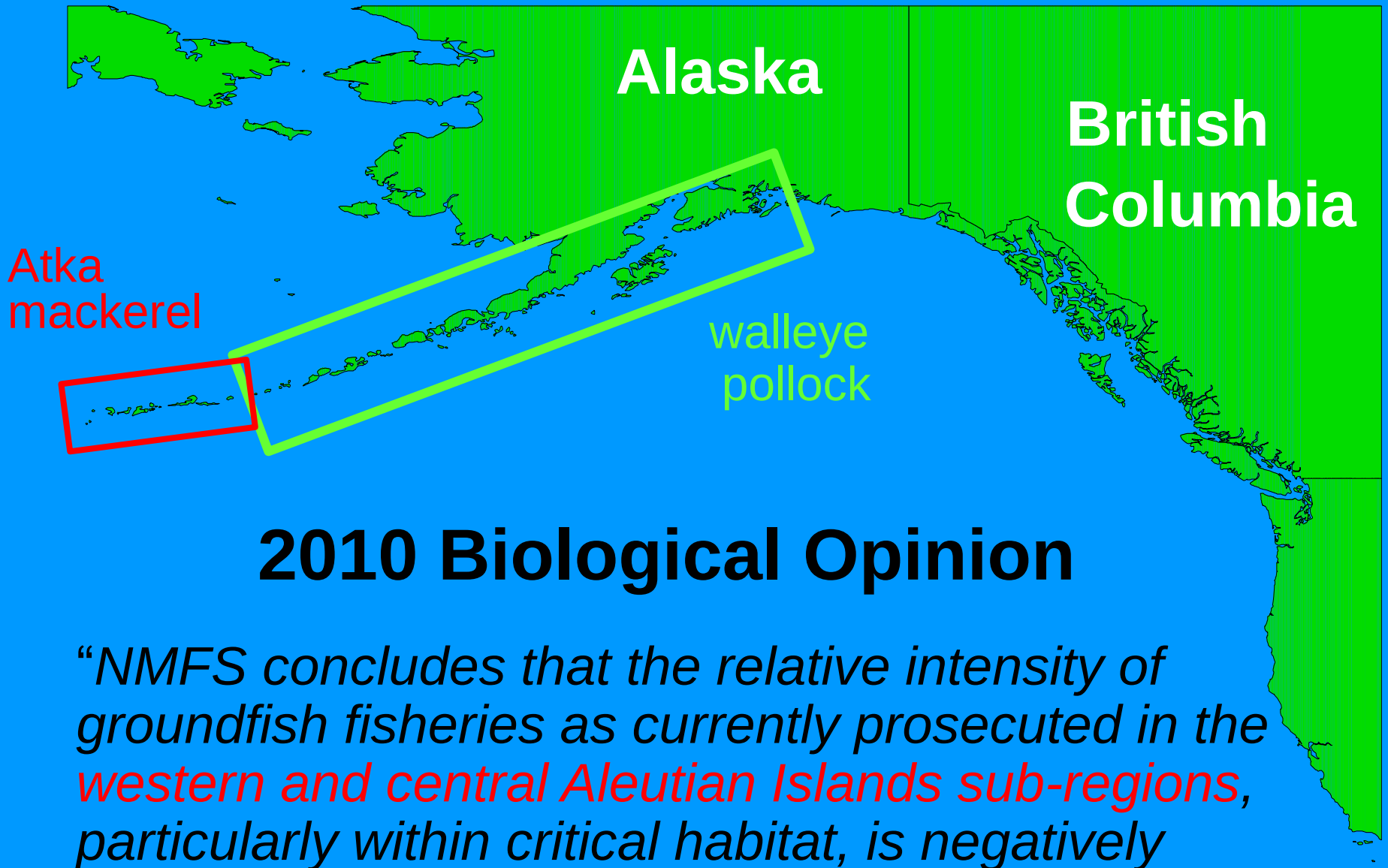
Is fishing for Atka mackerel responsible for the decline of Steller sea lions in the western and central Aleutian Islands?

Andrew W Trites
Rowenna Gryba
Ruth Joy
Brian Battaile
Marine Mammal Research Unit
University of British Columbia

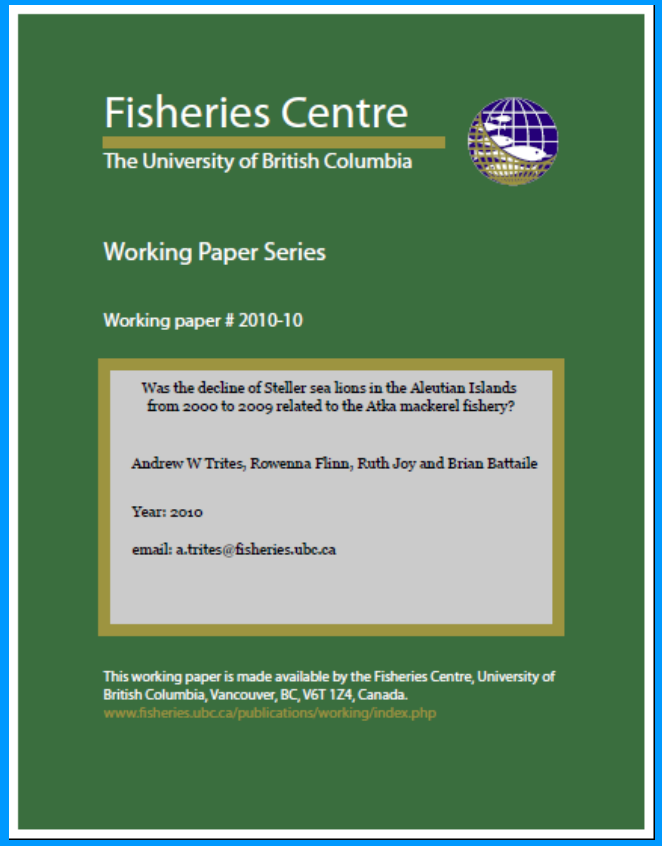


2010 Biological Opinion

"*NMFS concludes that the relative intensity of groundfish fisheries as currently prosecuted in the western and central Aleutian Islands sub-regions, particularly within critical habitat, is negatively associated with Steller sea lion population trends since 2000*"

page xxxiii, 2010 Biological Opinion

No negative relationship between fishing & sea lion trends since 2000



Fisheries Centre
The University of British Columbia

Working Paper Series

Working paper # 2010-10

Was the decline of Steller sea lions in the Aleutian Islands from 2000 to 2009 related to the Atka mackerel fishery?

Andrew W Trites, Rowenna Flinn, Ruth Joy and Brian Battaile

Year: 2010

email: a.trites@fisheries.ubc.ca

This working paper is made available by the Fisheries Centre, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.
www.fisheries.ubc.ca/publications/working/index.php

What did the BiOp say about your statistical analysis?
"Recent studies, however, show very inconclusive relationships between fishery removals of prey and SSL sub-population growth (e.g., Trites et al. 2010)".
2010 BiOp, Page 265

Maybe you missed something?
Lagged effects?

