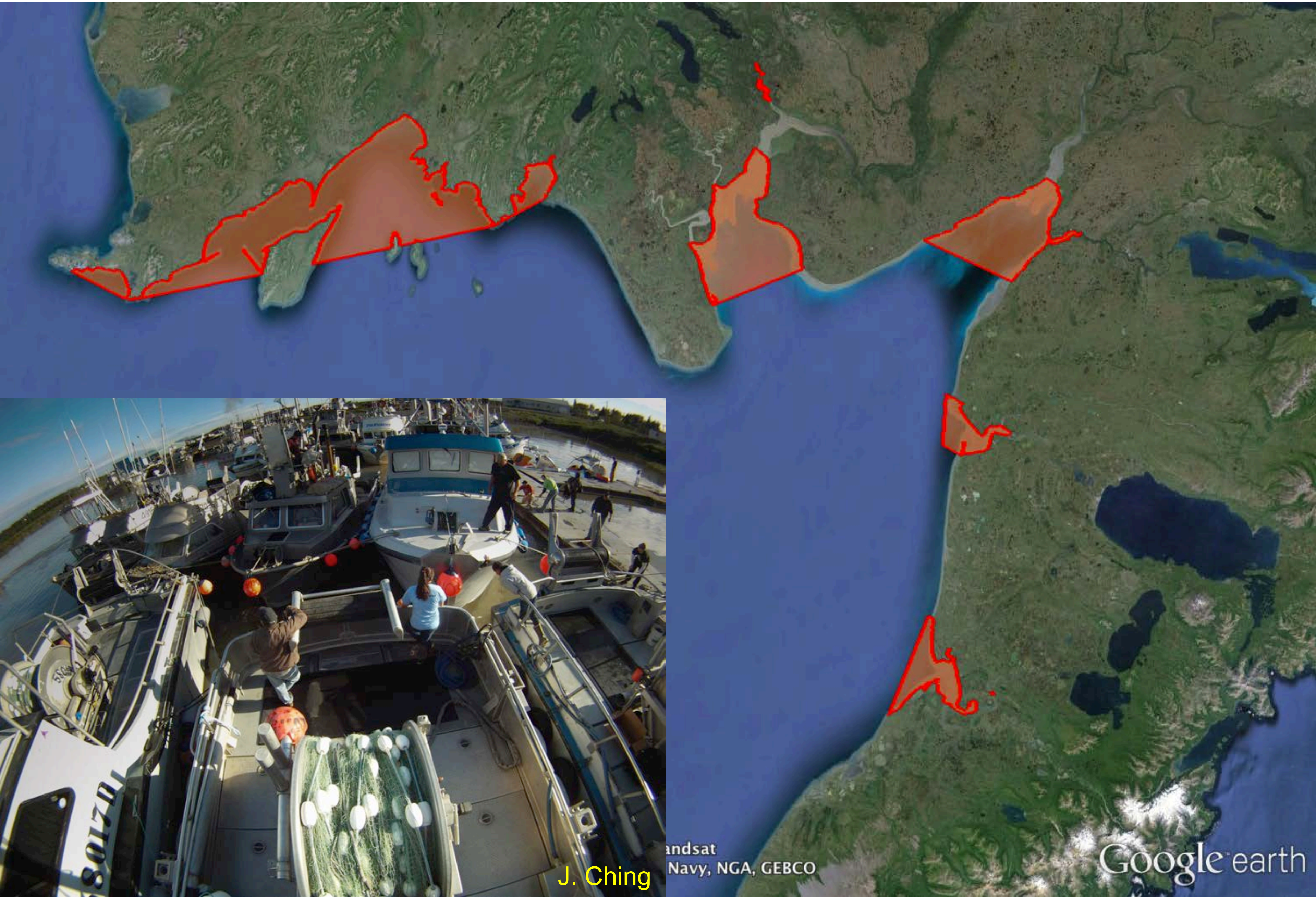
2014
2015
Return Year

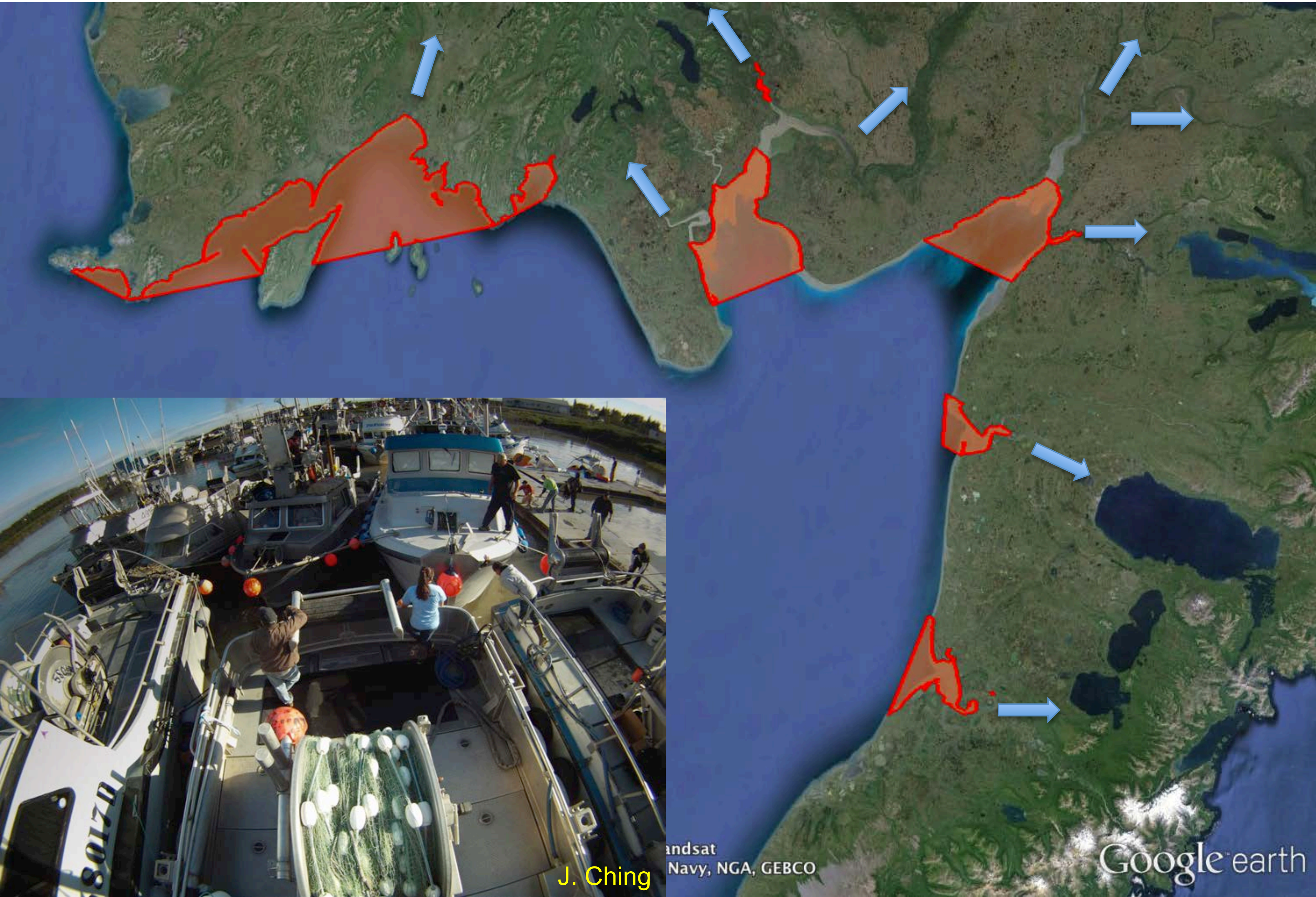
Commercial Sockeye Salmon Fishery in Bristol Bay, Alaska



Commercial Sockeye Salmon Fishery in Bristol Bay, Alaska



Commercial Sockeye Salmon Fishery in Bristol Bay, Alaska

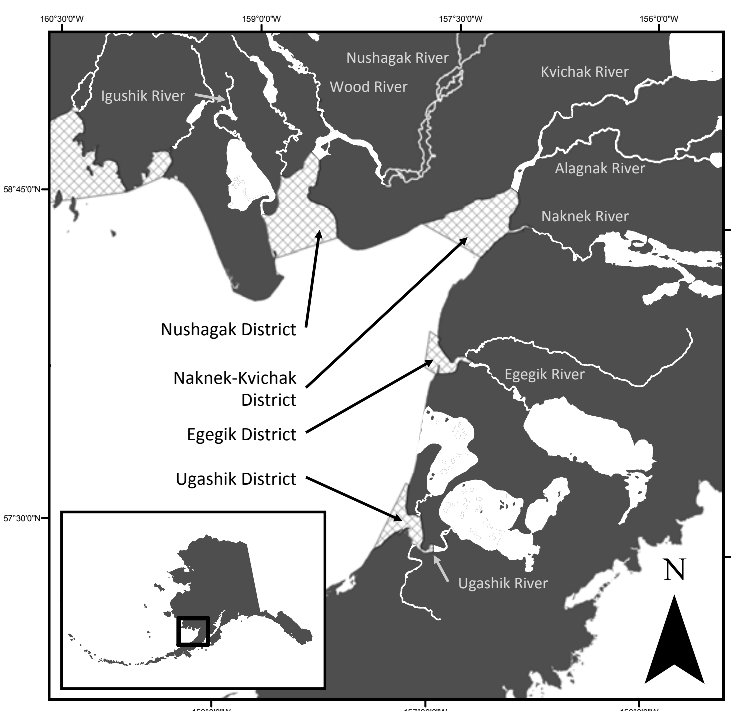


Purpose of MSE

- Simulate catch, escapement, and run size
  - Under alternative management strategies
- 100 years forward in time (2014+)
- Account for
  - Estimation uncertainty
  - Stochastic recruitment
  - Shifting production regimes
  - Implementation uncertainty
- Components
  - Biological (OM)
    - Simulate recruitment
  - Management
    - Daily effort allocation decisions

