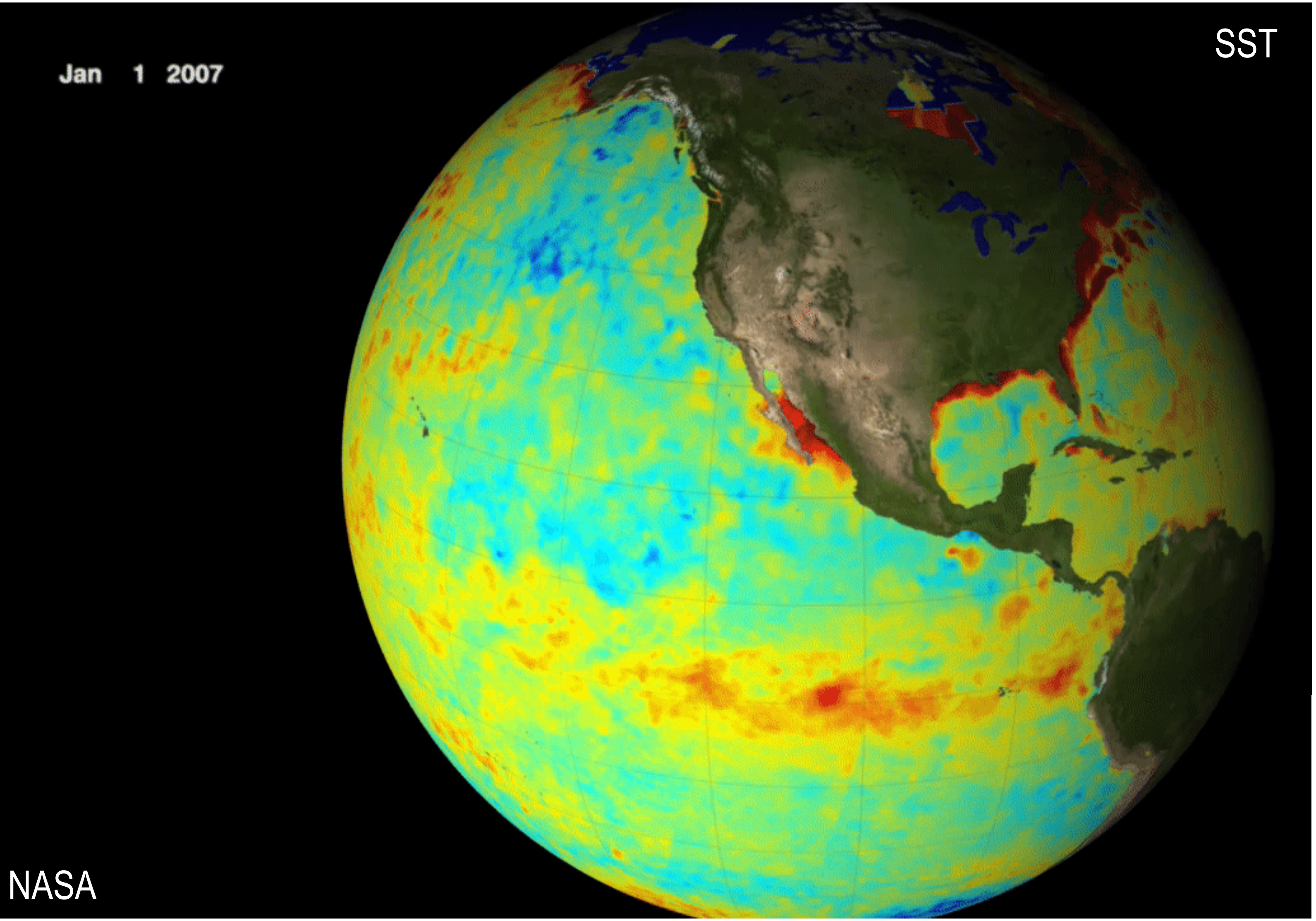
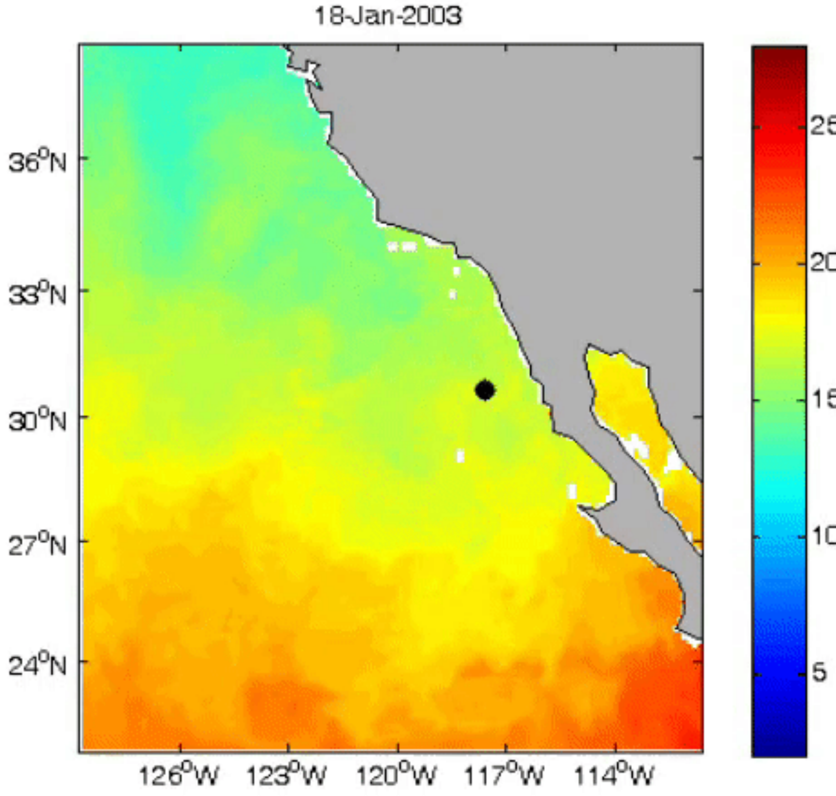
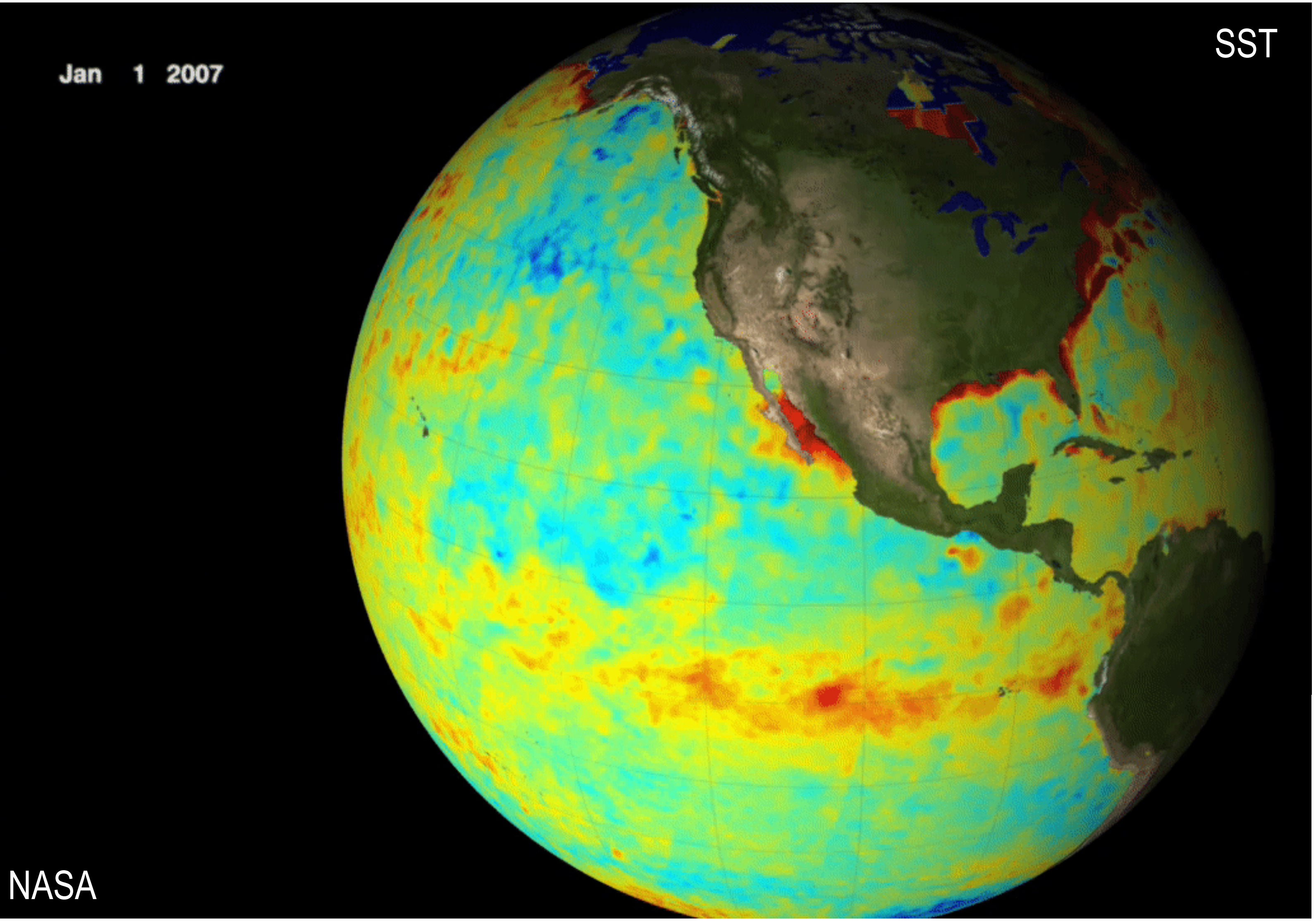
Dynamic Oceans and Dynamic Ecosystems

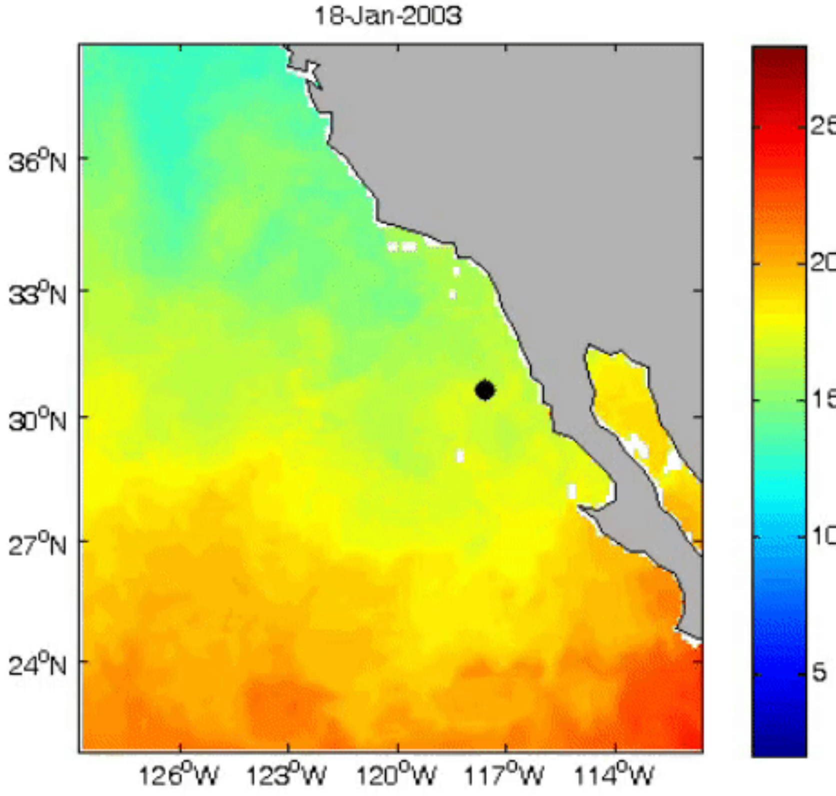




Elliott L. Hazen
Southwest Fisheries Science Center,
Environmental Research Division
UCSC – Cooperative Institute for Marine
Ecosystems and Climate
elliott.hazen@noaa.gov

Dynamic Oceans and Dynamic Ecosystems





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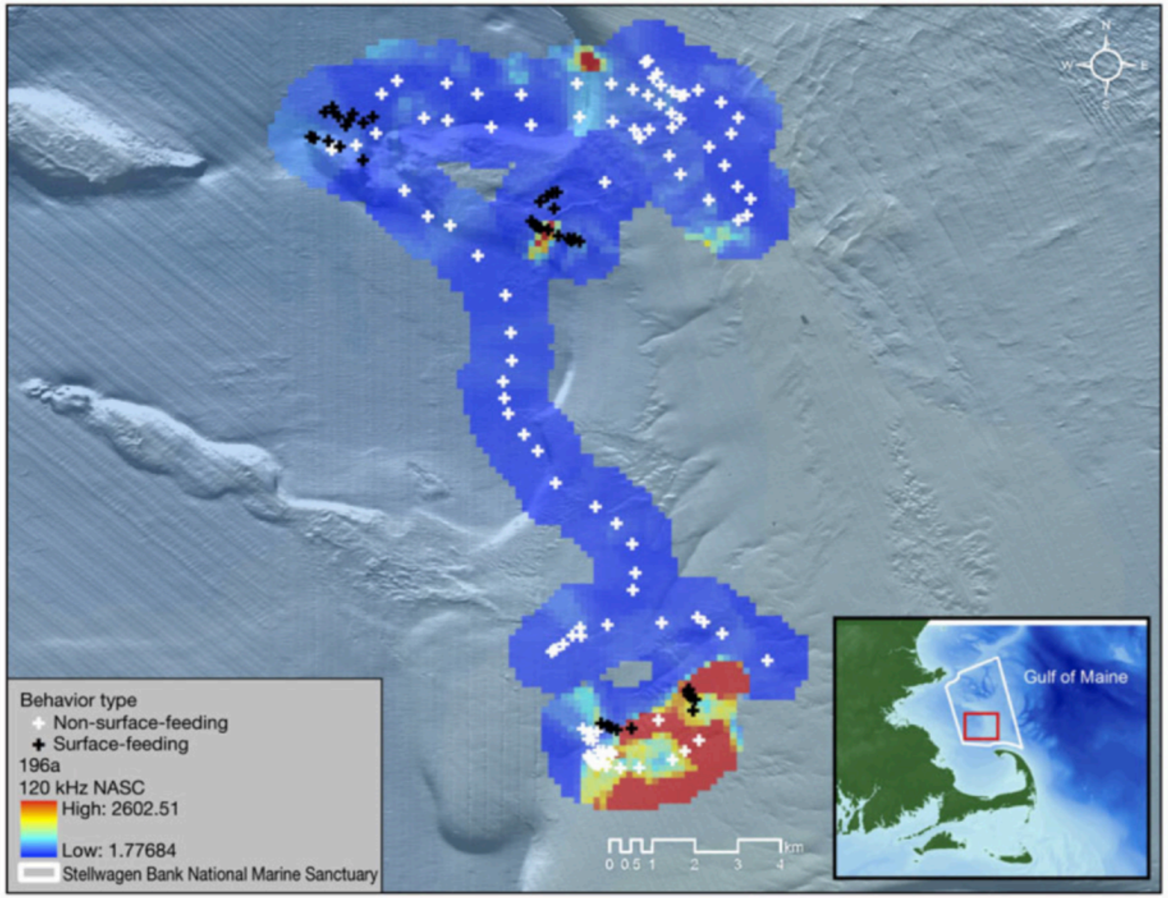
My research