Steller sea lion data

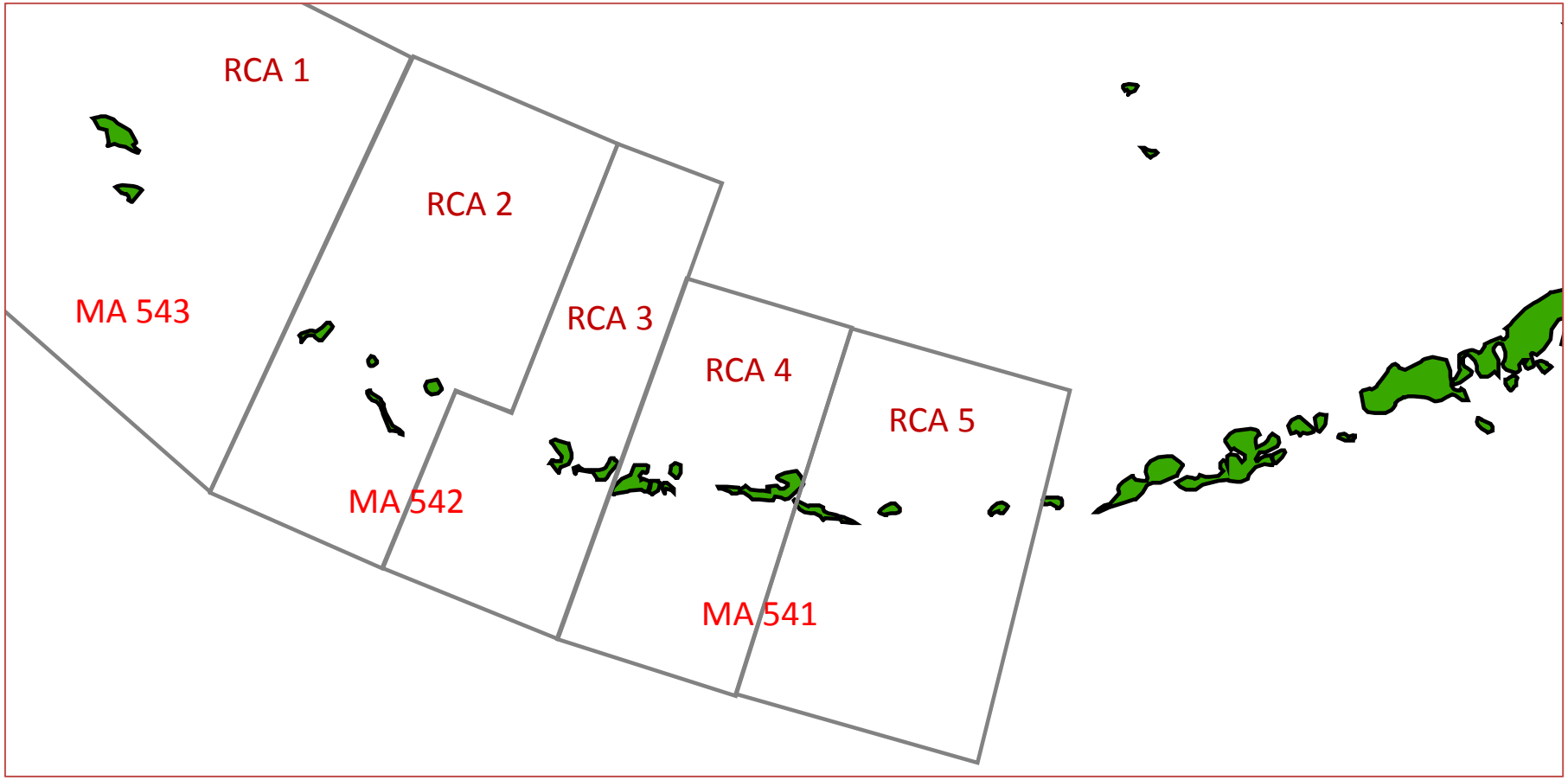
Central & Western Aleutians

- *Numbers of sea lions*
- *Changes in numbers*

- *non pups*
- *13 rookeries*
- *60 haulouts*
- *2000-2010*
- *pups*

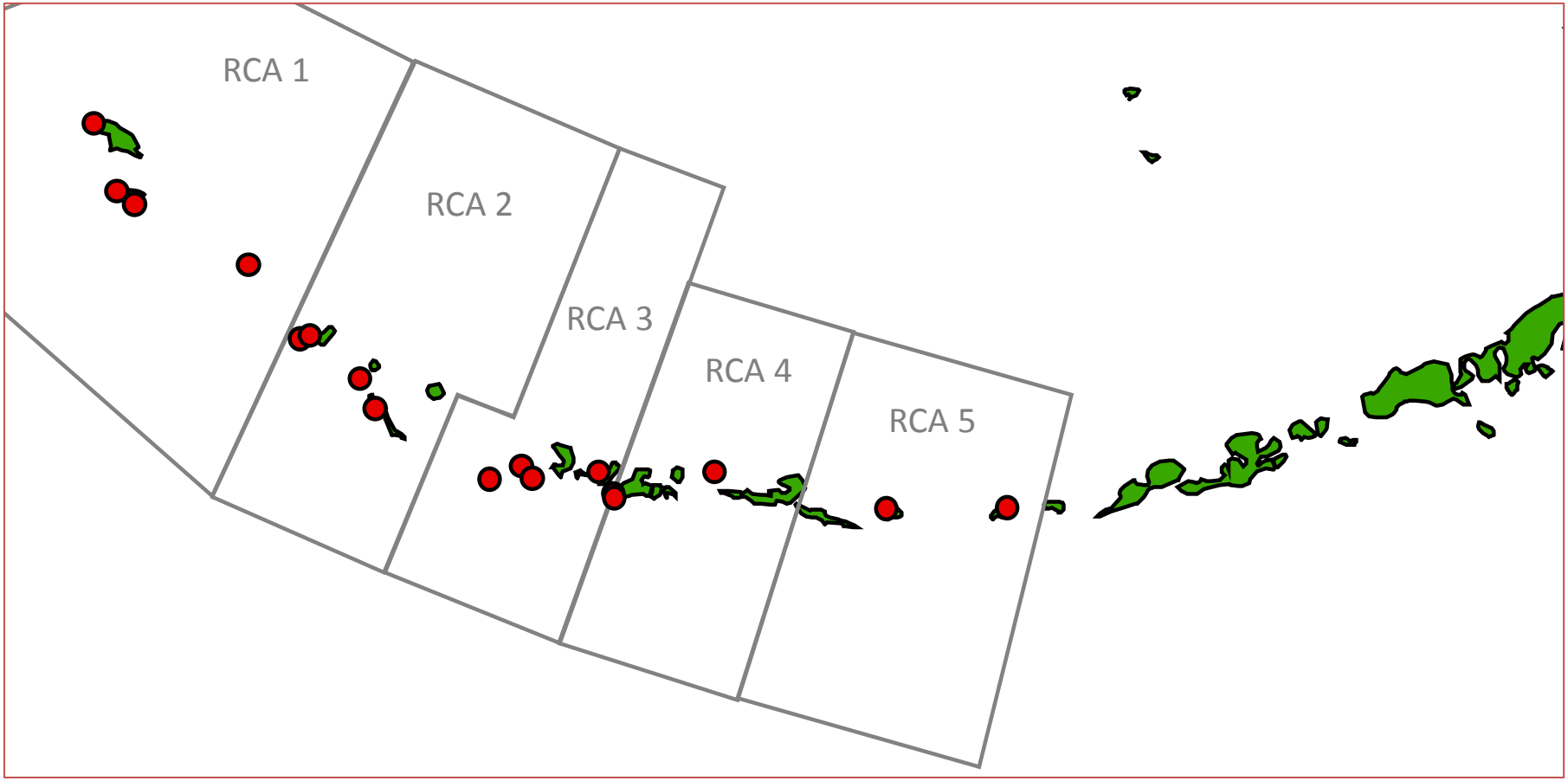
data from NMFS

Steller Sea Lion Rookeries & Haulouts



MA = Management Area
RCA = Rookery Cluster Area

Steller Sea Lion Rookeries & Haulouts



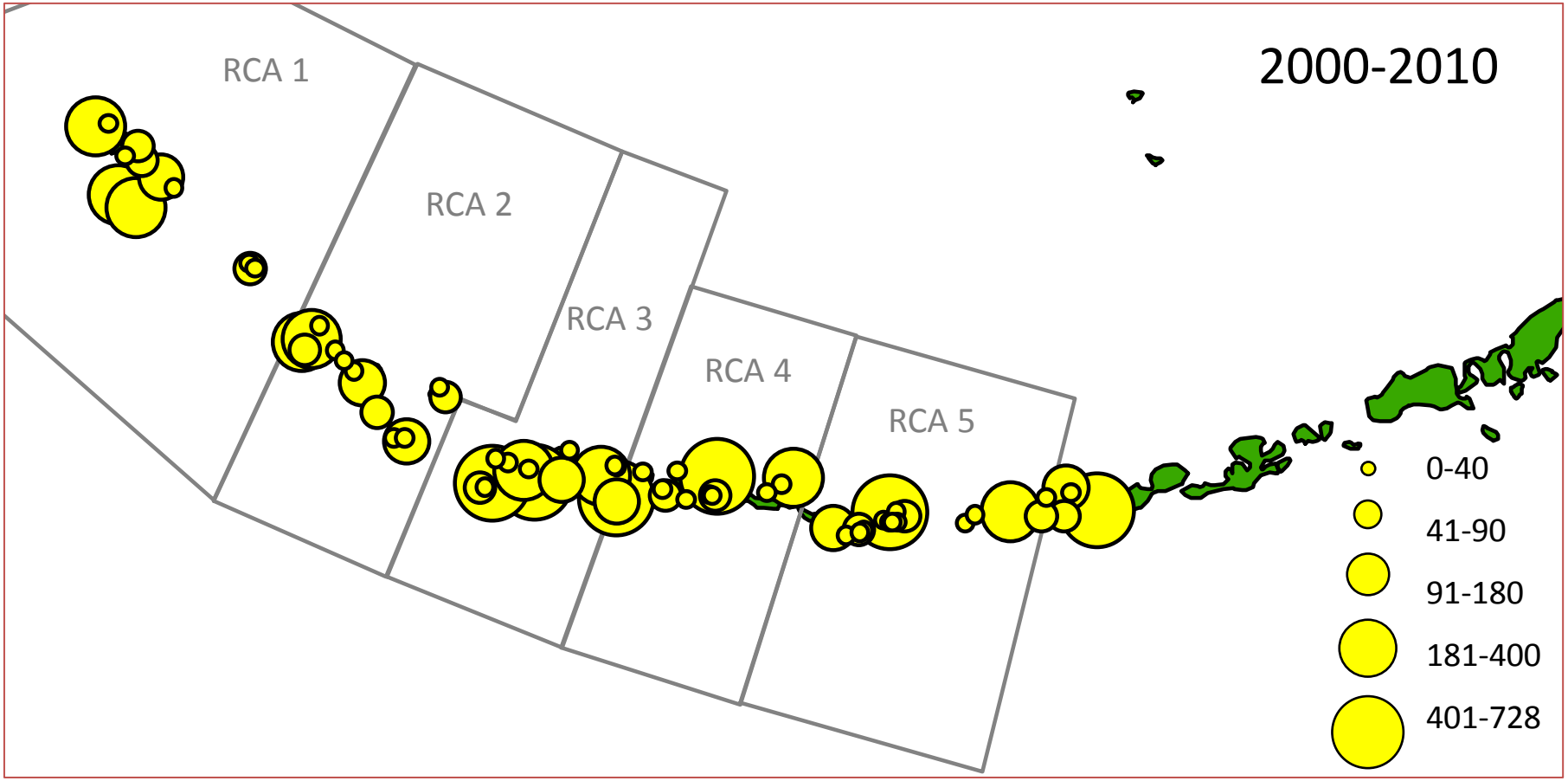
RCA = Rookery Cluster Area

Steller Sea Lion Rookeries & Haulouts

RCA = Rookery Cluster Area

Average Steller Sea Lion Numbers

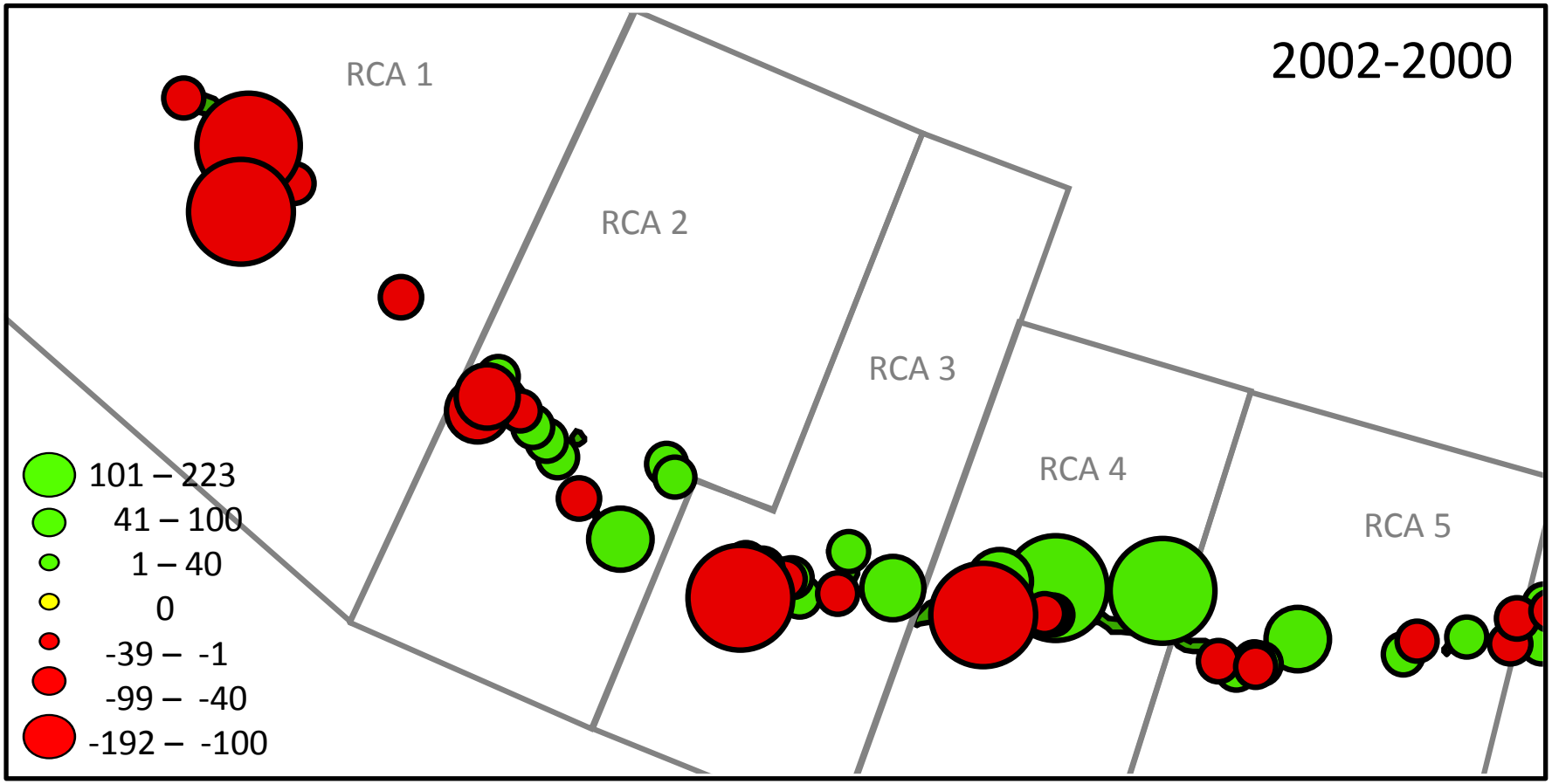
Average Steller Sea Lion Numbers



