Marine Top Predators as Climate and Ecosystem Sentinels

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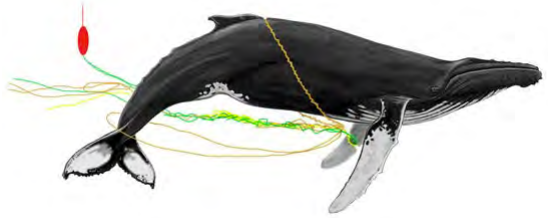
FUTURE Science Program PICES

New conditions, new risks



The Mercury News

News > Environment & Science

46 whales were confirmed entangled in fishing gear on West Coast in 2018, trending up from the year before

2 of 23

An entangled whale was spotted first in Laguna Beach, then in Newport Beach as rescue teams tried to help Monday, Dec. 11, 2017. (Photo courtesy of Ryan Lawler, Newport Coastal Adventure)

By ERIKA I. RITCHIE |

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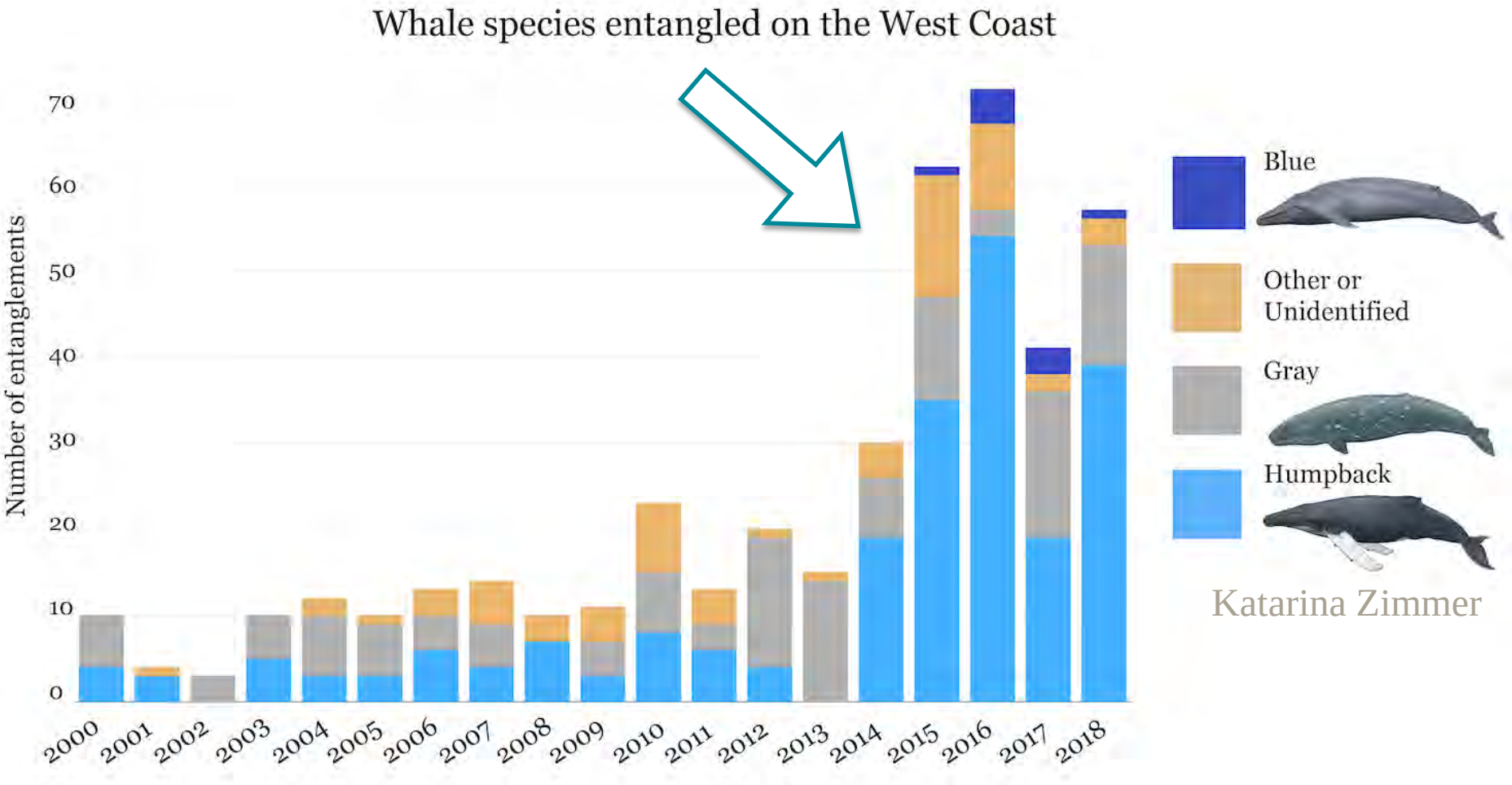
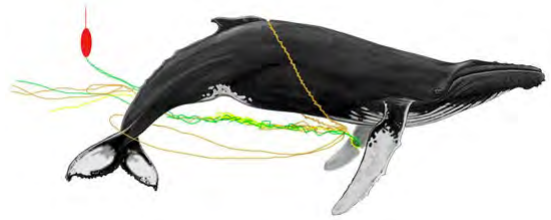


CSI:

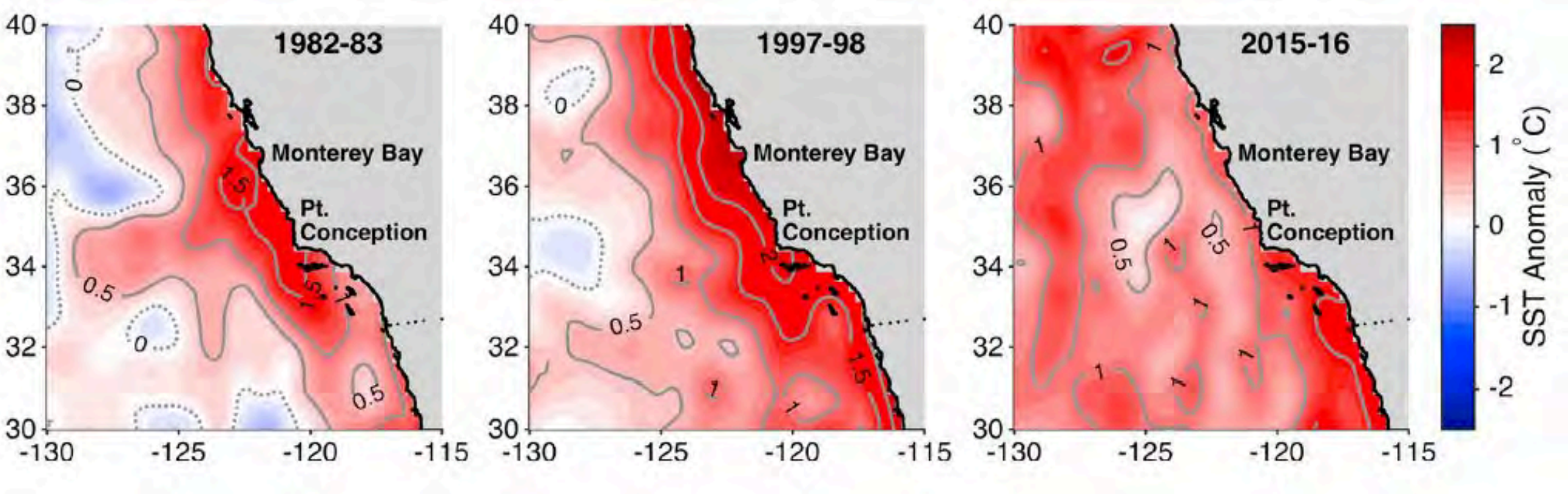
CRIME SCENE INVESTIGATION

2015-16 Whale Entanglements



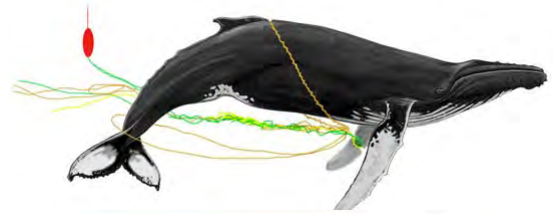
Key ecosystem ingredients:

Persistent marine heat wave



Jacox et al. 2016 *GRL*

2015-16 Whale Entanglements

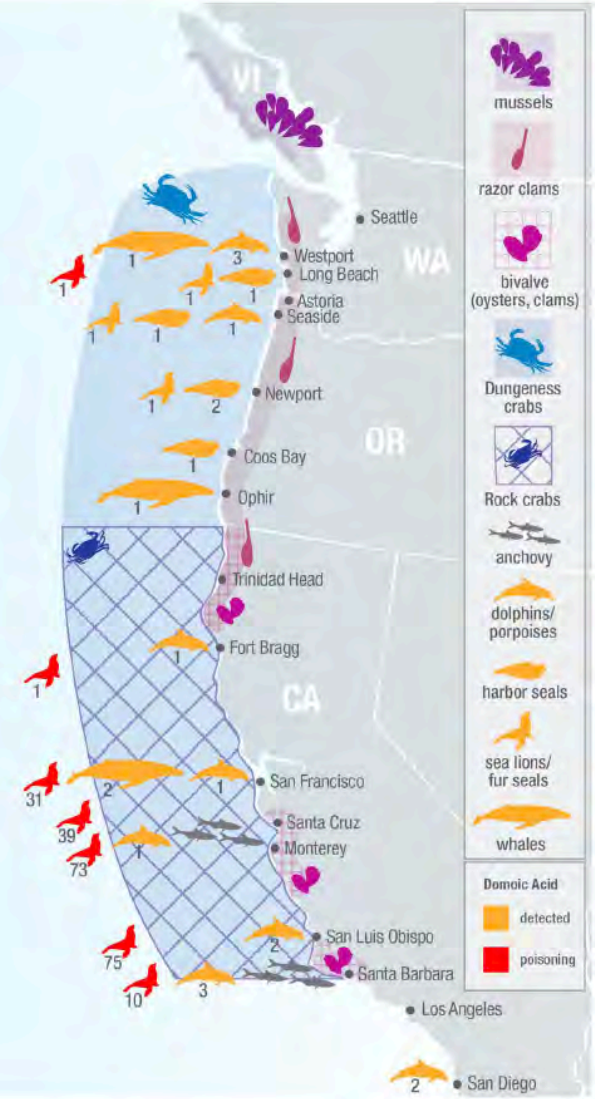


Key ecosystem ingredients:

Persistent marine heat wave

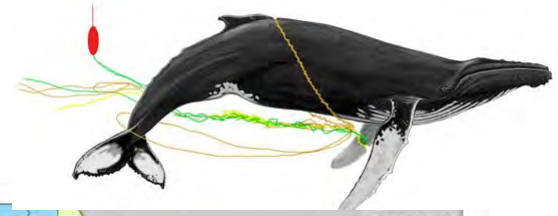
Record HAB + domoic acid delayed Dungeness crab fishery

2015	Shellfish Harvest and Fishery Closures with Maximum Domoic Acid Values
7-May	Quinault tribe razor clam harvest closure (WA)
8-May	Commercial, tribal & recreational razor clam harvest closure (WA)
9-May	Razor clam harvest closure (northern OR)
14-May	State wide razor clam harvest closure (OR)
15-May	Shellfish harvest closure (BC Canada)
29-May	Anchovy viscera maximum 1671 ppm (CA)
1-Jun	Anchovy, sardine fishery closure (CA)
3-Jun	Dungeness crab maximum 65 ppm (WA)
5-Jun	Dungeness crab fishery closure (WA)
3-Jul	Anchovy, sardine, mussel, & clam closures expanded to southern CA
11-Sep	Dungeness crab maximum 140 ppm (northern CA)
27-Oct	Razor clam maximum 170 ppm (southern OR)
3-Nov	Dungeness crab & rock crab warning for recreational harvest (CA)
6-Nov	Commercial rock crab fishery closed (CA)
8-Nov	Dungeness crab maximum 70 ppm (southern OR)
11-Nov	Dungeness crab & rock crab recreational & commercial fishery closure (CA)
22-Nov	Dungeness crab maximum 270 ppm (northern CA)
23-Nov	Rock crab maximum 1000 ppm (southern CA)
23-Nov	Delayed opening of commercial Dungeness crab fishery (WA, OR, CA)
9-Feb-2016	CA seeks federal disaster declaration for commercial crab fishery



McCabe et al. (2016)