Species Ecology, Movement, and Distribution



Hazen et al. 2008, *MEPS*

My research

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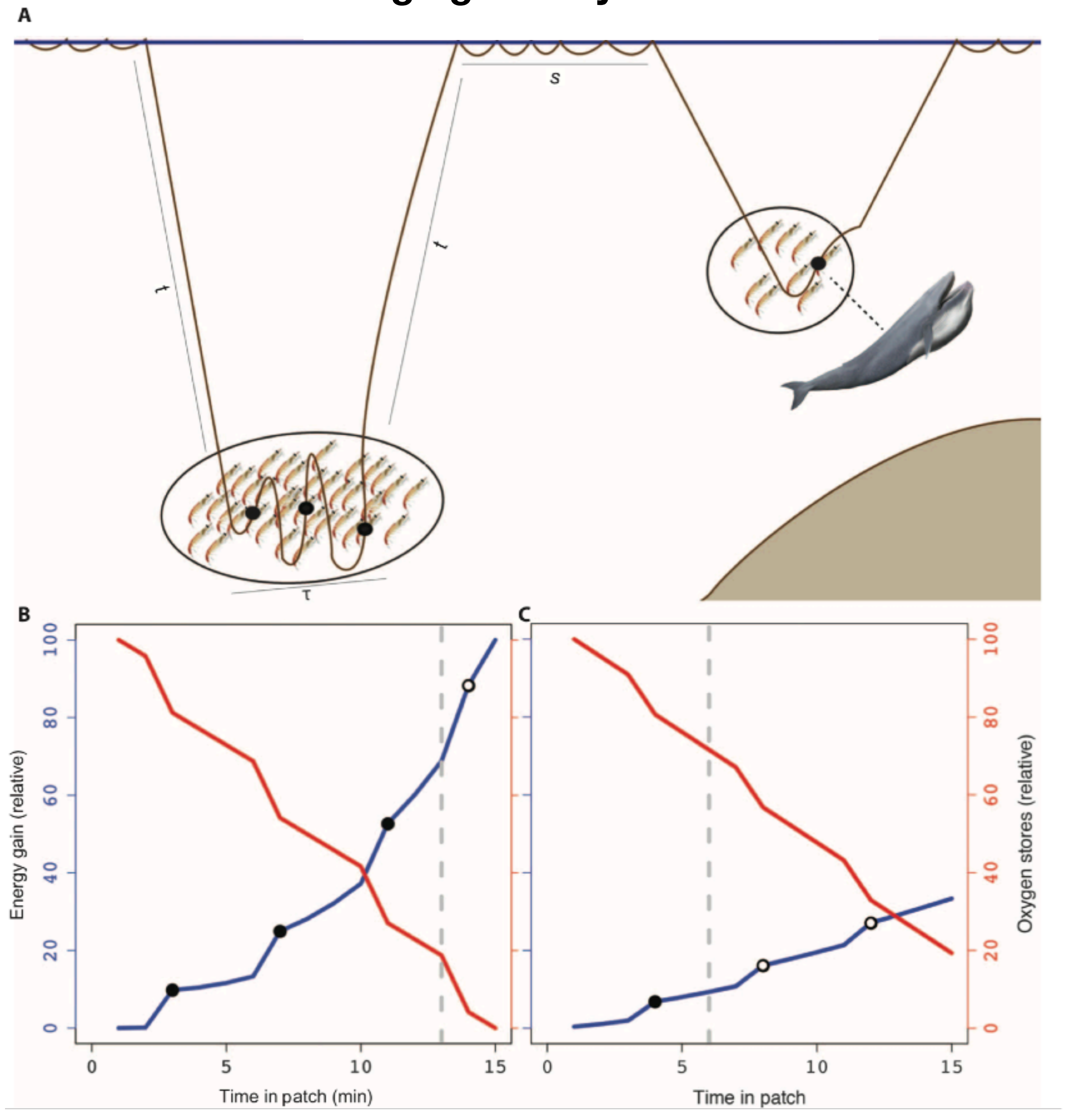
Foraging Theory and Behavior



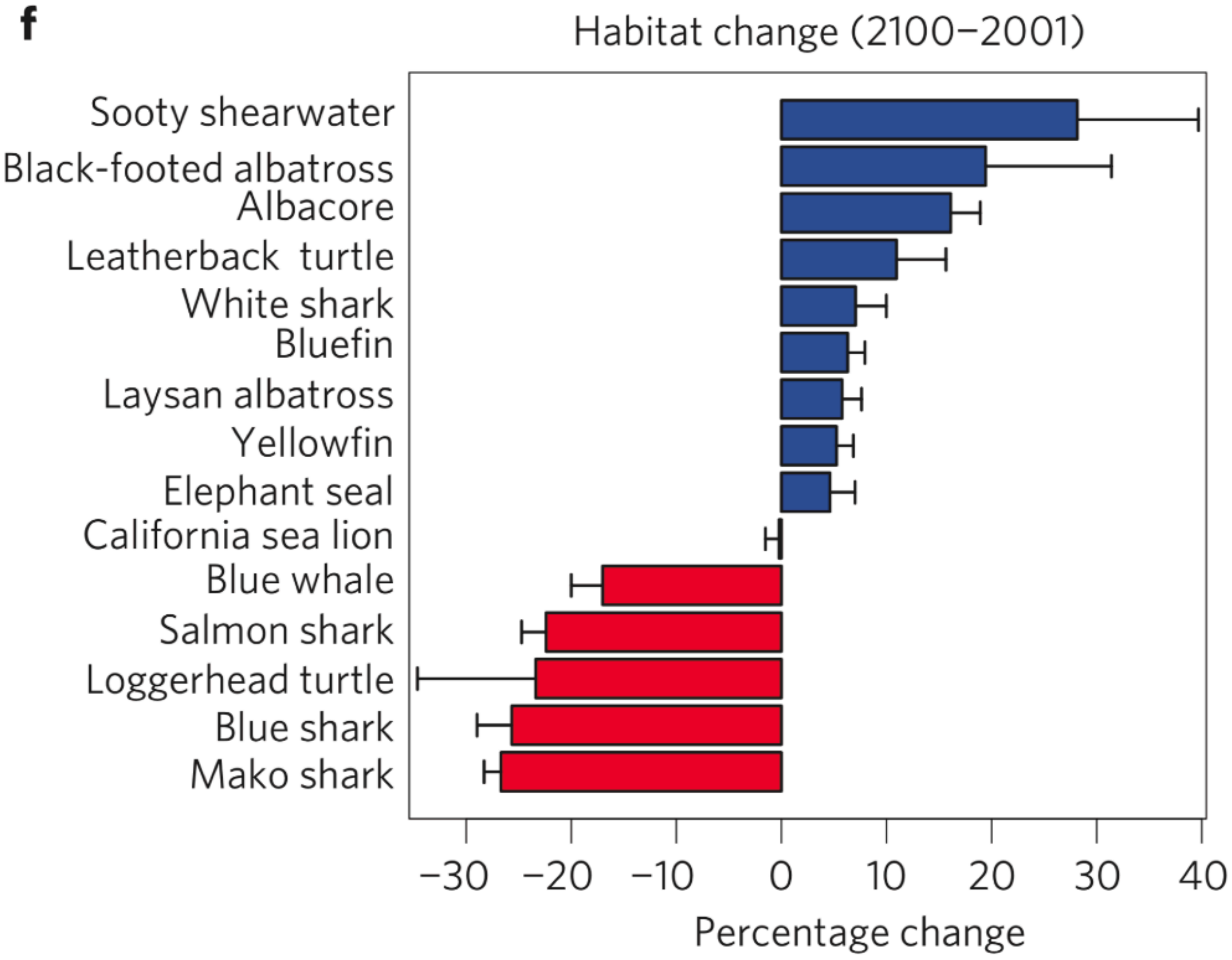
Hazen et al. 2015, *Science Advances*

My research

CLIMATE & ECOSYSTEMS GROUP

Species Ecology, Movement, and Distribution

Climate variability and change



Hazen et al. 2013, *Nature Climate Change*

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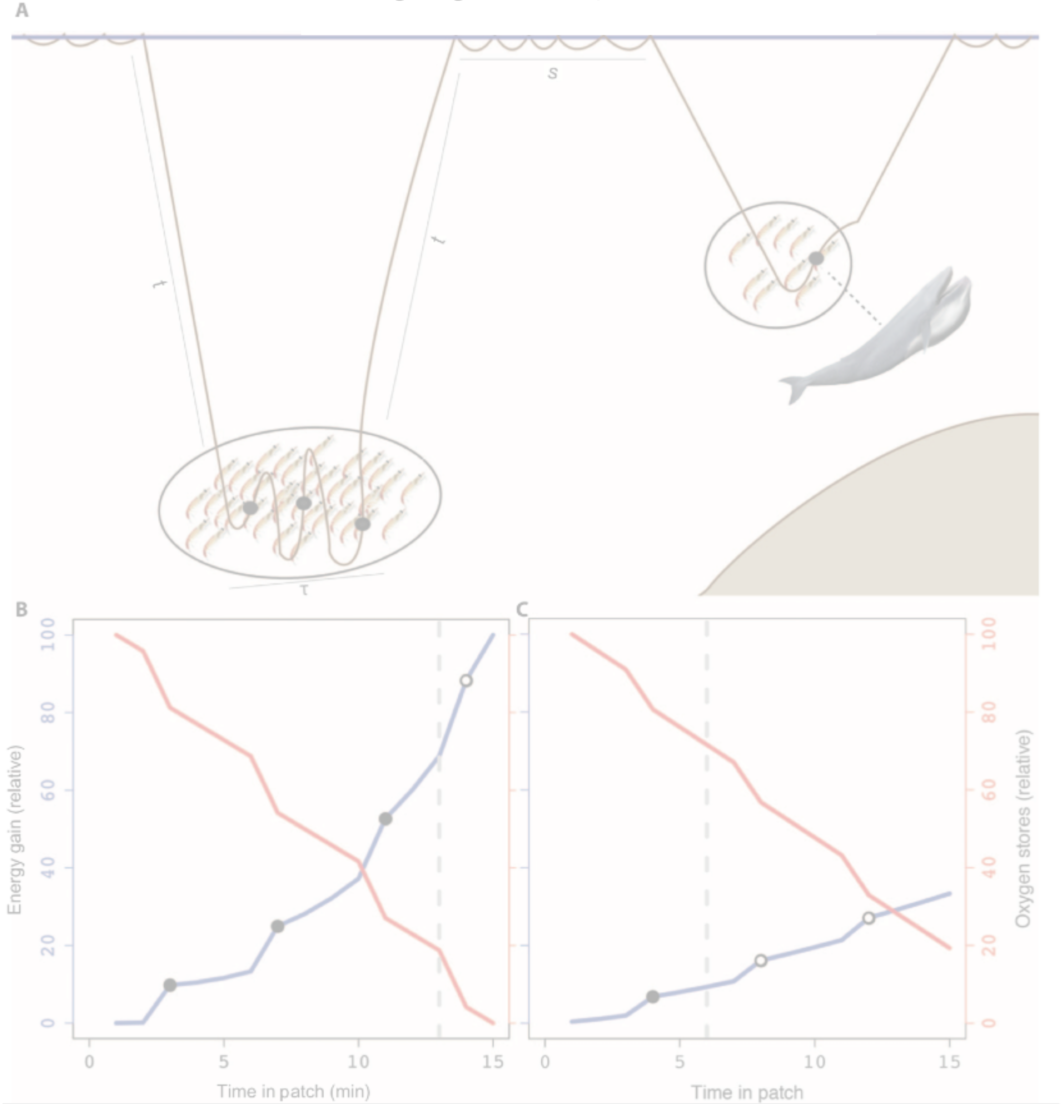

My research

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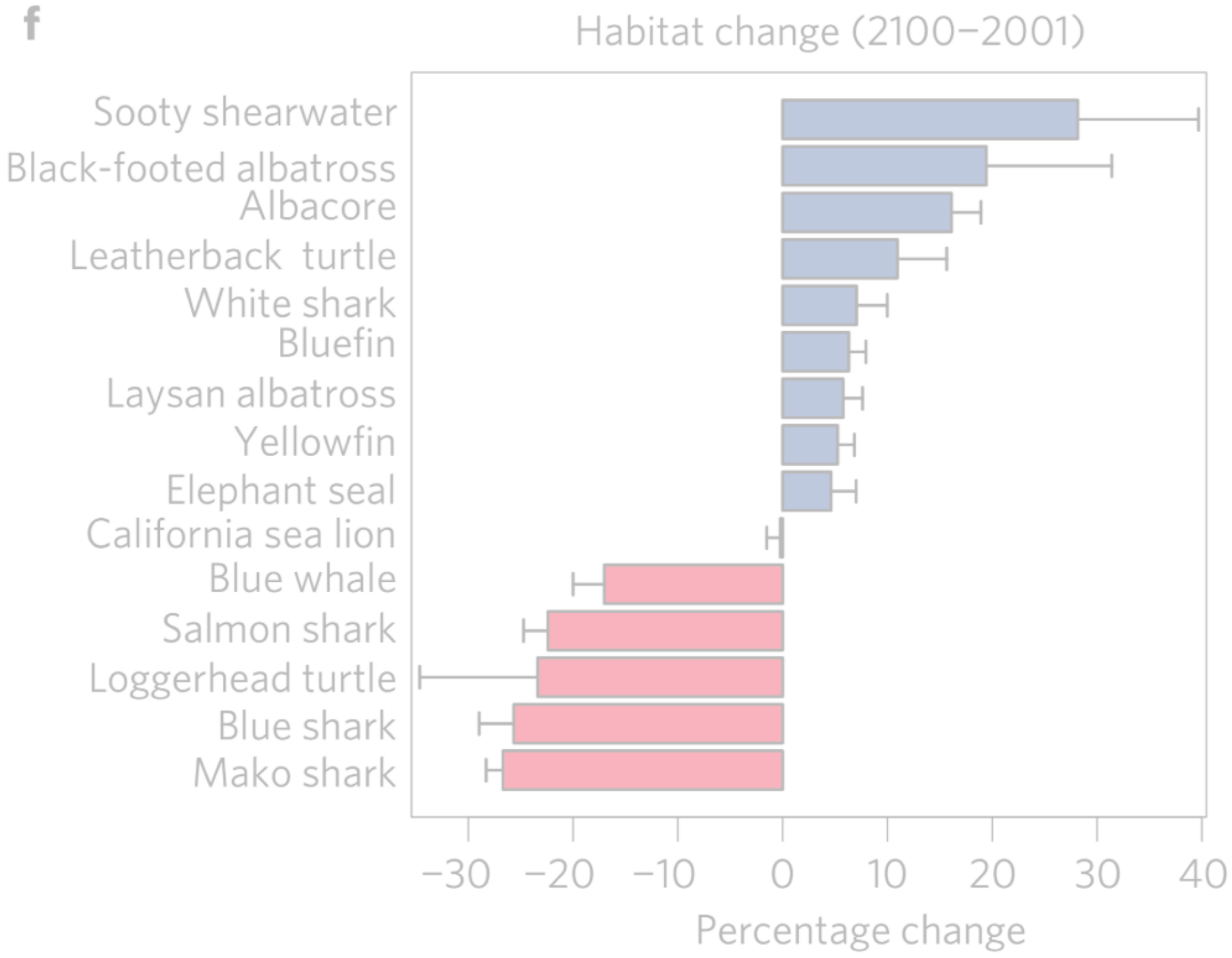
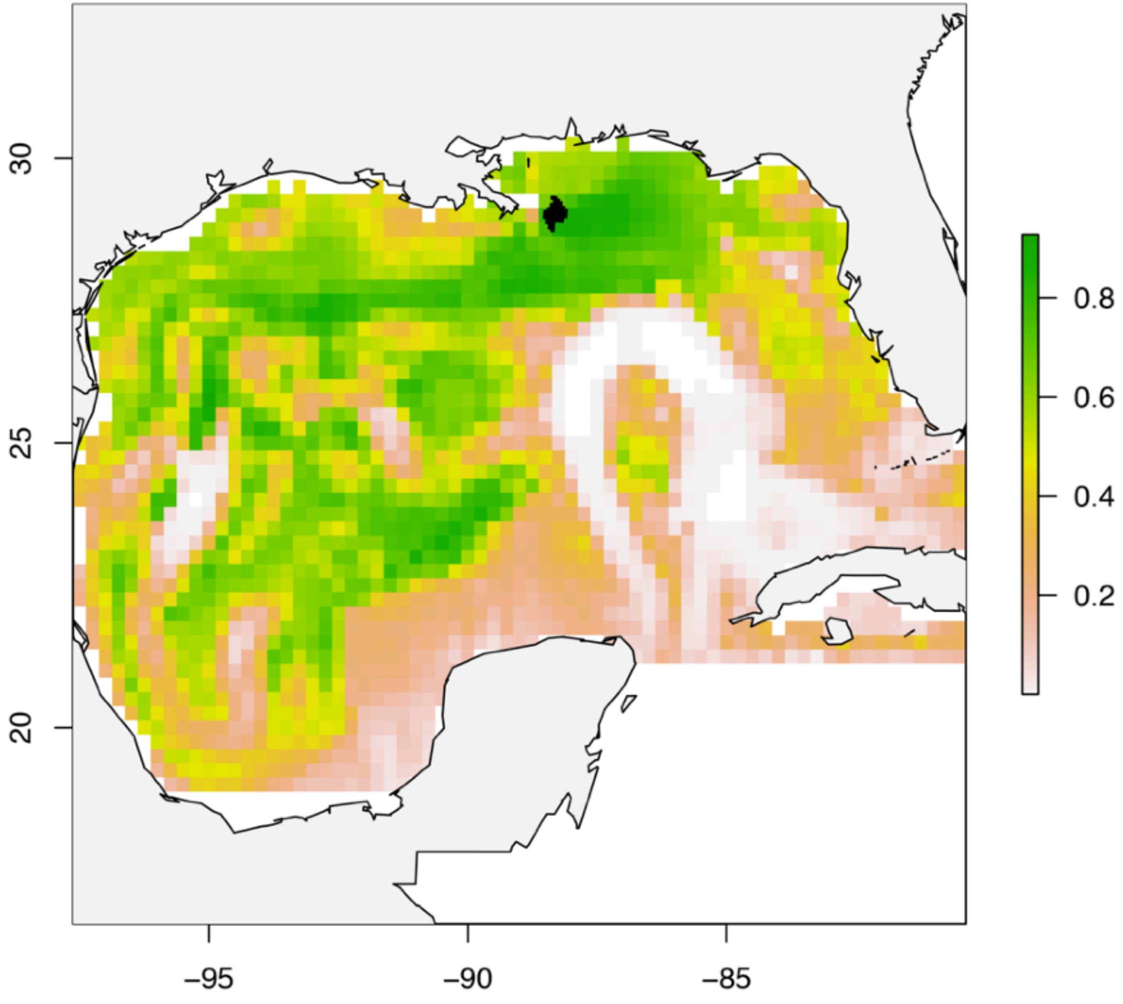