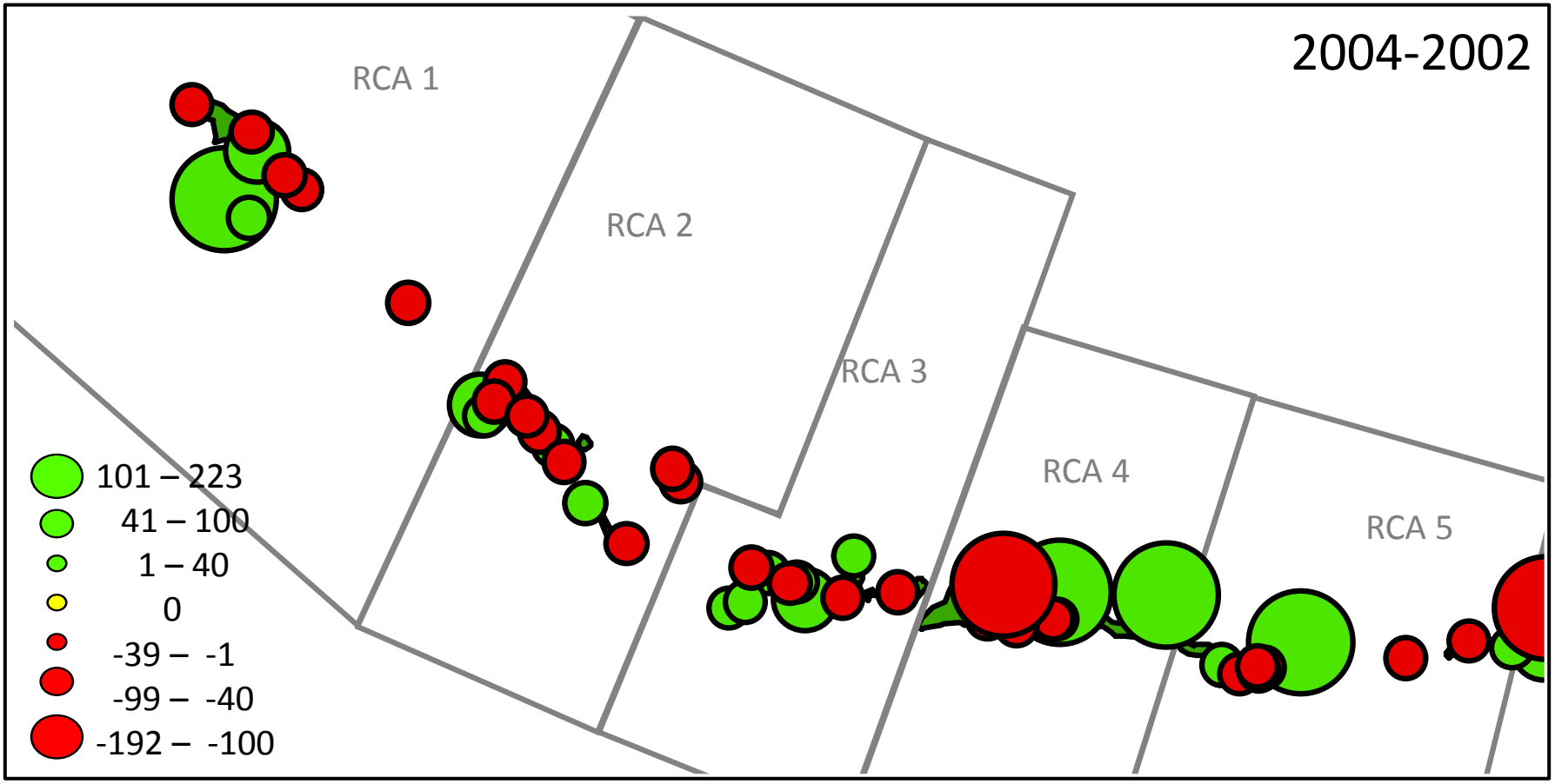
RCA = Rookery Cluster Area

Change in Sea Lion Numbers

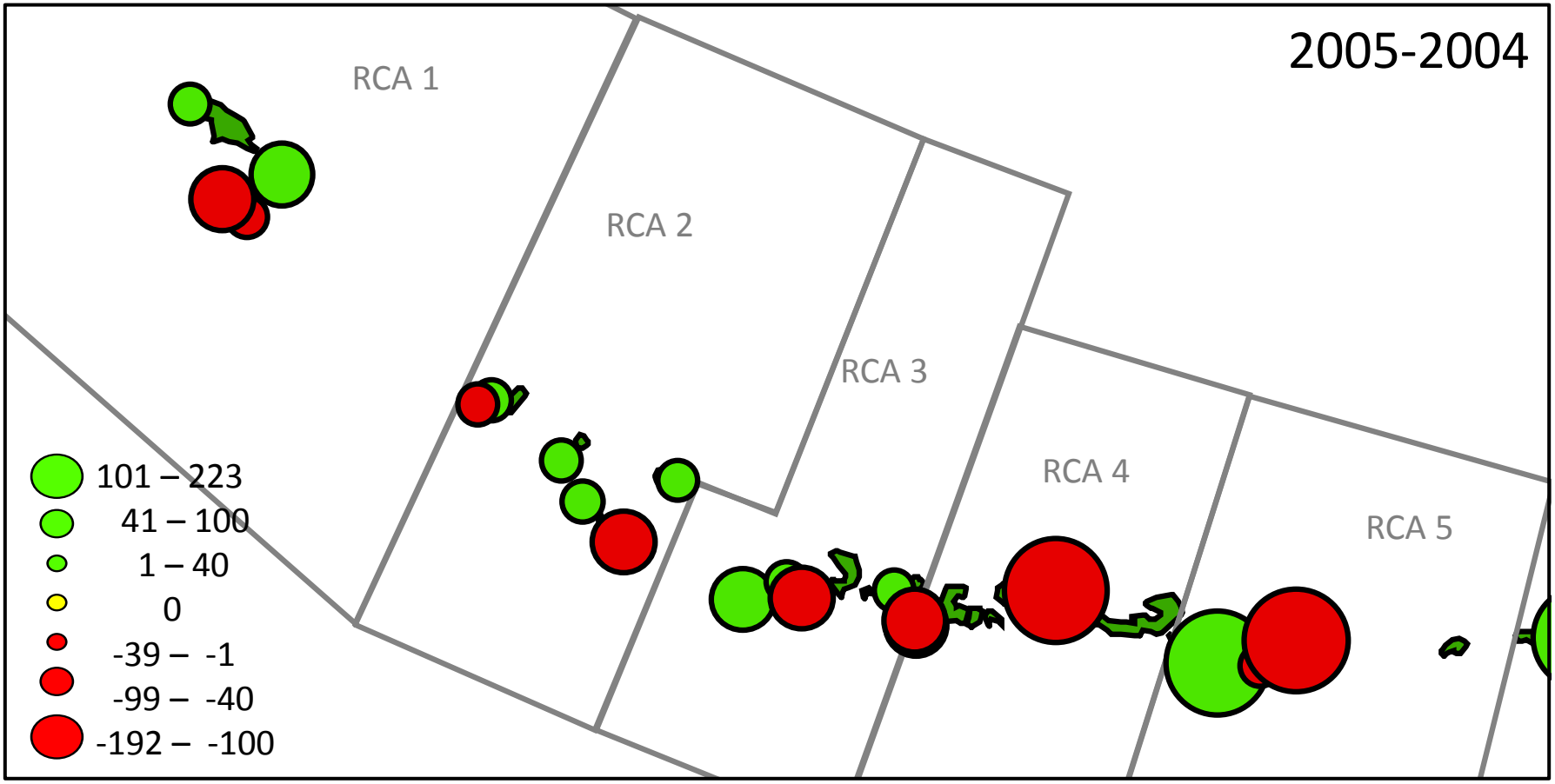
Change in Sea Lion Numbers

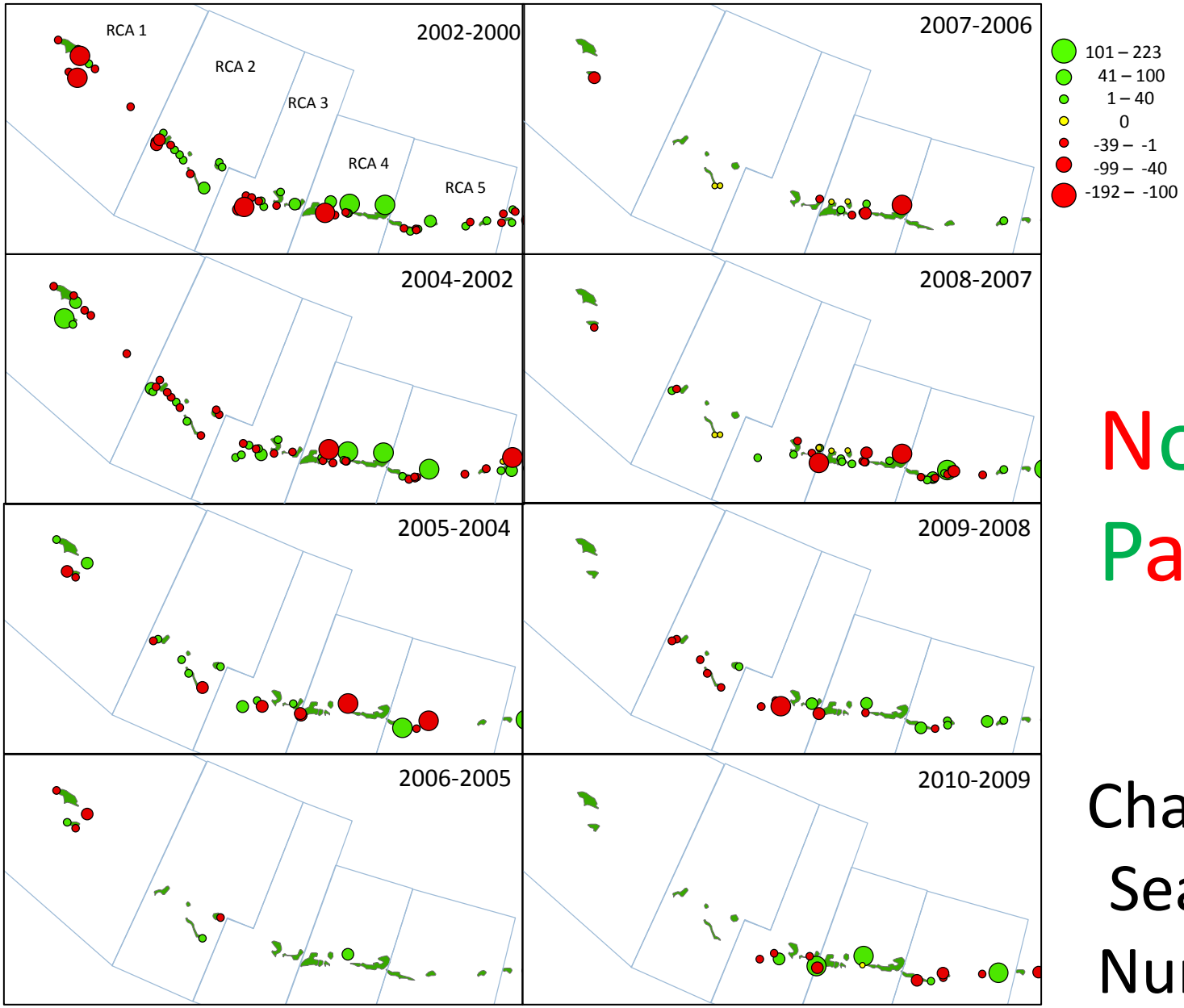


Change in Sea Lion Numbers



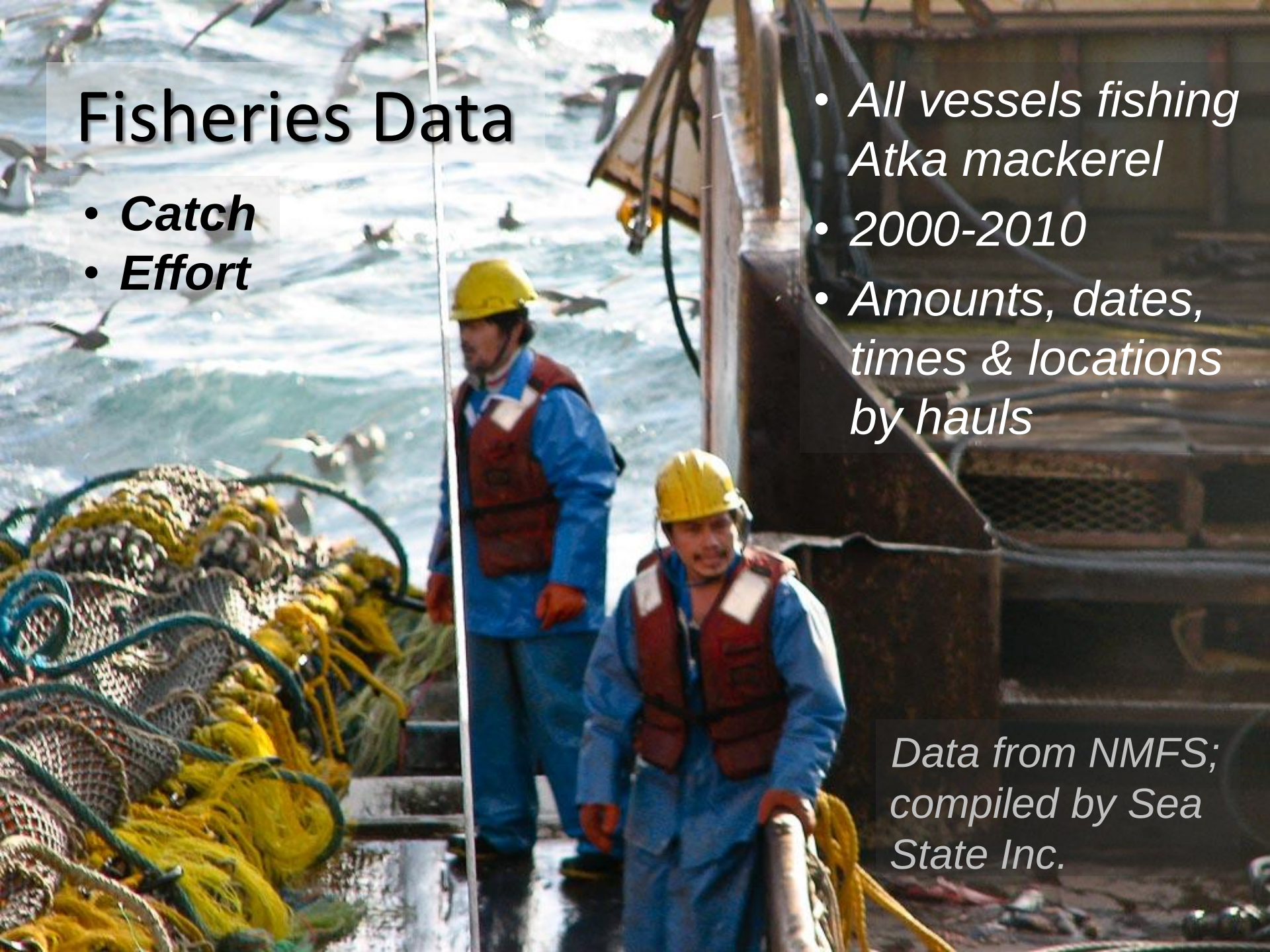
Change in Sea Lion Numbers





No Pattern

Change in Sea Lion Numbers



Fisheries Data

- ***Catch***
- ***Effort***

- *All vessels fishing Atka mackerel*
- *2000-2010*
- *Amounts, dates, times & locations by hauls*

Data from NMFS; compiled by Sea State Inc.

Fishery

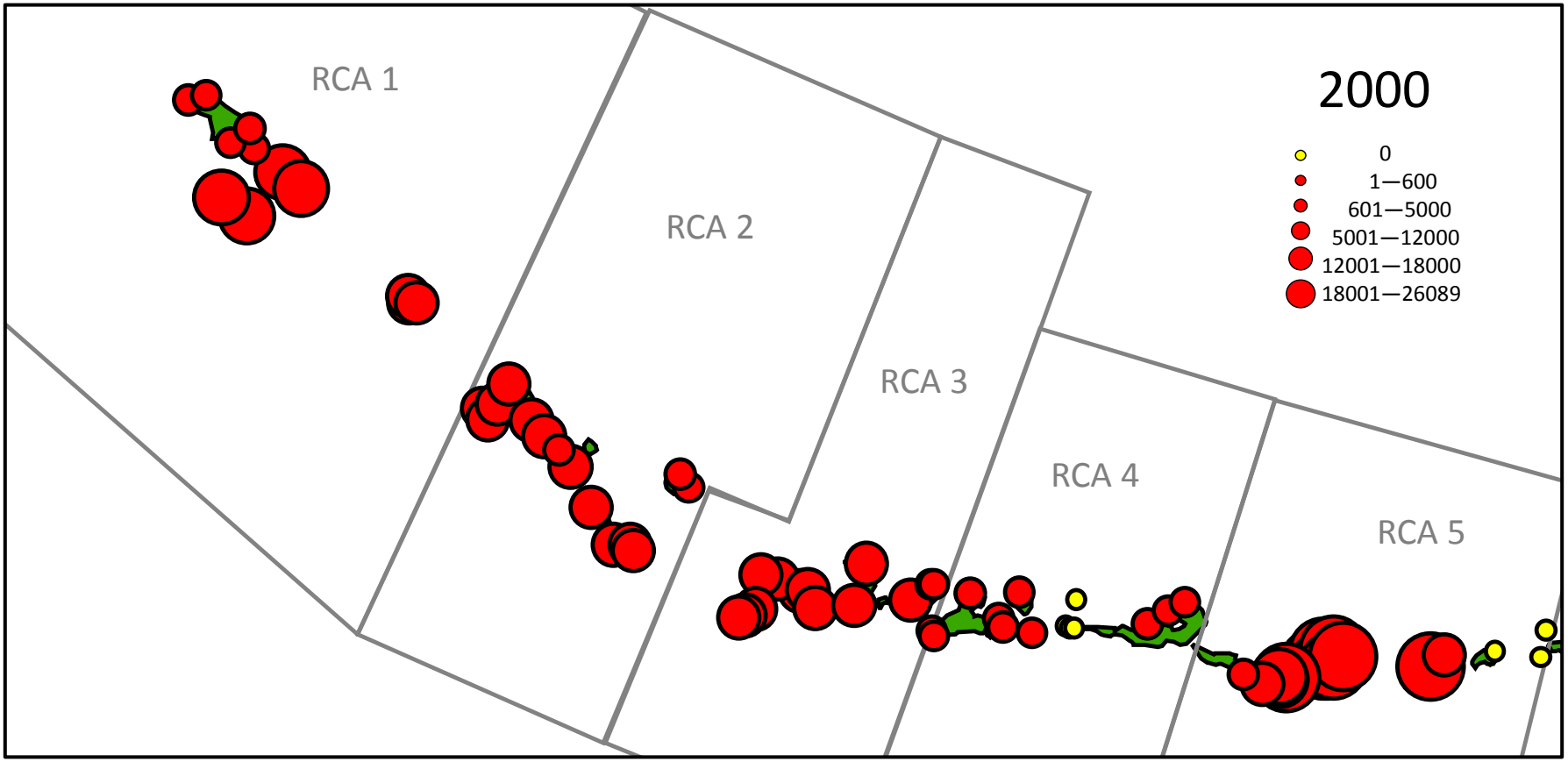
- *4-11 vessels*
- *2 observers*
- *VMS coverage*