2015-16 Whale Entanglements



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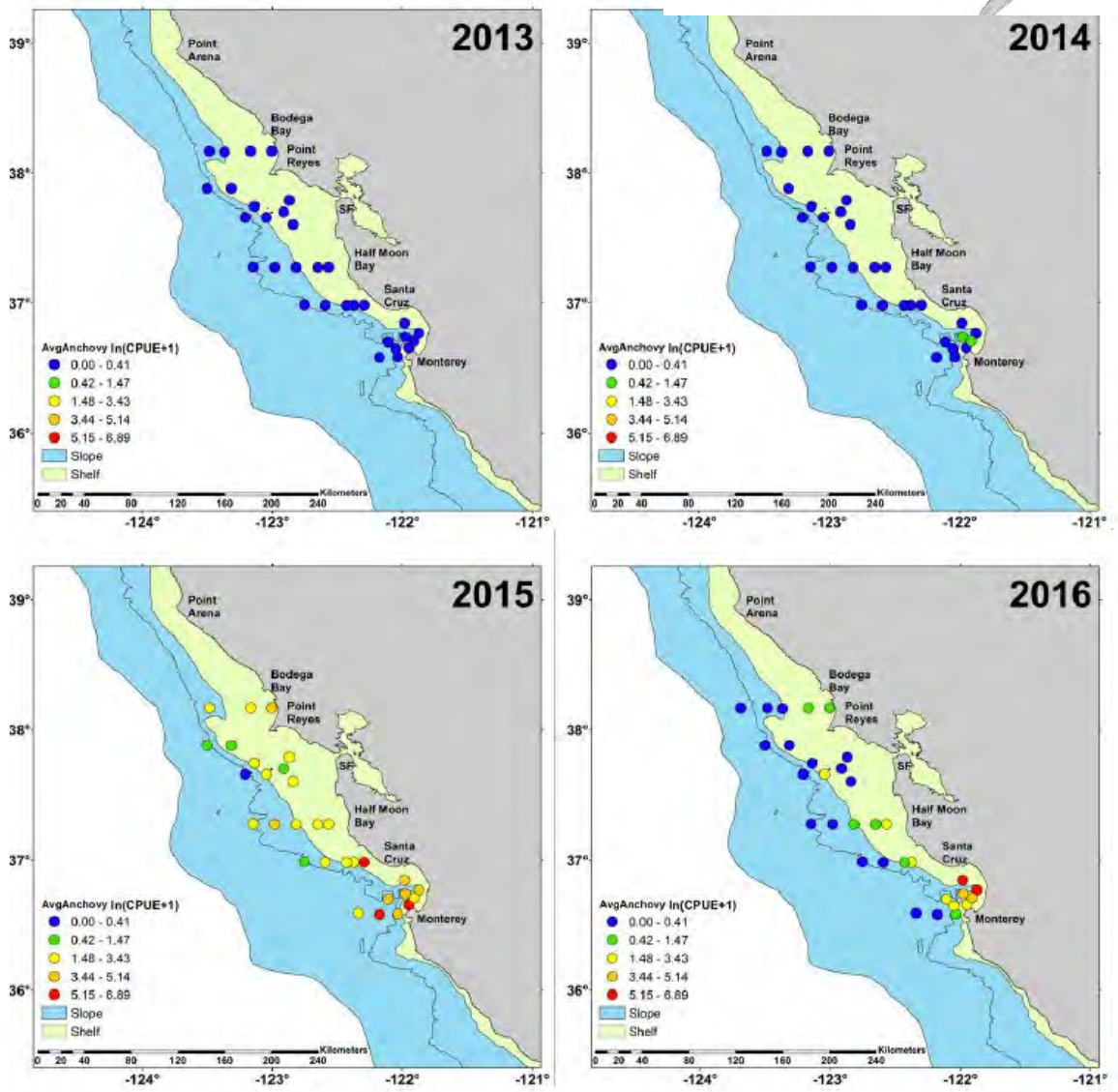
Record HAB + domoic acid delayed Dungeness crab fishery

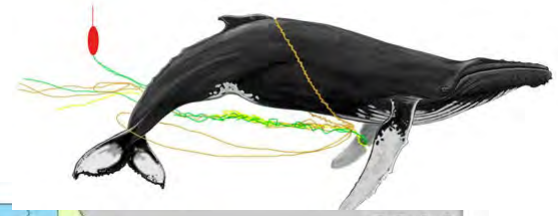
Low krill off shelf break & high concentration of anchovies on shelf



May-June Anchovy CPUE from trawls

Santora et al. in review *Nature Communications*

2015-16 Whale Entanglements



Key ecosystem ingredients:

Persistent marine heat wave

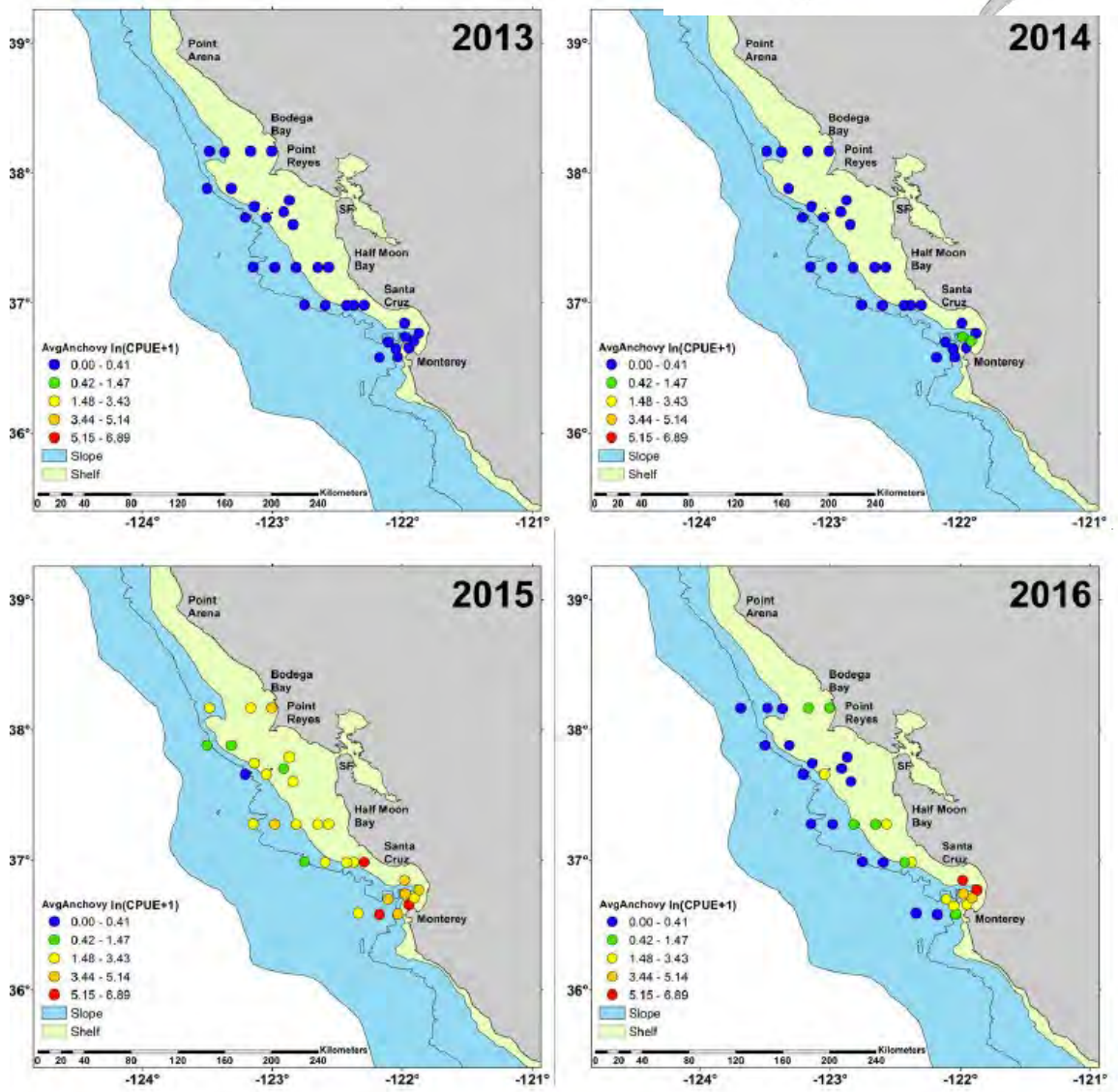
Record HAB + domoic acid delayed Dungeness crab fishery

Low krill off shelf break & high concentration of anchovies on shelf

Recovering whale populations + Humpback whale prey switching

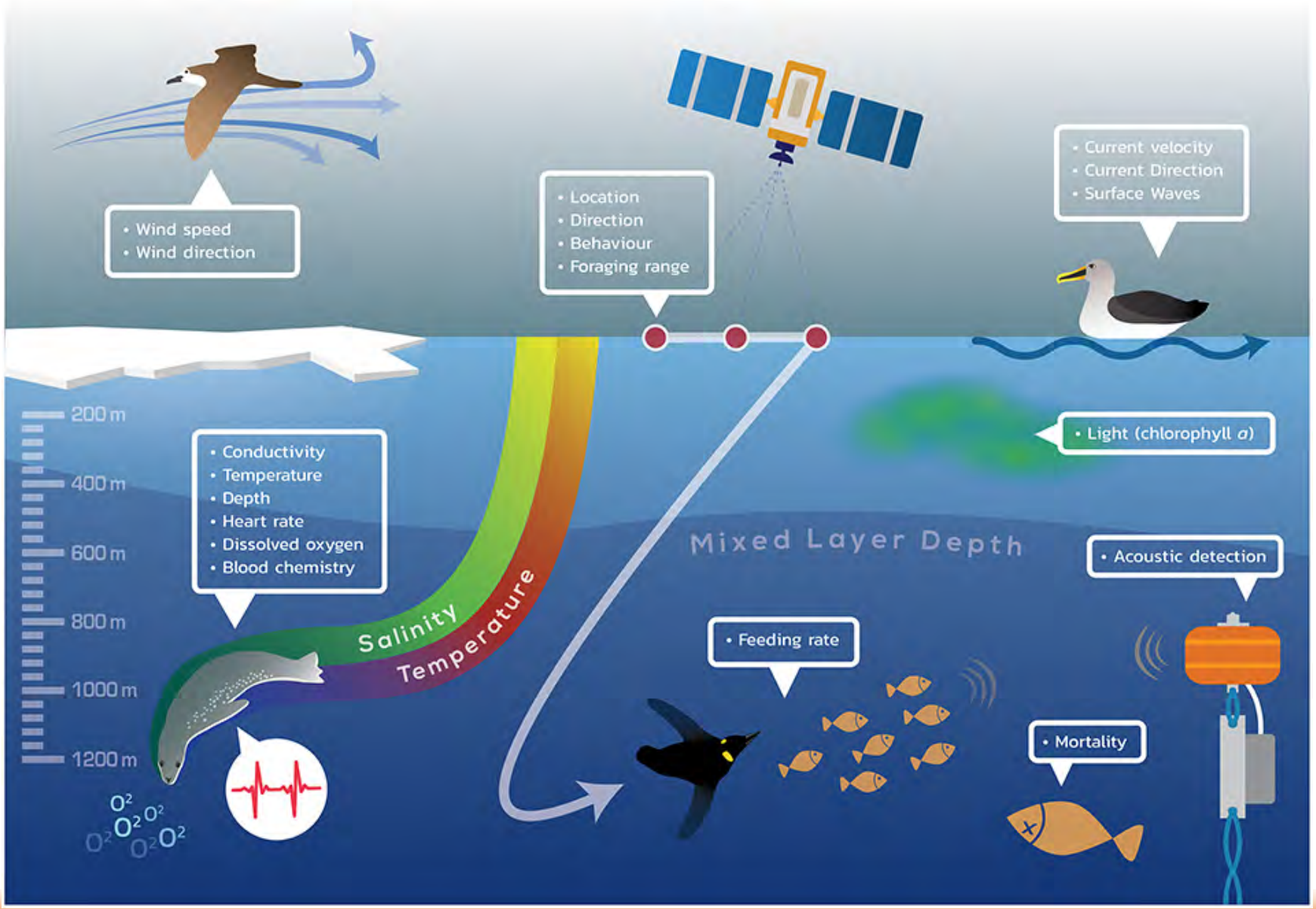
End result: unusual time-space overlap between **foraging humpback whales** and **crab pots**

Santora et al. in review *Nature Communications*



May-June Anchovy CPUE from trawls

What is an ecosystem sentinel?