Hazen et al. 2013, *Nature Climate Change*



Hazen et al. 2016, *Scientific Reports*

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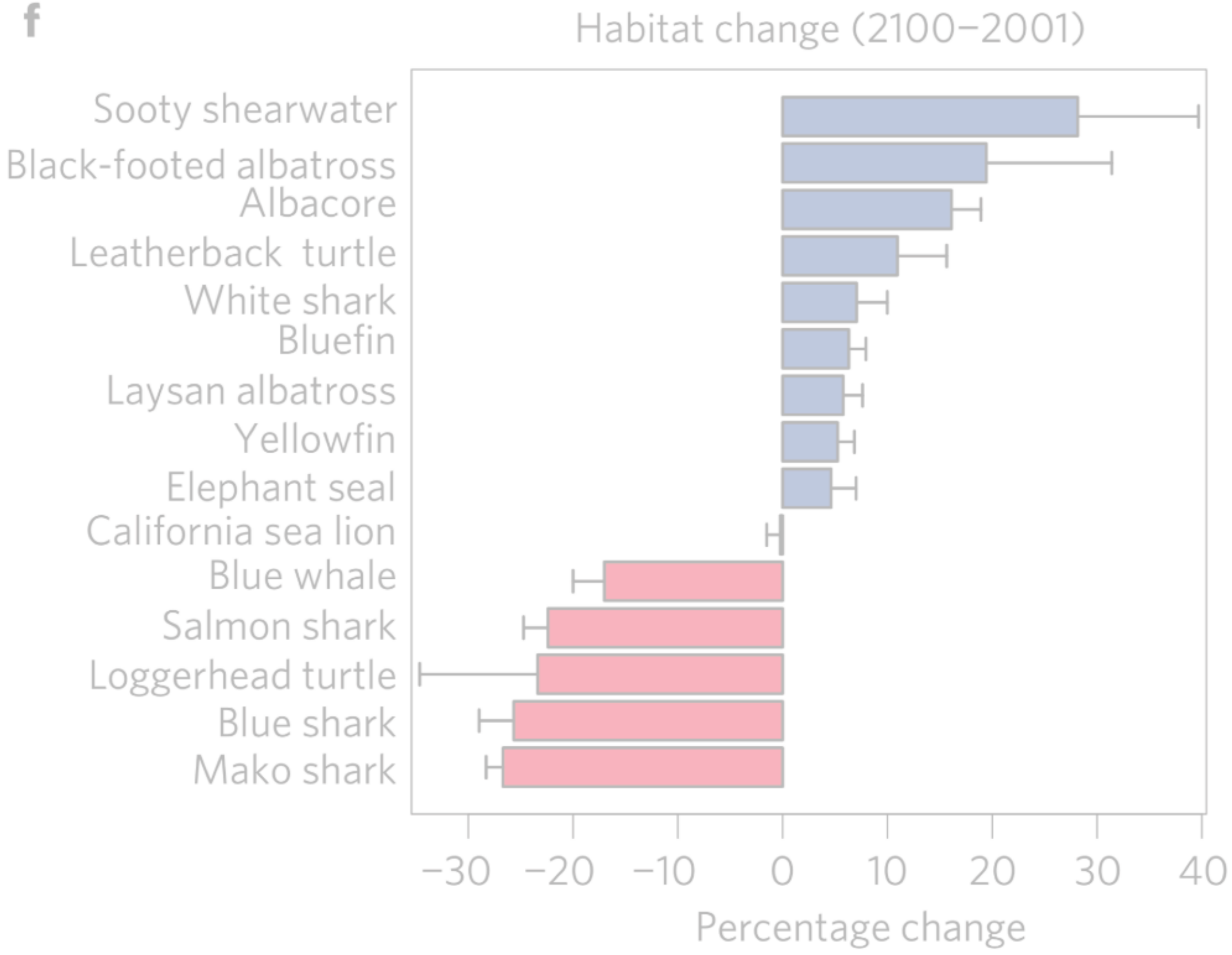
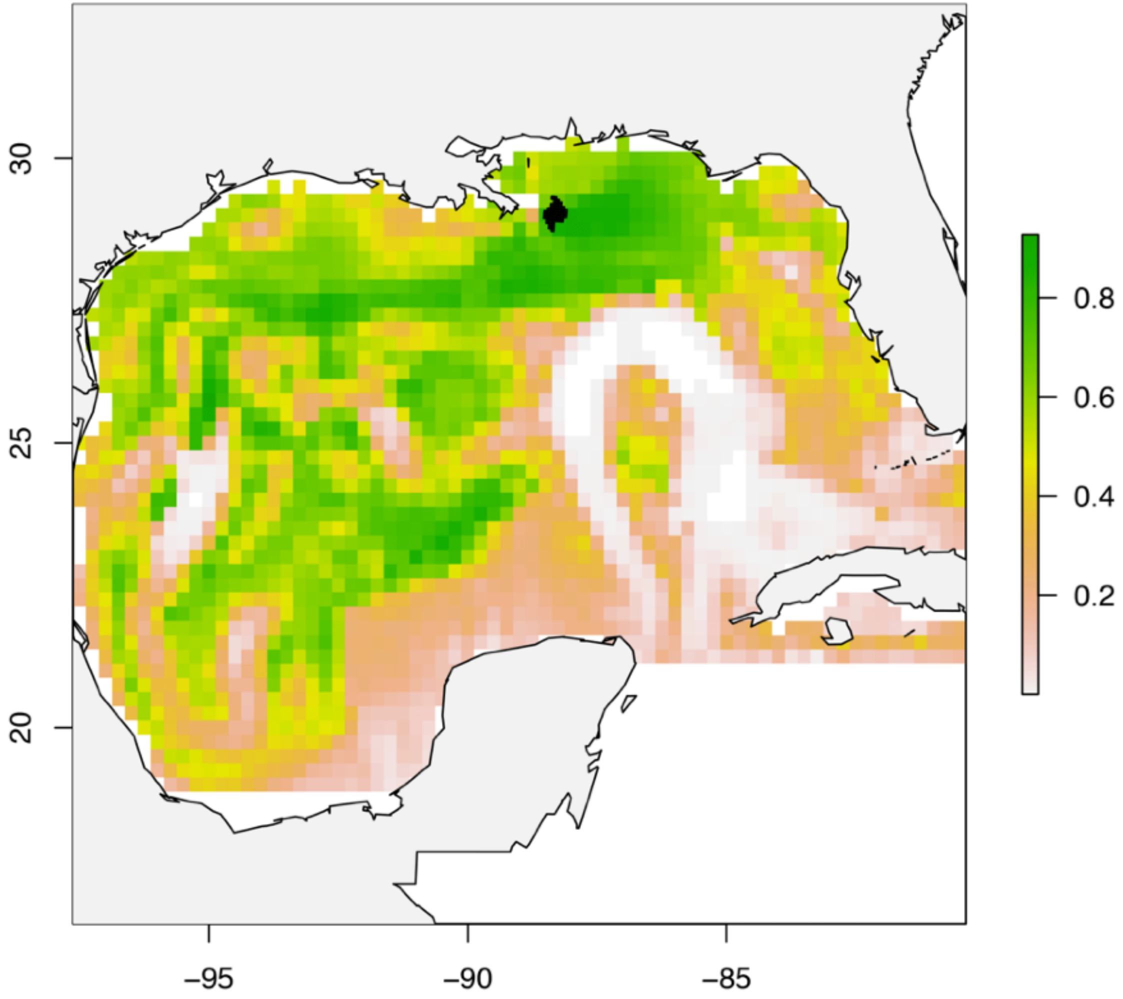
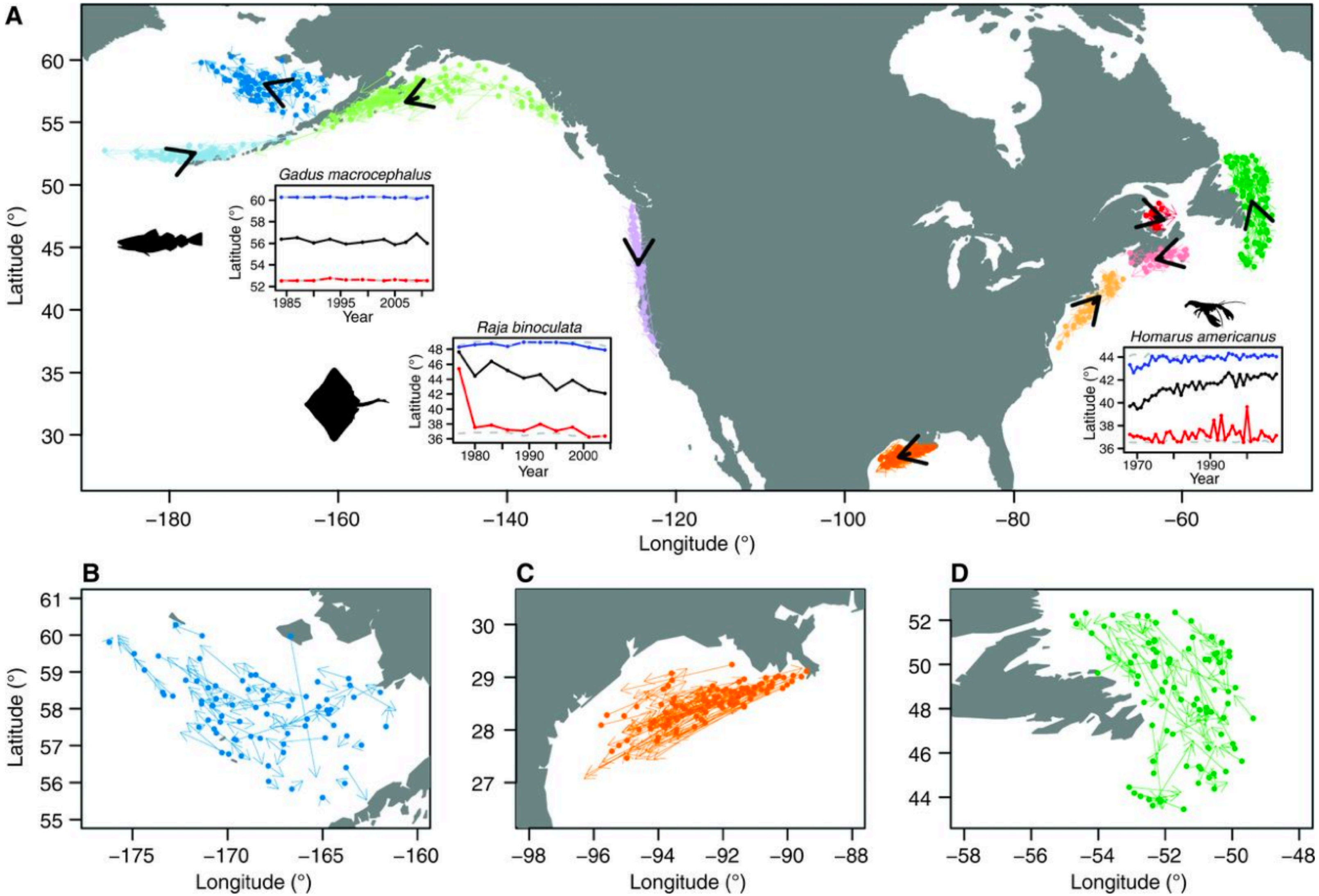