Trial Management Strategies

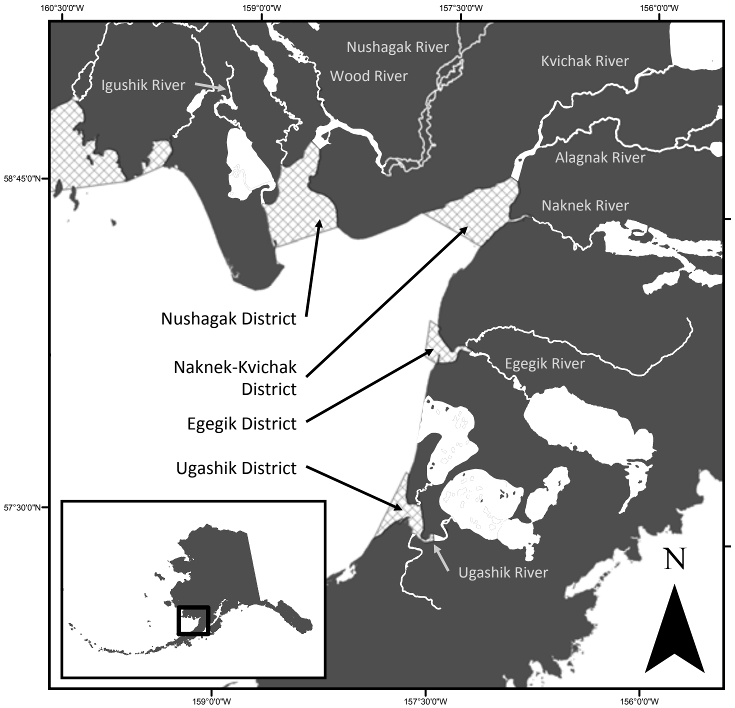
- Current escapement goals
- ADFG proposed escapement goals (2012)
- ADFG BEG (Smsy) estimates Fair et al. (2012)
- TR-based escapement goals with in-season assessment



Stock	Current SEG
Igushik	225
Wood	1,100
Nushagak	590
Kvichak	2,000
Alagnak	320
Naknek	1,100
Egegik	1,100
Ugashik	850

Trial Management Strategies

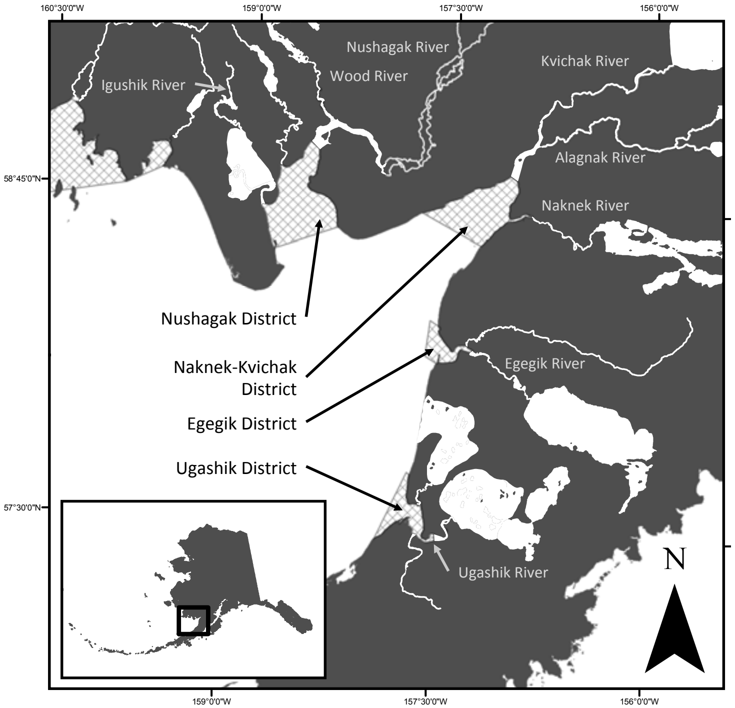
- Current escapement goals
- ADFG proposed escapement goals (2012)
- ADFG BEG (Smsy) estimates Fair et al. (2012)
- TR-based escapement goals with in-season assessment



Stock	Current SEG	Proposed SEG
Igushik	225	300
Wood	1,100	1,300
Nushagak	590	700
Kvichak	2,000	2,000
Alagnak	320	320
Naknek	1,100	1,450
Egegik	1,100	1,450
Ugashik	850	1,000

Trial Management Strategies

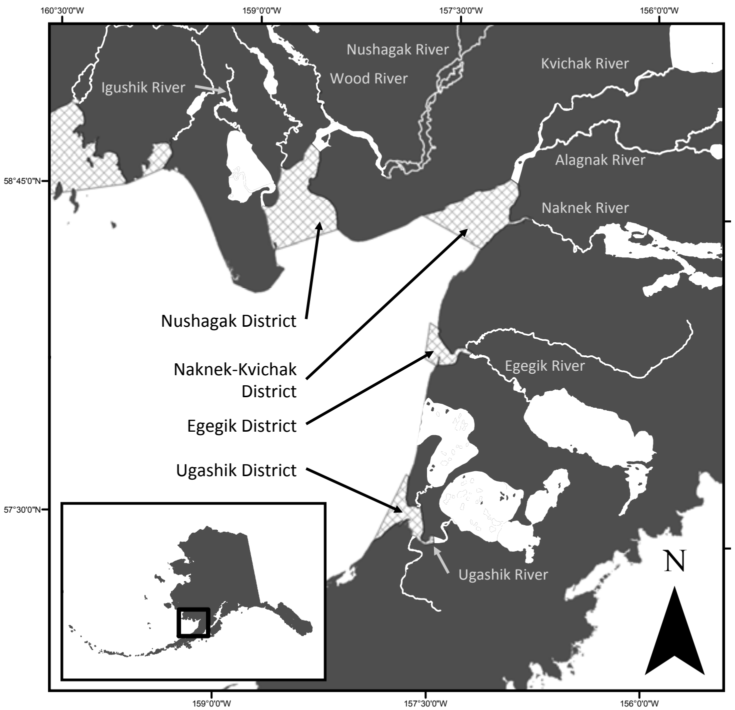
- Current escapement goals
- ADFG proposed escapement goals (2012)
- ADFG BEG (Smsy) estimates Fair et al. (2012)
- TR-based escapement goals with in-season assessment



Stock	Current SEG	Proposed SEG	BEG
Igushik	225	300	291
Wood	1,100	1,300	1,550
Nushagak	590	700	801
Kvichak	2,000	2,000	2,000
Alagnak	320	320	320
Naknek	1,100	1,450	1,858
Egegik	1,100	1,450	5,242
Ugashik	850	1,000	2,602

Trial Management Strategies

- Current escapement goals
- ADFG proposed escapement goals (2012)
- ADFG BEG (Smsy) estimates Fair et al. (2012)
- TR-based escapement goals with in-season assessment



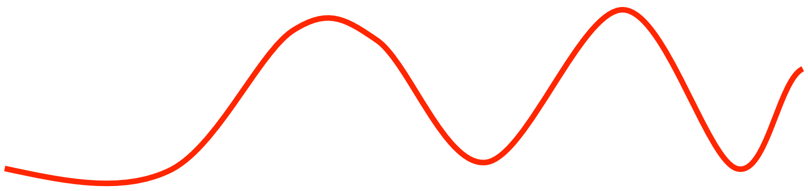
Stock	Current SEG	Proposed SEG	BEG	TR-based EG		
				Lower	Upper	TR Breakpoint
Igushik	225	300	291	225	430	720
Wood	1,100	1,300	1,550	1,100	1,500	3,200
Nushagak	590	700	801	590	825	1,200
Kvichak	2,000	2,000	2,000	2,000	2,000	
Alagnak	320	320	320	320	320	
Naknek	1,100	1,450	1,858	1,100	1,900	3,300
Egegik	1,100	1,450	5,242	1,100	1,750	4,700
Ugashik	850	1,000	2,602	850	1,600	2,500