- Global Ocean Observing System
- What can animals measure and tell us about the environment?
- Direct measurements are useful, but **what about** ecosystem thresholds

Harcourt et al. 2019 *F Mar Sci*

What is an ecosystem sentinel?

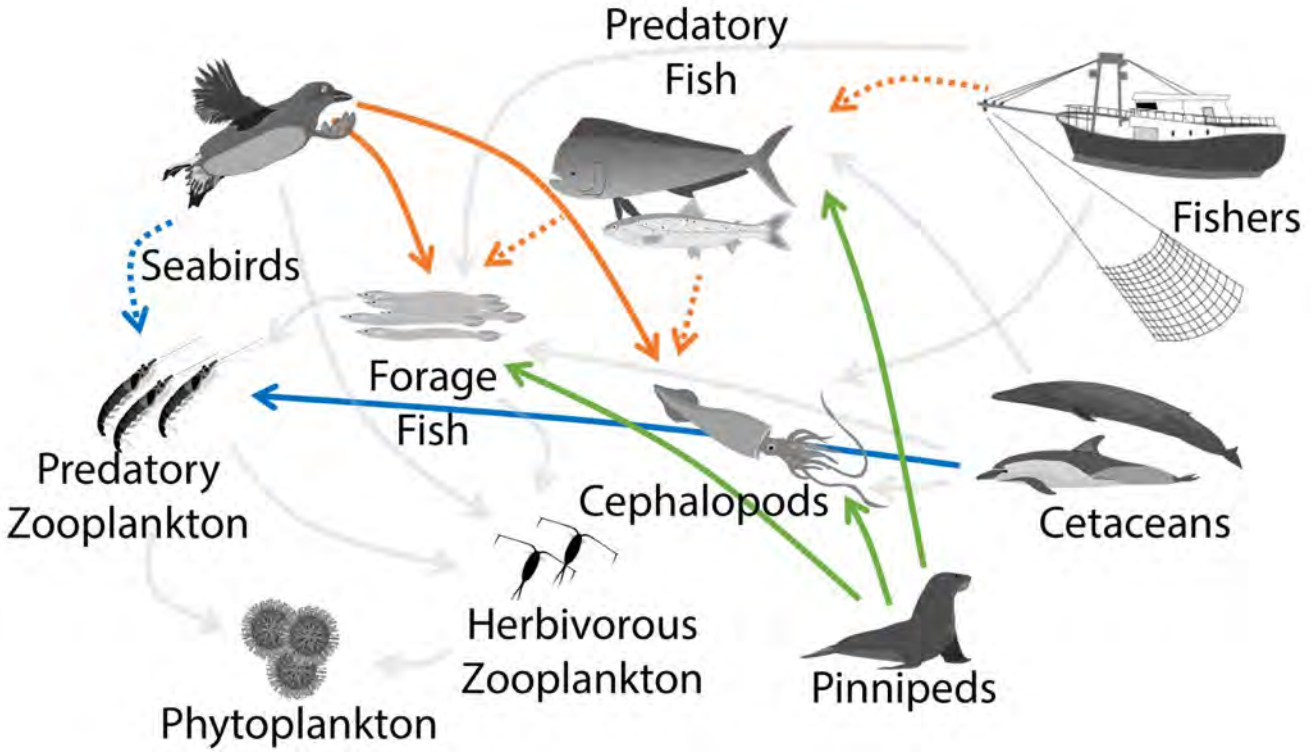
"A sentinel species provides the perspectives and methodologies to tease apart the complexity of marine ecosystems." - Tabor and Aguirre 2004 *EcoHealth*

"…where do we look for signals of how climate change influences ecosystems? Lakes and reservoirs are an important part of the answer." - Williamson et al. 2009 *Science*

"Species dependent on sea ice, such as the polar bear (*Ursus maritimus*) and the ringed seal (*Phoca hispida*), provide the clearest examples of sensitivity to climate change." - Moore 2008 *J. Mammology*

Identifying and monitoring sentinels

An ecosystem sentinel as a species that responds to ecosystem variability and/or change in a timely, measurable, and interpretable way, and can indicate an otherwise unobserved change in ecosystem structure or function



Ecosystem Sentinel	
Metric	
Unobserved Ecosystem Component	
Future Ecosystem Response	

Hazen et al. 2019 *Frontiers in Ecology and the Environment*

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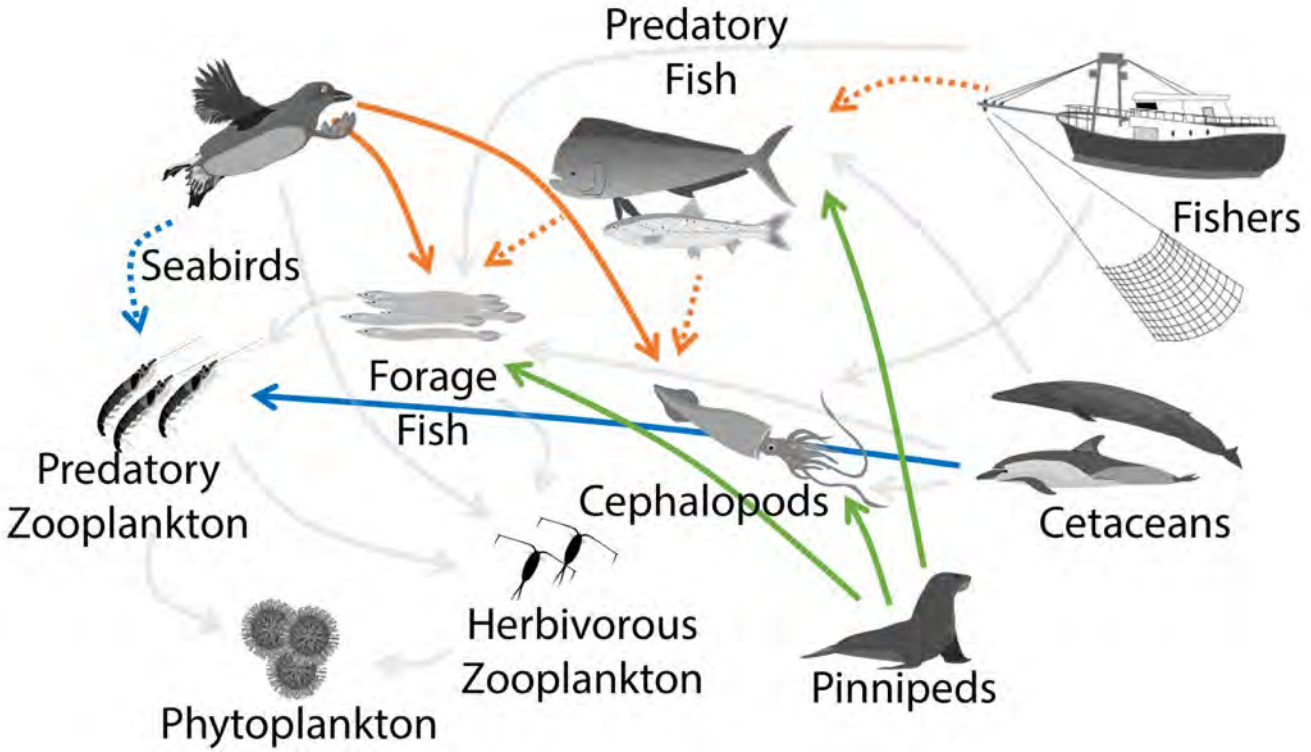

Ecosystem Sentinel	Sea Lion
Metric	Population trends
Unobserved Ecosystem Component	Forage fish Cephalopods Predatory fish
Future Ecosystem Response	

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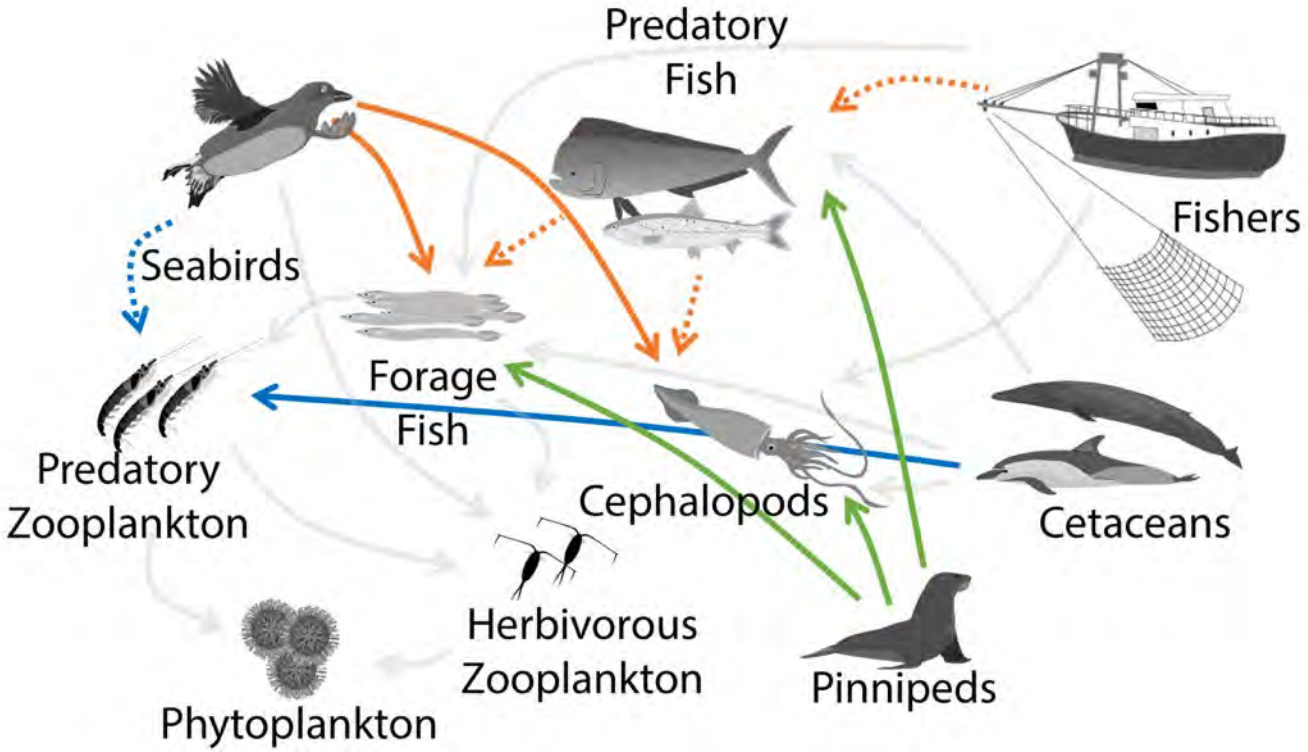

Ecosystem Sentinel	Sea Lion	Alcid seabirds (Auks)
Metric	Population trends	Diet and/or egg production
Unobserved Ecosystem Component	Forage fish Cephalopods Predatory fish	Forage fish Cephalopods
Future Ecosystem Response		