- *11% exploitation rate on age 3+*
- *2010 biomass 844,000 tons*

~1 billion fish

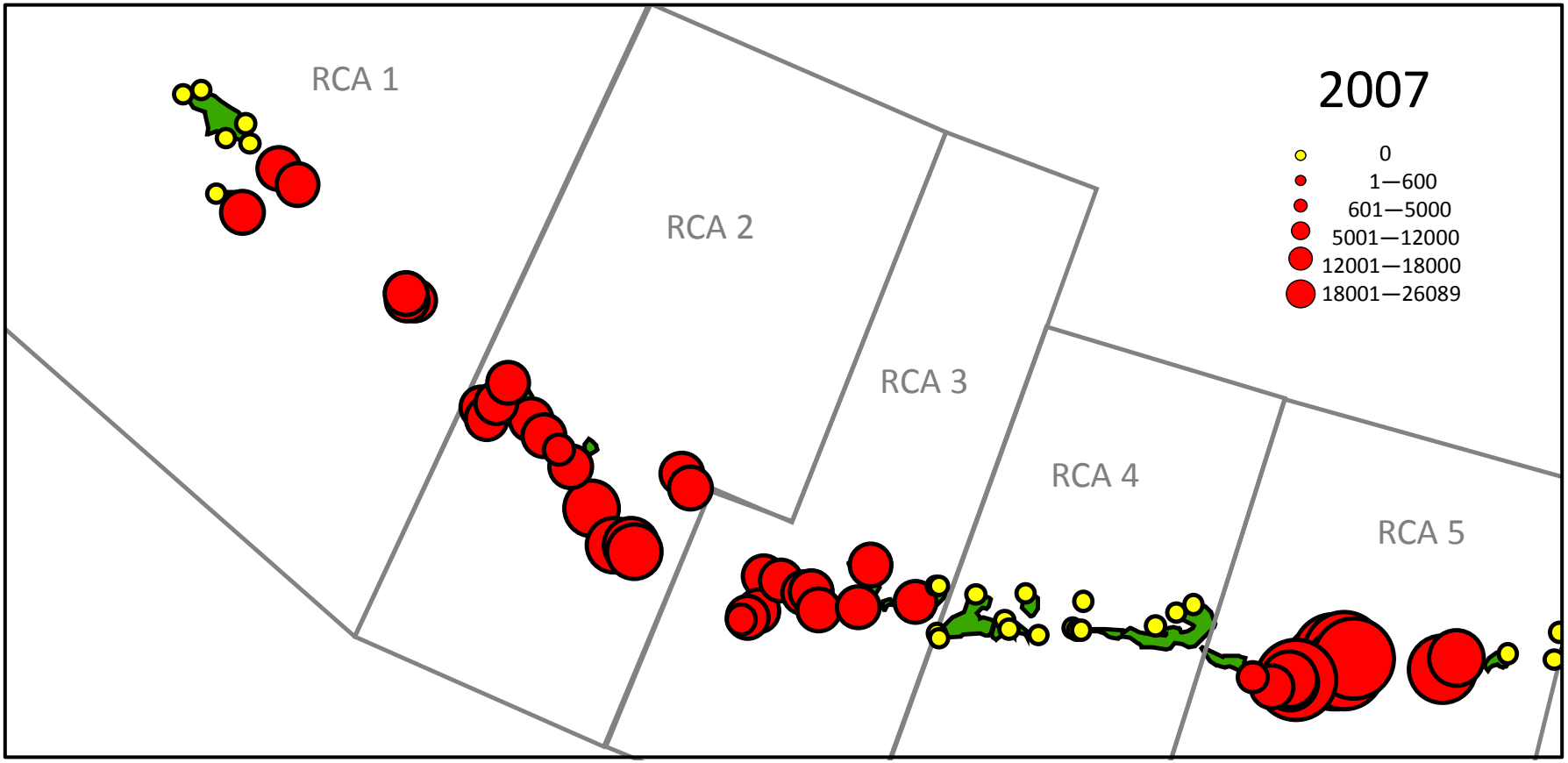
~10,000 sea lions

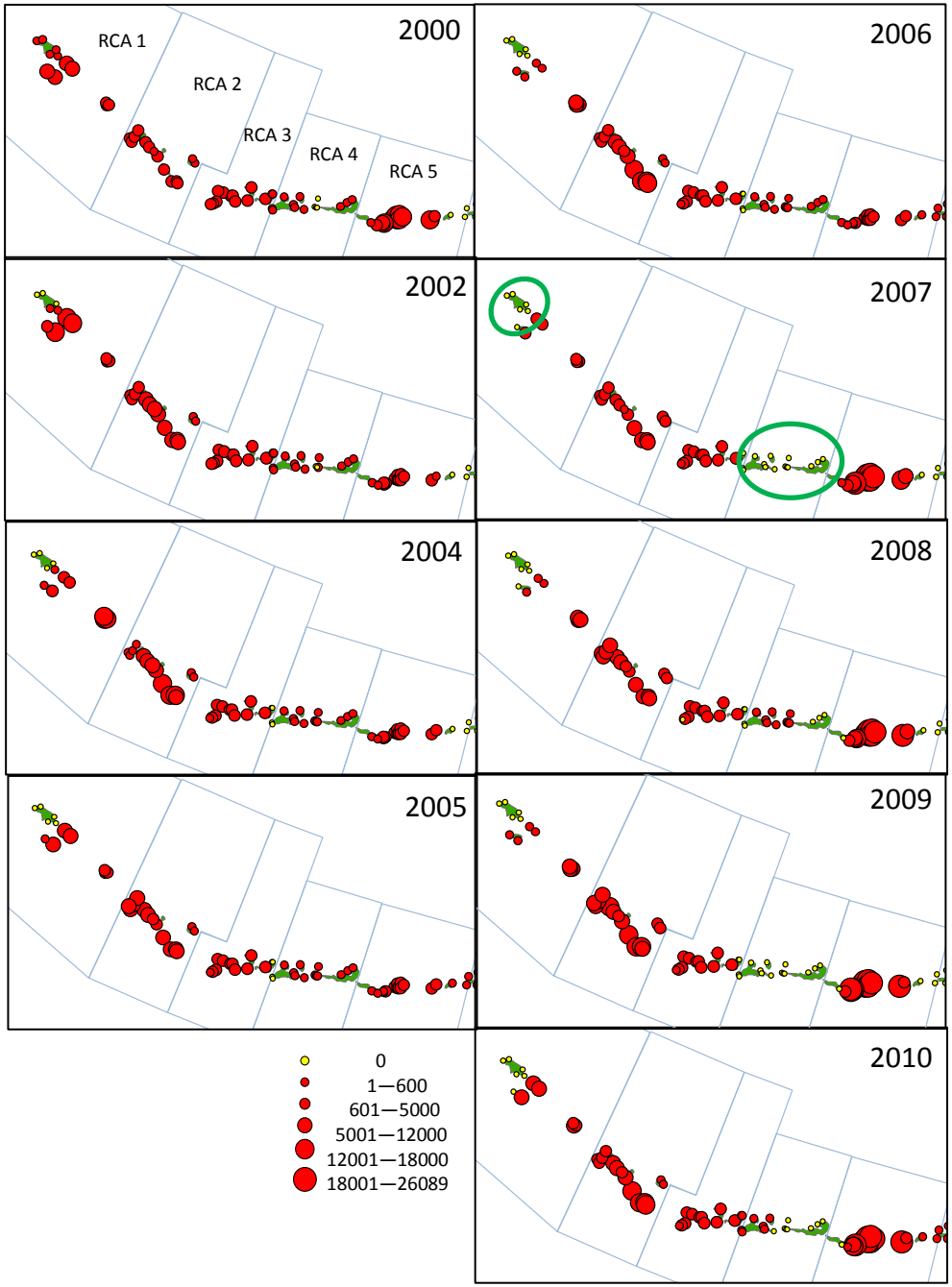
Total catch of Atka within 40nm



Calculated catch within 10, 20 & 40 nm of rookeries and haulouts

Total catch of Atka within 40nm

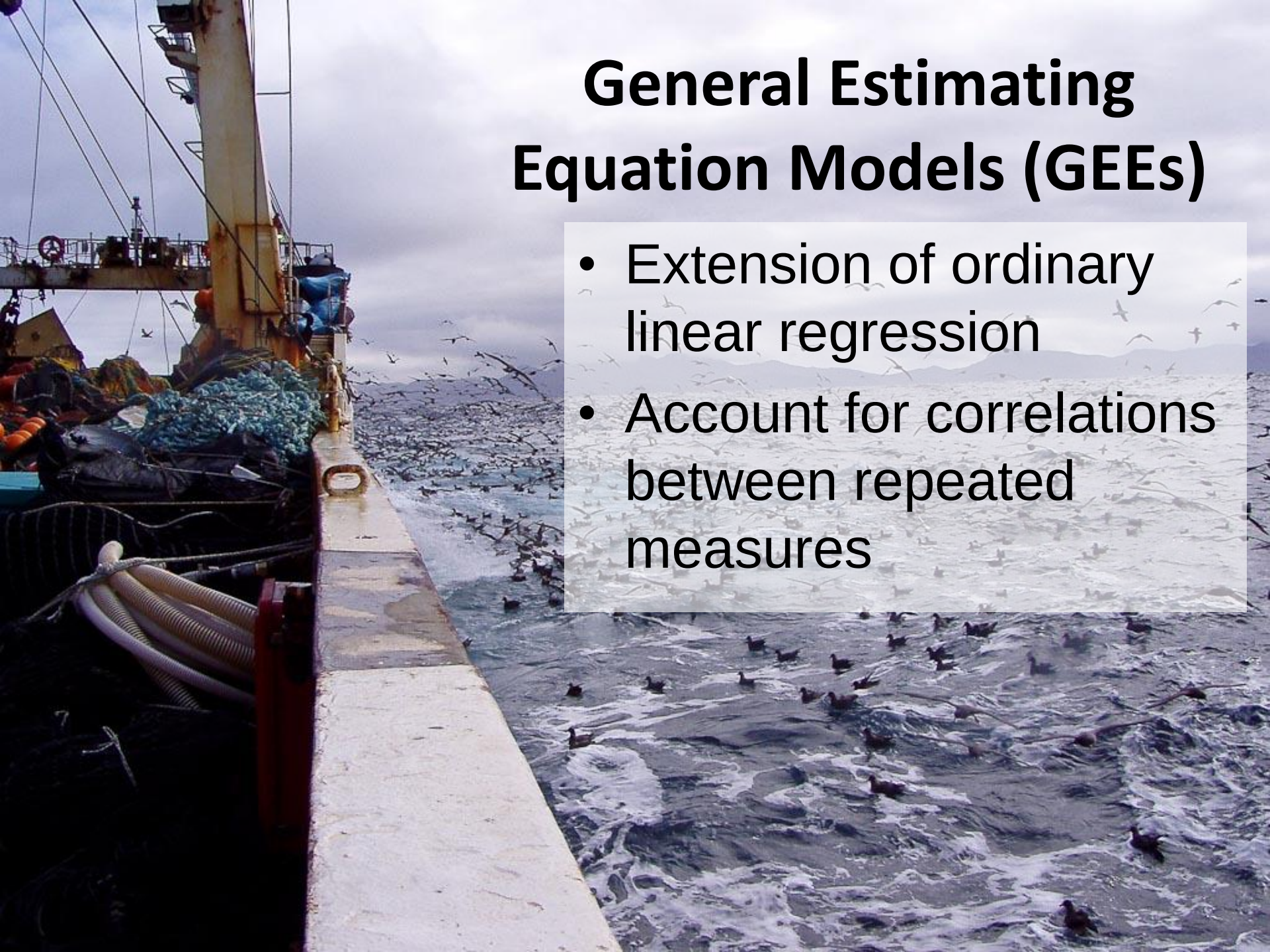




Total catch within 40nm

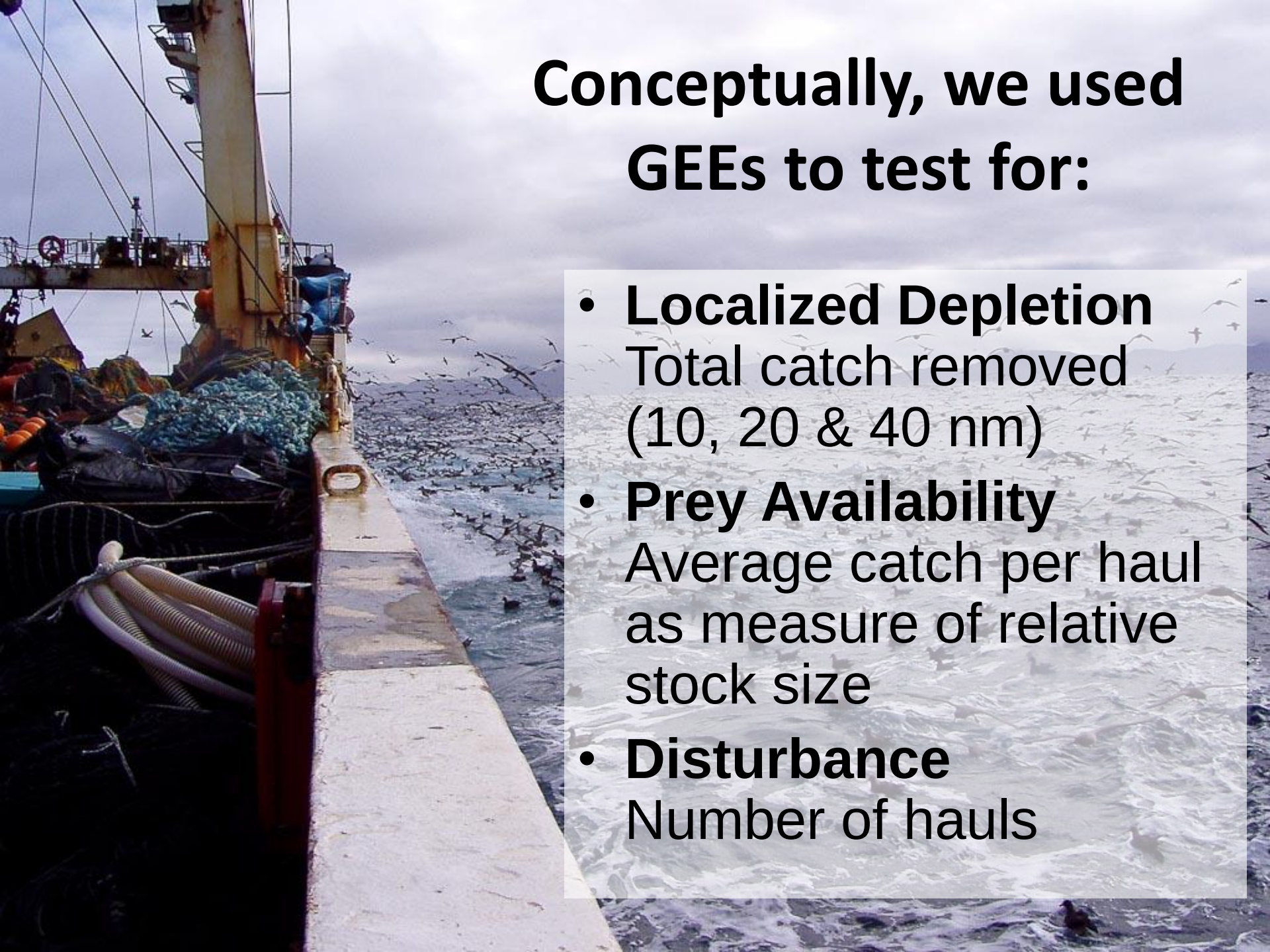
Some sites have had little or no fishing

Fishing Intensity varied in time & space



General Estimating Equation Models (GEEs)

- Extension of ordinary linear regression
- Account for correlations between repeated measures



Conceptually, we used GEEs to test for:

- **Localized Depletion**
  Total catch removed (10, 20 & 40 nm)
- **Prey Availability**
  Average catch per haul as measure of relative stock size
- **Disturbance**
  Number of hauls

GEE Model

$$SSLcnt_{ij} = \exp\left(\beta_0 + \beta_{trawl} trawl_{ij} + \beta_{year\,j} year_j + \beta_{trawl:year} year{:}\, trawl_{ij} + \beta_{lon} lon\right)$$

- 216 potential models
- assessed spatial independence of data using longitude
- 129 actual models

Possible Findings

NO relationships

NEGATIVE relationships

- **more fishing results in fewer sea lions**

POSITIVE relationships

- **More fishing associated with more sea lions**

Results

24 significant relationships

~~NEGATIVE relationships~~

- ~~more fishing results in fewer sea lions~~

~~2%~~

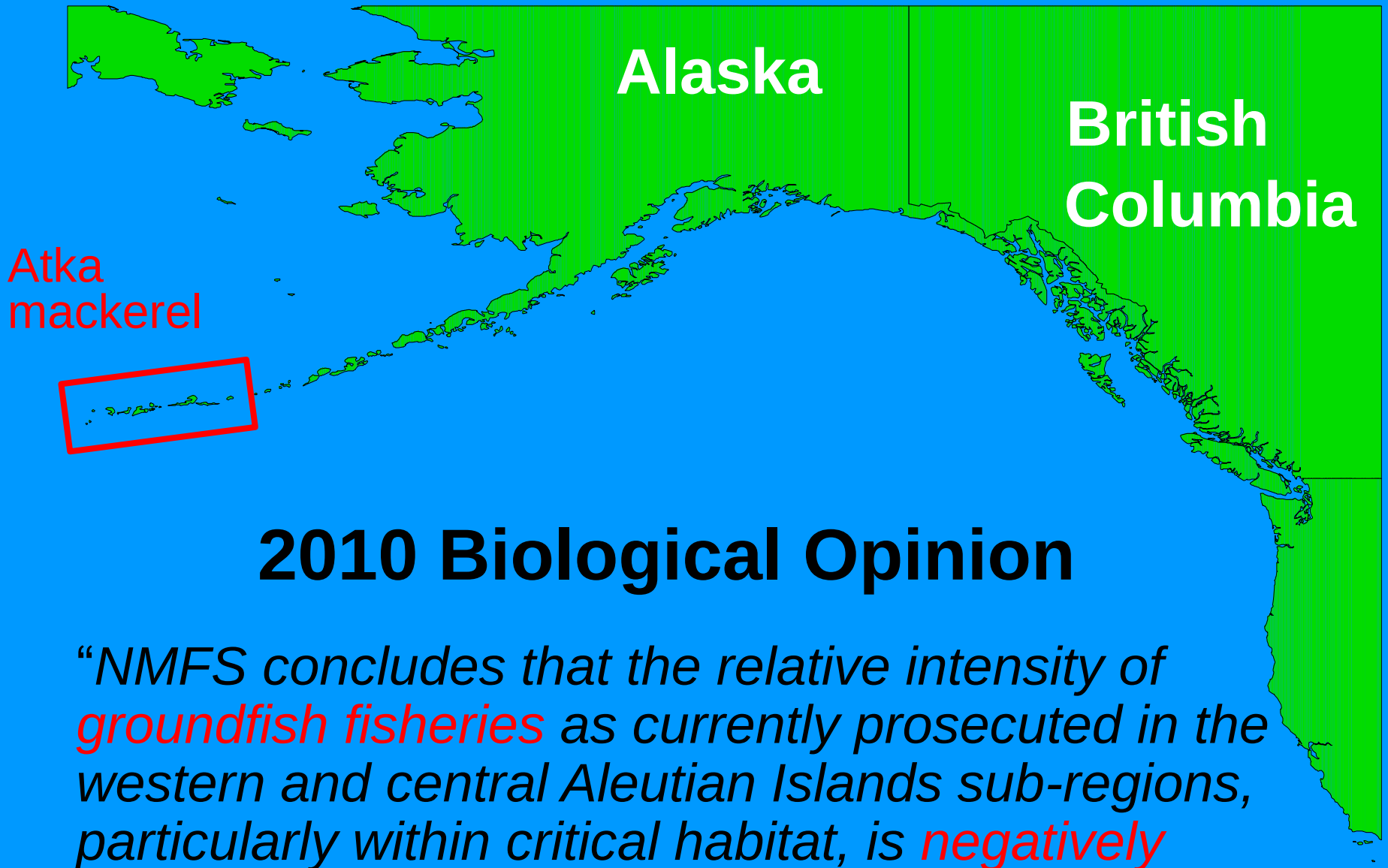
~~(3)~~

POSITIVE relationships

- More fishing associated with more sea lions

16%

(21)