Simulating Recruitment Regimes

- Single Regime

- Fixed Breakpoint

- Regime Transition



Hidden Markov Ricker

- Bayesian Ricker model
- Estimate regime-specific parameters

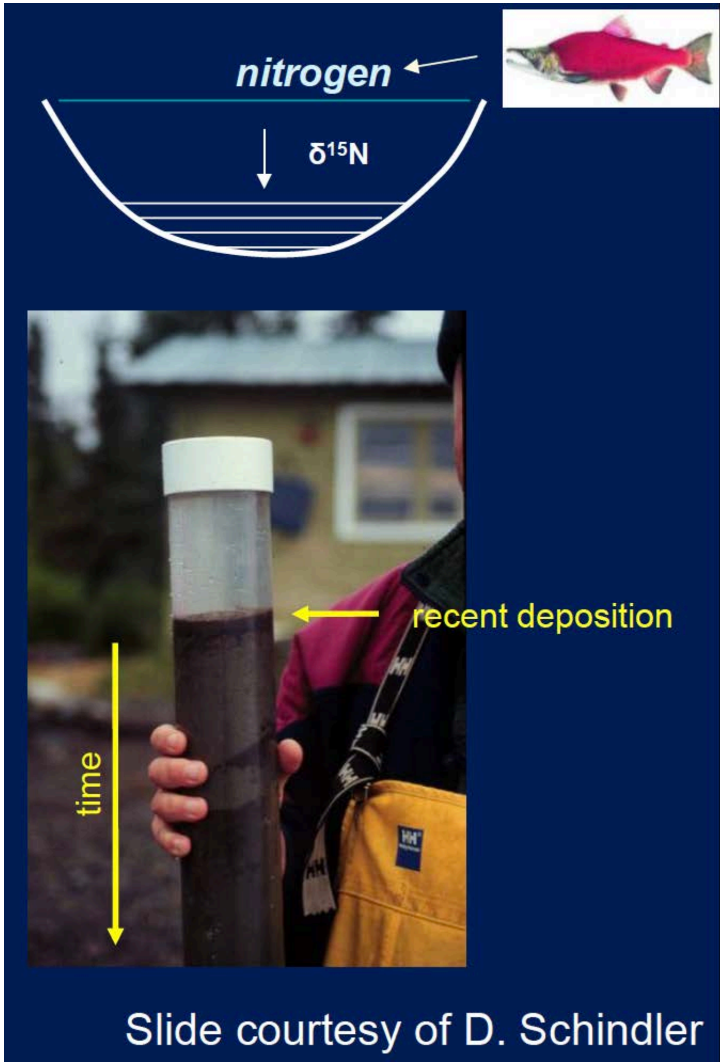
$$\hat{\alpha}_r, \hat{\beta}_r, \hat{\sigma}_r$$

- Treat regime (state) transition as a 1st order Markov process
  - $Regime_t$ conditioned on $Regime_{t-1}$
- Estimate state transition probability matrix

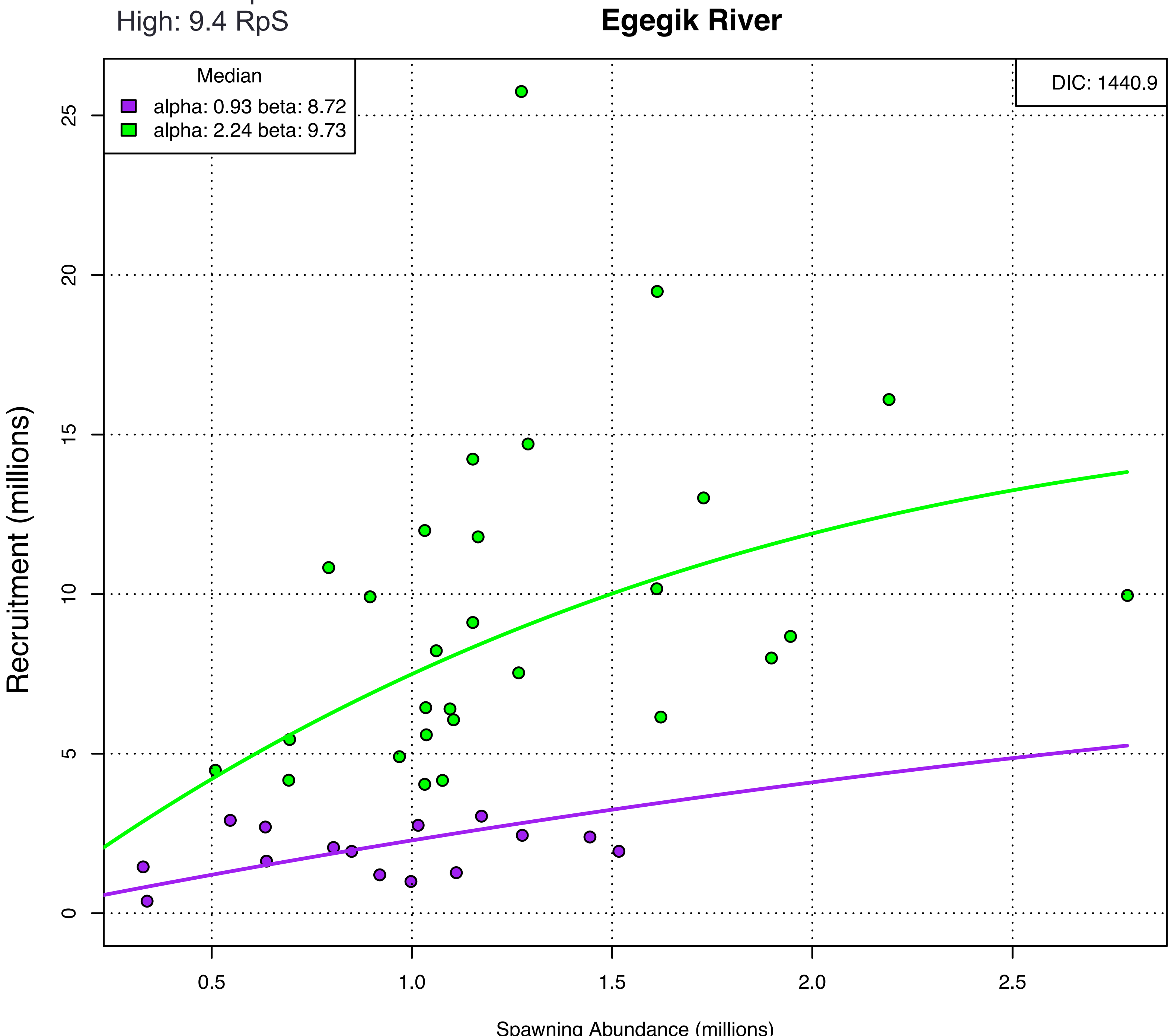
$$\pi_{i,j} = \begin{bmatrix} p_{i=1,j=1} & p_{i=1,j=2} \\ p_{i=2,j=1} & p_{i=2,j=2} \end{bmatrix}$$

- Prior on β_r (equilibrium/unfished abundance)
  - Paleolimnological data

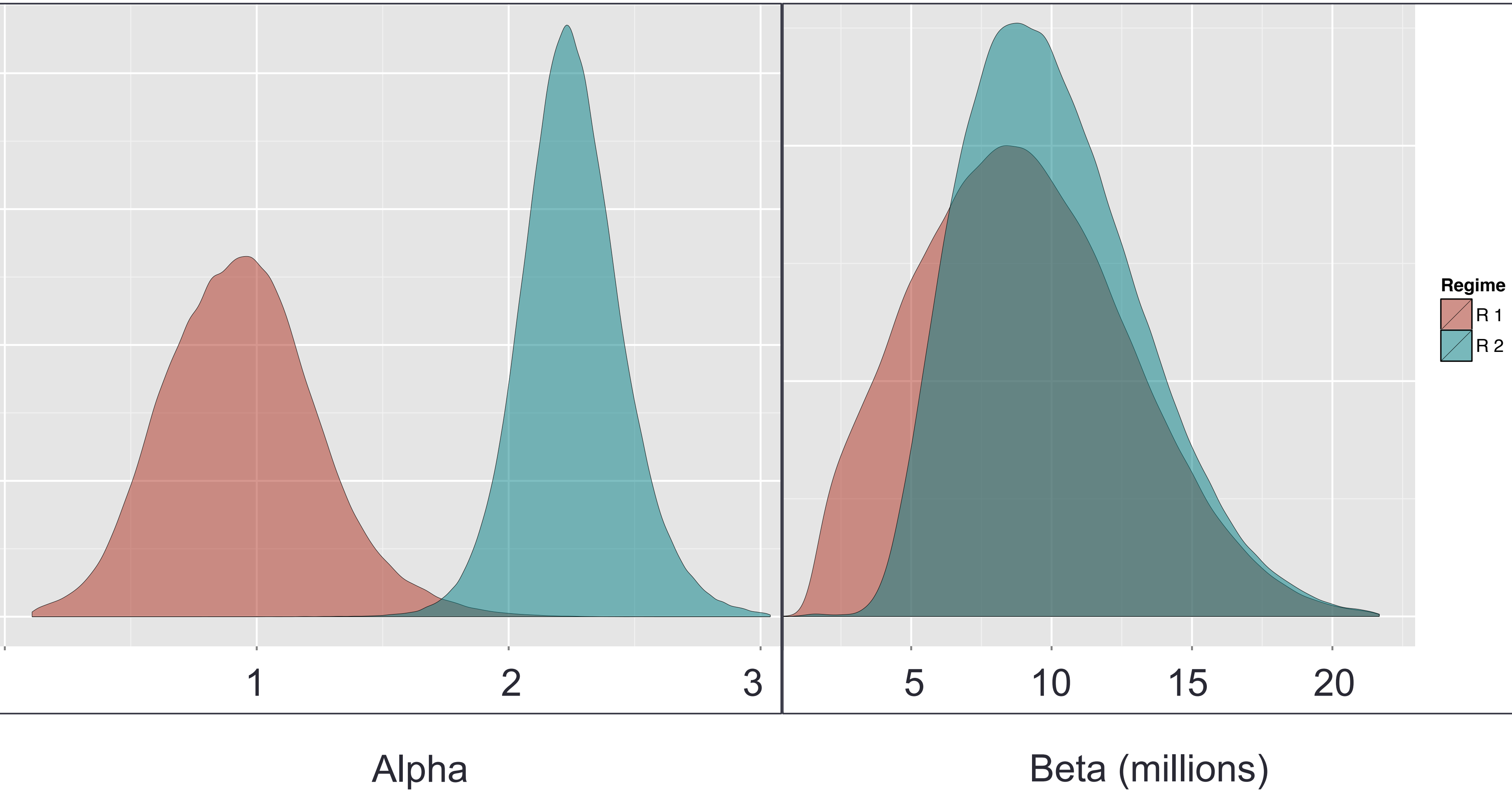
- Reconstructed salmon abundance from lake sediment isotopes
  - Schindler et al. (2005) Ecology