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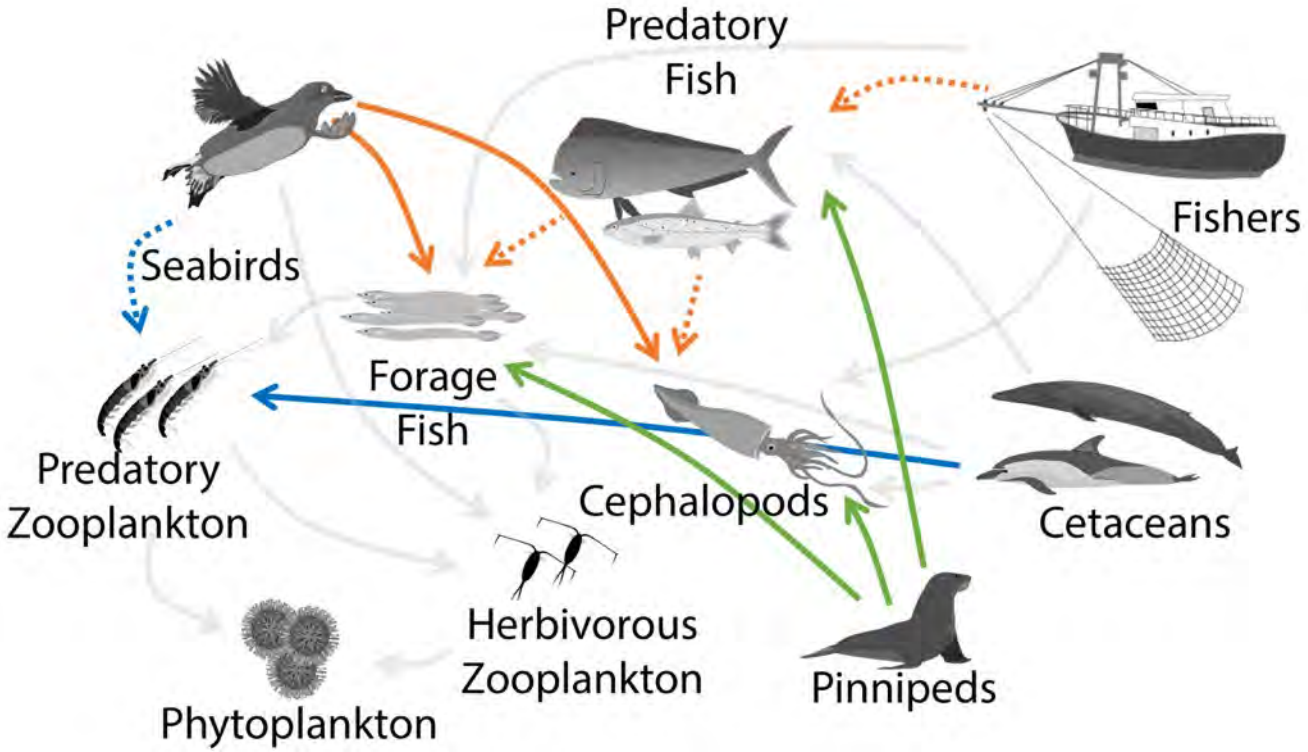

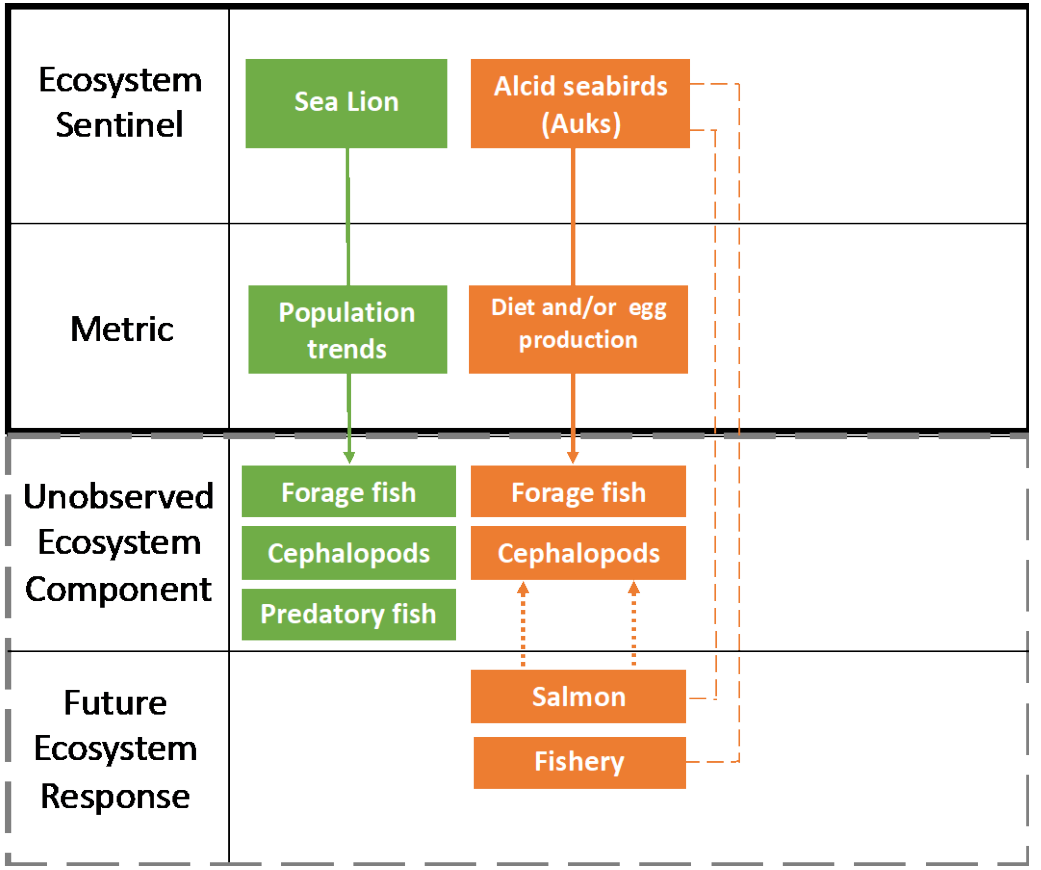

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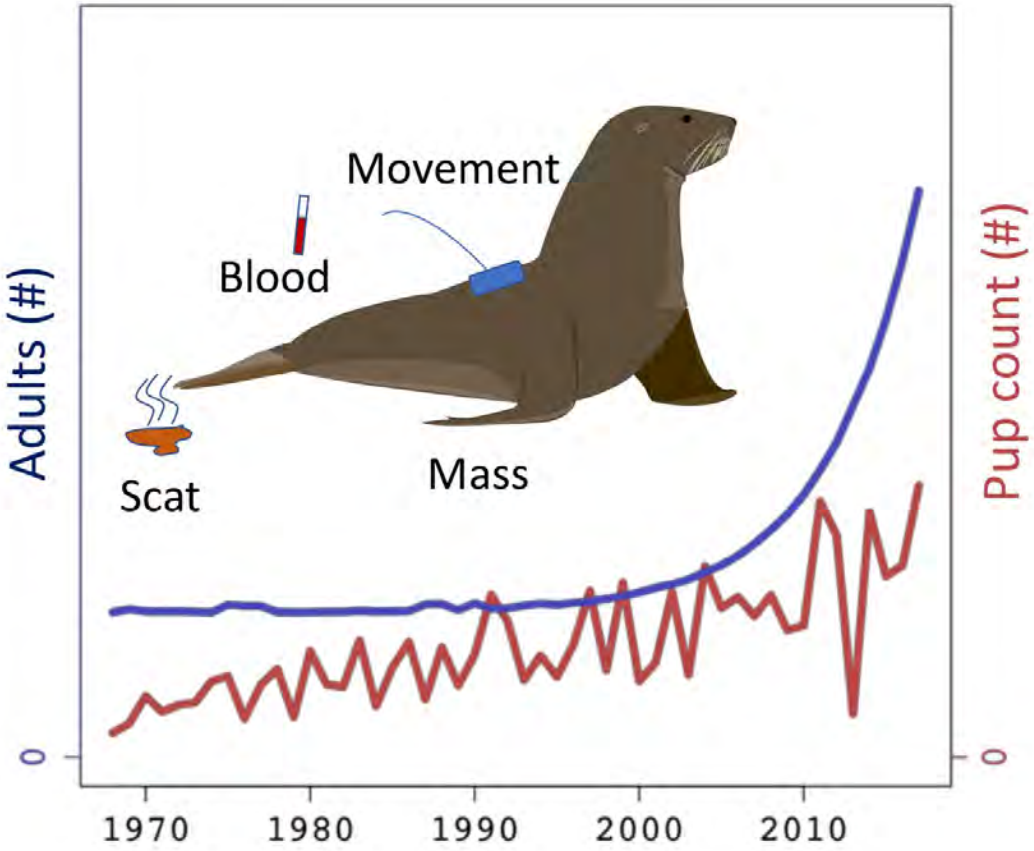

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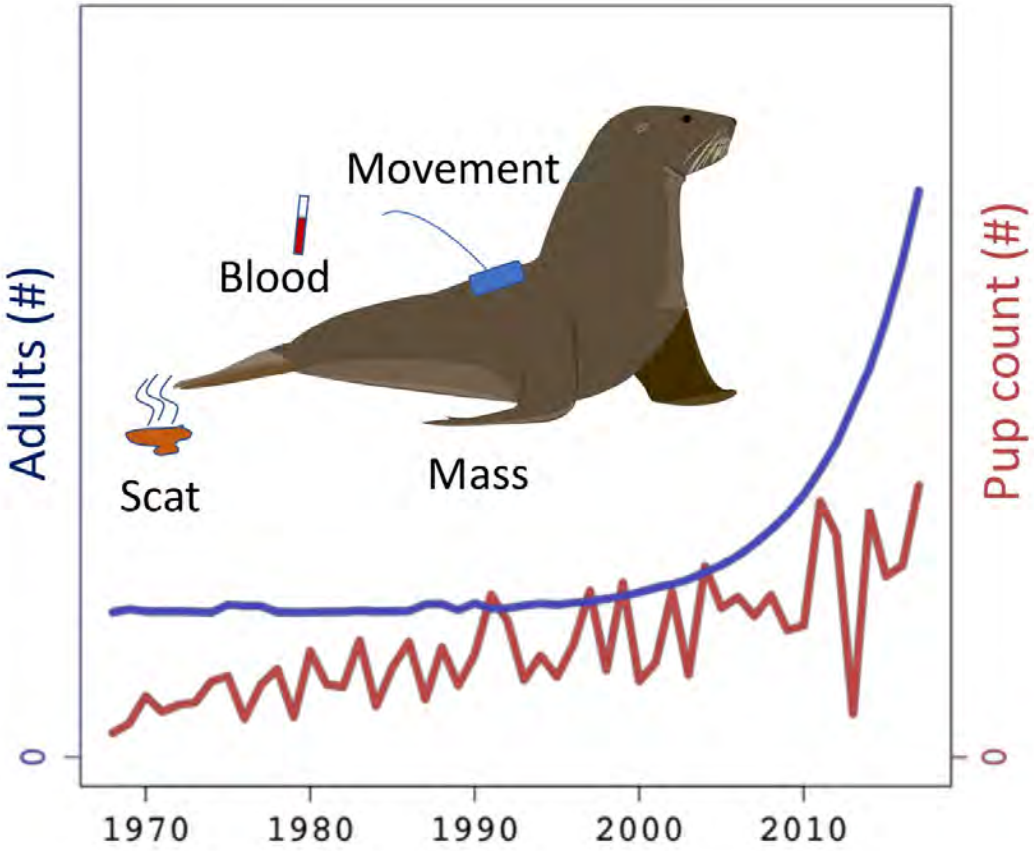