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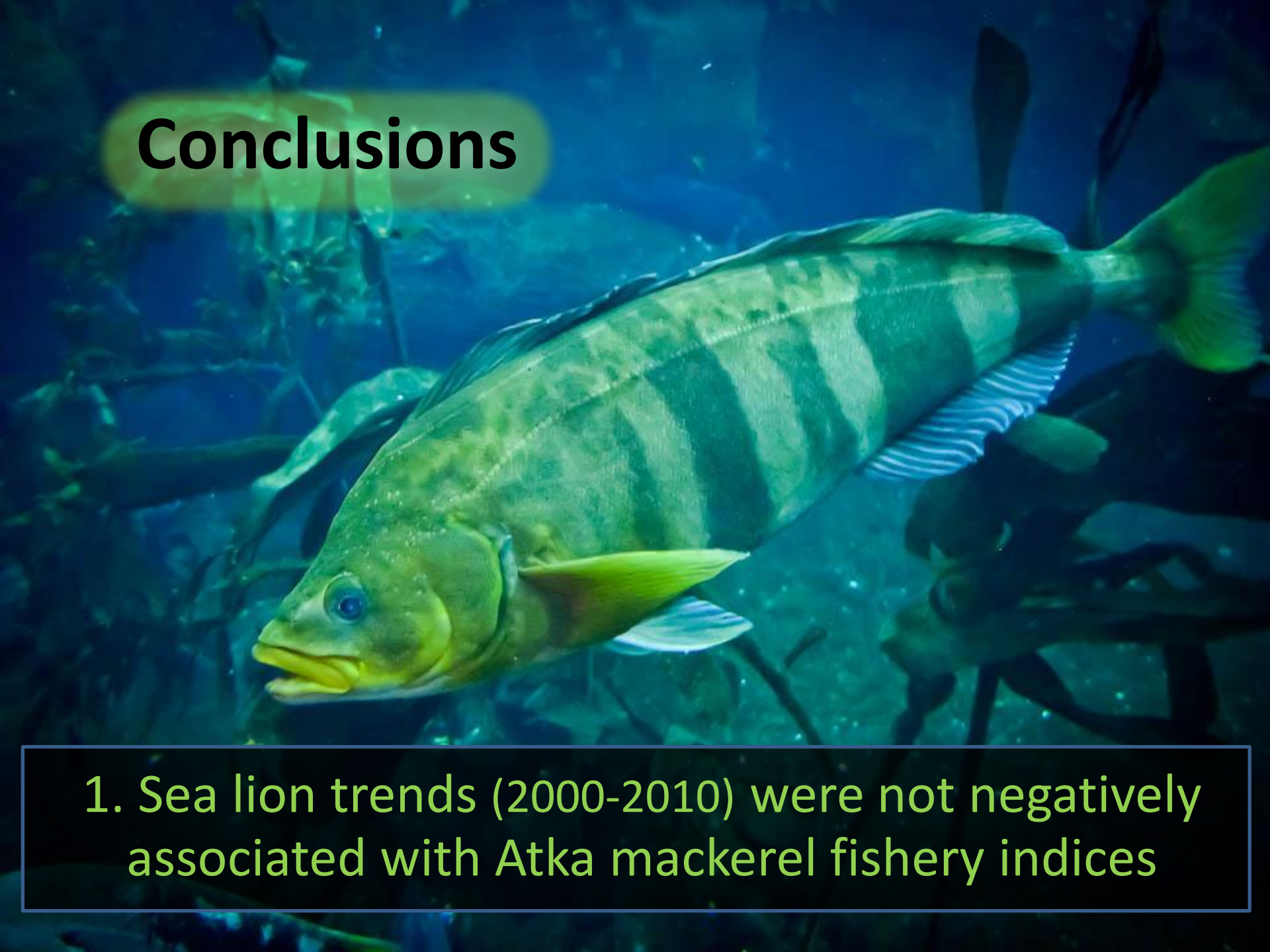
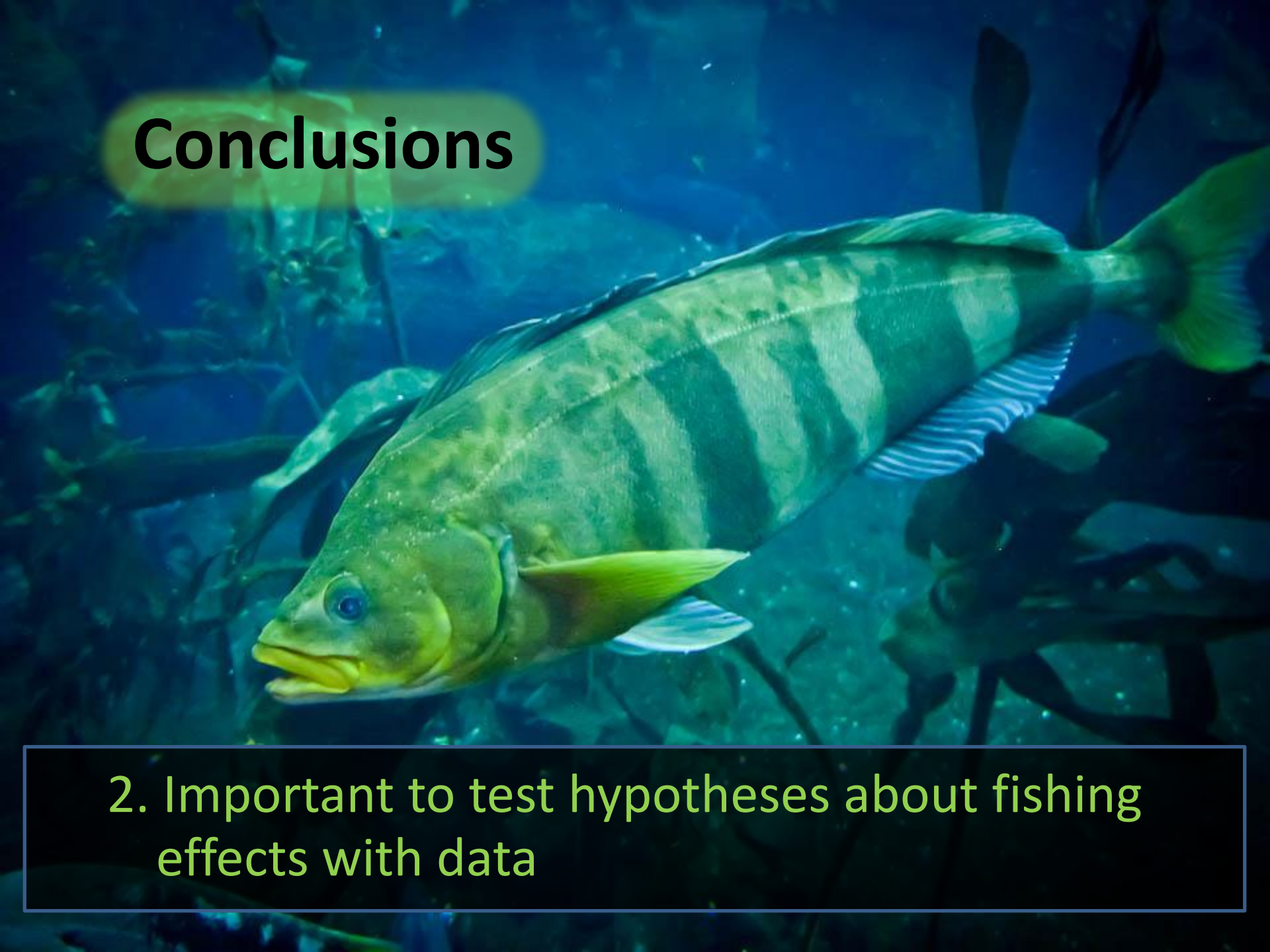


Conclusions

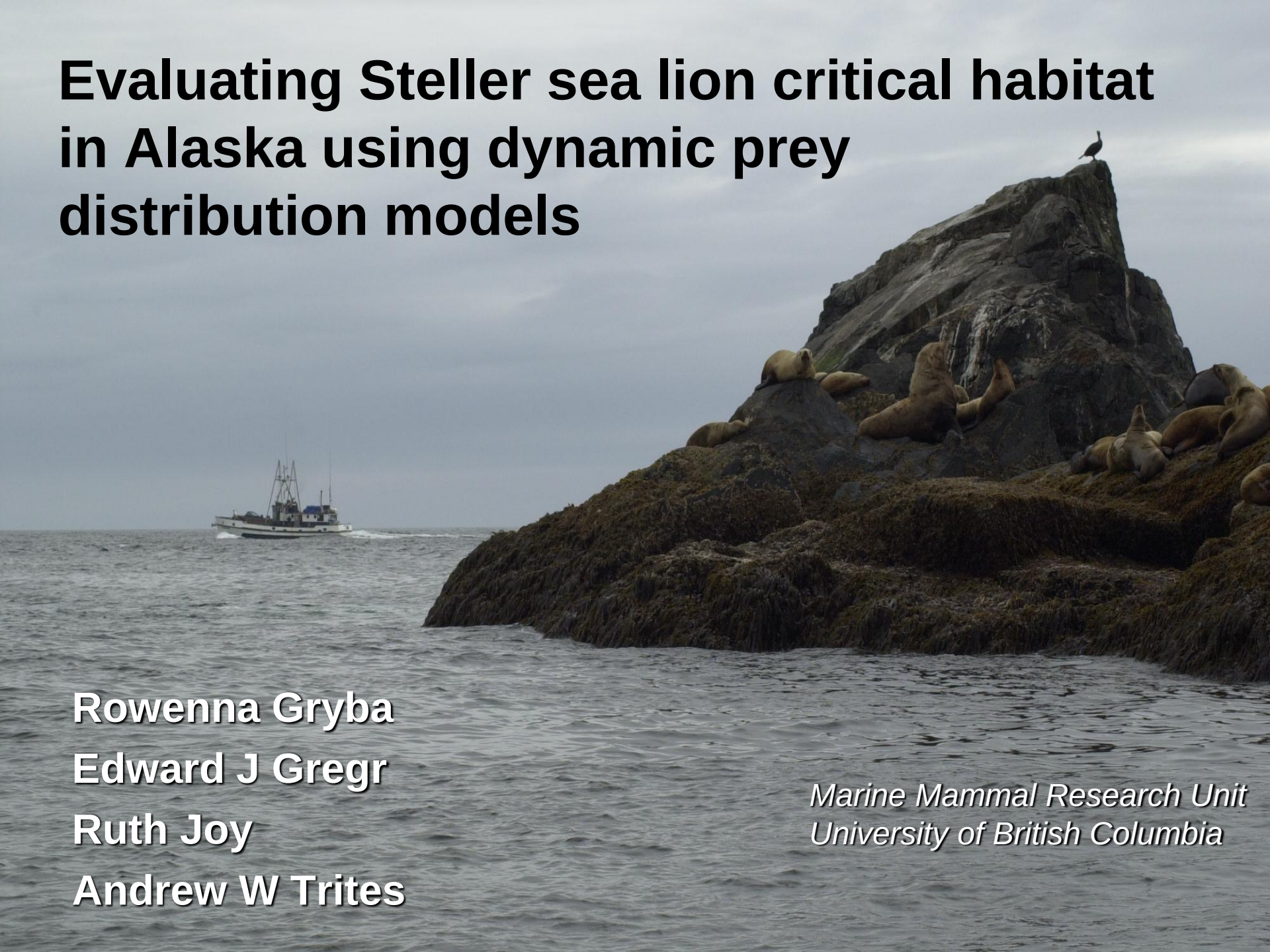
1. Sea lion trends (2000-2010) were not negatively associated with Atka mackerel fishery indices



Conclusions

2. Important to test hypotheses about fishing effects with data

Evaluating Steller sea lion critical habitat in Alaska using dynamic prey distribution models



Rowenna Gryba

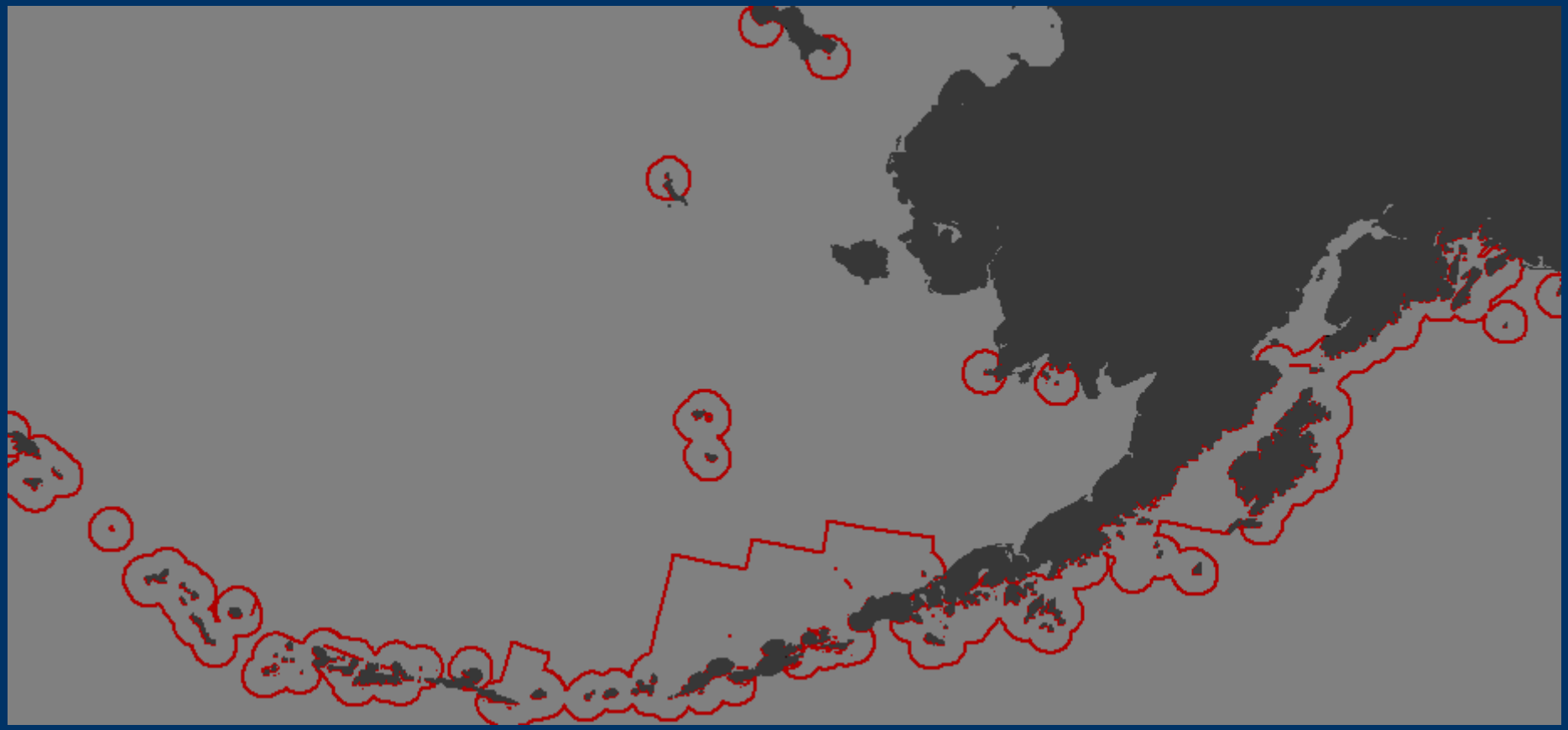
Edward J Gregr

Ruth Joy

Andrew W Trites

Marine Mammal Research Unit
University of British Columbia

Steller sea lion critical habitat



- historic distribution of fishing – 1993
- presumed foraging areas – 1993

How to evaluate critical habitat?