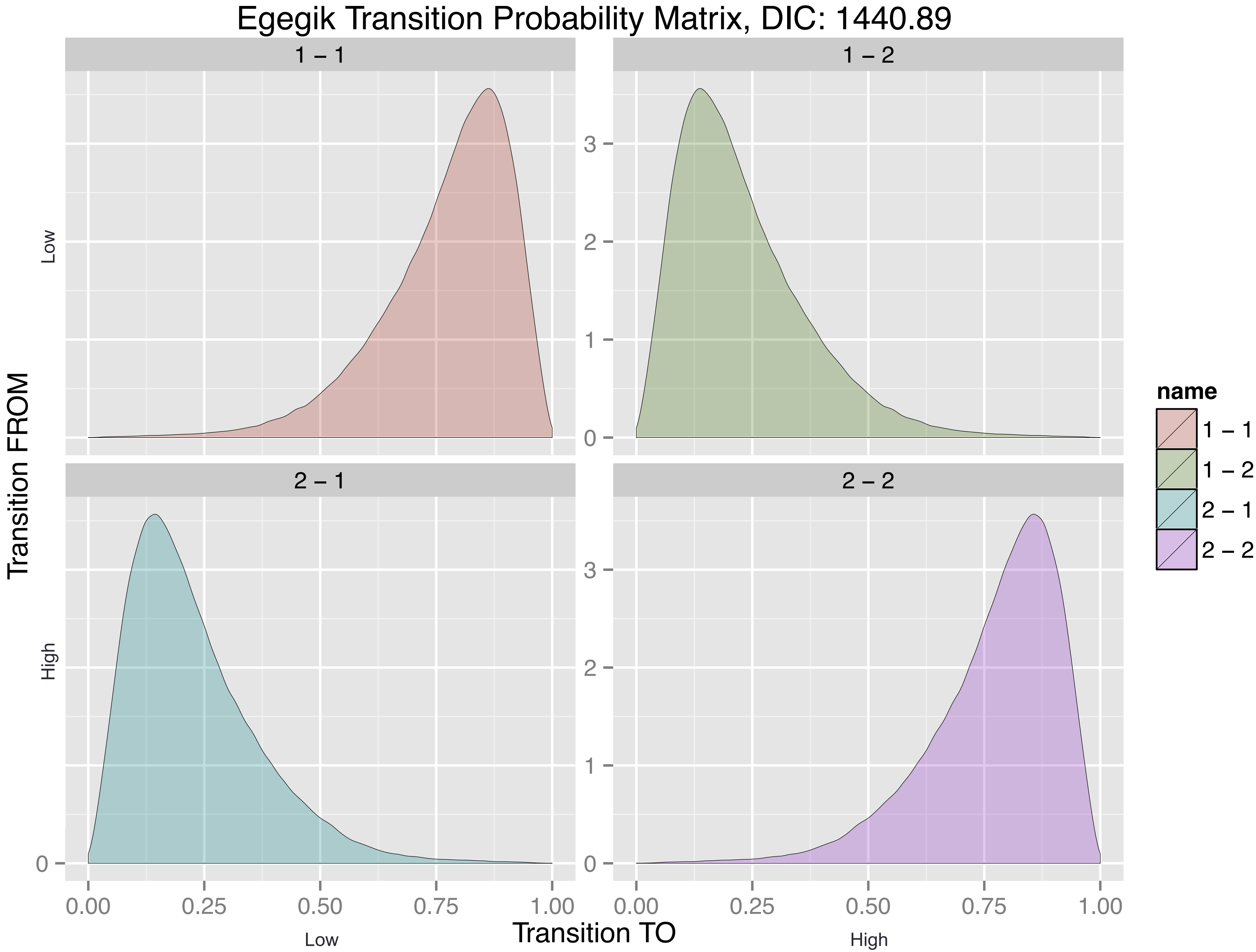


Low: 2.5 RpS
High: 9.4 RpS

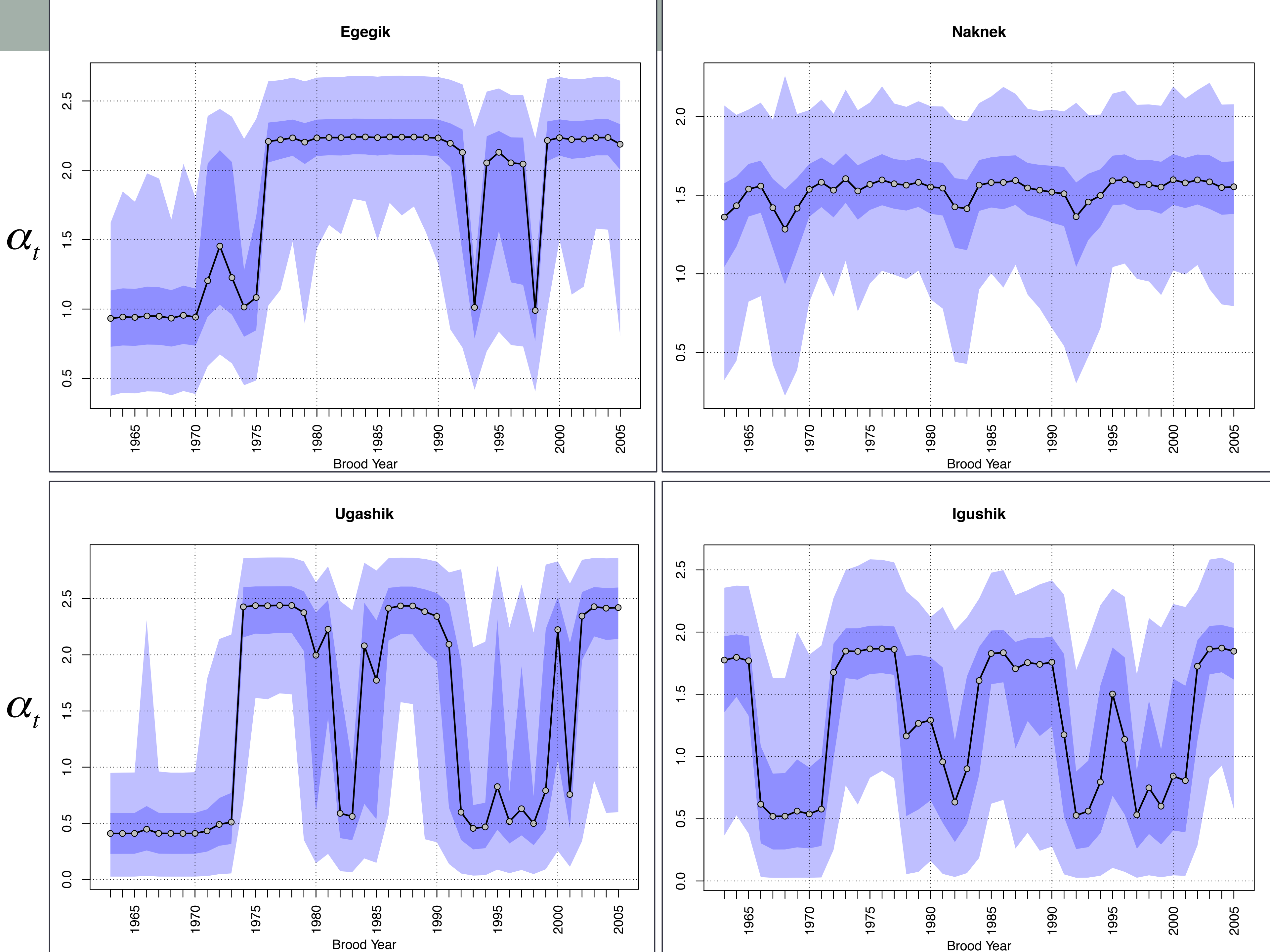


Egegik Ricker Parameters





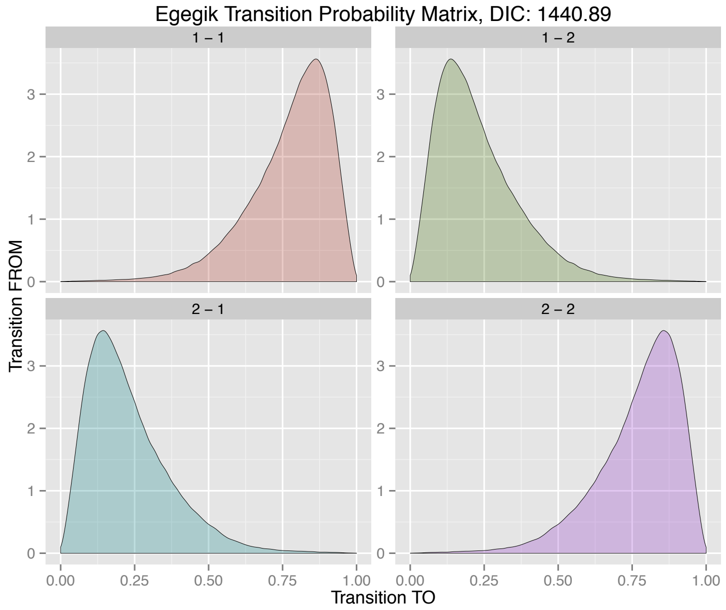
Egegik Transition Probability Matrix, DIC: 1440.89
1 – 1
1 – 2
2 – 1
2 – 2
Low
High
Transition FROM
Transition TO
Low
High
0
1
2
3
0
1
2
3
0
0.00
0.25
0.50
0.75
1.00
0.00
0.25
0.50
0.75
1.00
name
1 – 1
1 – 2
2 – 1
2 – 2