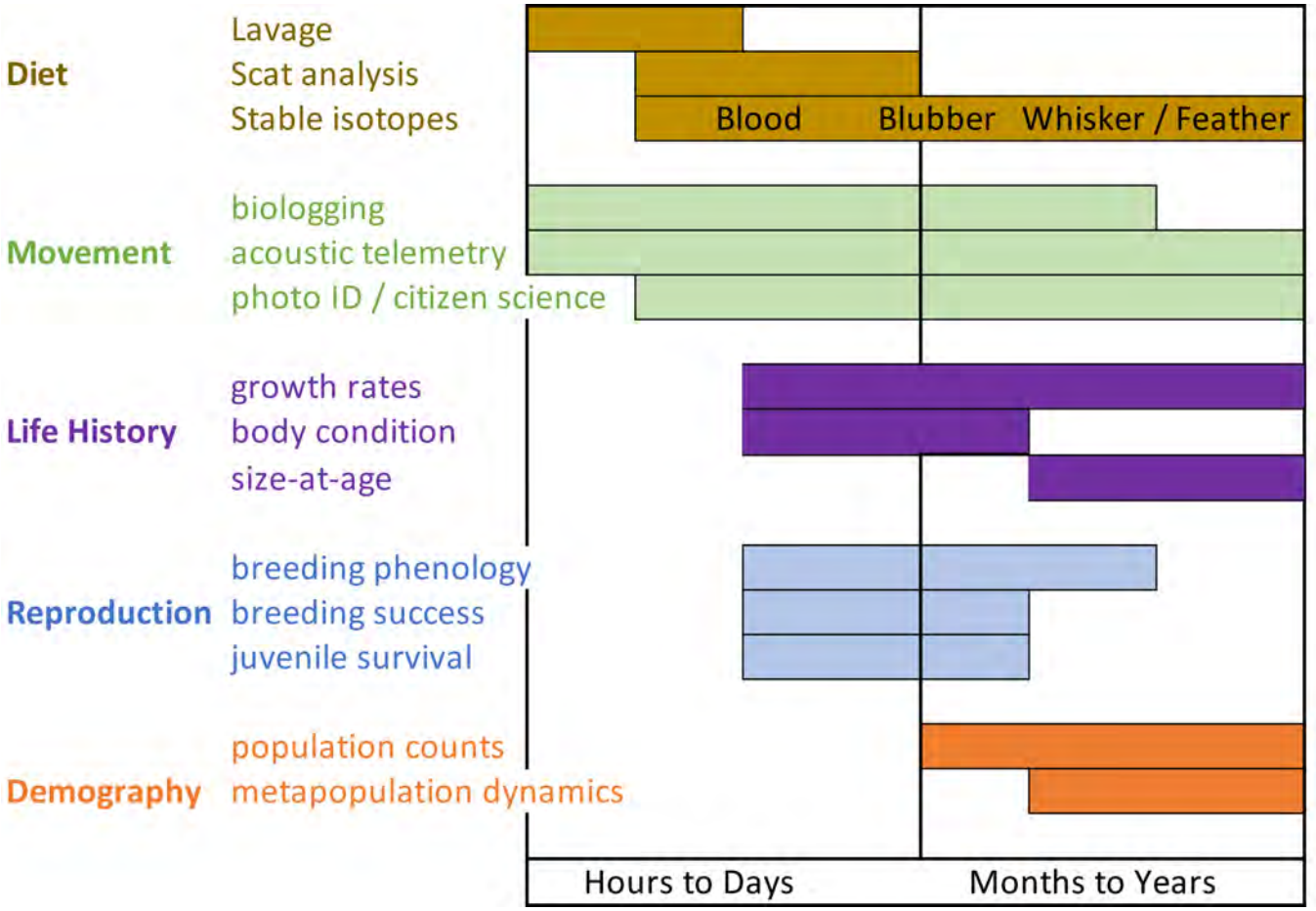

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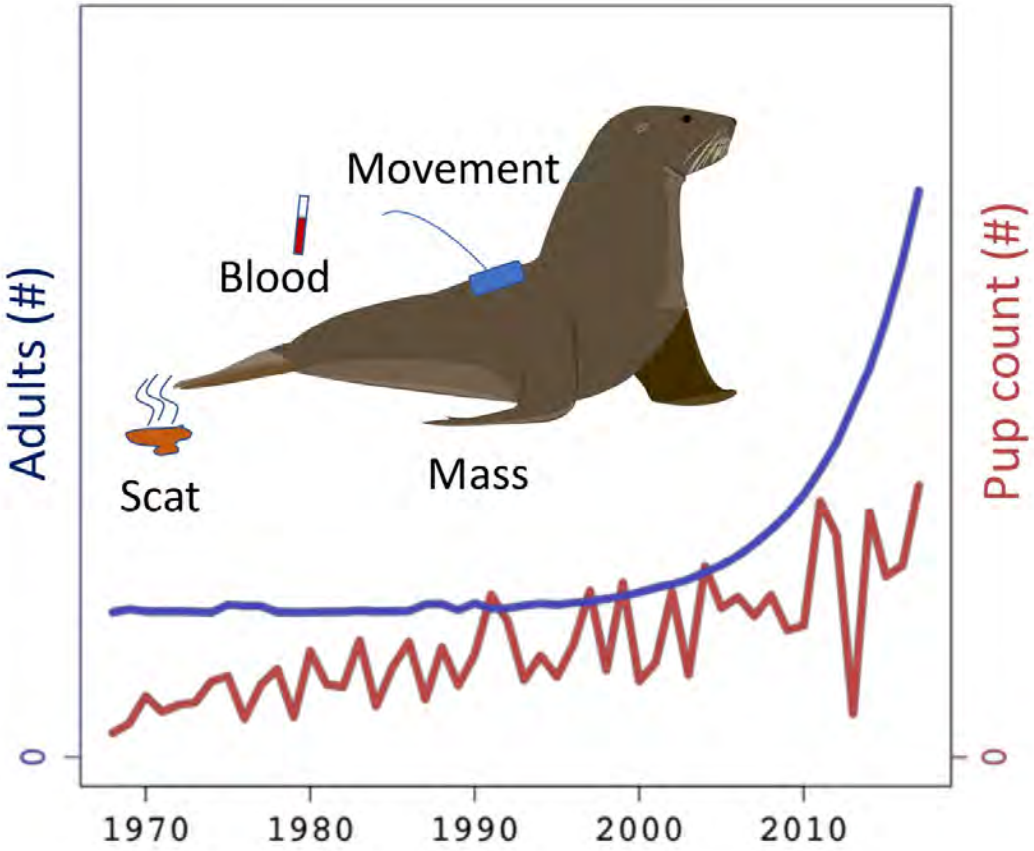

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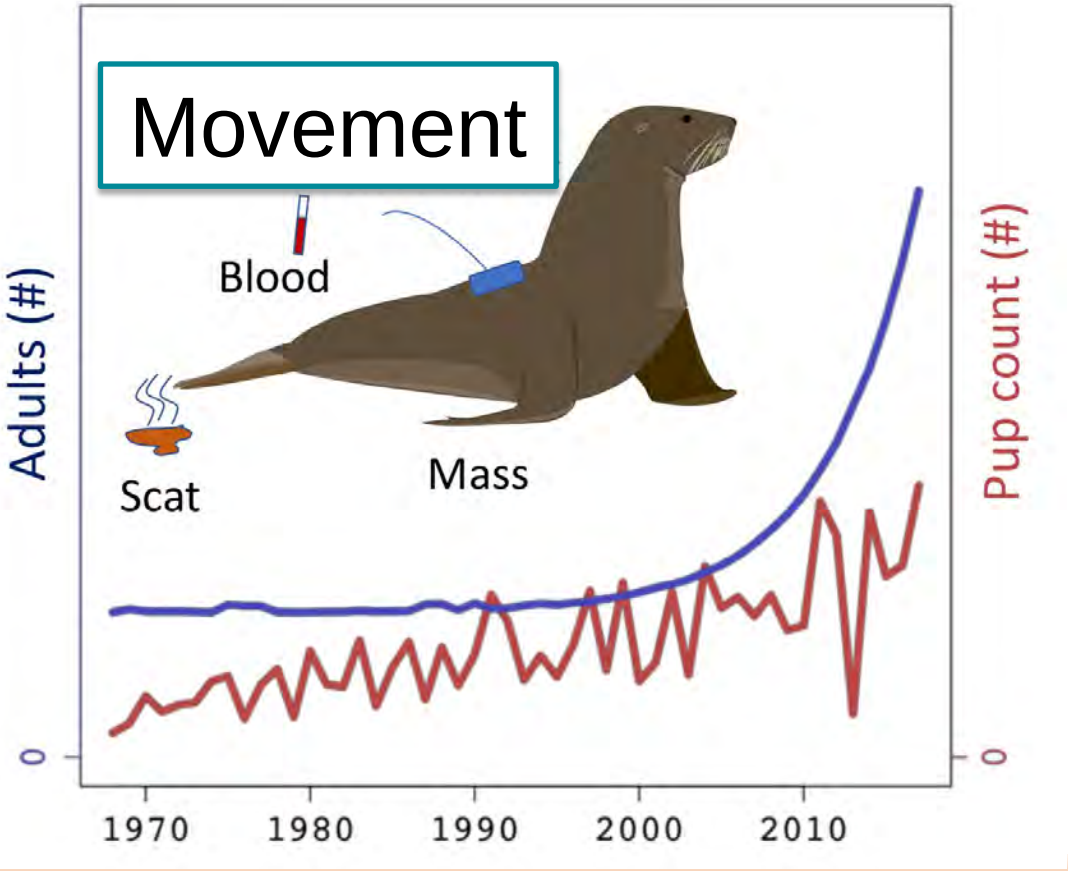
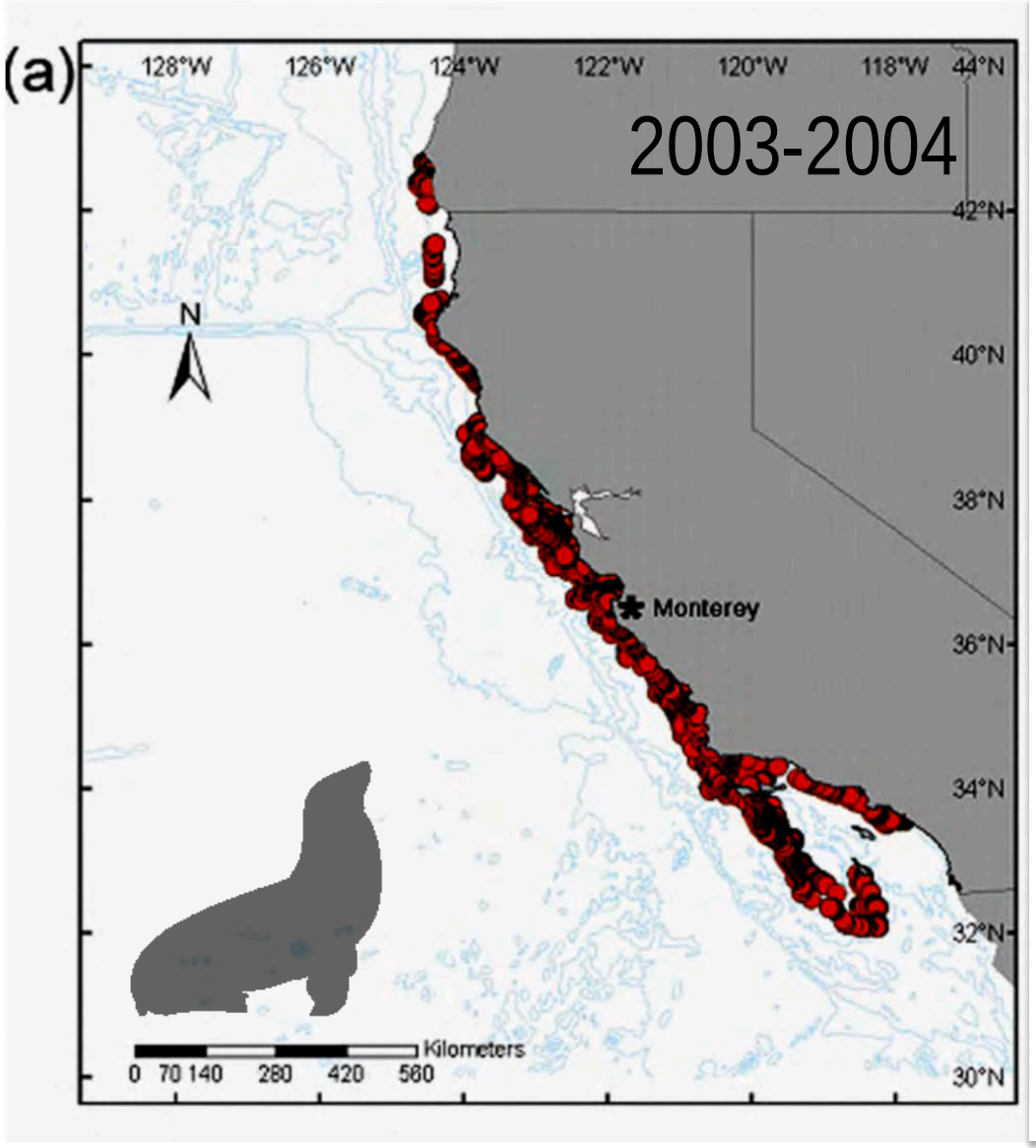