Hazen et al. 2013, *Nature Climate Change*



Hazen et al. 2016, *Scientific Reports*

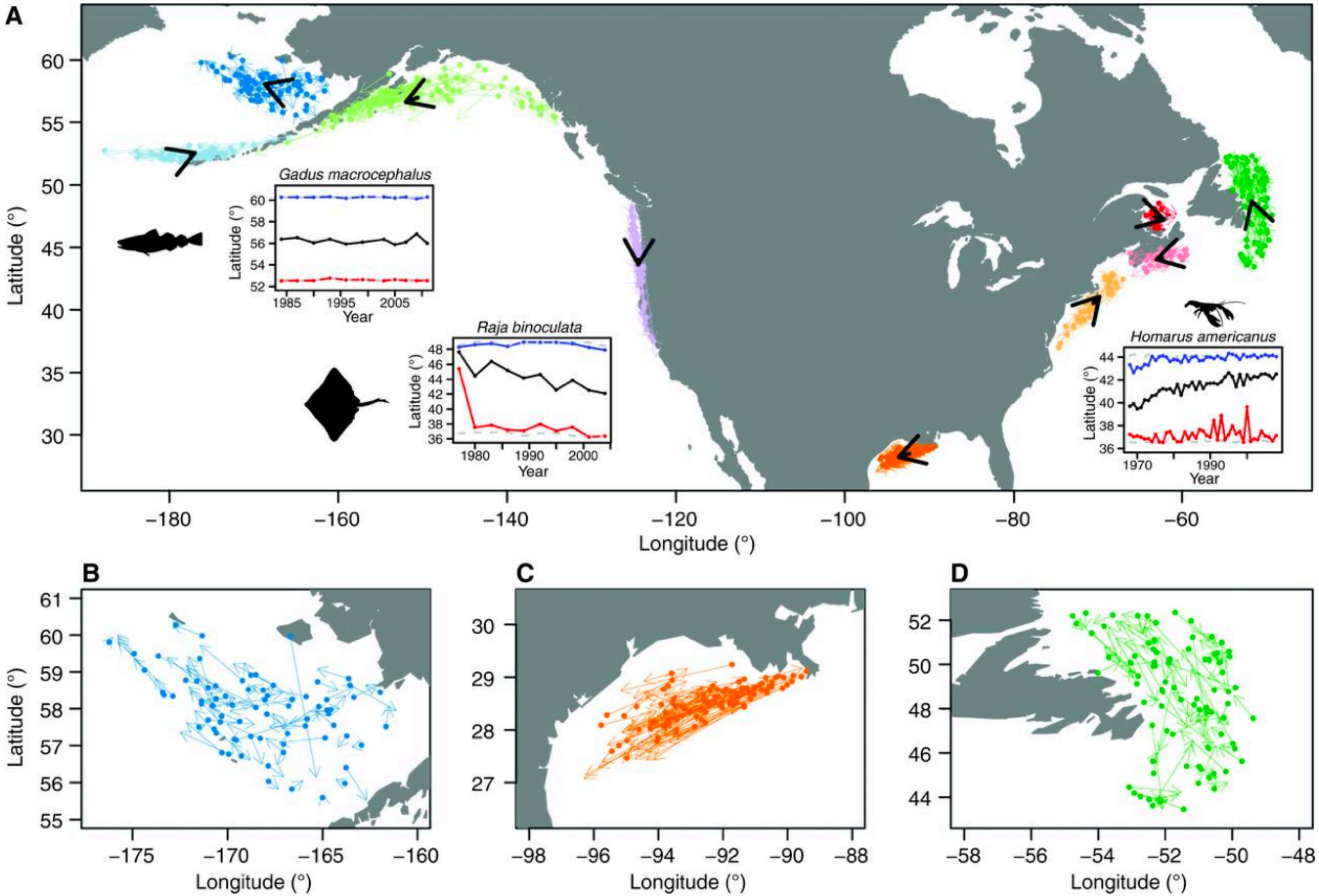
Climate change and fisheries



Pinsky et al. 2013 *Science*

Climate change and fisheries

- Species range shifts



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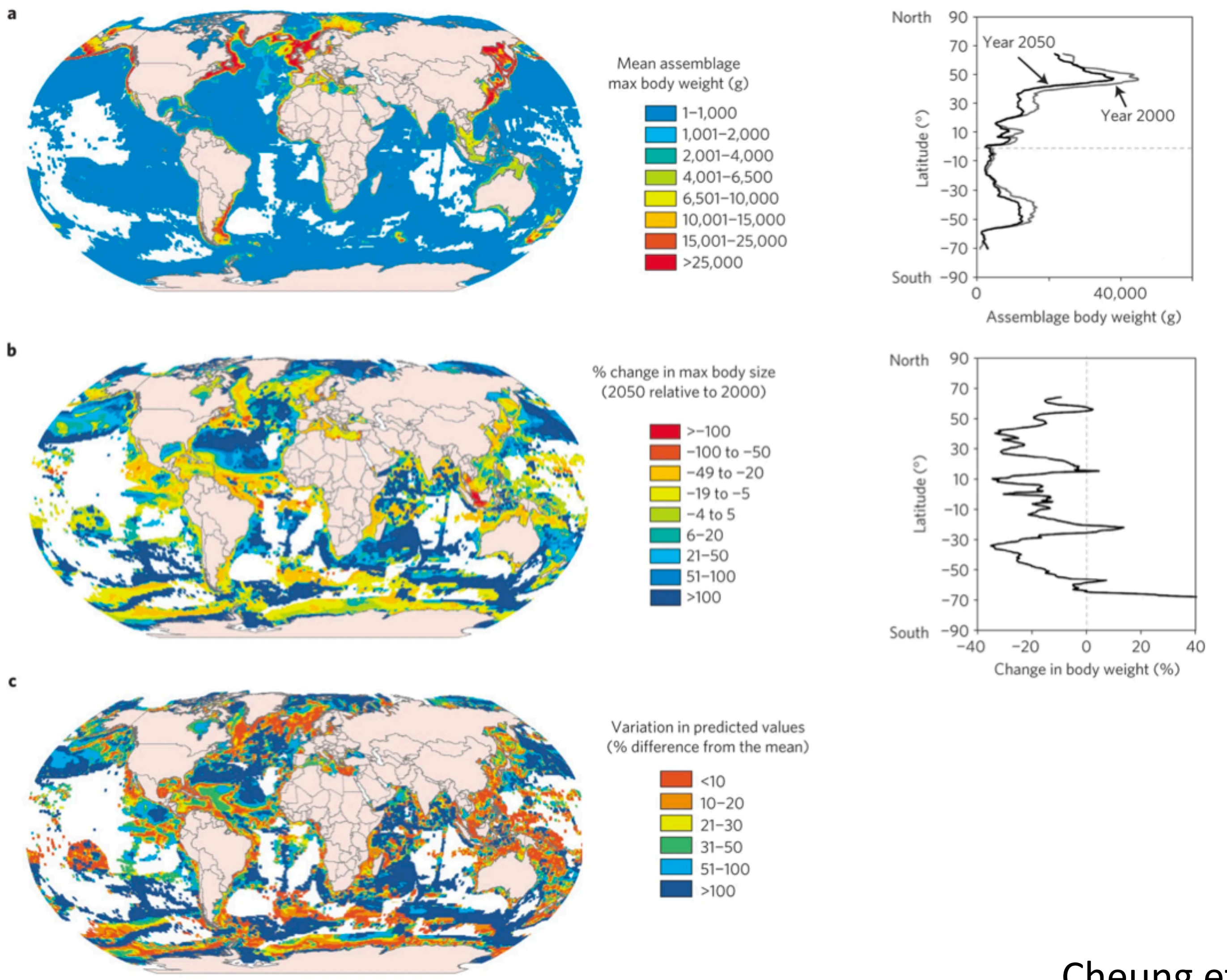
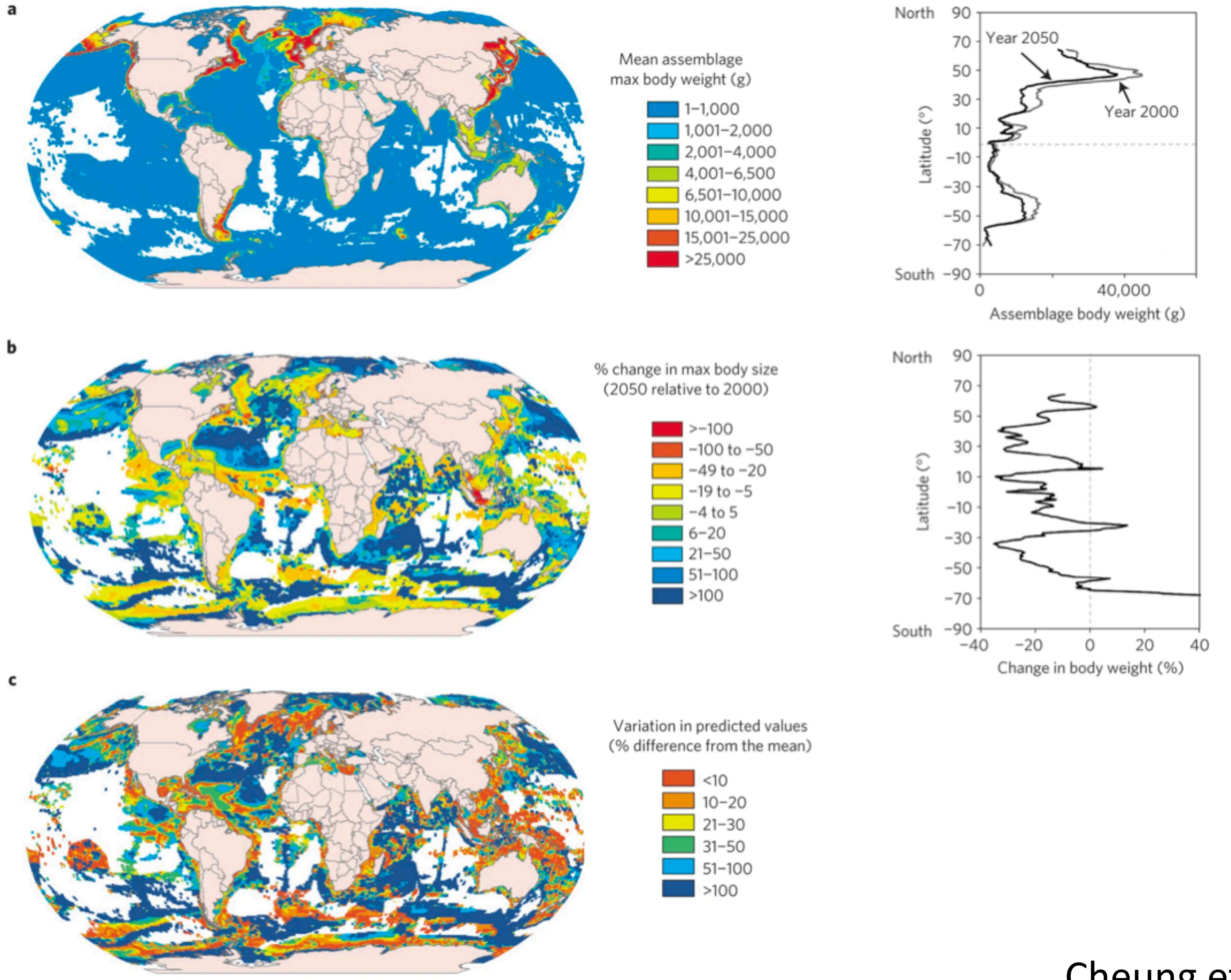


Cheung et al. 2013 *Nature Climate Change*

Climate change and fisheries

- Species shrinking



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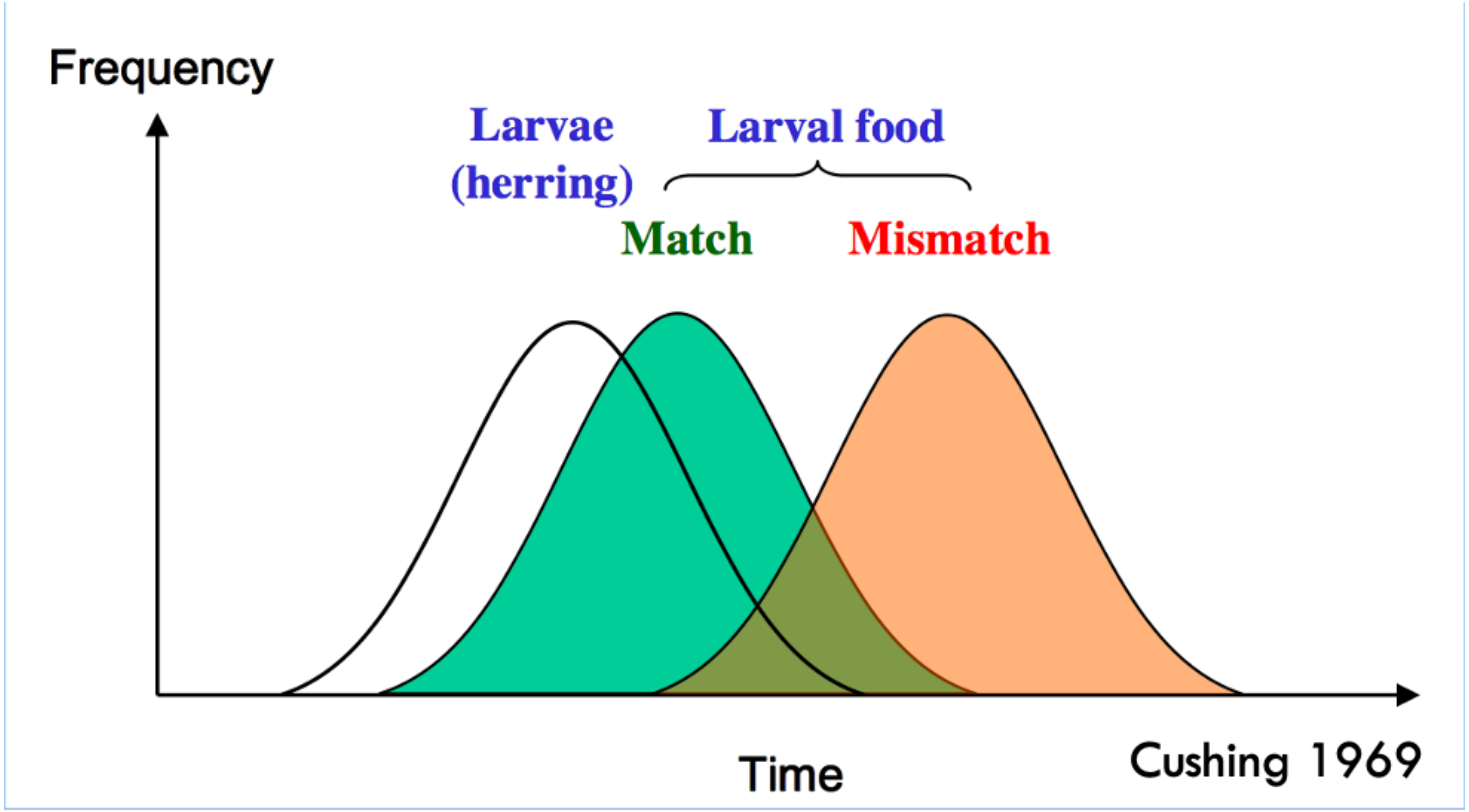
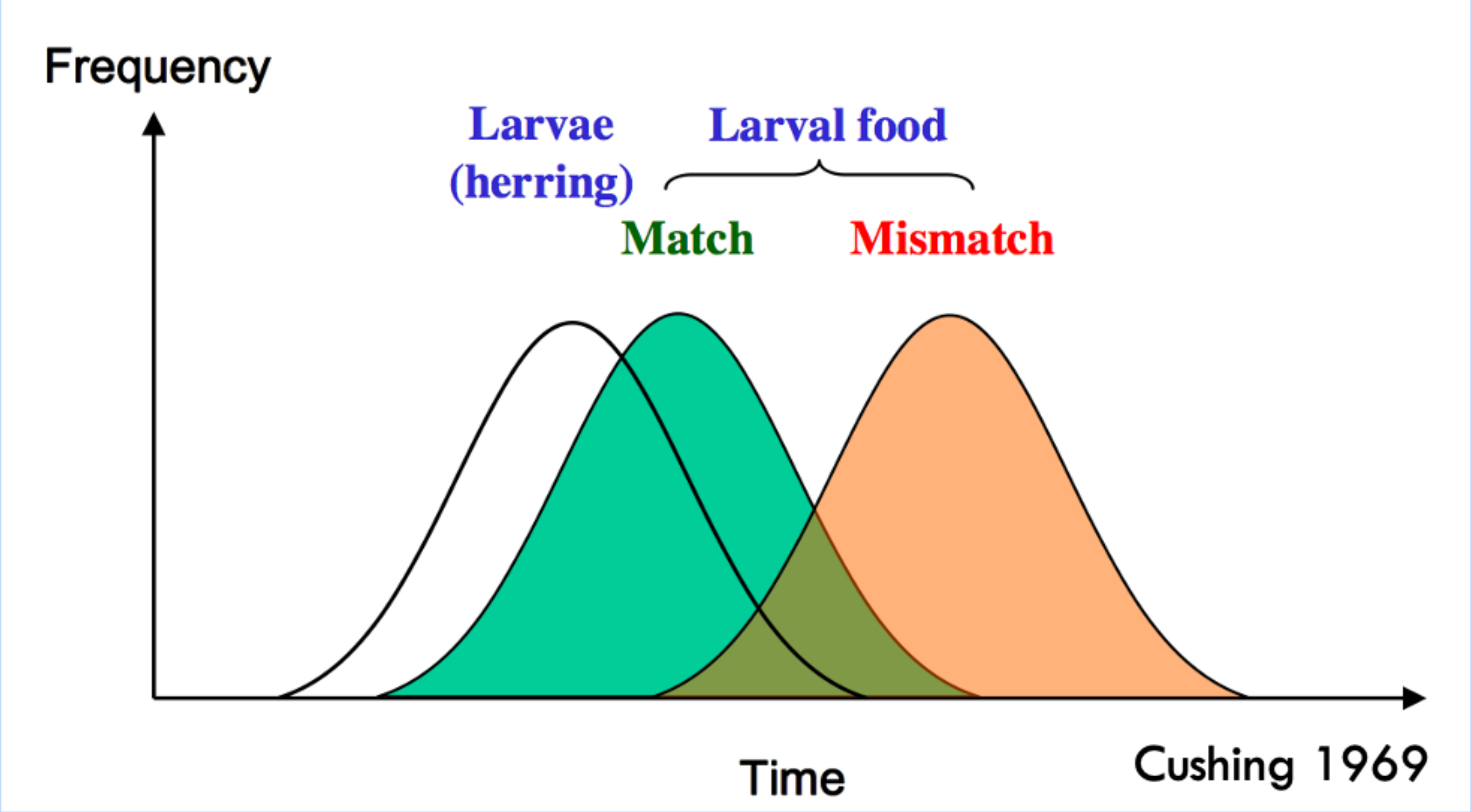
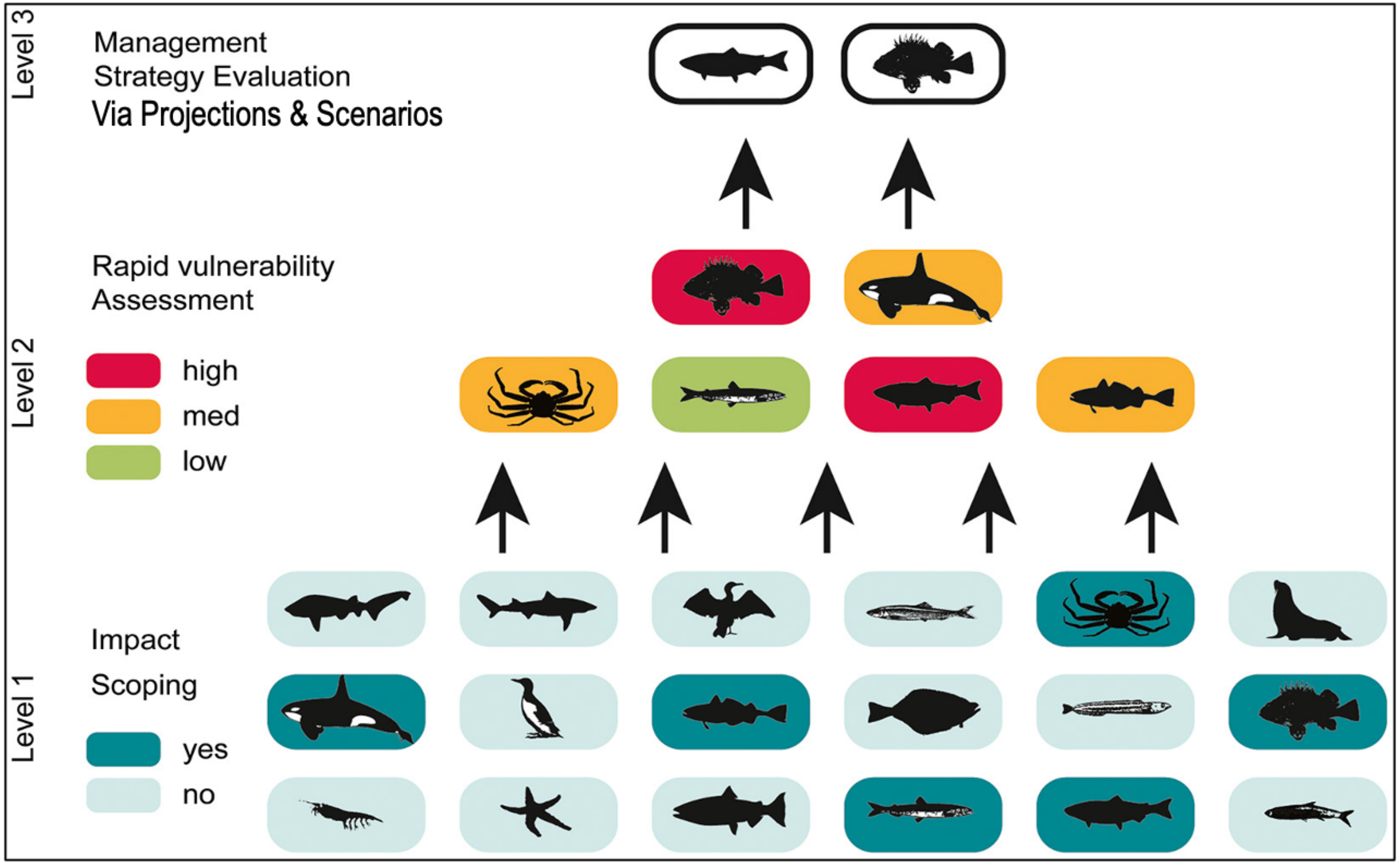