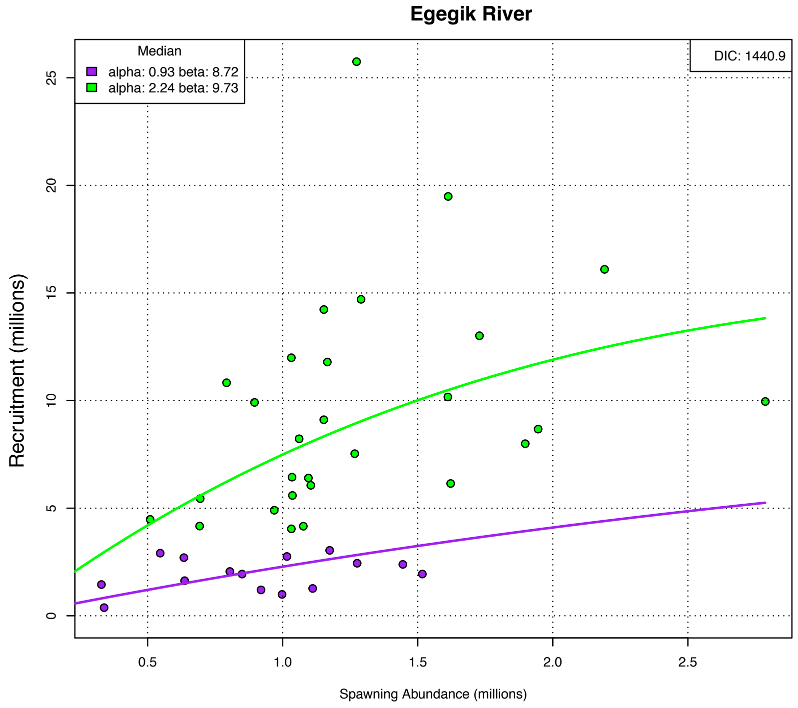


α_t
Egegik
Naknek
Brood Year
Brood Year
α_t
Ugashik
Igushik
Brood Year
Brood Year
0.0
0.5
1.0
1.5
2.0
2.5
1965
1970
1975
1980
1985
1990
1995
2000
2005

Operating Model

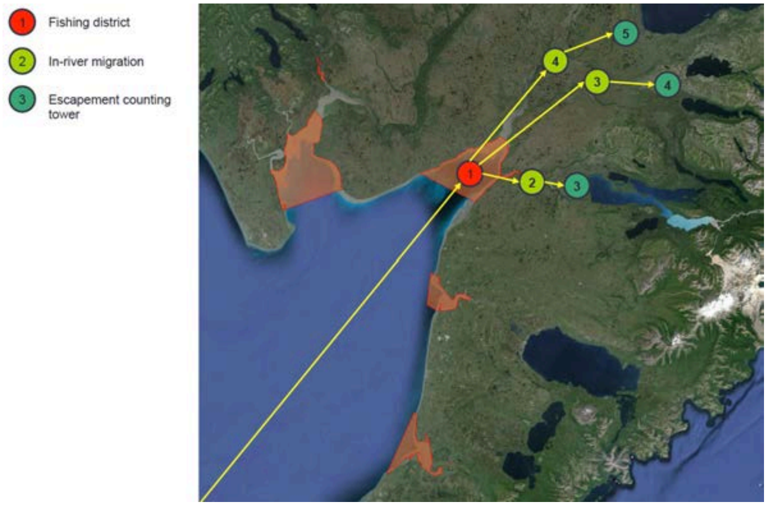
- Generate future regime states for 100 years based on TPM
- Simulate future recruitment
  - State-specific Ricker parameters
    - Drawn from joint posterior in each realization
  - Adding random lognormal recruitment deviations



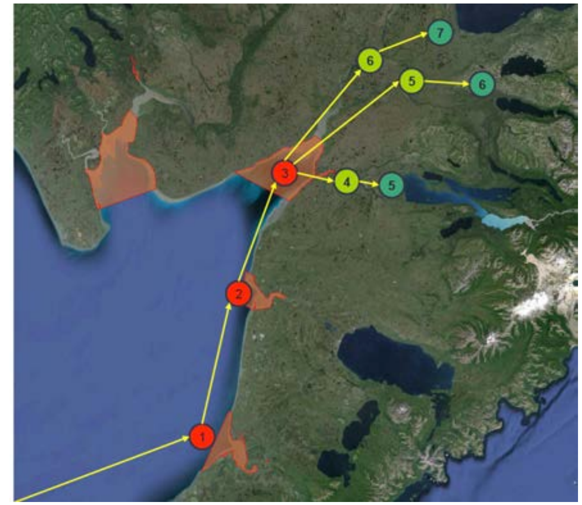


Implementation Uncertainty

Mixed-stock Harvest



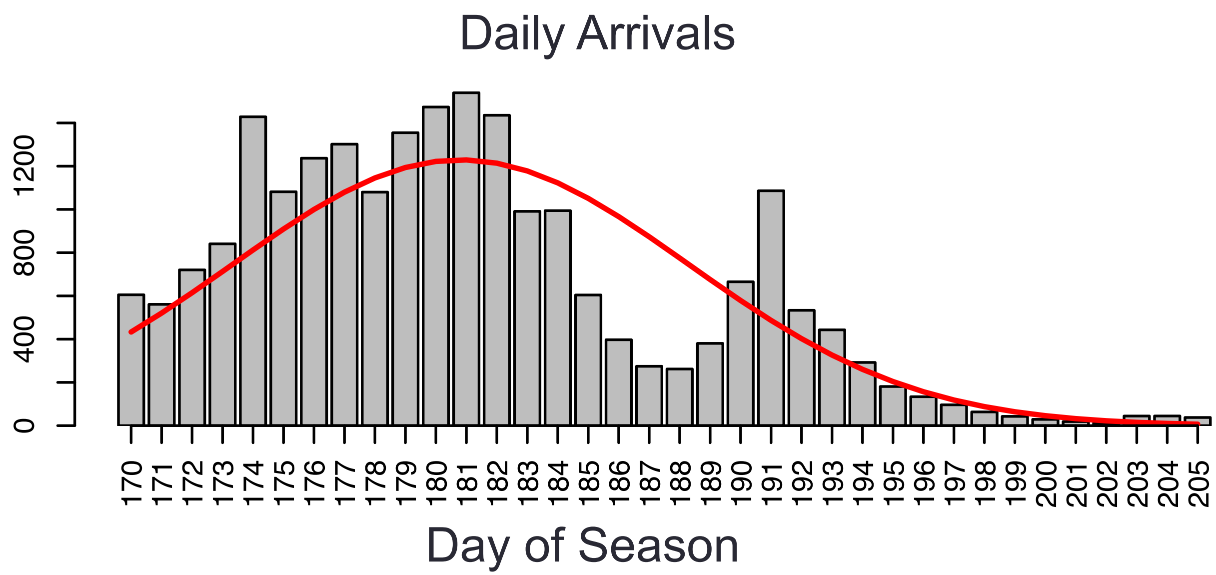
Interception Catch



Variation in Arrival

2015 Run Size

$P_{t,p,s,d}$

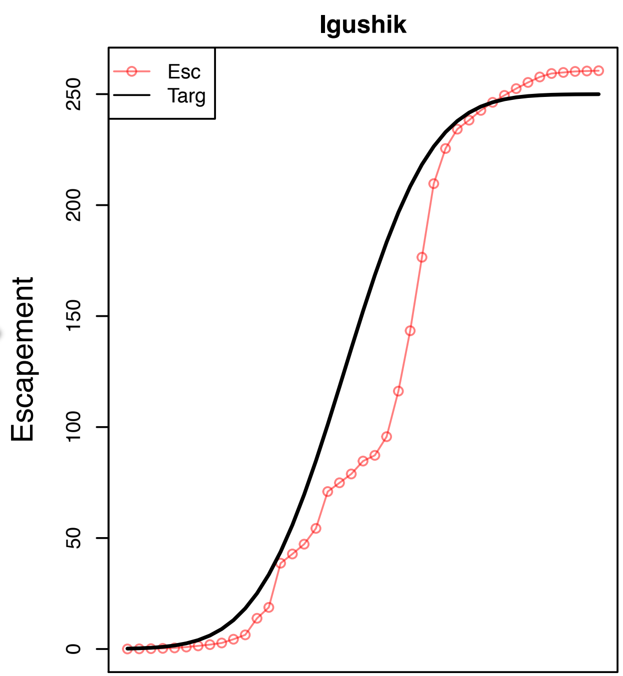


Management Model

- Simulate in-season management process
  - Difficulty in achieving escapement goals
  - Districts open/closed
    - Depending on whether stock is ahead/behind $target_{day}$
  - Simulated manager receives partially-delayed information