Hazen et al. 2019 *Frontiers in Ecology and the Environment*

2005 in the Northeast Pacific



Weise et al. 2006, GRL

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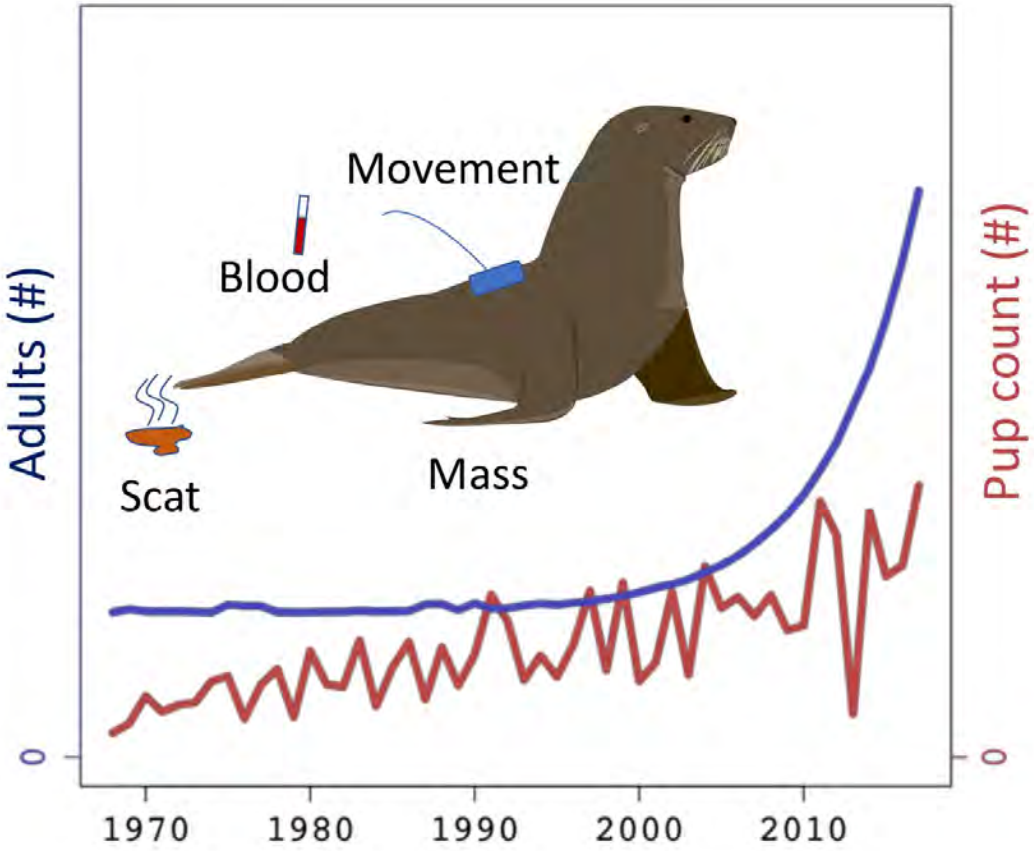

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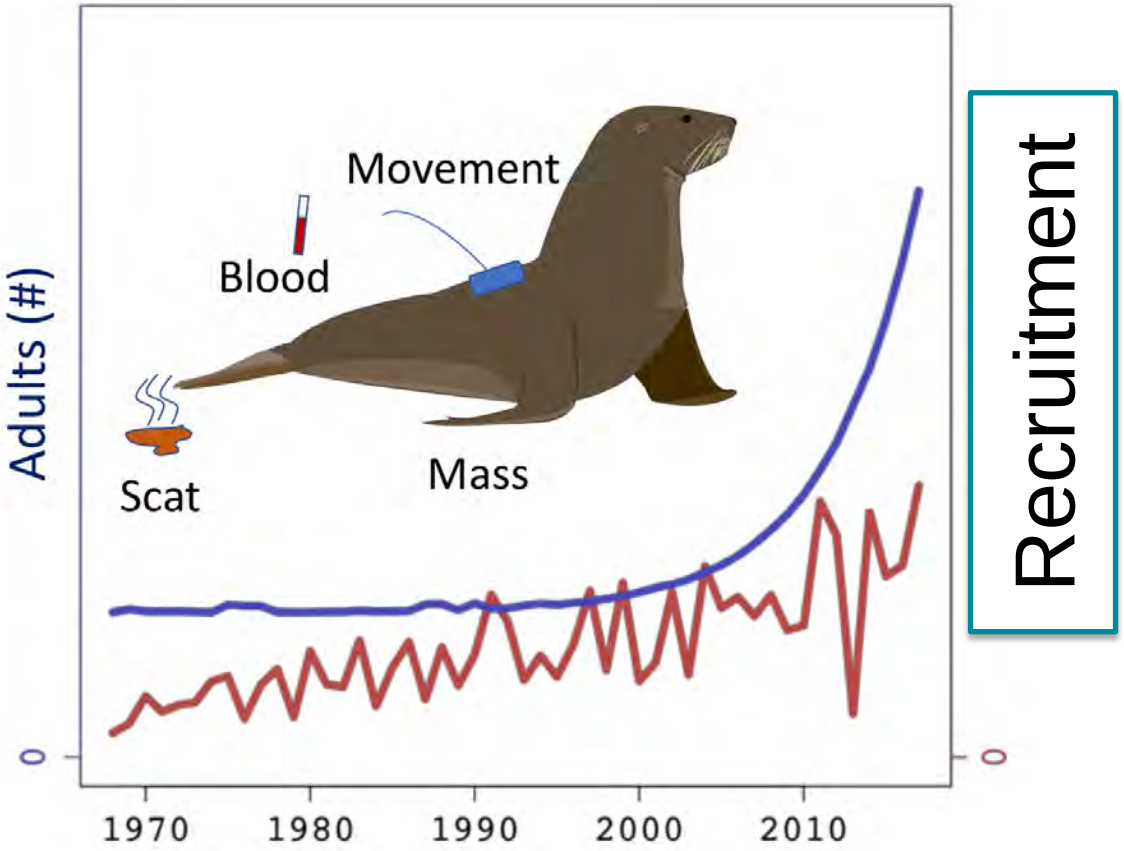

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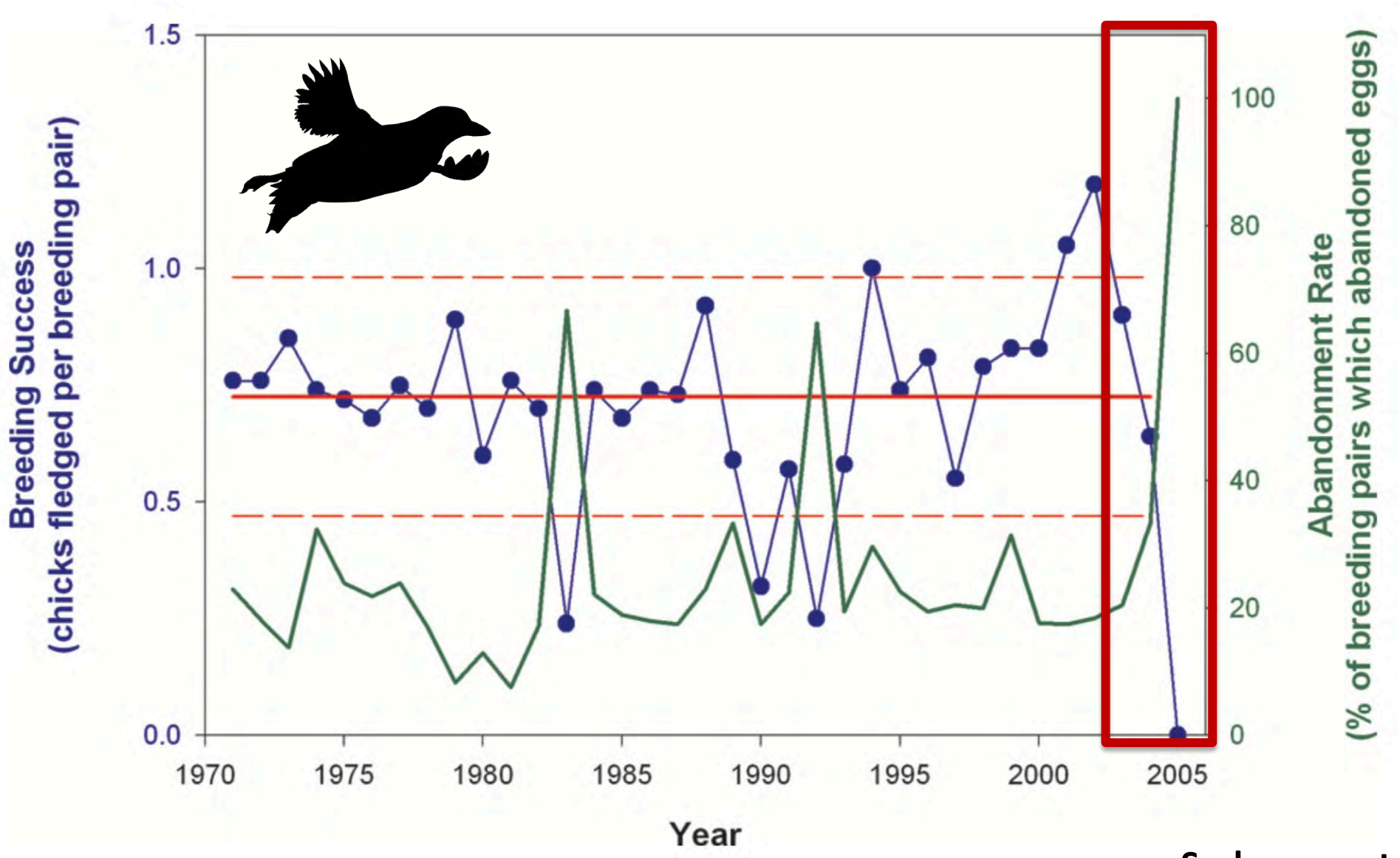
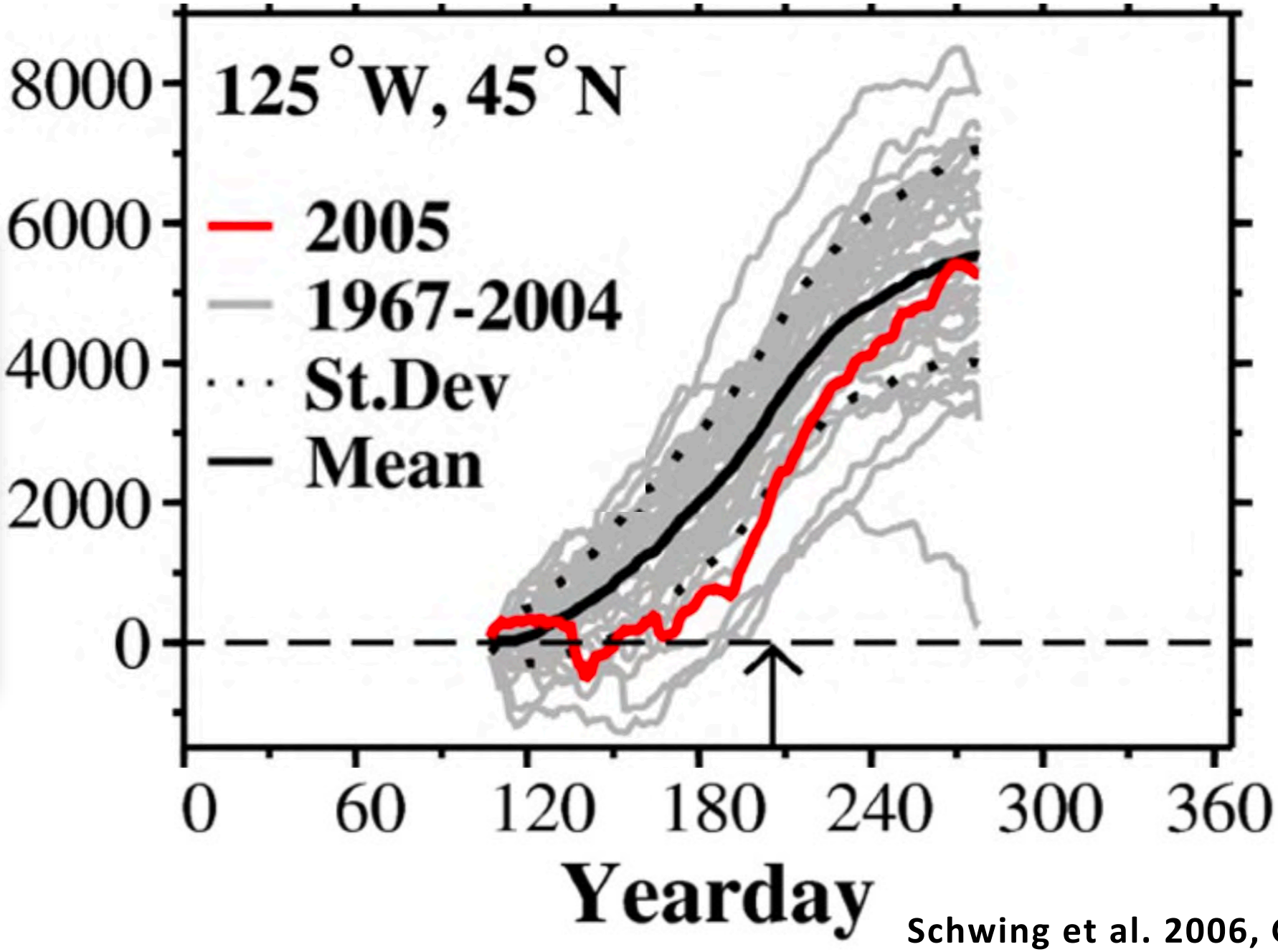


Sydeman et al. 2006, GRL

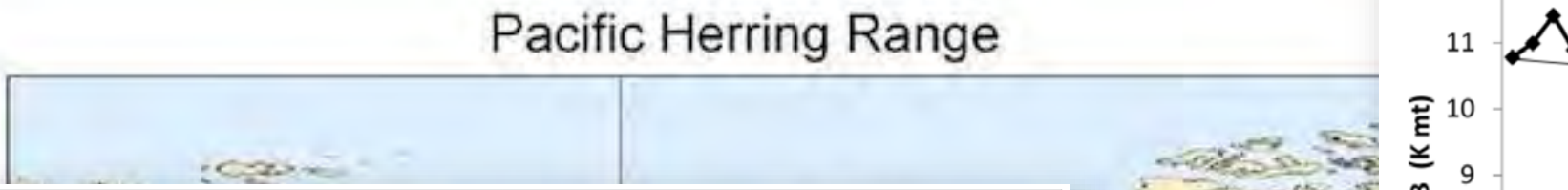
Upwelling

What delay in upwelling leads to an ecosystem response?