Climate change and fisheries

- Phenological shifts - match & mismatch



Climate change and fisheries management



Holsman et al. in 2017

Extreme events - the blob

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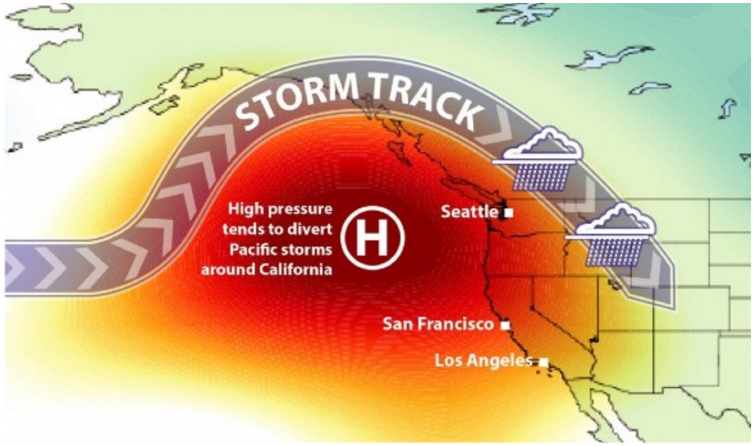

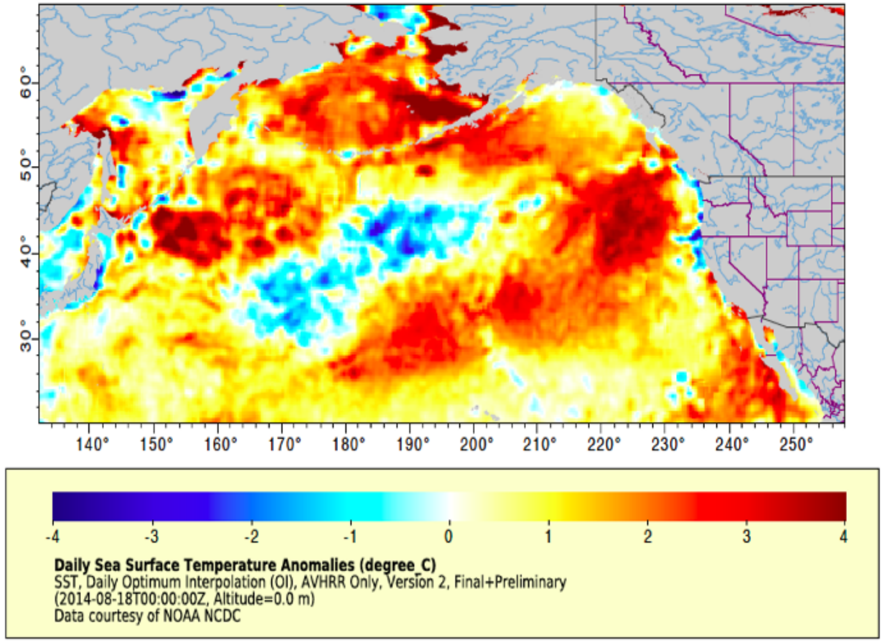

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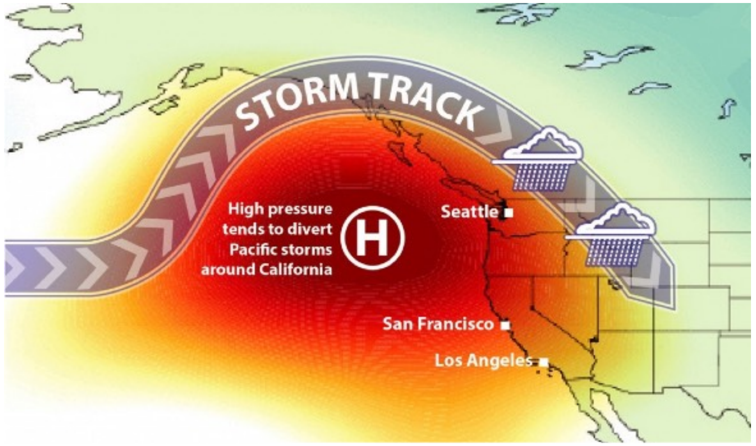
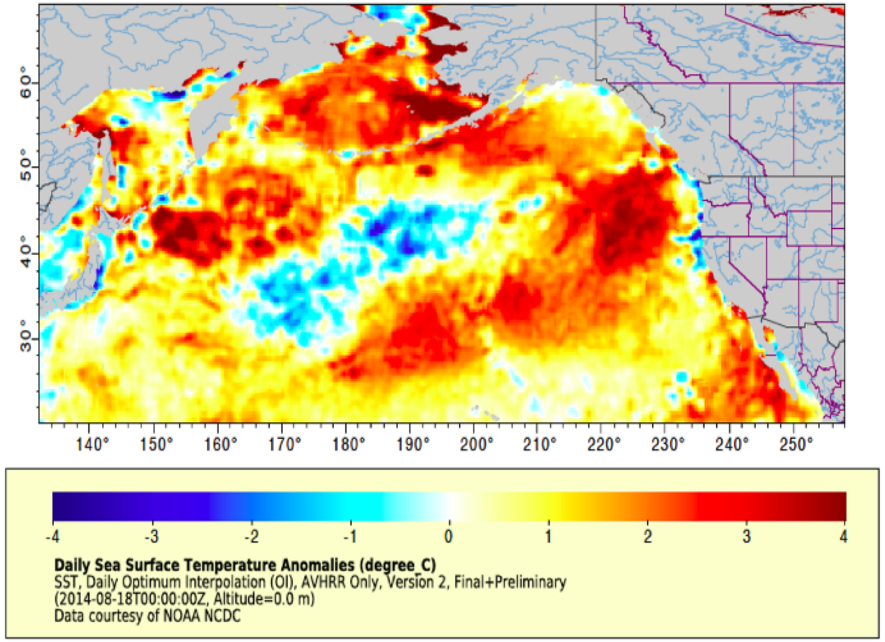
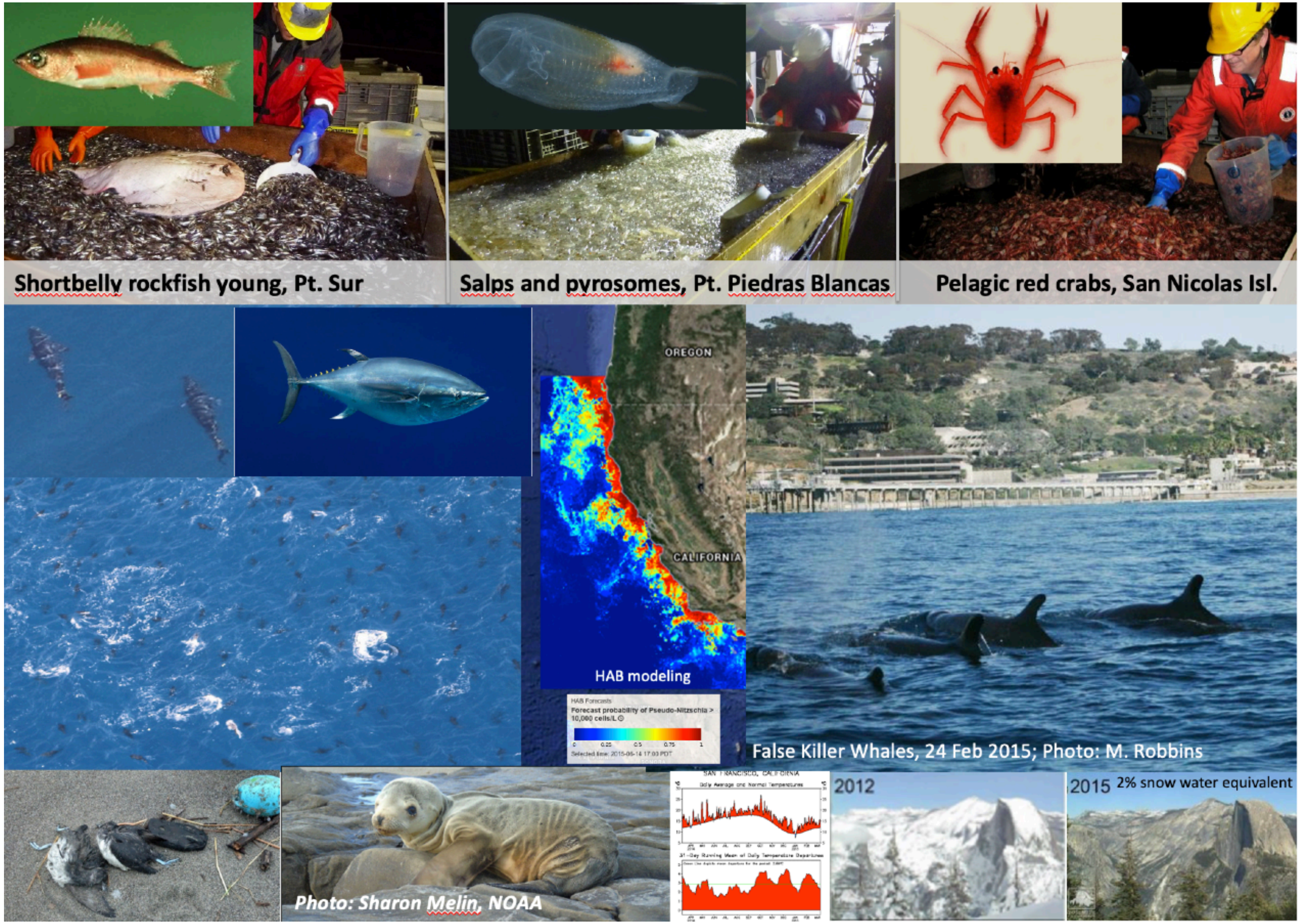
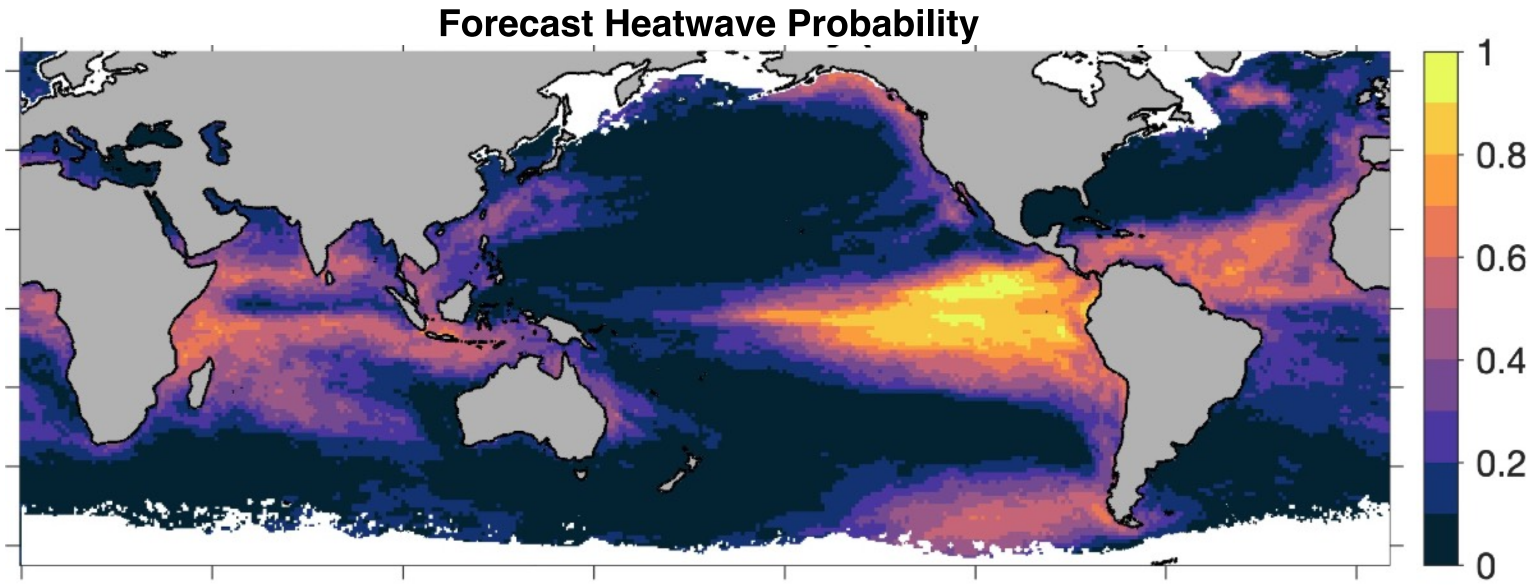
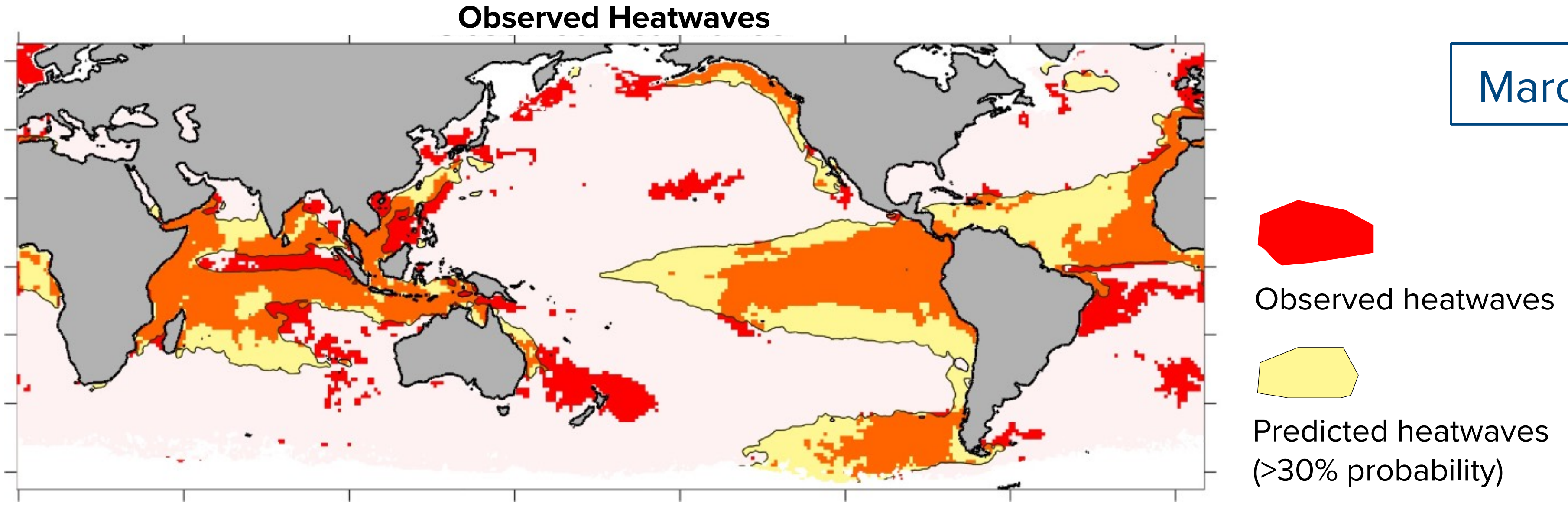