- Overlap with fisheries
- Prey resources

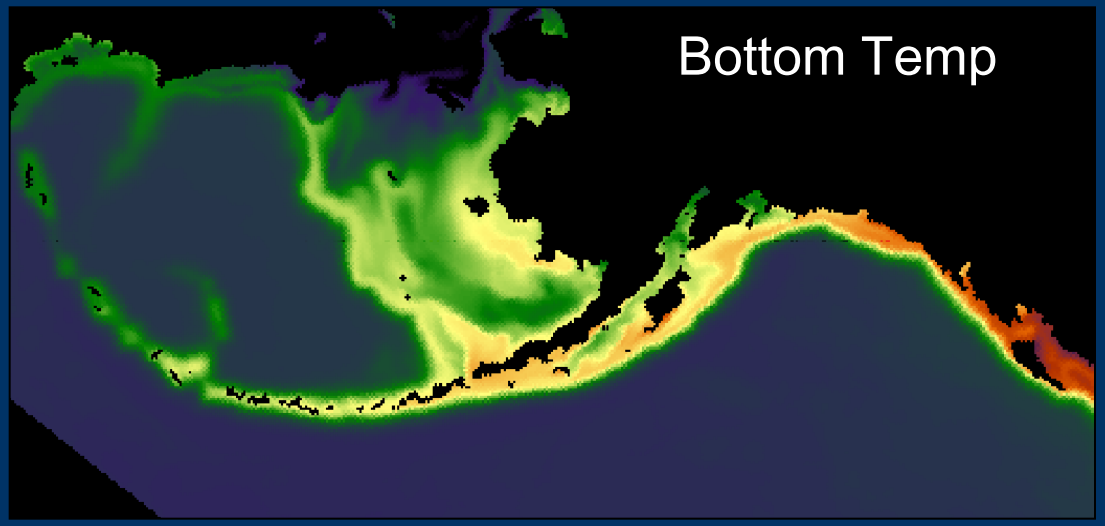
➡ dynamic distributions of fish

Data

NMFS Trawl Survey

- walleye pollock
- Pacific cod
- Atka mackerel

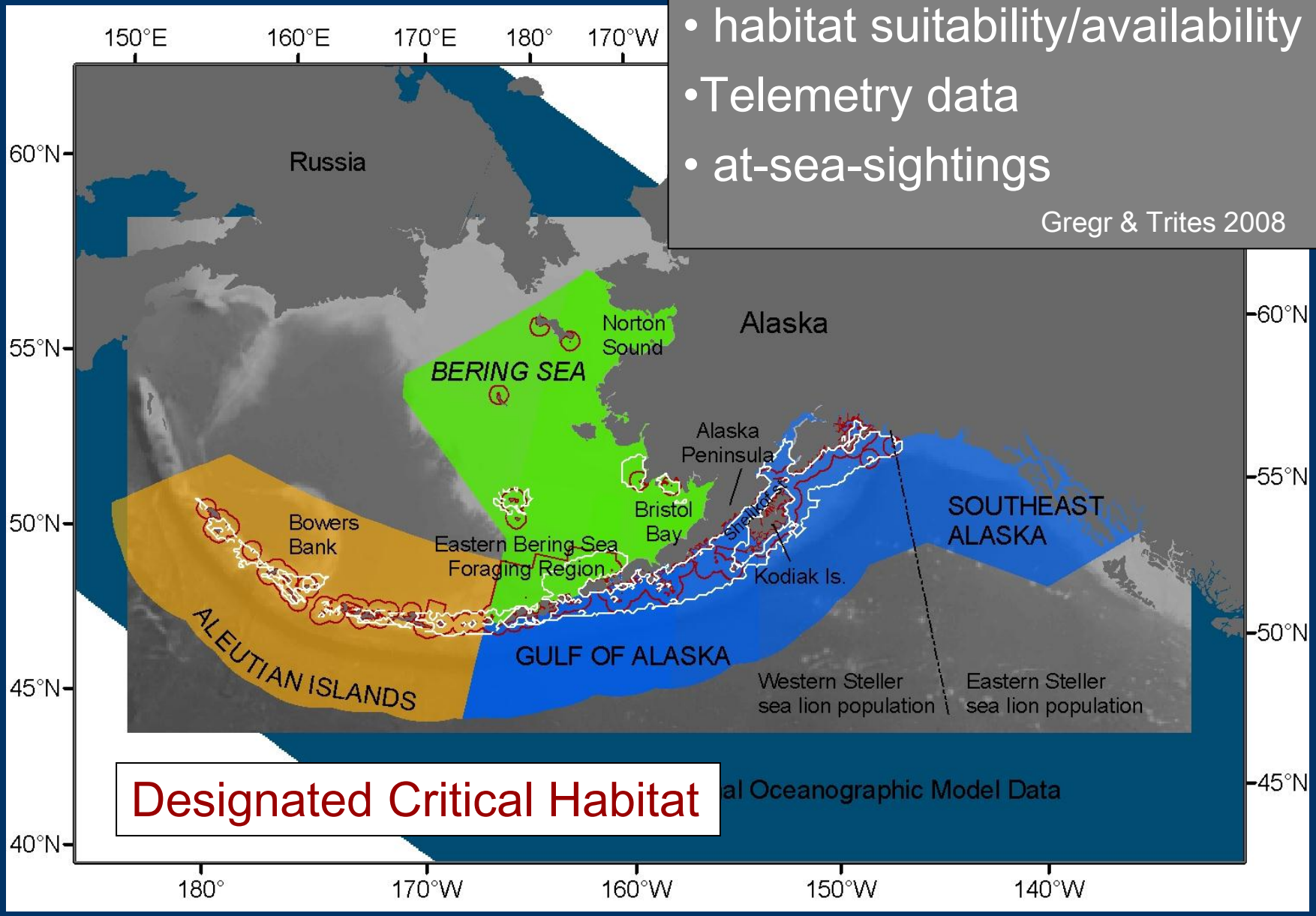
} 2000-2004 June/July



Alternate Critical Habitat

- habitat suitability/availability
- Telemetry data
- at-sea-sightings

Gregr & Trites 2008



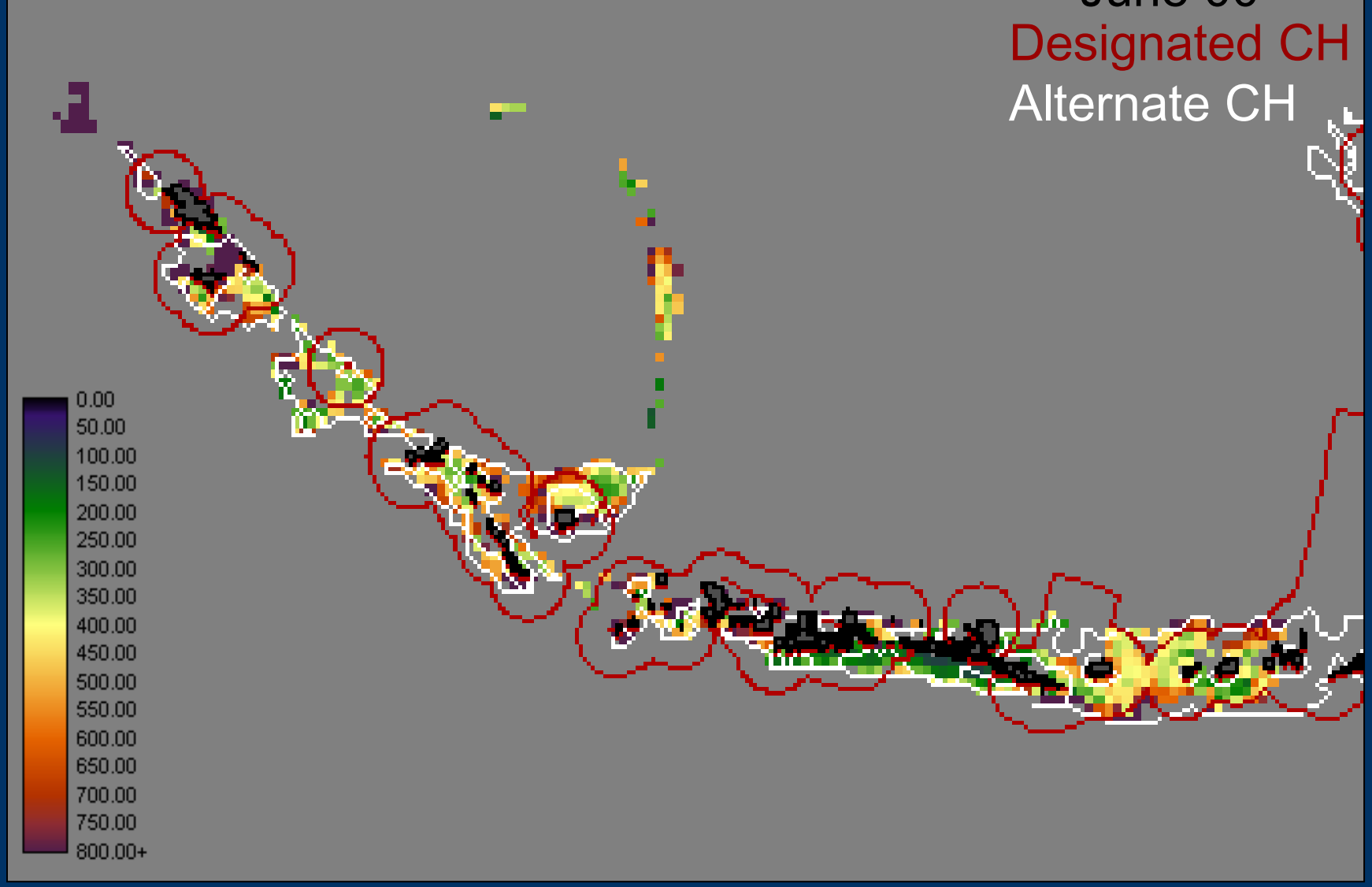
Designated Critical Habitat

Modeling

- Generalized least square models (GLS)
- Three regions
  - Bering Sea
  - Gulf of Alaska
  - Aleutian Islands

Aleutian Islands

- Atka mackerel
  - *vertical/horizontal current vectors*
  - temperature (mld, bottom)
  - bathymetry
  - sea surface temperature
  - sea surface height
- walleye pollock
  - bathymetry, sea surface height, bottom temperature, bottom salinity
- Pacific cod
  - bathymetry, sea surface height, sea surface temperature, mld temperature, salinity (mld, bottom)



Atka mackerel, walleye pollock and pacific cod combined biomass

Conclusions

- Prey distributions are a good tool to assess critical habitat boundaries
- Efficiency of critical habitat boundaries varies between regions
- Critical habitat should be refined using prey distributions and oceanographic information

Atka Mackerel

Proximate
Analysis
&
Feeding
Studies

Historical Overview

- Rosen & Trites (2000) – junk food hypothesis
  - Low-Cal *or* Nutra-Lite Hypothesis
  - First suggestion that quality could be important if animals do not eat enough
  - Perpetual time warp

Act I

- Rosen & Trites (2004, 2005) – mechanisms
  - Sea lions can do well on low-lipid diet if they can eat enough of it
  - Young (<1) have high energy requirements and small stomachs

Act II

- Rosen et al. (2007, 2012) – effects of seasons

Act III

Captive Feeding Studies

UBC / Van Aq	36
Alaska SeaLife	1
Mystic Aq	0

Mammal Rev. 2009, Volume 39, No. 4, 284–306. *Printed in Singapore.*

Steller sea lions *Eumetopias jubatus* and nutritional stress: evidence from captive studies

DAVID A. S. ROSEN
Marine Mammal Research Unit, University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada

ABSTRACT

1. Numbers of Steller sea lions *Eumetopias jubatus* in the North Pacific have declined. According to the nutritional stress hypothesis, this decline is due to reduced food availability. Data from studies conducted on pinnipeds in the laboratory are used here to test if the nutritional stress hypothesis can explain the decline of Steller sea lions.

2. Overall, there is strong evidence for biologically meaningful differences in the nutritional quality of major prey species. Steller sea lions can partly compensate for low-quality prey by increasing their food consumption.

3. There appear to be no detrimental effects of low-lipid prey on sea lion growth or body composition when sea lions can consume sufficient quantities of prey. However, the ability to increase consumption is physiologically limited, particularly in young animals. Overall, it is more difficult to maintain energy intake on a diet of low-quality prey than on a normal diet.

4. Under conditions of inadequate food intake (either due to decreased prey availability or quality, or increased energy requirements) the overall impacts of nutritional stress are complex, and are dependent upon season, prey quality, age and the duration and intensity of the nutritional stress event.

5. Studies on pinnipeds in the laboratory have been instrumental in identifying the conditions under which changes in sea lion prey can result in nutritional stress and the nature of the physiological impacts of nutritional stress events.

Keywords: conservation, diet, metabolism, nutrition, pinnipeds

Mammal Review (2009), **39**, 284–306
doi: 10.1111/j.1365-2907.2009.00150.x

INTRODUCTION

The precipitous decline of Steller sea lions *Eumetopias jubatus* in the North Pacific has generated a tremendous scientific effort to understand the reasons for the population change, supported by an unprecedented level of funding for conservation-directed research (see Morell, 2008). The numerous individual hypotheses put forward to explain the decline are concerned with both proximate and ultimate factors that range in scale from ecosystem changes to individual sea lion physiology (Anonymous, 2008). To make things more complex, many of these hypotheses are inter-related (Guenette *et al.*, 2006; Atkinson, DeMaster & Calkins, 2008b).

One hypothesis that has received a great deal of attention has become known as the nutritional stress hypothesis. Calkins & Goodwin (1988) are generally credited with first providing evidence of nutritional concerns among wild Steller sea lions. They noted:

Correspondence: D. A. S. Rosen. E-mail: rosen@zoology.ubc.ca

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General Conclusions

- Sea lions can adjust intake in response to changes in prey quality
- Lower prey quality requires eating more
- **But** the amount of prey they can consume is limited by physiological constraints and finite foraging time
- Young sea lions are the most constrained, especially <1 year

General Conclusions

- **IF** intake is **SUFFICIENT,** prey quality doesn't affect body mass or health
- **IF** intake is **INSUFFICIENT,** sea lions can make physiological adjustments to dampen effects

General Conclusions

- **However,** these adaptations are finite and depend upon season, age, etc.
- If intake remains insufficient, there are physiological consequences due to prey quality in addition to energy deficits.