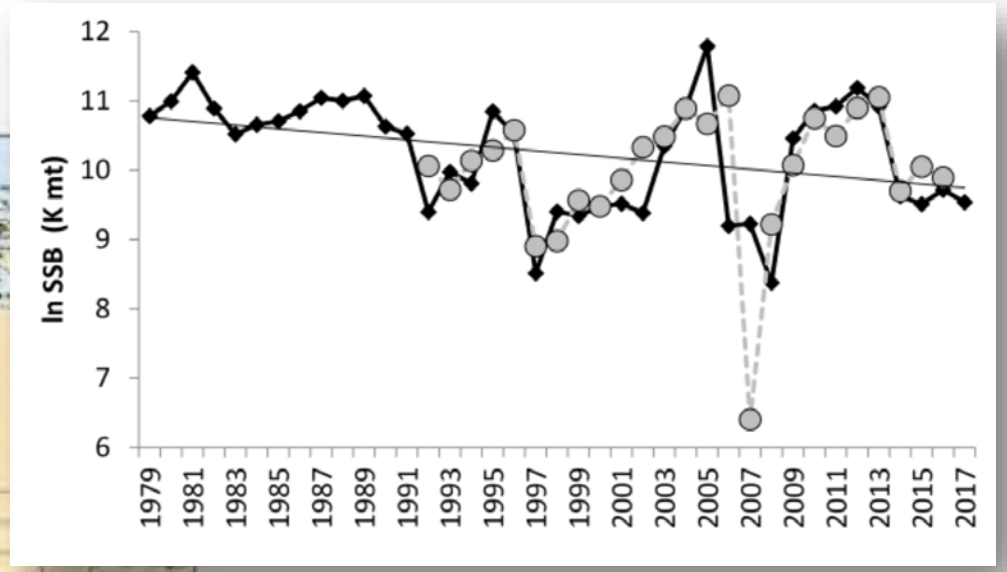
Schwing et al. 2006, GRL

California Herring EBFM



Herring predator	CCS summer diet[1]	Summer California diet	Winter California diet	GOF (Sep-Dec) diet	GOF (Oct-Mar) diet	GOF-MB (Dec-Mar) diet	GOF (Mar-Apr) diet	Source - Winter diet central California (years)
Chinook salmon	9%	4%	27%	3% (1-5%)	16% (5-27%)	29% (10-49%)	24% (9-39%)	1955 GOF [28]; 1980-86 GOF [29]
humpback whale	~13%	x [2]	~19%	~5%		~33% (26-40%)		1920, 1922 MB [66]; 1988, 1990 GOF [67]
common murre	7%	0%	6%		20% (12-28%)		28%	1974-75 Sep-Apr MB [68]; 1985-88 coastal GOF only [69]
harbor seal	6%	8%	1%					1968-1973 cenCA [70]; 1991-2 SFB, MB, Elkhorn Slough [71-73]; 2007-8 SFB [74]
Pacific hake	11%	7%						1989 (Jul-Sep) Pt. Conception - Cape Blanco [75]
rhinoceros auklet [3]	6%	1%	1%					1974-75 Sep-Apr MB [68]
California sea lion [3]	4%	1%	<1%					1998-9 Feb-Apr MB [76]; 2009 Nov-Dec MB (Thayer et al. unpubl. data)

83 predators eat CC herring



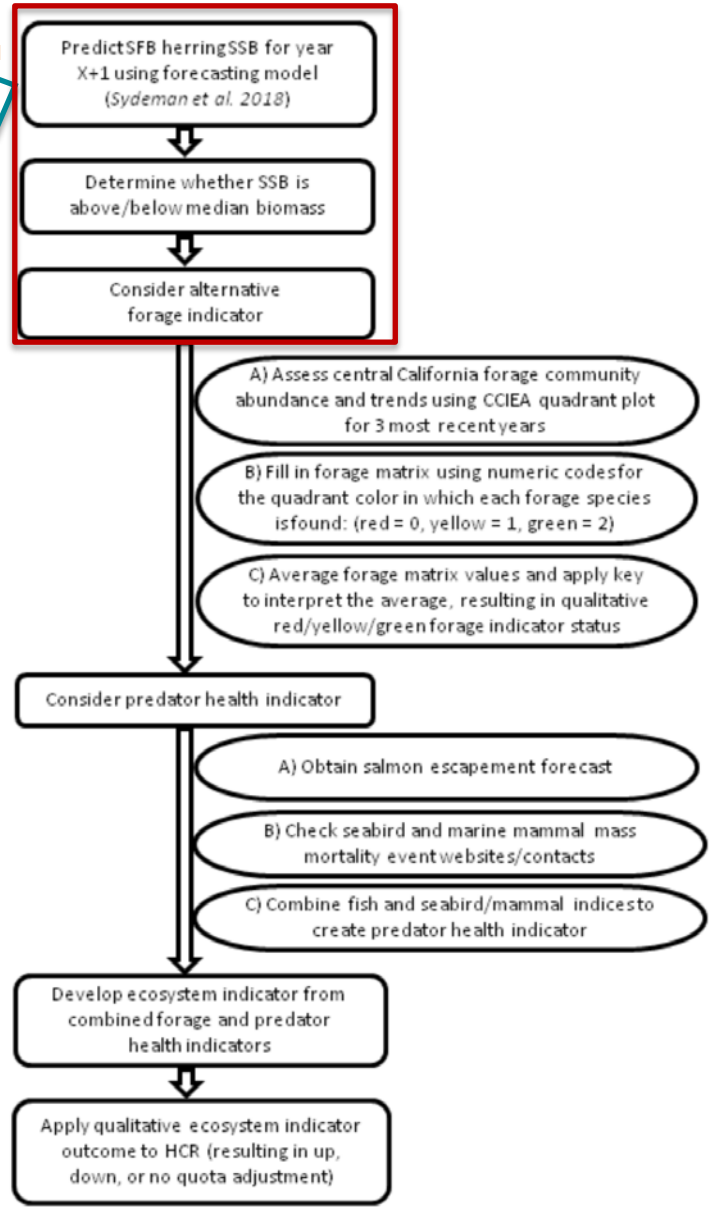
Timeseries of SFB herring SSB, observed (solid black line with triangles) vs. predicted (dashed gray line with circles)

Thayer et al. in review *Mar Policy*

Top predators in forage fish EBFM

+

SST+ model for Herring



California Herring

Sydeman et al. 2018 *Fish Res*; Thayer et al. in review *Mar Policy*

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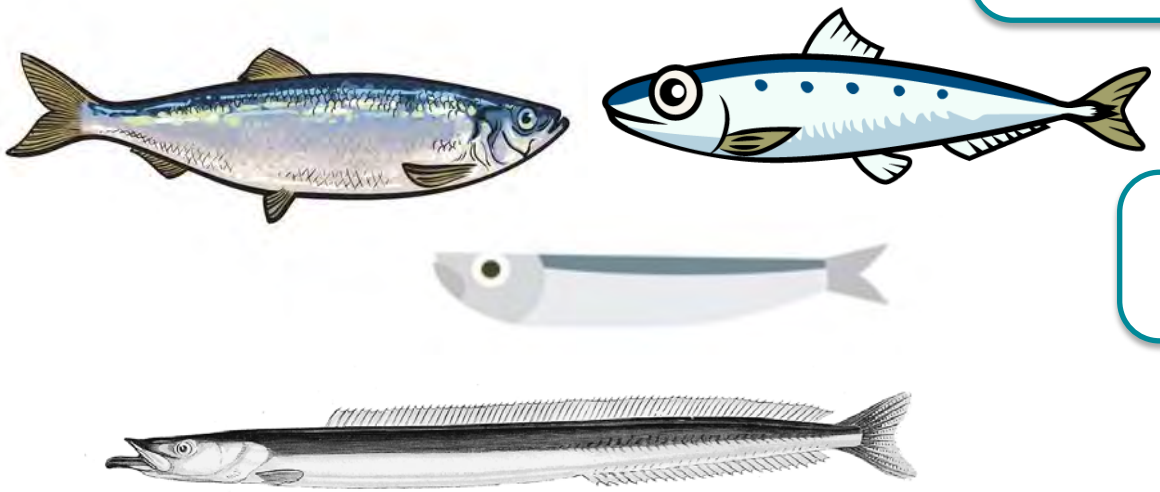
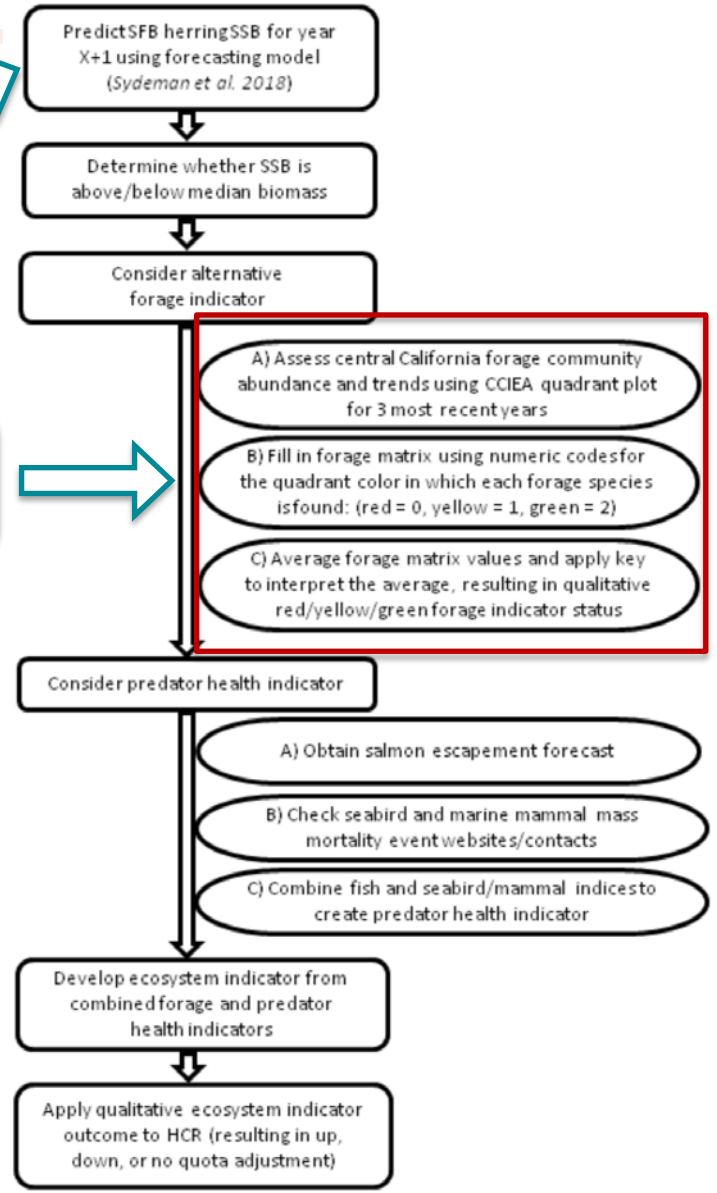


SST+ model for Herring

What is the state of alternative forage?