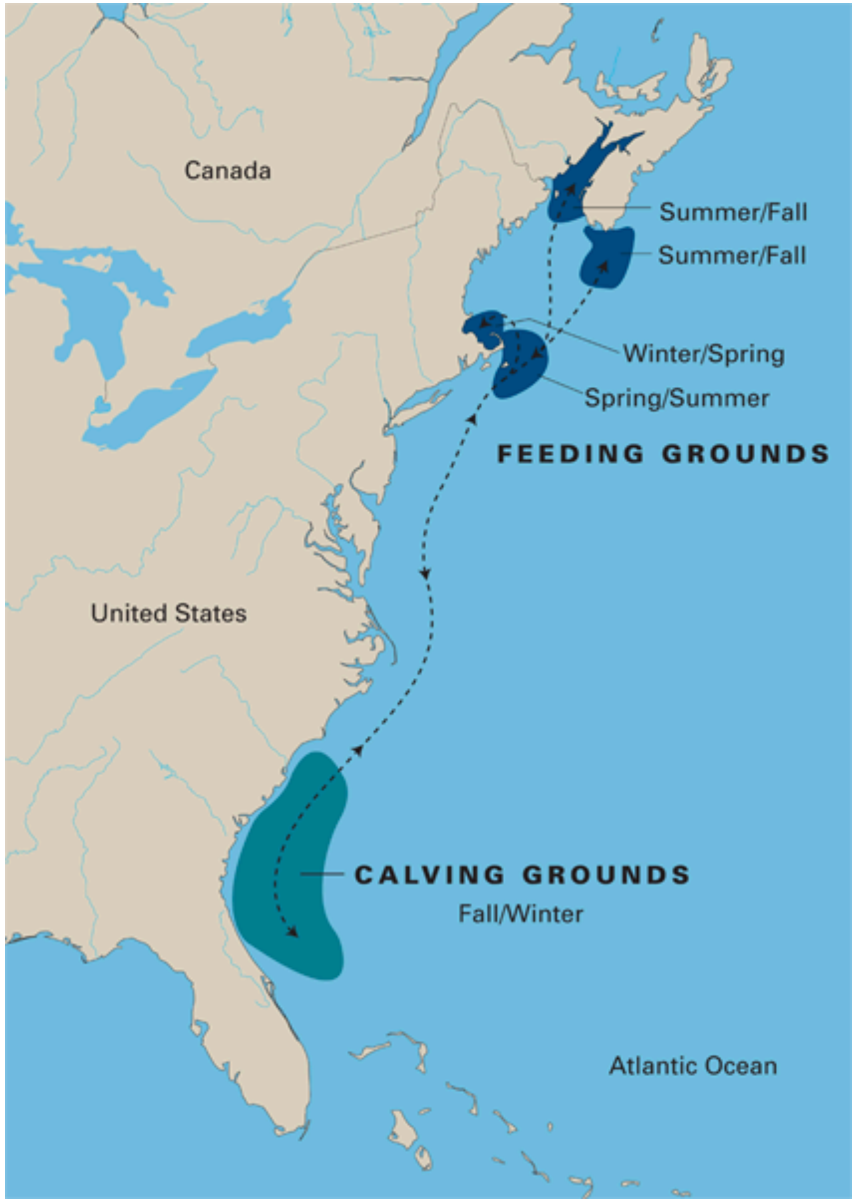
July 1997 forecast

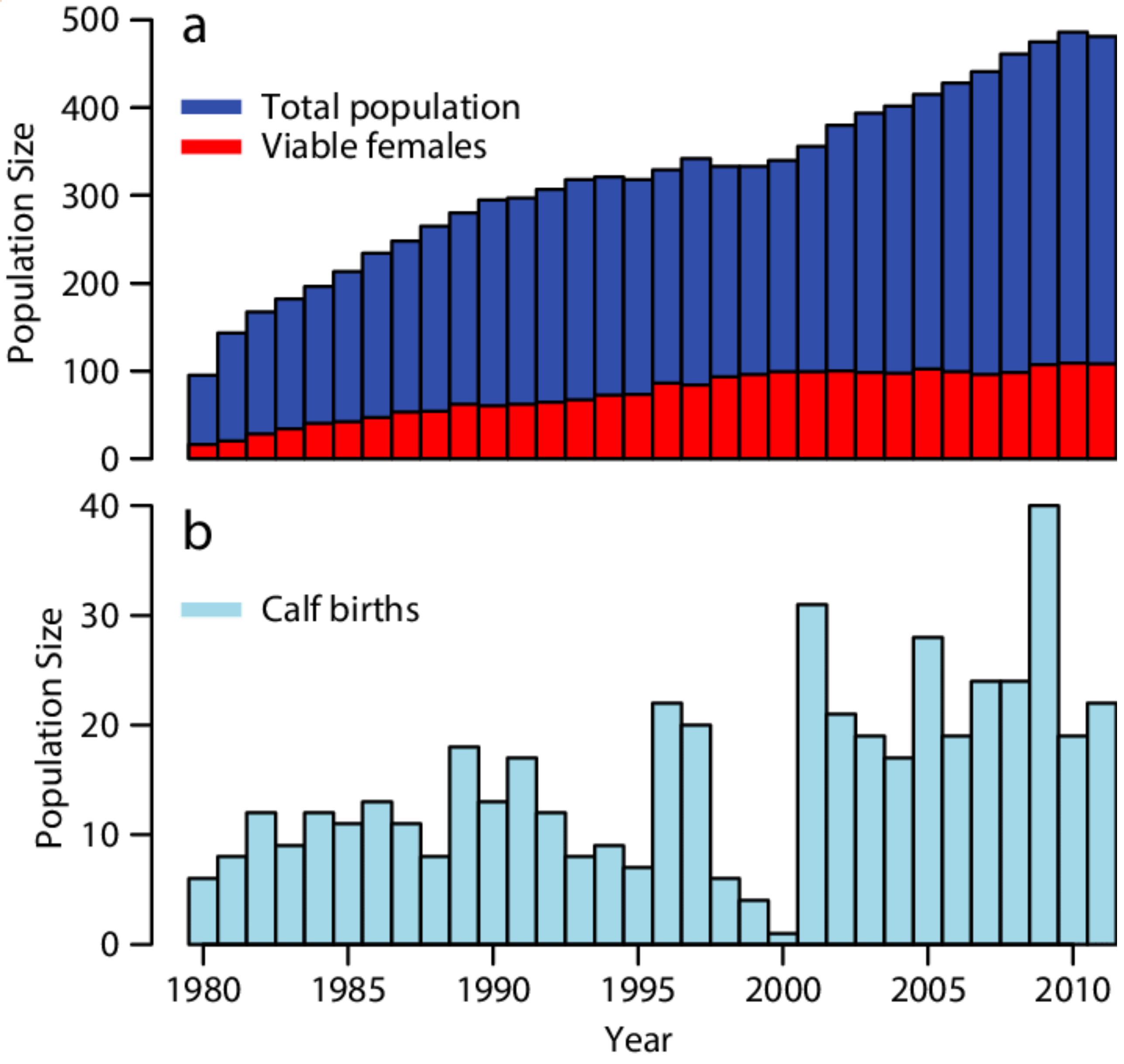
8 month lead time

March 1998 heatwaves

Jacox et al. 2022 *Nature*

New conditions, new risks





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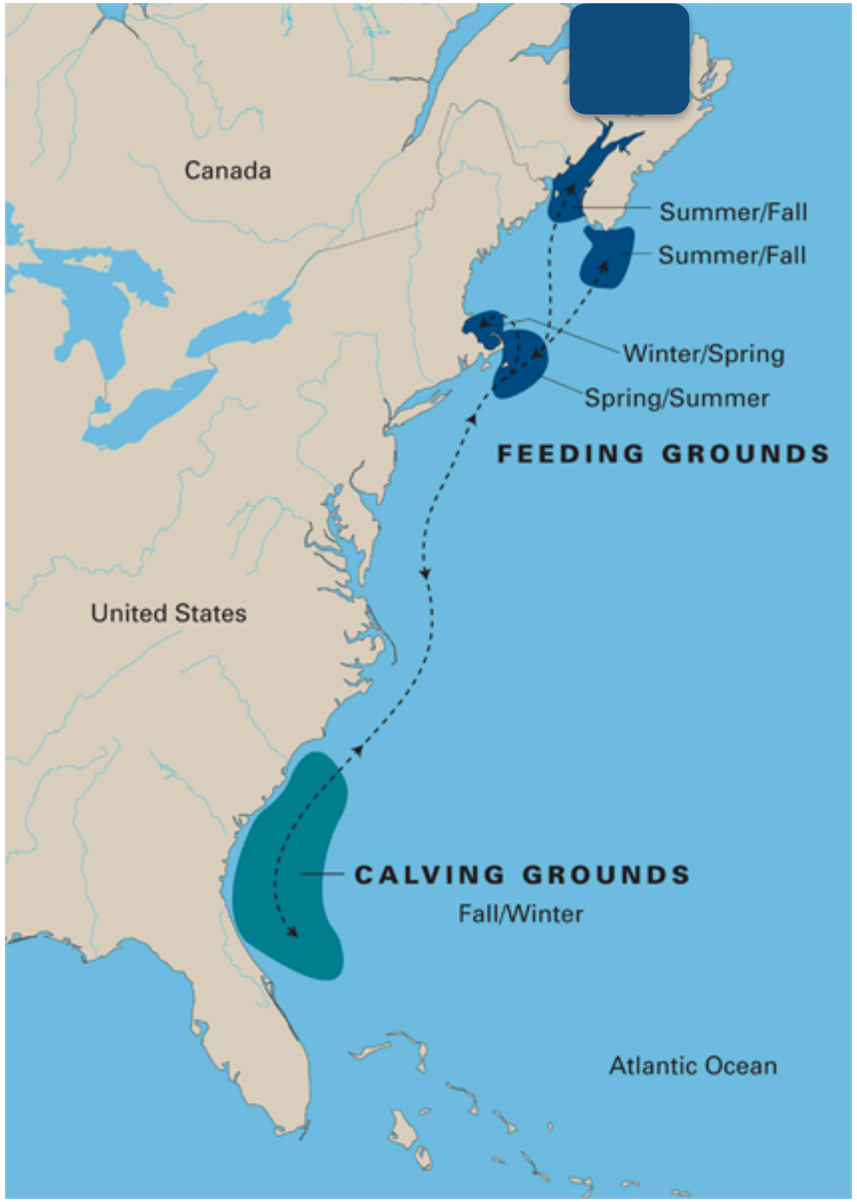