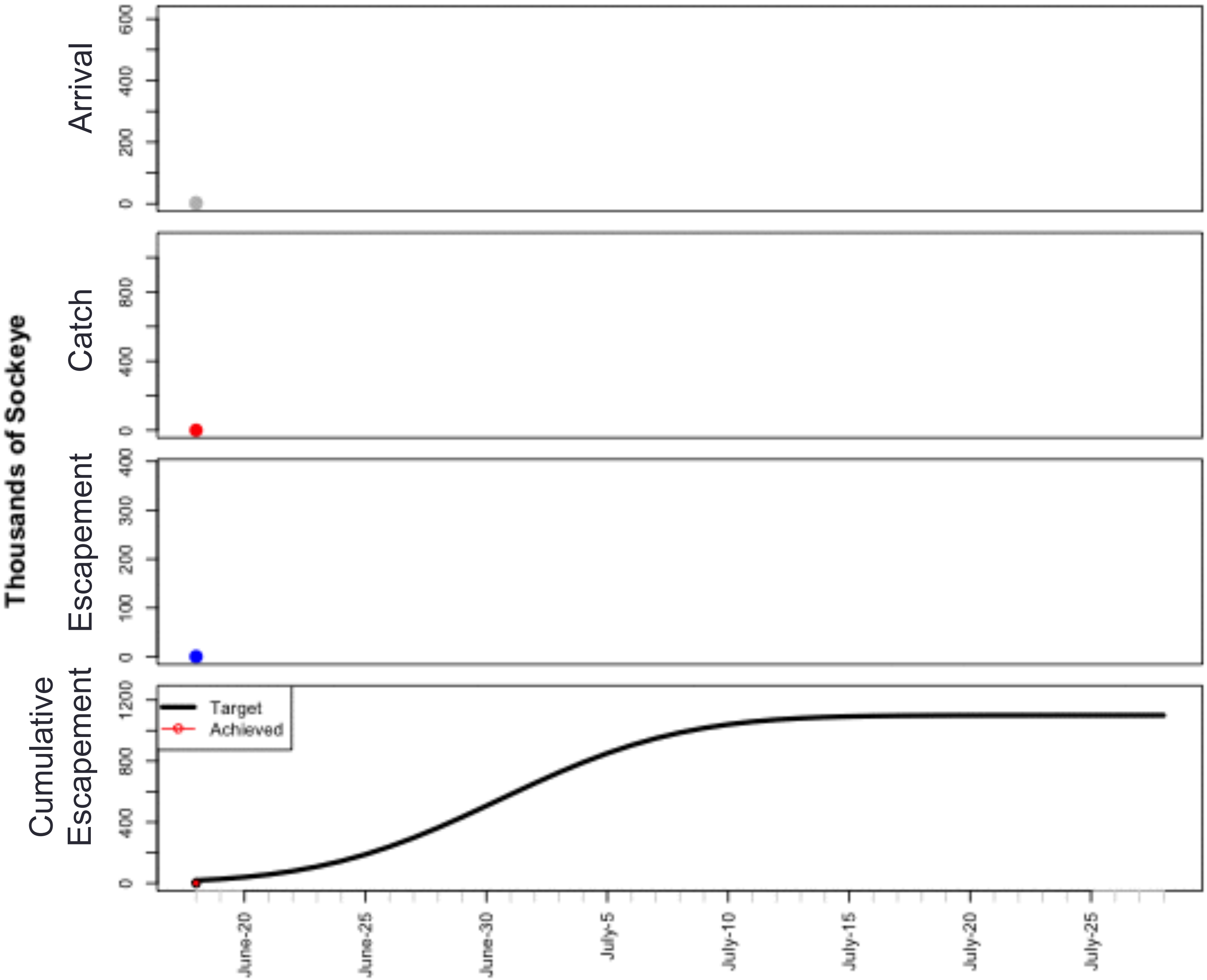
Inputs

- $Arrivals_{day}$
- Esc Goal
- Esc $Target_{day}$

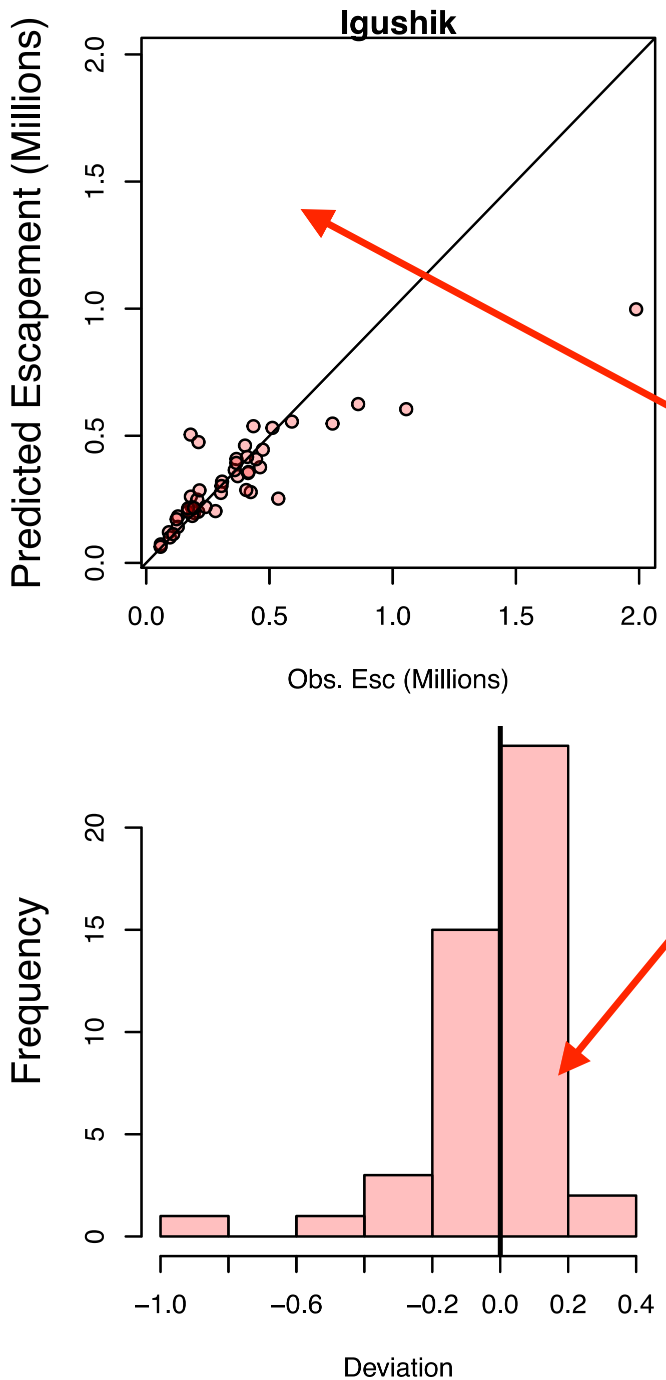


Outputs

- $Harvest_{day}$
- Esc_{day}

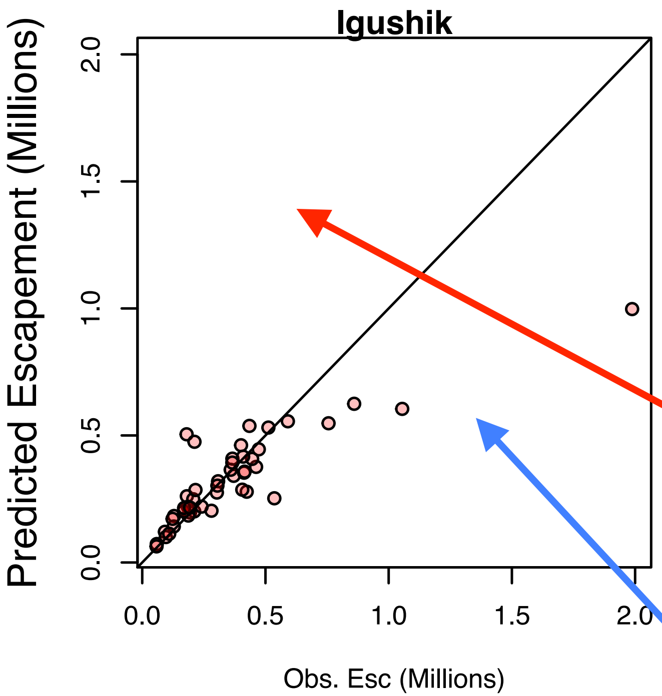

Thousands of Sockeye
Arrival
Catch
Escapement
Cumulative Escapement
Target
Achieved
June-20
June-25
June-30
July-5
July-10
July-15
July-20
July-25