California Herring



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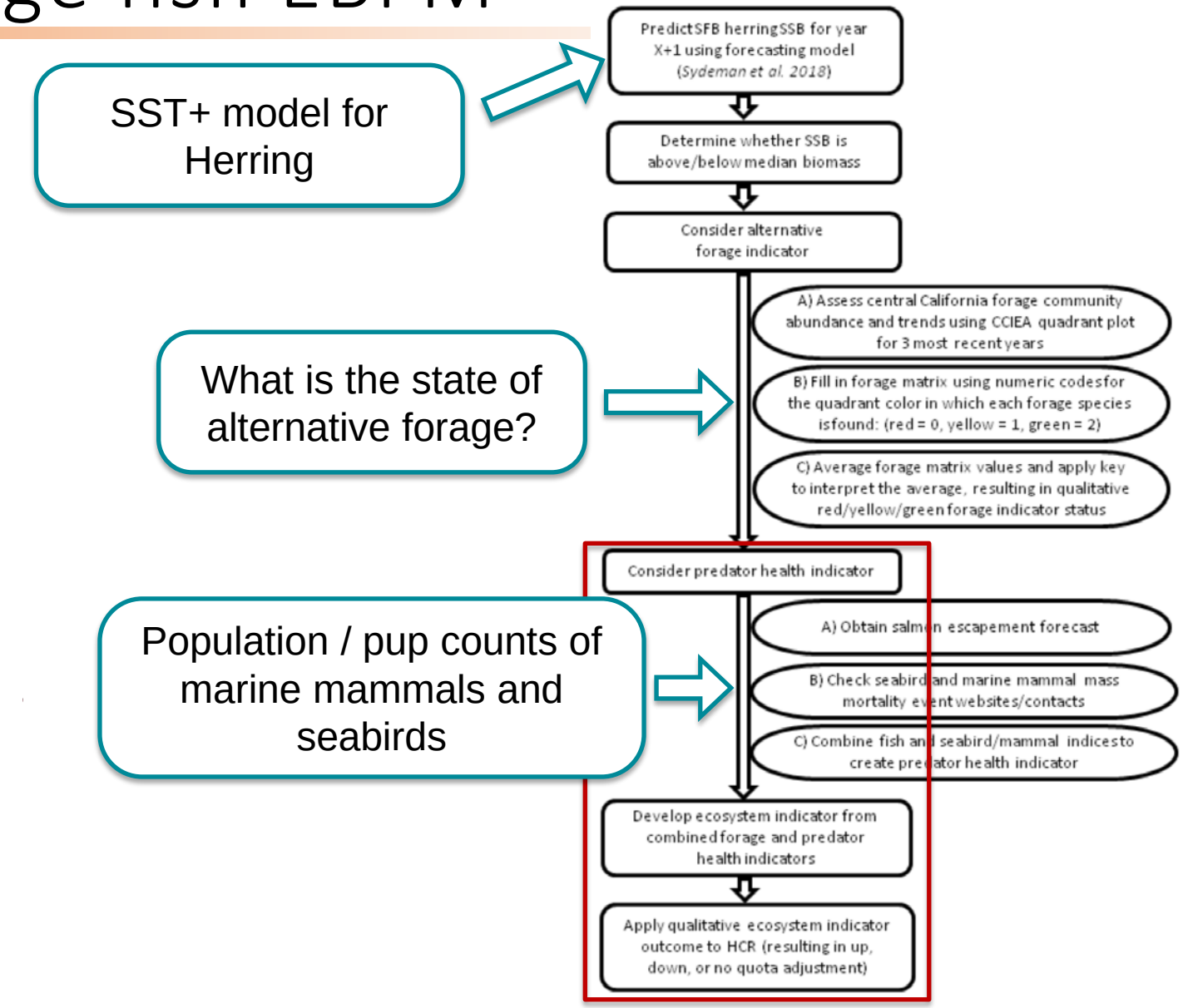
Top predators in forage fish EBFM

SST+ model for Herring

What is the state of alternative forage?

Population / pup counts of marine mammals and seabirds

California Herring



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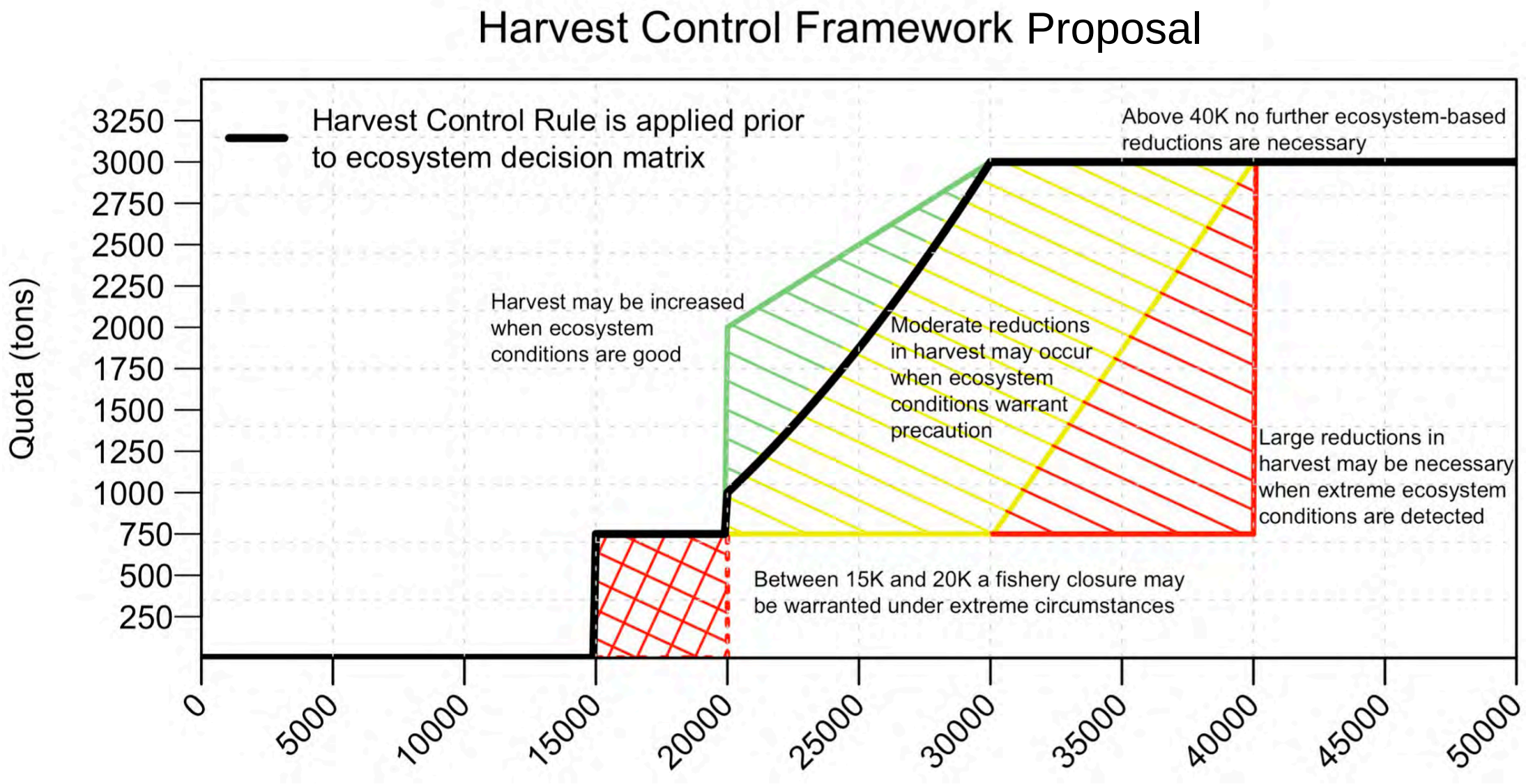

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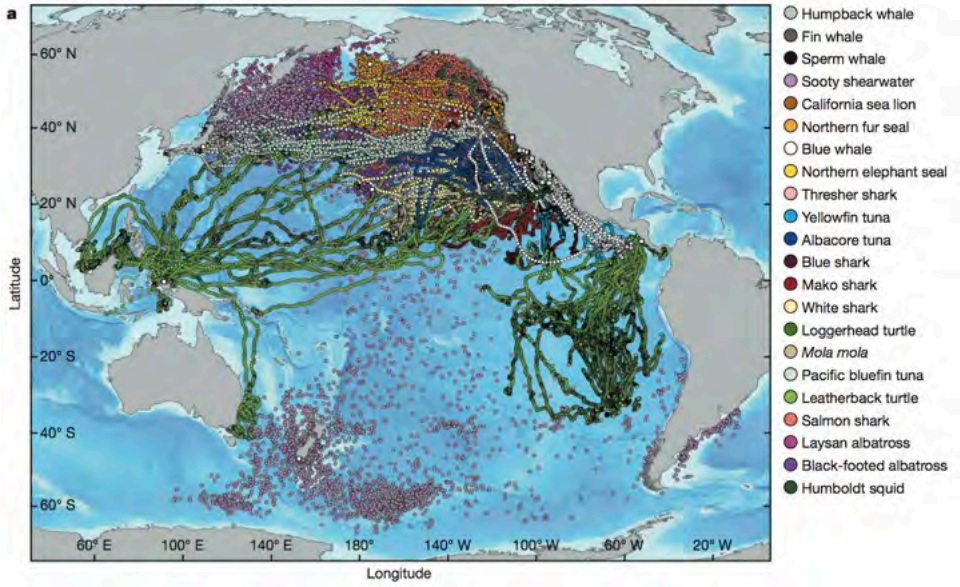
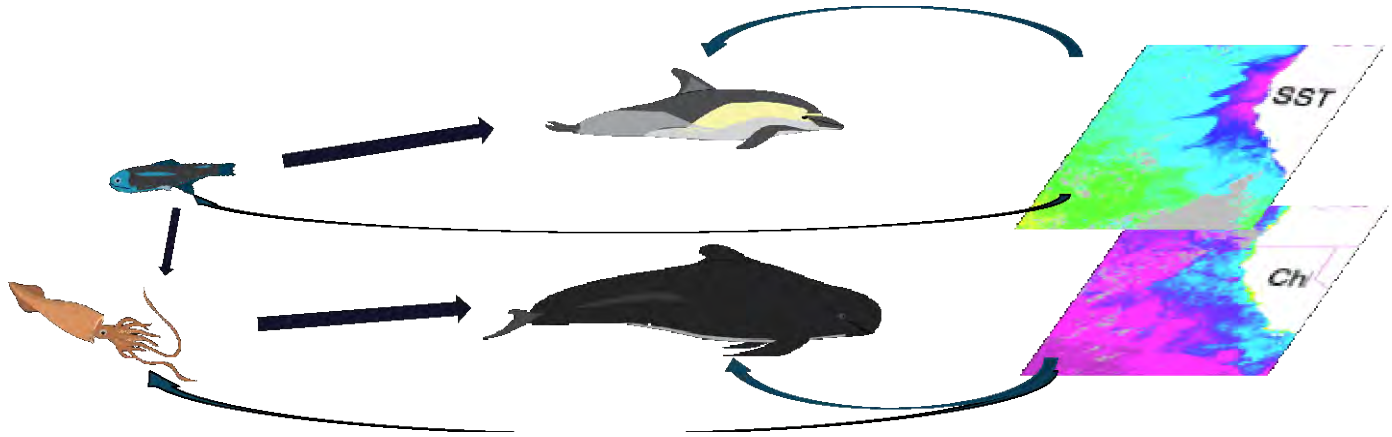
Conclusions

- Marine top predators offer a unique perspective into ocean processes, making them ideal sentinels.





Conclusions

CLIMATE & ECOSYSTEMS GROUP

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- Choosing appropriate sentinels can aid management in rapidly changing ecosystems

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- Marine top predators offer a unique perspective into ocean processes, making them ideal sentinels.
- Choosing appropriate sentinels can aid management in rapidly changing ecosystems
- As such, marine sentinels should be explicitly considered as a tool to support Ecosystem Based Fisheries Management

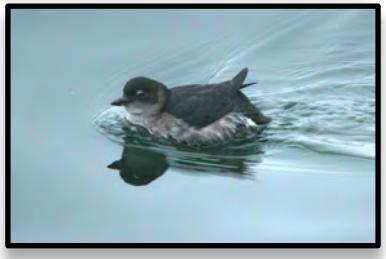
Acknowledgements

FUTURE Science Program PICES

Yutaka Watanuki, Takashi Yamamoto, Rob Suryan, Marisol Garcia Reyes, Kevin Weng, Chandra Goetsch, Briana Wittiveen, Barb Muhling






NASA

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NOAA U.S. DEPARTMENT OF COMMERCE

BANANA SLUGS OF CALIFORNIA

PICES

MBON Marine Biodiversity Observation Network

INTEGRATED OCEAN OBSERVING SYSTEM

TOPP