Atka Mackerel
&
Steller
Sea Lions

Predictions

Name: Dave Rosen and Andrew Trites
University of British Columbia

Date: January 16, 2012

QUESTION 4: Are there certain times of the year when the quality of Atka mackerel may make it difficult for Steller sea lions to meet their energetic requirements? Discuss the implications. Show your work [30 points]*

The quality of Atka mackerel might have an effect if the amount sea lions require exceeds their physical digestive/ingestion capacity (i.e., food mass per body mass is too high to sustain long-term)

Energy required (per kg body mass) / Fish Energy density (per kg fish mass) = Food required (as % body mass)

25/30
You are missing some months of fish composition data

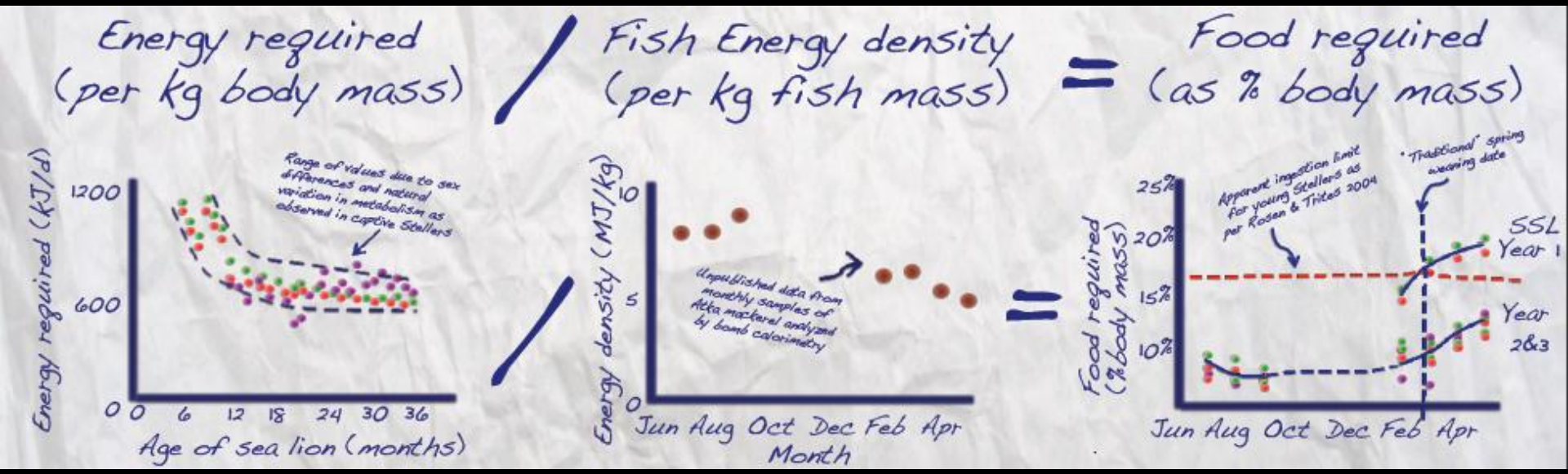
The available data suggests that the high energy requirements of sea lions and low prey quality of Atka mackerel in the spring (regardless of abundance) might make things difficult for Steller sea lions.

This interaction is potentially greatest for younger sea lions, such as those that wean in their first year!

*** Abstract title: Lacka mackerel? Is Atka mackerel "good enough" for Steller sea lions?**

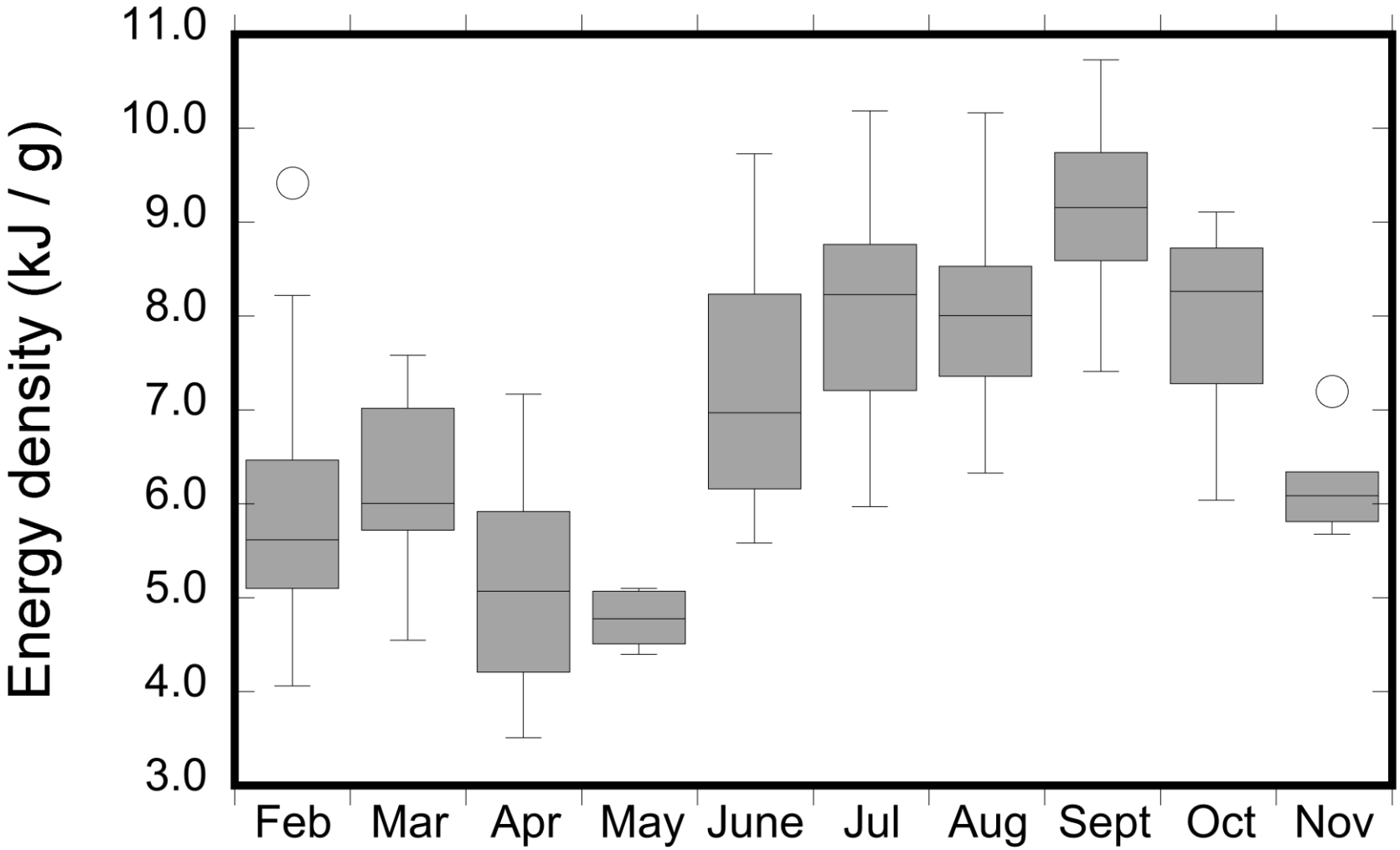
Financial support was provided to the North Pacific Universities Marine Mammal Research Consortium by the North Pacific Marine Science Foundation, the North Pacific Fisheries Foundation and the National Oceanic and Atmospheric Administration (NA07NMF4390197).

Junk Food Hypothesis / Mechanism



Energy density of Atka mackerel by month

MA 541, 542, 543



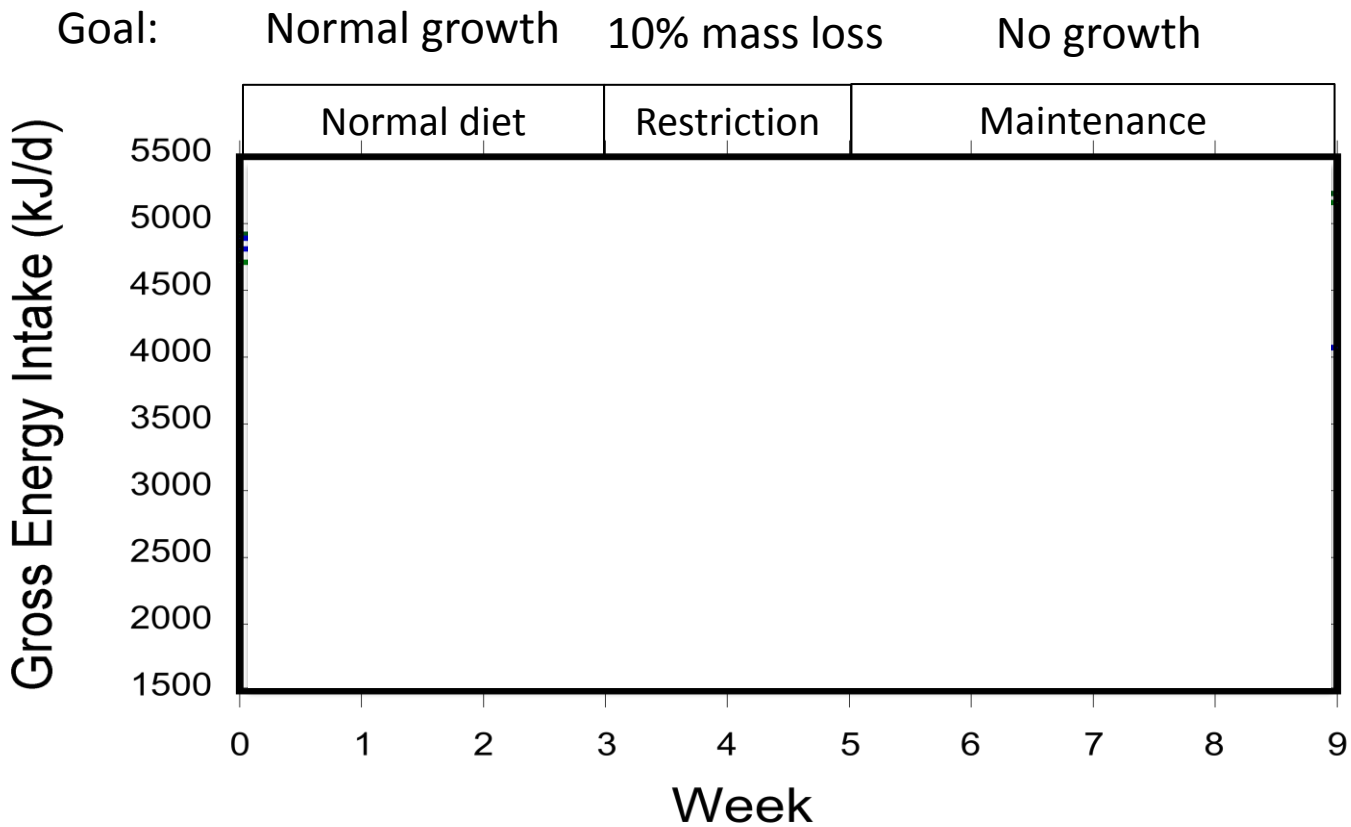
Steller sea lion Atka mackerel feeding trials

- Four Steller sea lions
- Isocaloric Atka mackerel and herring diets
- Altering levels of energetic intake.

- Monitor body mass, composition, and blood chemistry (incl. RNA markers of nutritional stress).

- Experiment repeated spring and fall with seasonally appropriate Atka mackerel.

Steller sea lion Atka mackerel feeding trials
(*Spring results*)



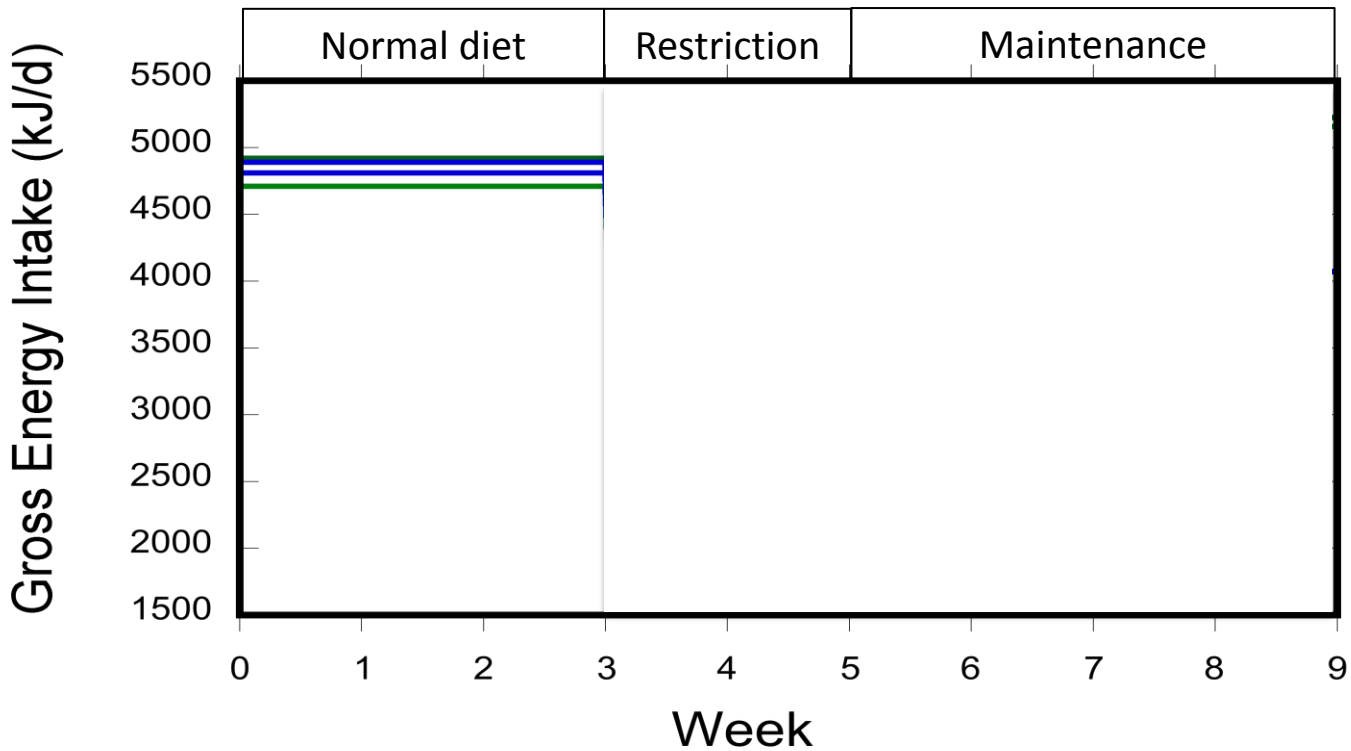
Normal diet:

Slightly greater growth on herring with same gross energy intake (reflecting differences in net energy calculations)