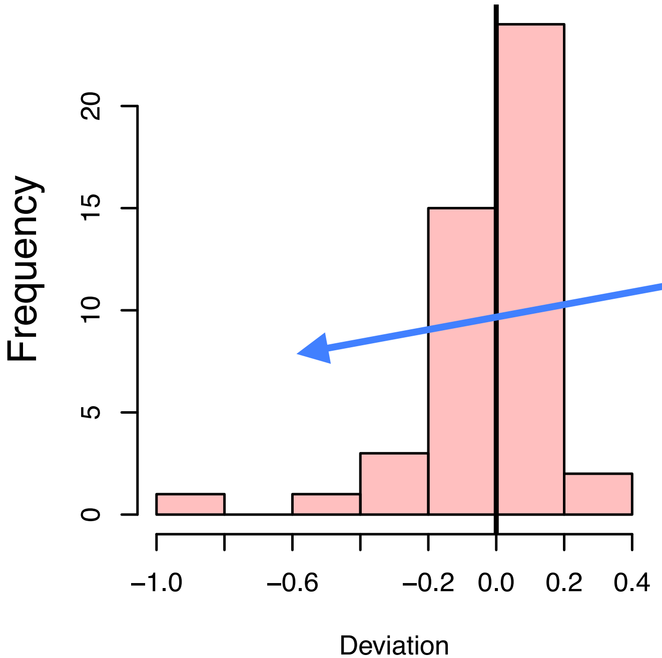
Management Model Realism Escapements: 1963 - 2008



Predicted Esc. > Obs. Esc

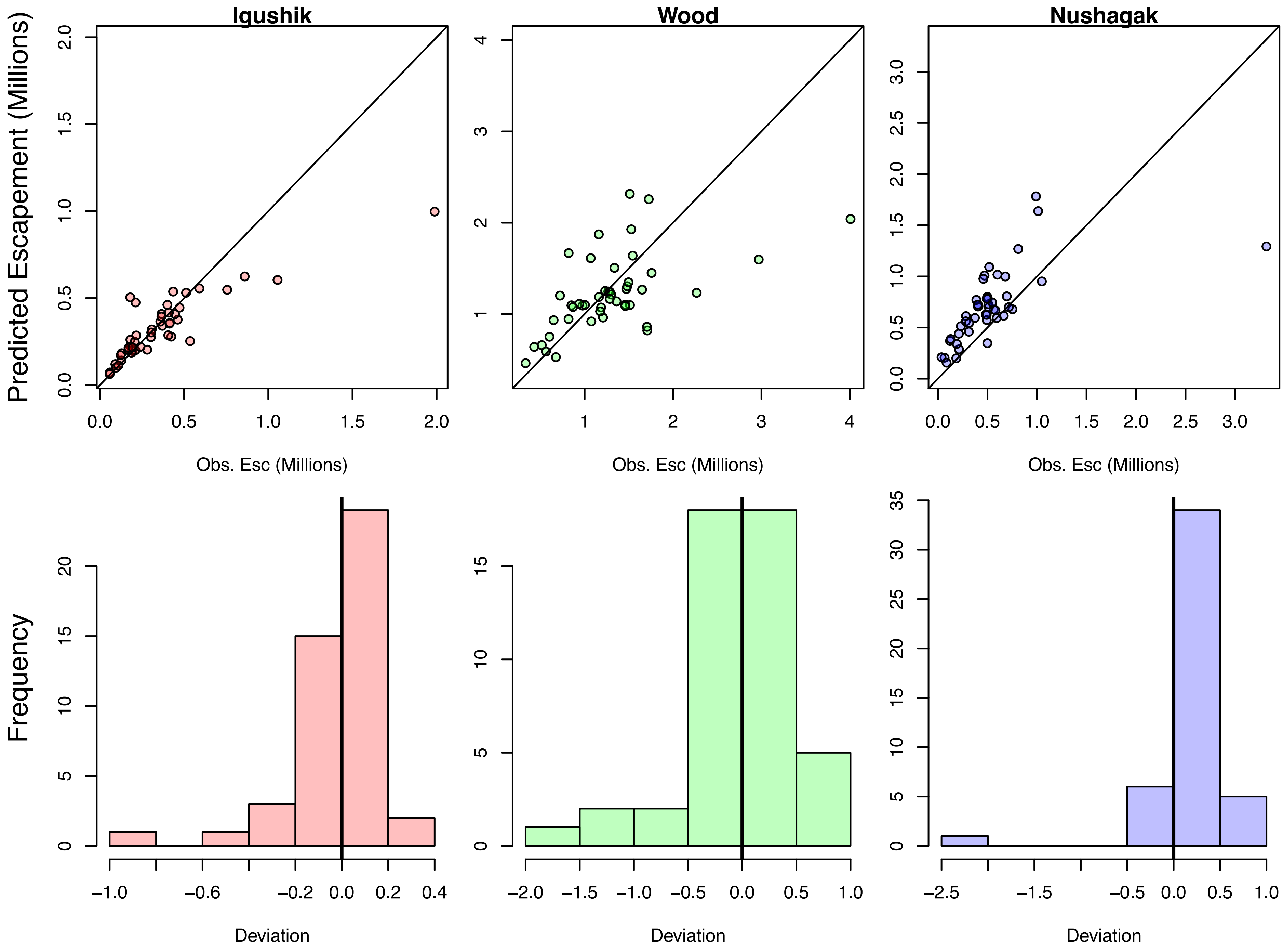
Management Model Realism Escapements: 1963 - 2008





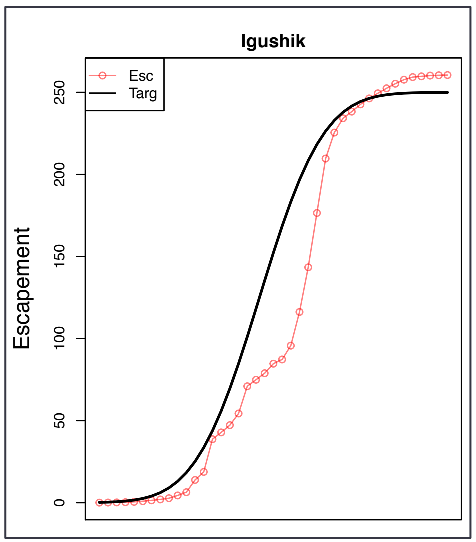
Predicted Esc. > Obs. Esc

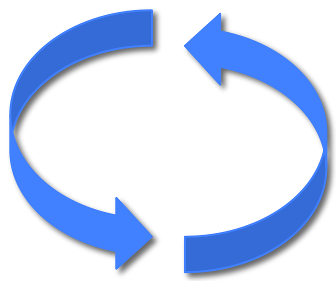
Predicted Esc. < Obs. Esc

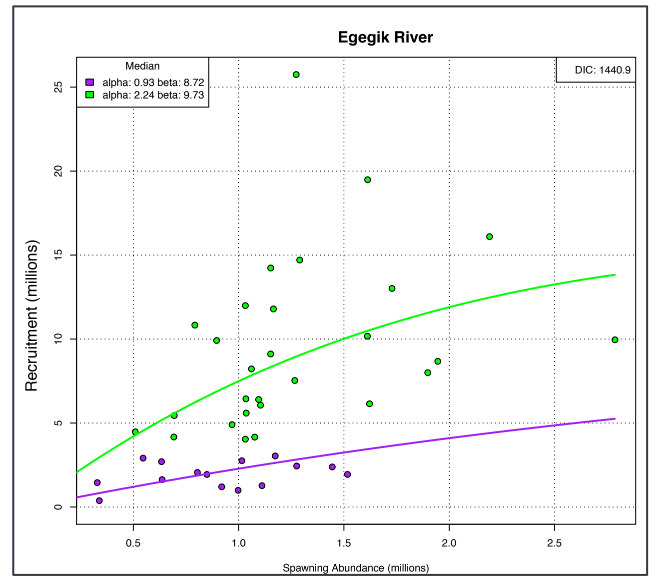

Igushik
Wood
Nushagak
Predicted Escapement (Millions)
Obs. Esc (Millions)
Frequency
Deviation

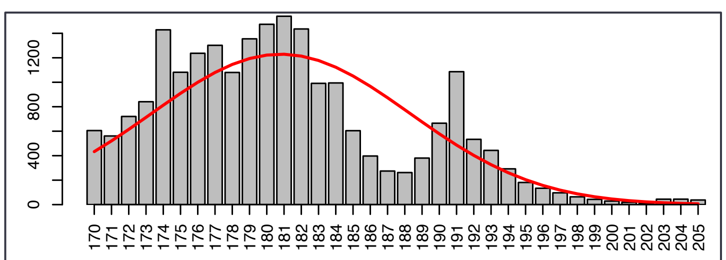
The Complete MSE Framework

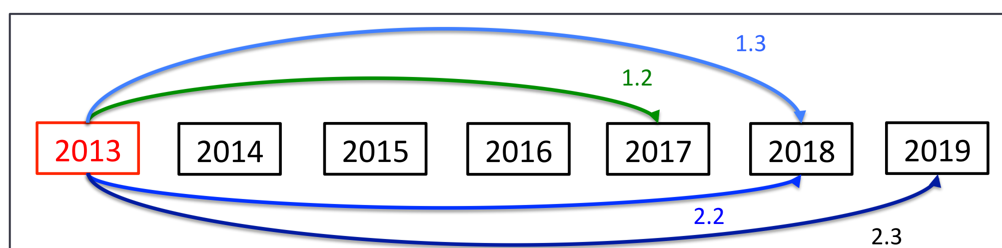
- Simulate recruitment, escapement and catch
  - Over 100 years, 100x