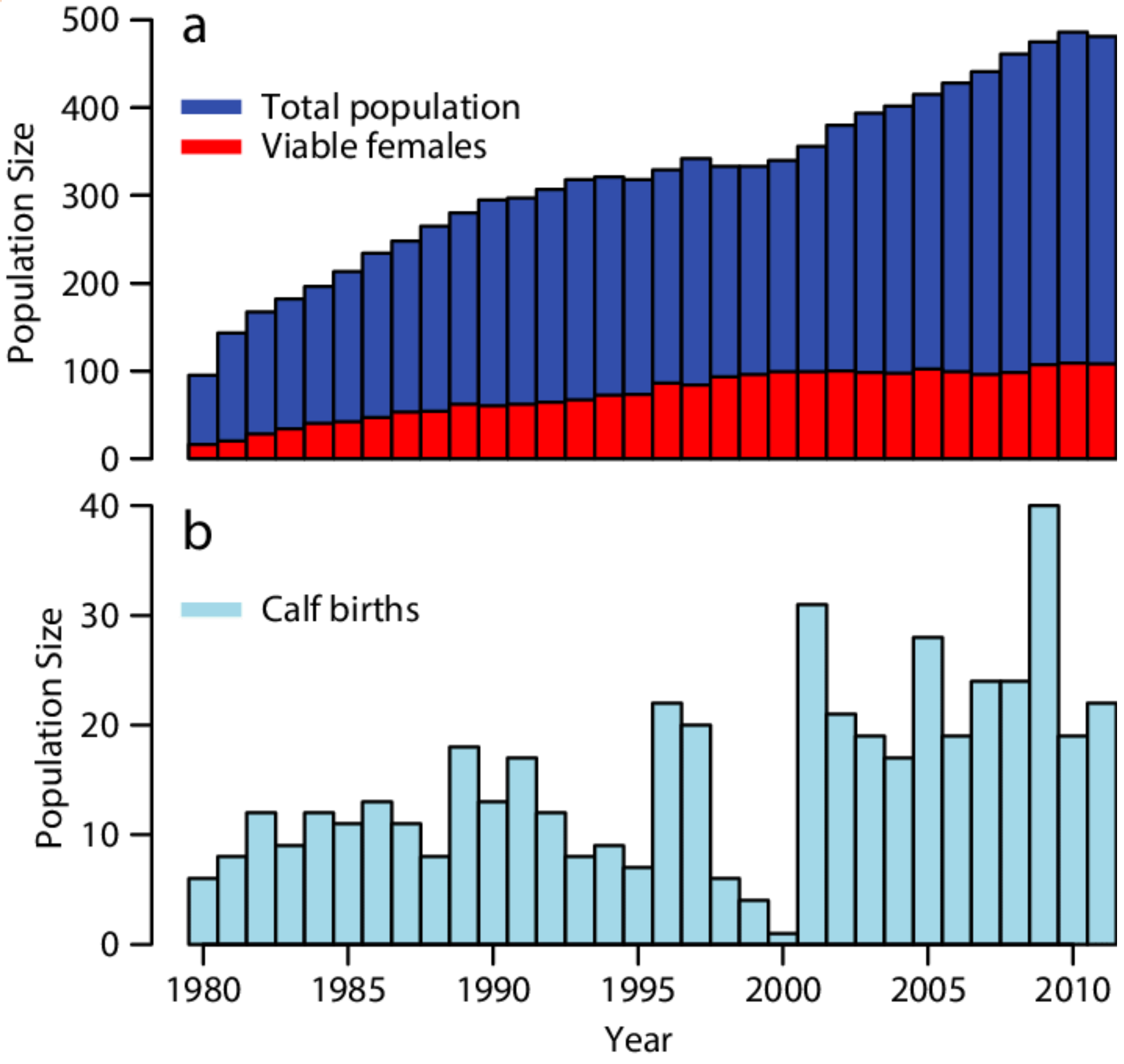

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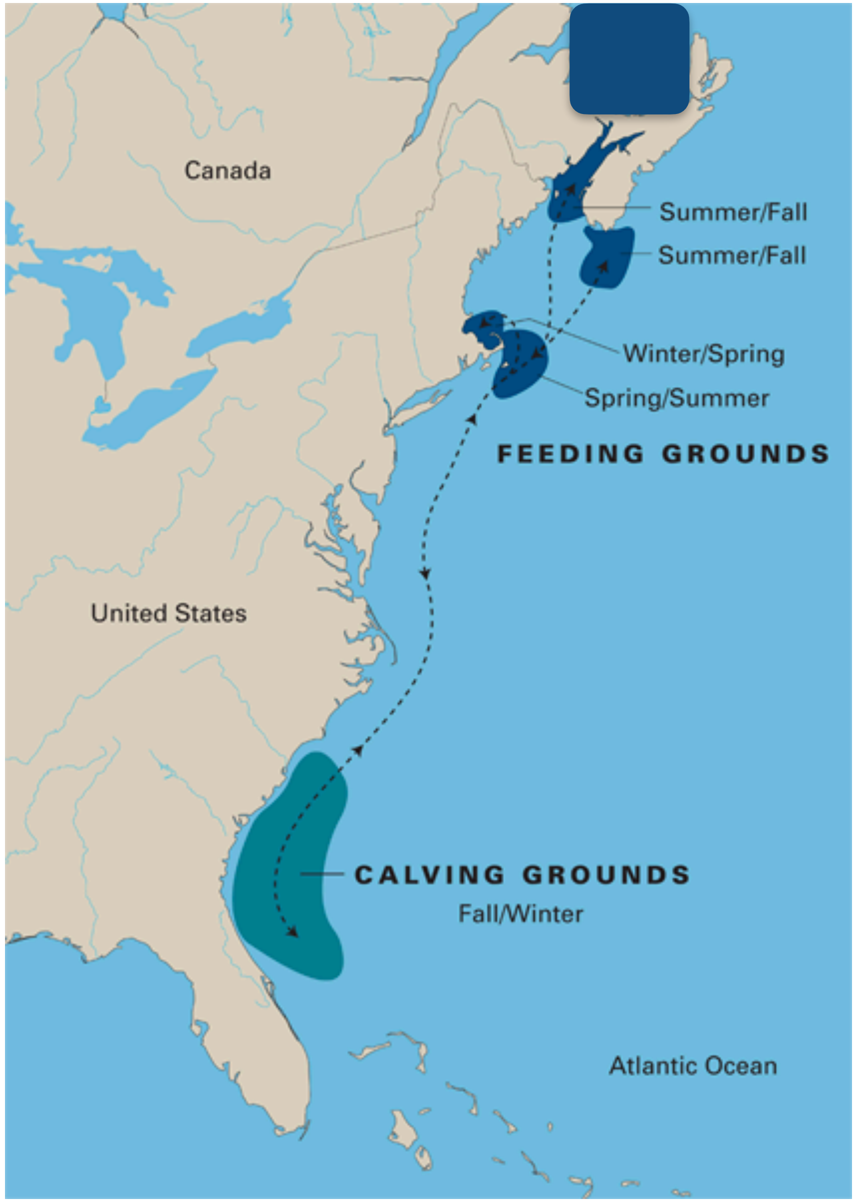

Starboard, a female right whale, died off Canada's coast after dragging snow crab traps for days.

NOAA/NEFSC/PETER DULEY

The North Atlantic right whale faces extinction

By **Elizabeth Pennisi** | Nov. 7, 2017 , 5:40 PM

New conditions, new risks

Lobster fishery reduces floating rope in hopes of protecting North Atlantic right whales

At least 18 of the endangered mammals died in Canadian and U.S. waters last year

Nancy Russell · CBC News · Posted: Apr 04, 2018 6:00 AM AT | Last Updated: April 4

A North Atlantic right whale entangled in Cape Cod, Mass. Lobster fishermen on P.E.I. are taking steps this year to reduce the chances of whales getting caught in their gear. (Center for Coastal Studies/NOAA permit #932-1905)

FOOD FOR THOUGHT

To Save Whales, Maine's Iconic Lobster Industry May Have To Change

March 24, 2018 · 9:46 AM ET

FRED BEVER

FROM maine public

North Atlantic right whales are at risk of extinction because they often become ensnared in ropes used to g
along the Northeastern U.S. and Canadian coastline.

David L. Ryan/Boston Globe via Getty Images

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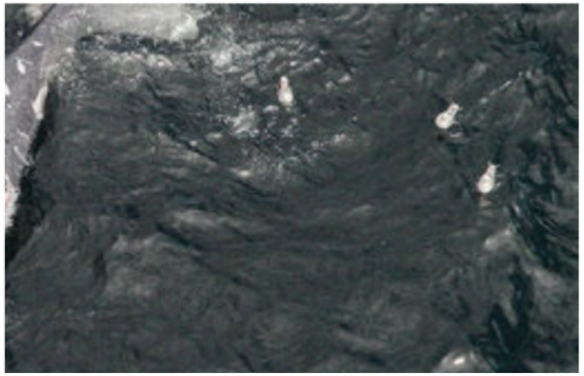
SC/PETER DULEY

North Atlantic right wha

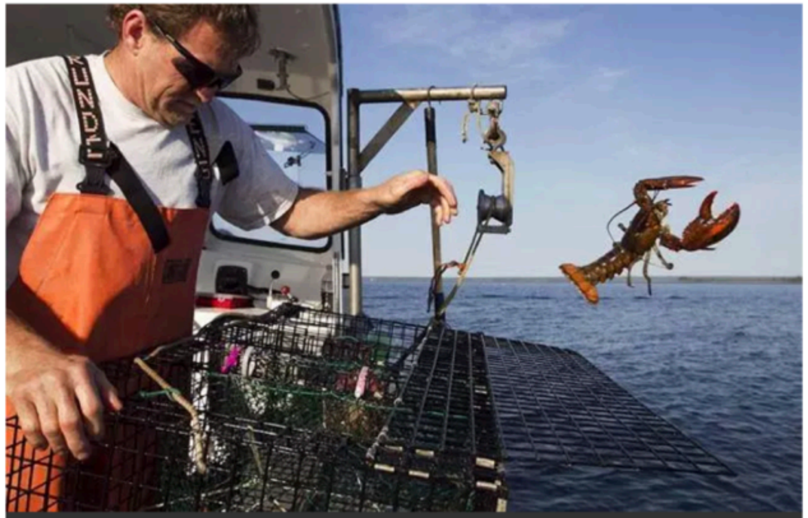
eth Pennisi | Nov. 7, 2017 , 5:40 PM



Ottawa will enforce new lobster fishing measures along N.B. coast to protect right whales

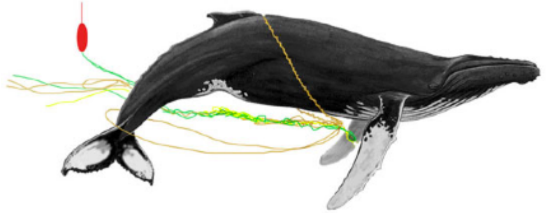
By Graeme Benjamin Global News

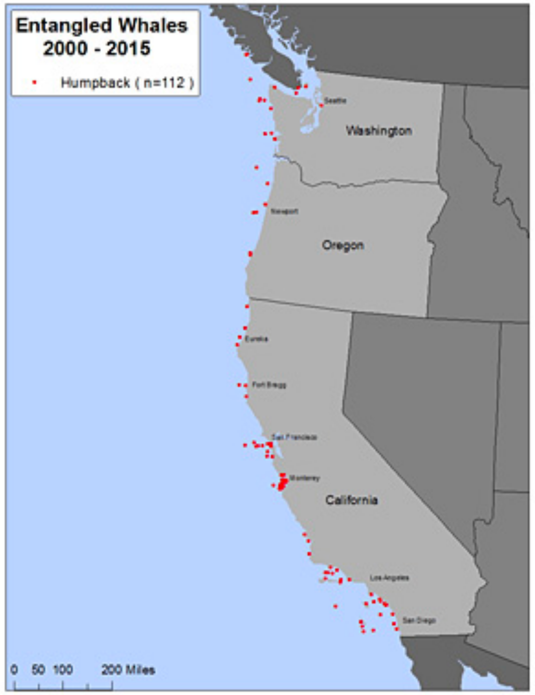
Comments | Facebook | Twitter | Email | Print | ...