Mass change: Herring +2.9%

Atka +0.0%

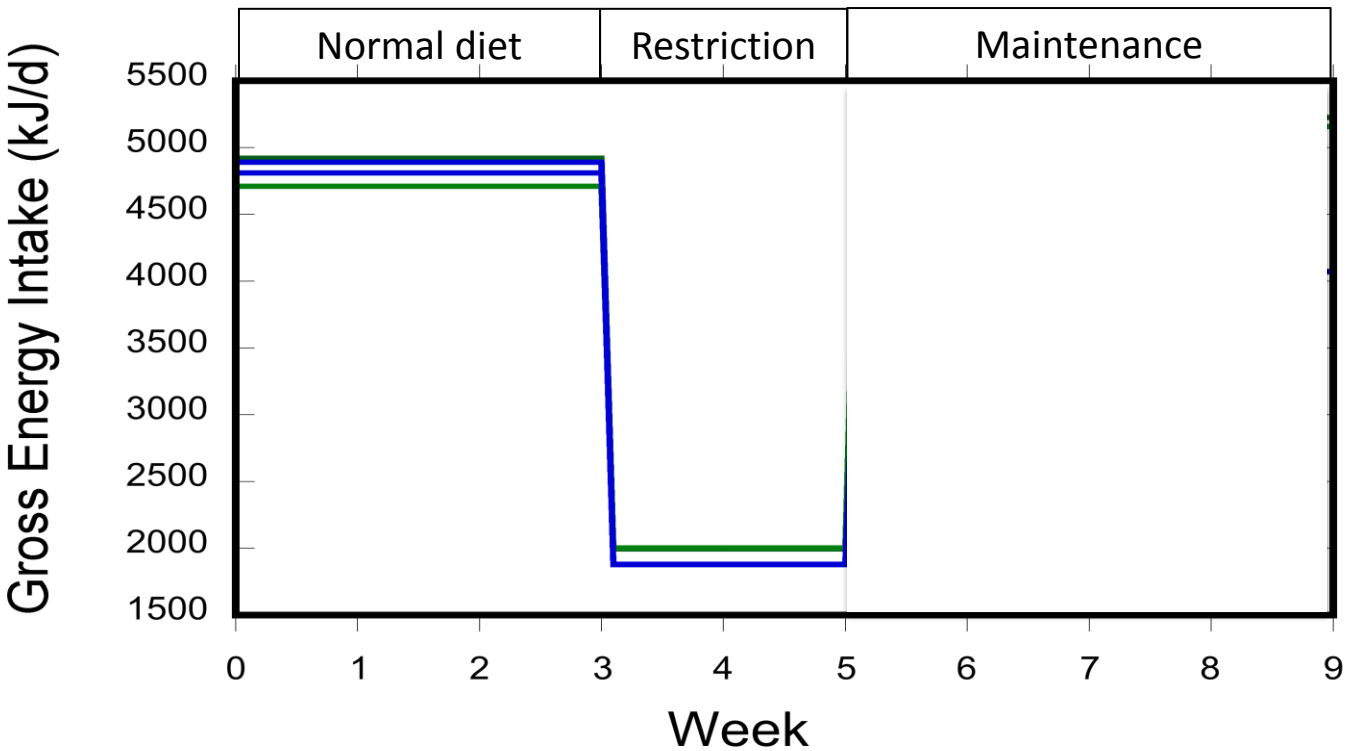
Goal: Normal growth 10% mass loss No growth



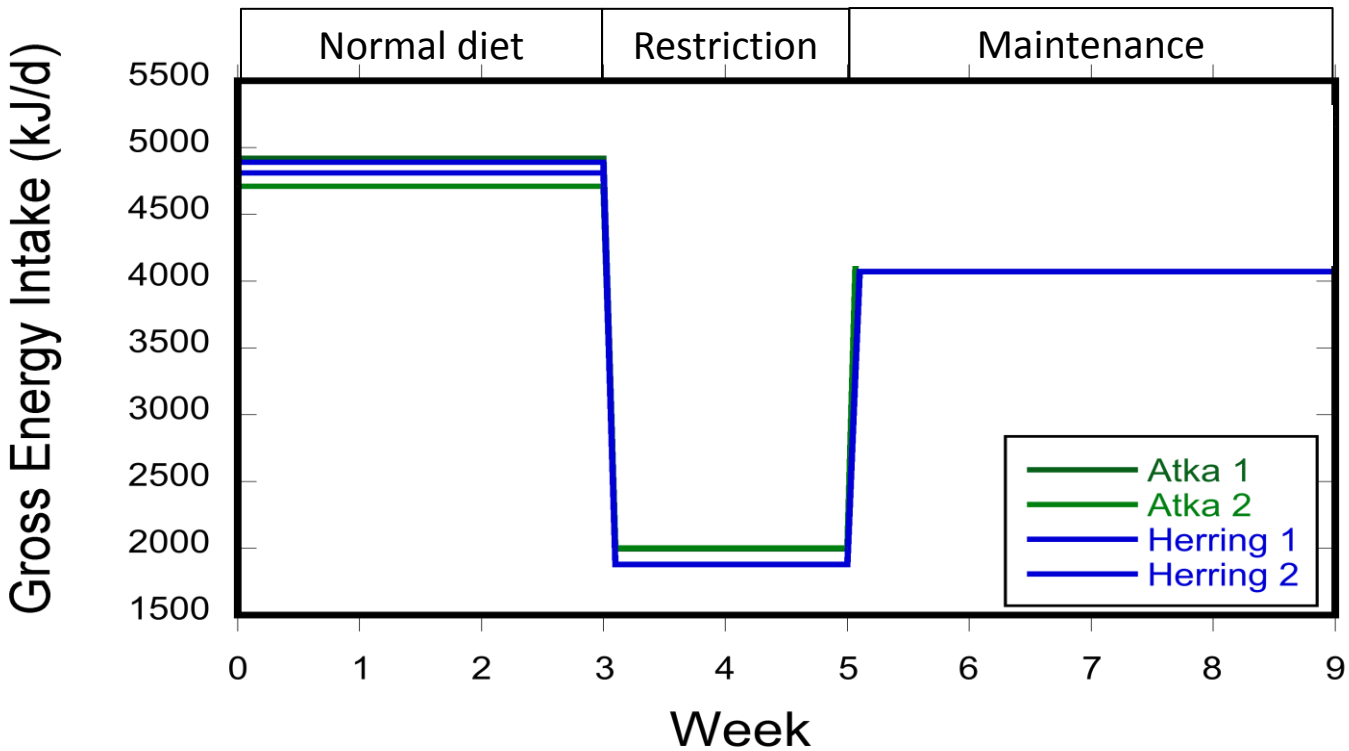
Restriction:

Slightly greater mass loss on AM with same gross energy intake

Mass change:	Herring +2.9%	Herring -7.2%	
	Atka +0.0%	Atka -10.1%	
Goal:	Normal growth	10% mass loss	No growth



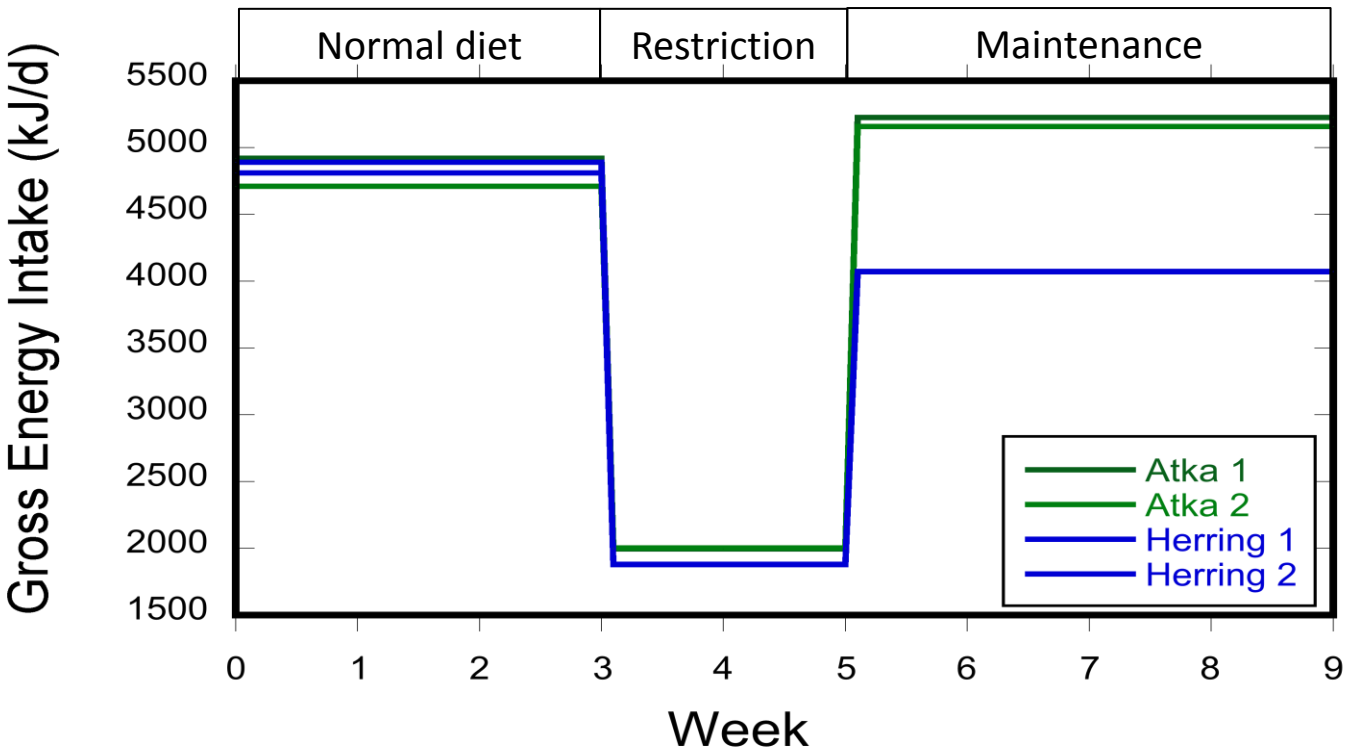
Mass change:	Herring +2.9%	Herring -7.2%	
	Atka +0.0%	Atka -10.1%	
Goal:	Normal growth	10% mass loss	No growth



Maintenance:

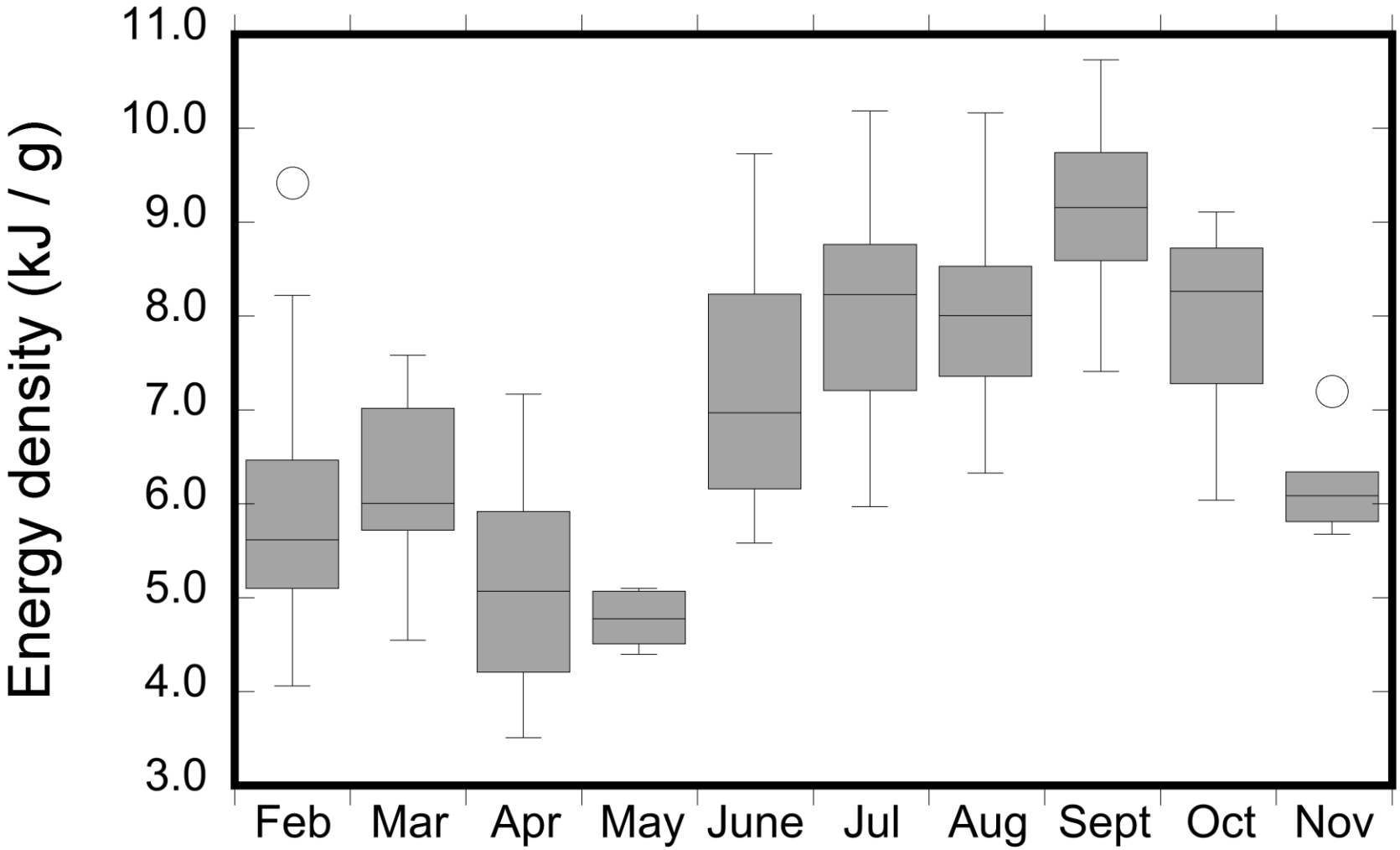
Requires >25% more gross energy to maintain body mass after restriction

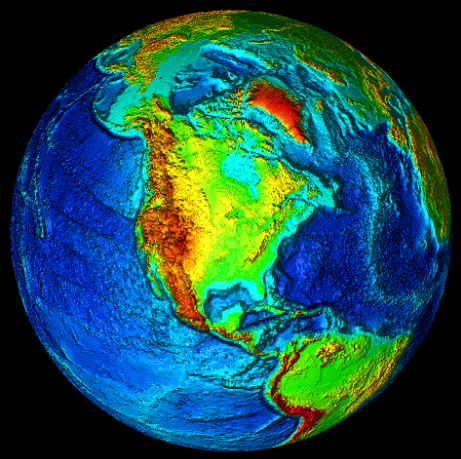
Mass change:	Herring +2.9%	Herring -7.2%	Herring +2.5%
	Atka +0.0%	Atka -10.1%	Atka -0.7%
Goal:	Normal growth	10% mass loss	No growth



Energy density of Atka mackerel by month

MA 541, 542, 543

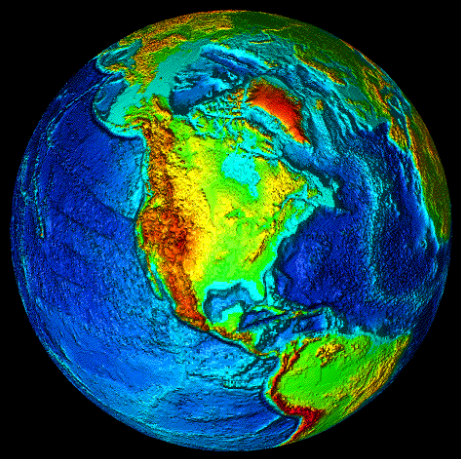




Other Studies

Hui *et al*. 2012. Steller sea lions and fisheries: competition at sea? *in prep.*

Trites *et al*. 2012. Diets of Steller sea lions in SE Alaska from 2000-2012. *in prep.*



Traditional Knowledge

“Cod were almost unknown until the sea lion herds diminished in 1873; now they are very common. The Atka mackerel was unknown on Attu before 1875, when it appeared unexpectedly. The natives say that it drove the sea lions away.”

Weissinger (1961)

Thank You
www.marinemammal.org
UBC