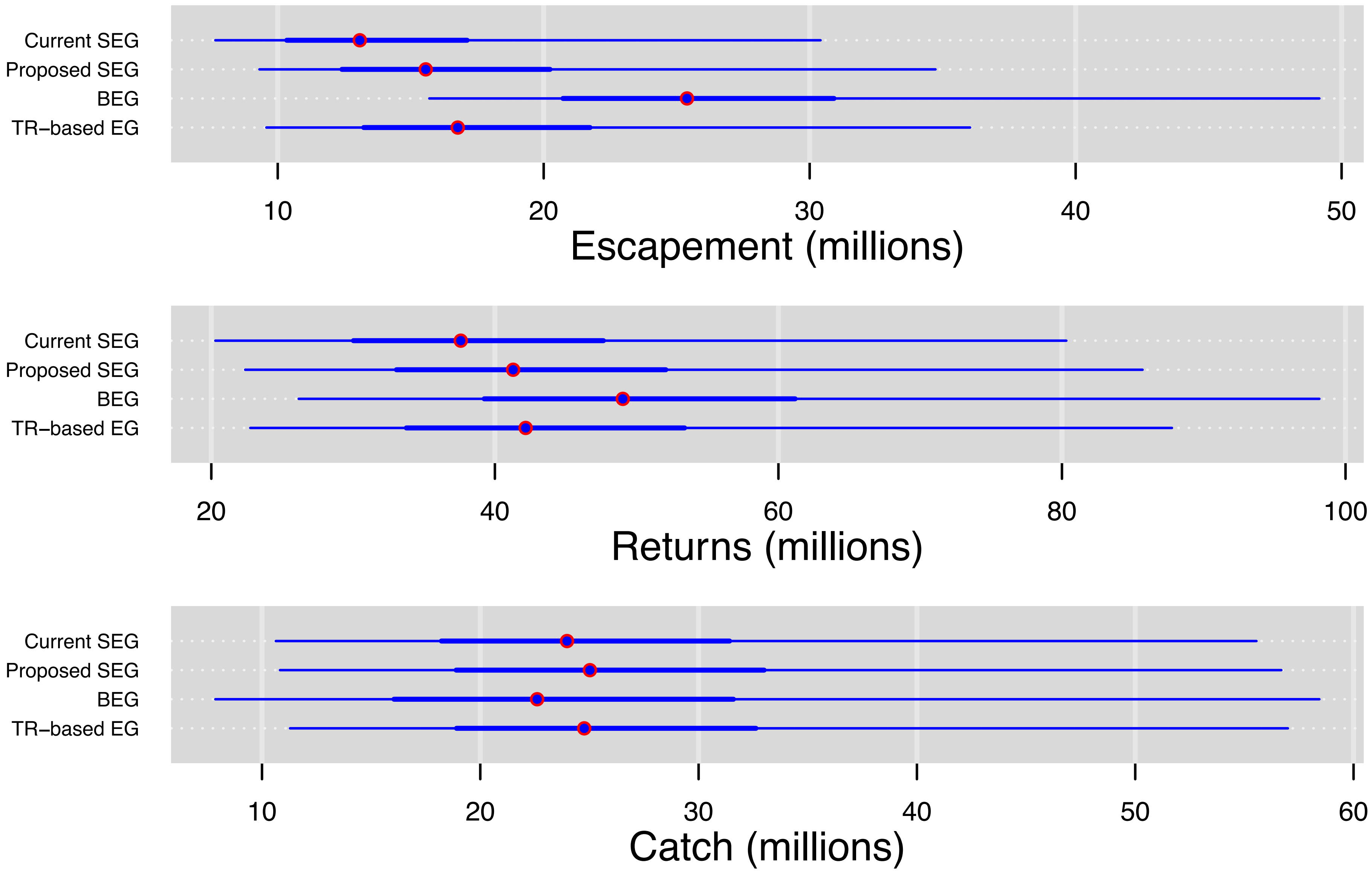




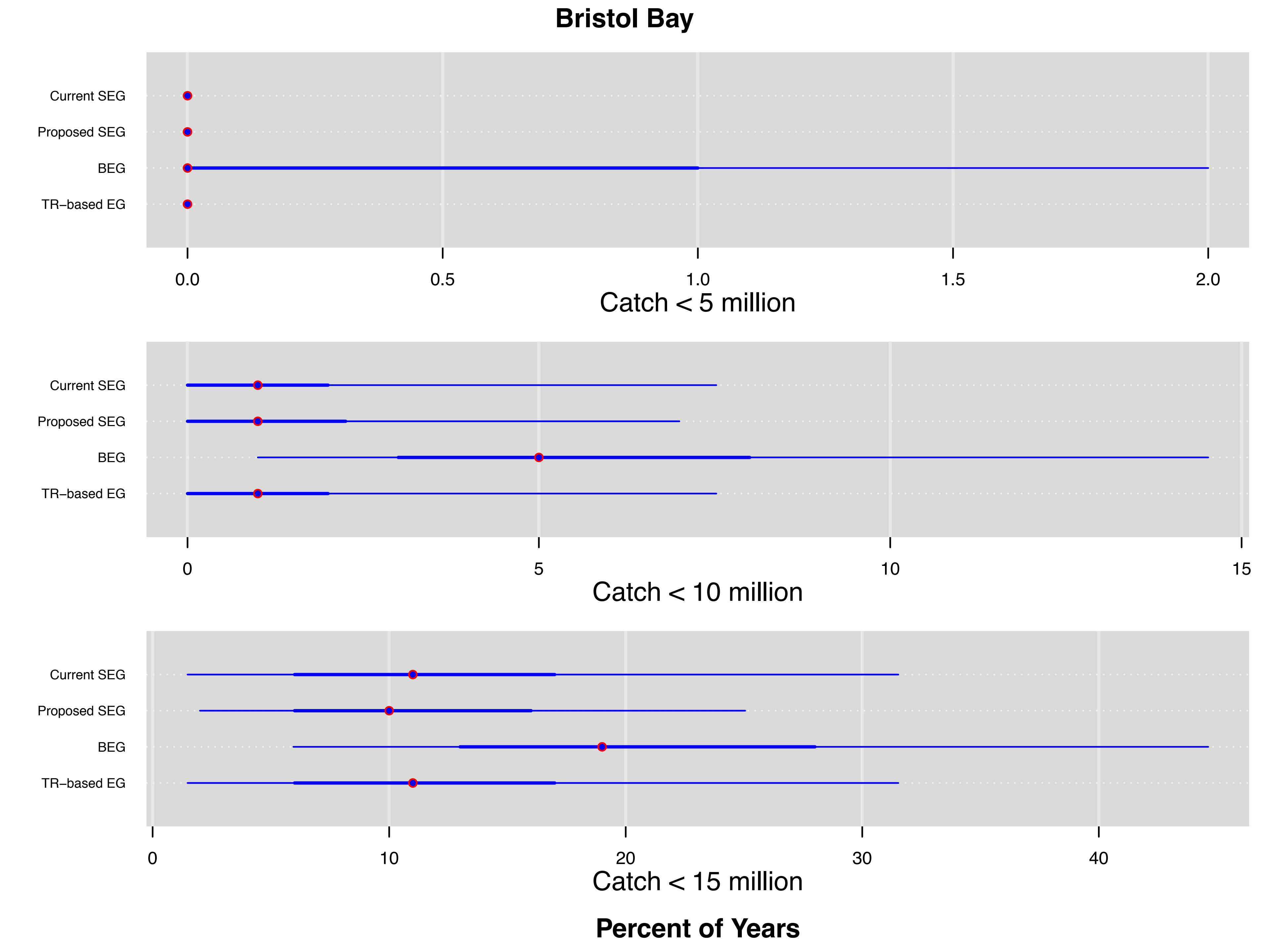




Bristol Bay



Current SEG
Proposed SEG
BEG
TR–based EG
10
20
30
40
50
Escapement (millions)
Current SEG
Proposed SEG
BEG
TR–based EG
20
40
60
80
100
Returns (millions)
Current SEG
Proposed SEG
BEG
TR–based EG
10
20
30
40
50
60
Catch (millions)


Bristol Bay
Current SEG
Proposed SEG
BEG
TR–based EG
0.0
0.5
1.0
1.5
2.0
Catch < 5 million
Current SEG
Proposed SEG
BEG
TR–based EG
0
5
10
15
Catch < 10 million
Current SEG
Proposed SEG
BEG
TR–based EG
0
10
20
30
40
Catch < 15 million
Percent of Years

Concluding Thoughts on MSE

- MSE is an important tool for identifying optimal practices
  - By explicitly including multiple sources of uncertainty and variability
- MSE may be useful to address a broad range of questions
  - Assessment model design, climate change readiness, EBFM, value of information and survey design
- MSE must be conducted as a collaborative process with stakeholders
  - Determine value functions and alternative performance metrics
  - Ensure public understanding and support
- Tighter integration with economic modelling is necessary
  - Fully assess management outcomes
  - Quantify drivers of behavior that lead to implementation uncertainty
- Careful consideration of goals and uncertainty is necessary from the outset

Thank you for listening…

Contact:

curry.cunningham@noaa.gov