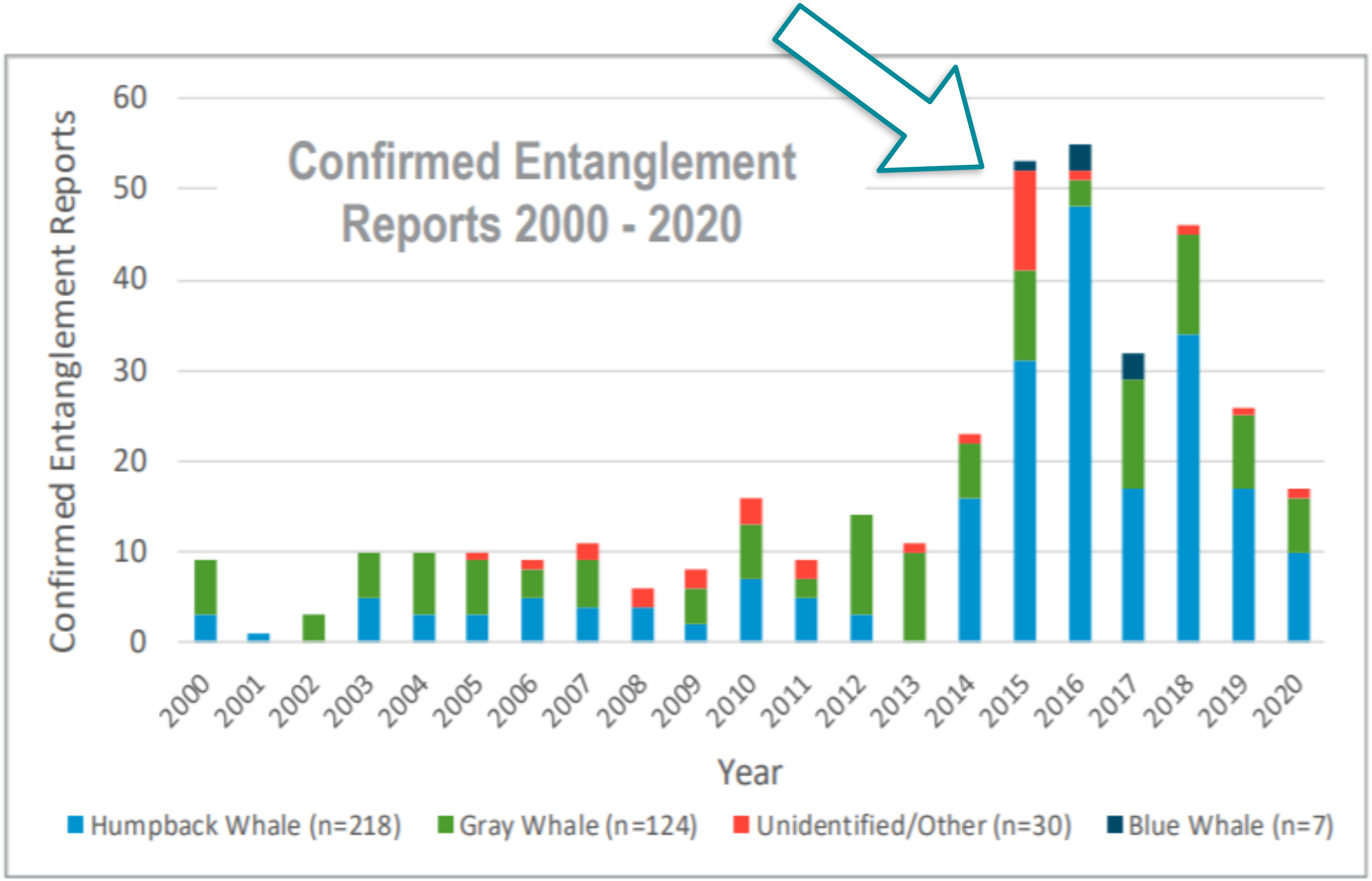


THE CANADIAN PRESS/AP/Robert F. Bukaty, File

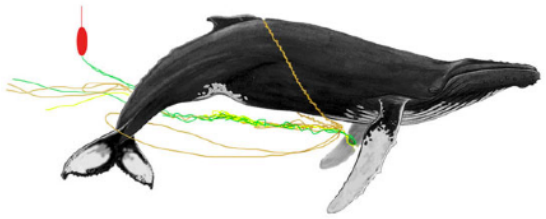
2015-16 Whale Entanglements

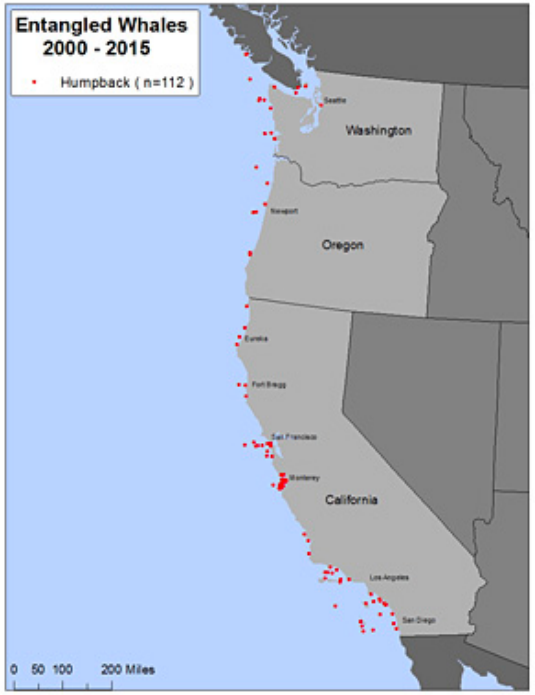


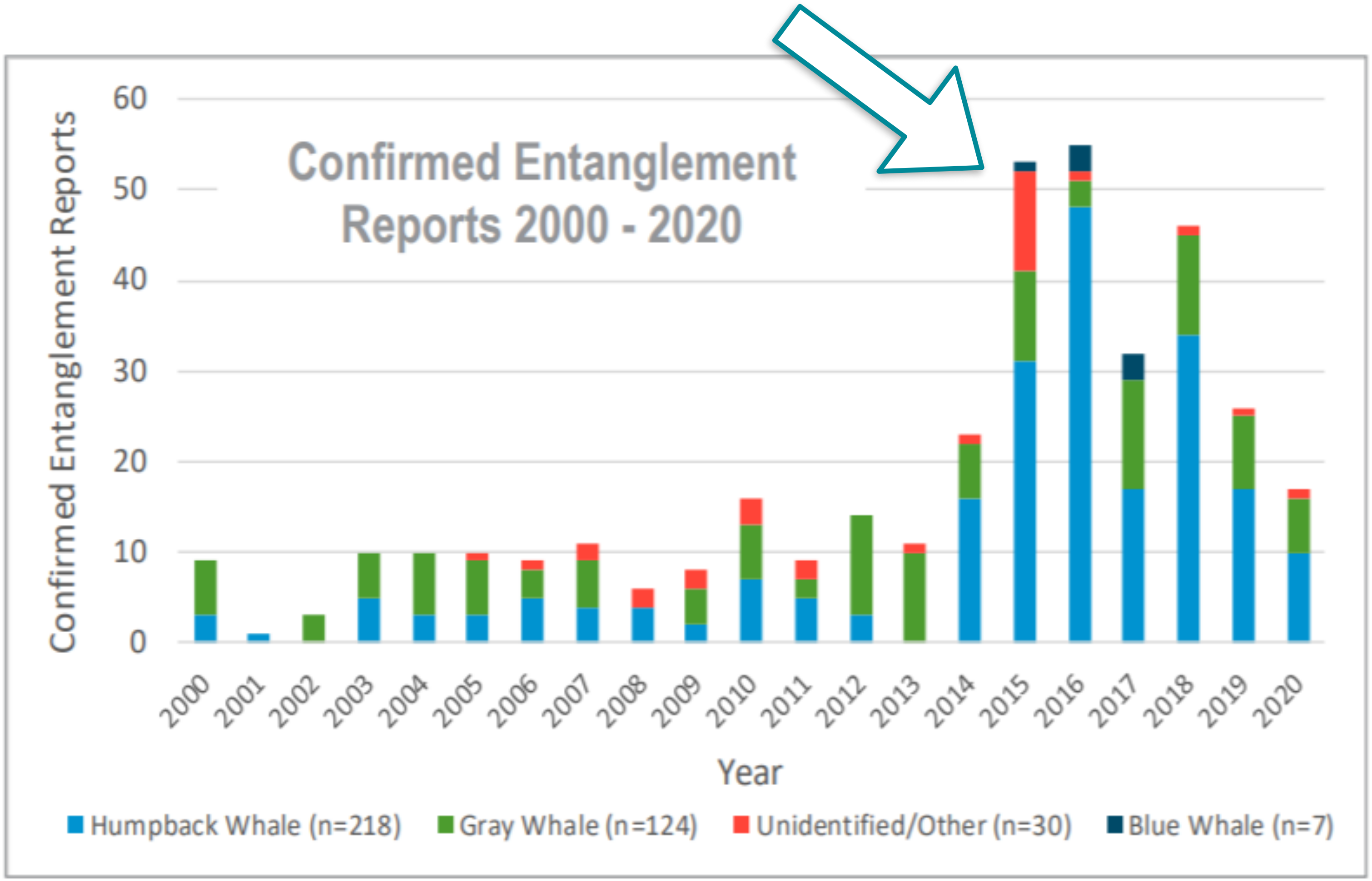




2015-16 Whale Entanglements

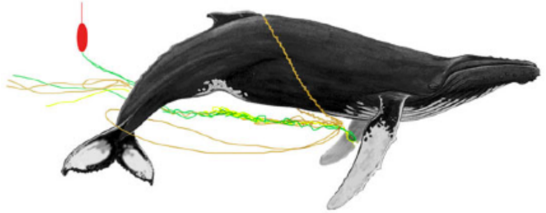






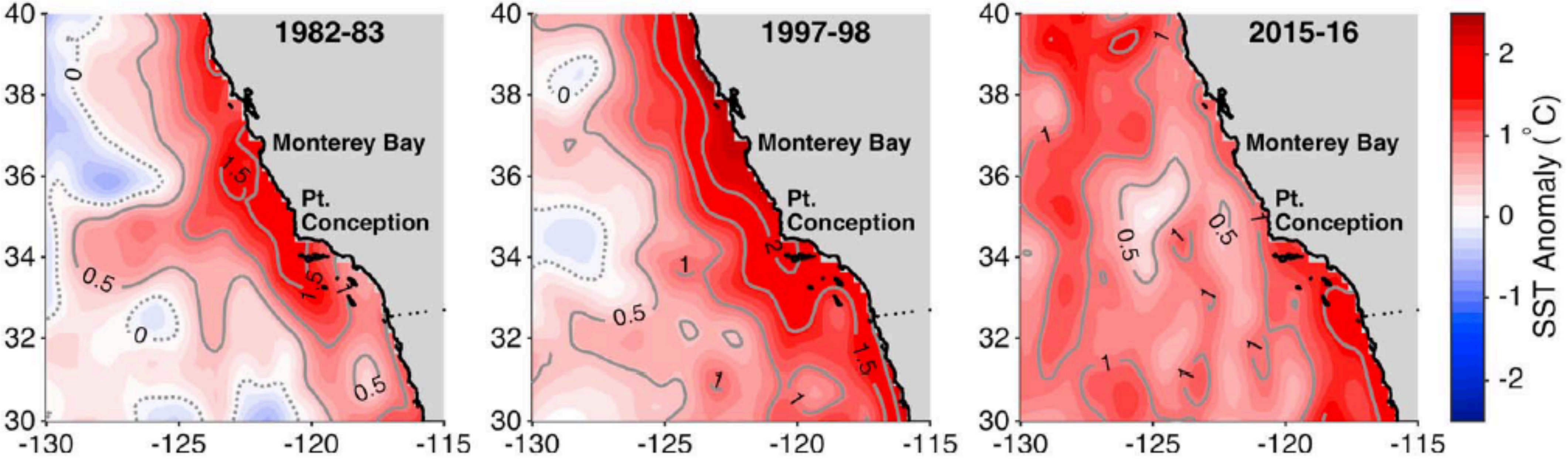
CSI: CRIME SCENE INVESTIGATION

2015-16 Whale Entanglements



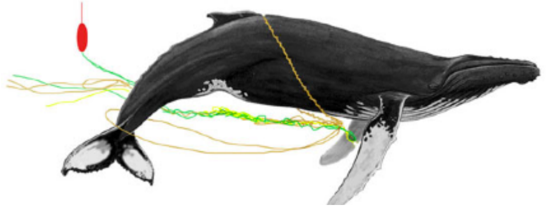
Key ecosystem ingredients:

Persistent marine heat wave



Jacox et al. (2016)

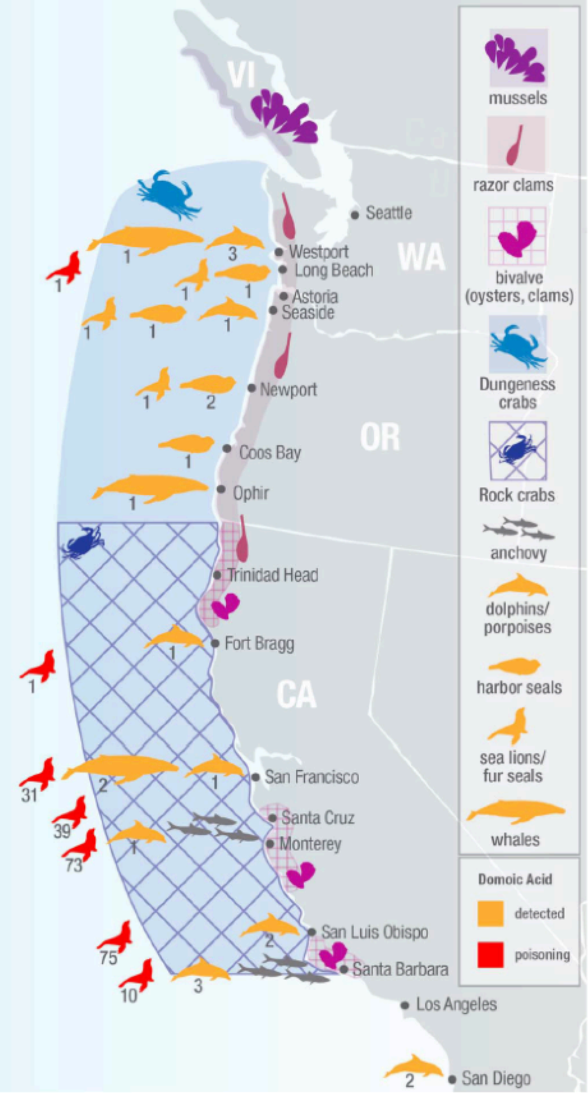
2015-16 Whale Entanglements



Key ecosystem ingredients:

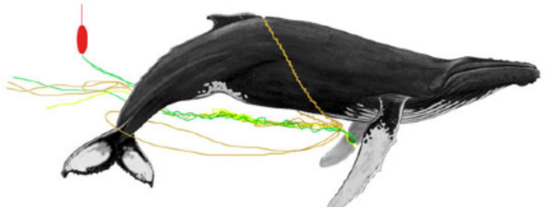
Persistent marine heat wave

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

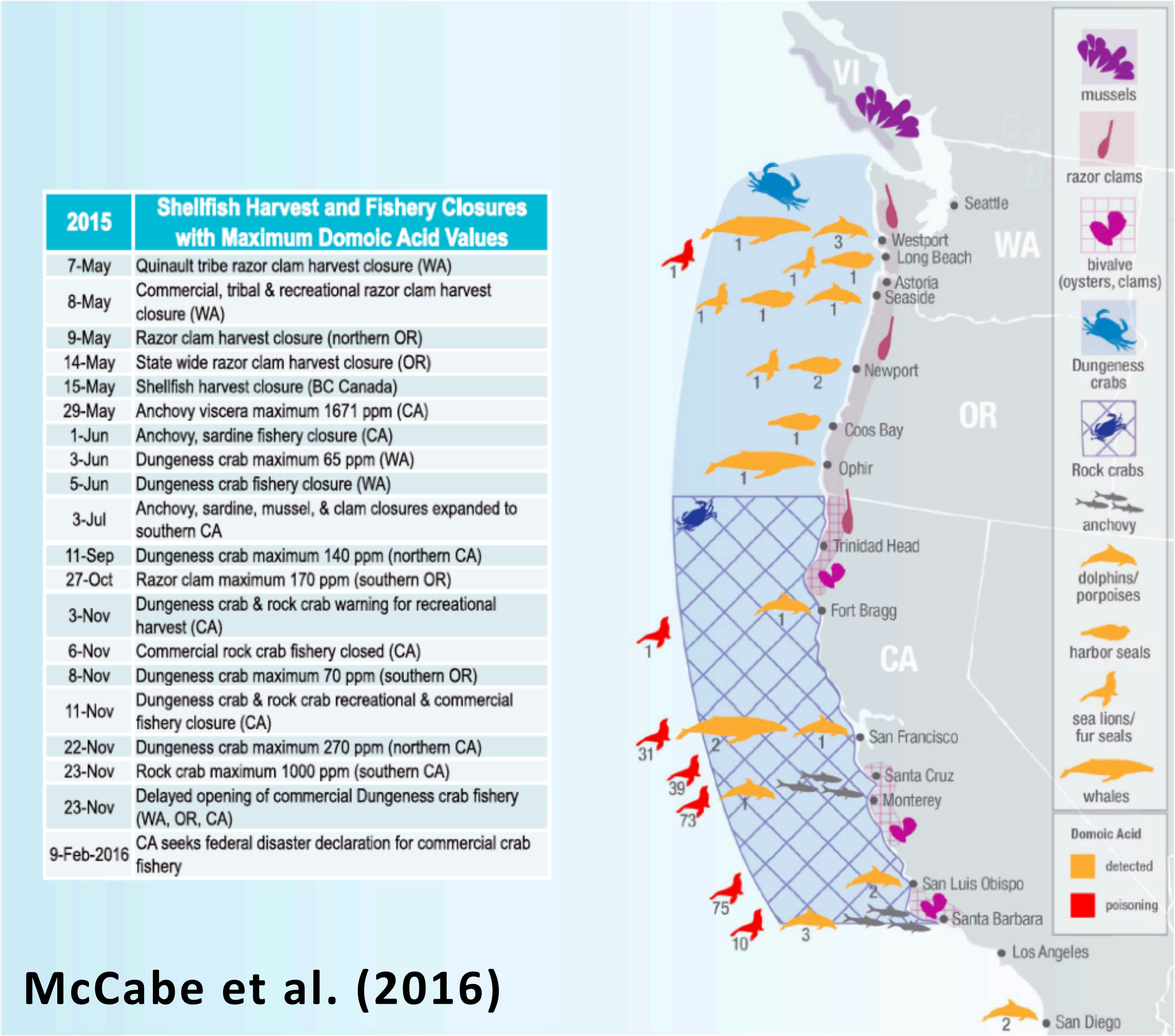


Key ecosystem ingredients:

Persistent marine heat wave

↓

Record HAB + domoic acid delayed Dungeness crab fishery



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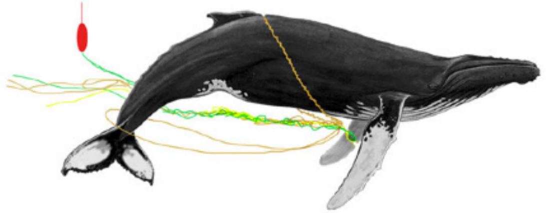

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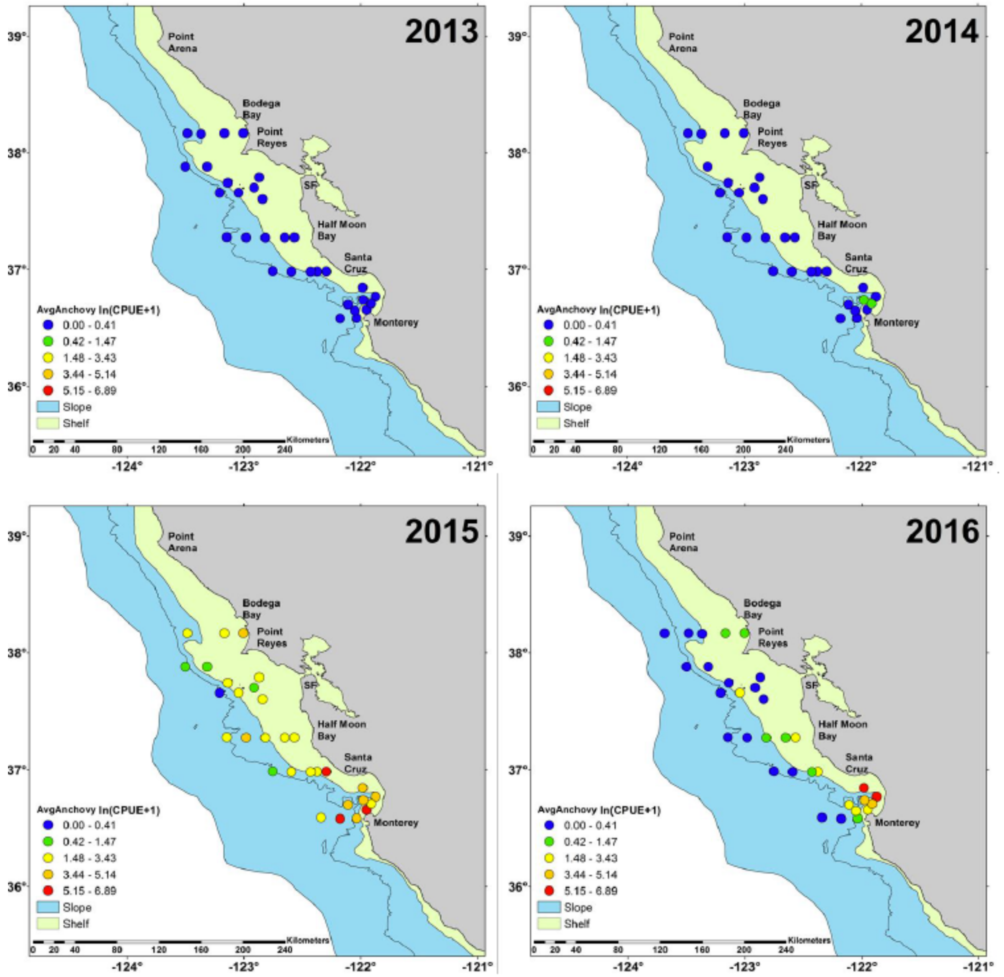
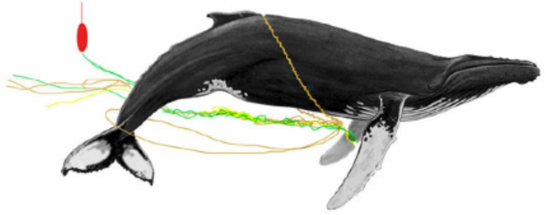
Record HAB + domoic acid delayed Dungeness crab fishery

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



May-June Anchovy CPUE from trawls (Santora et al. 2020 *Nat Comm*)

2015-16 Whale Entanglements



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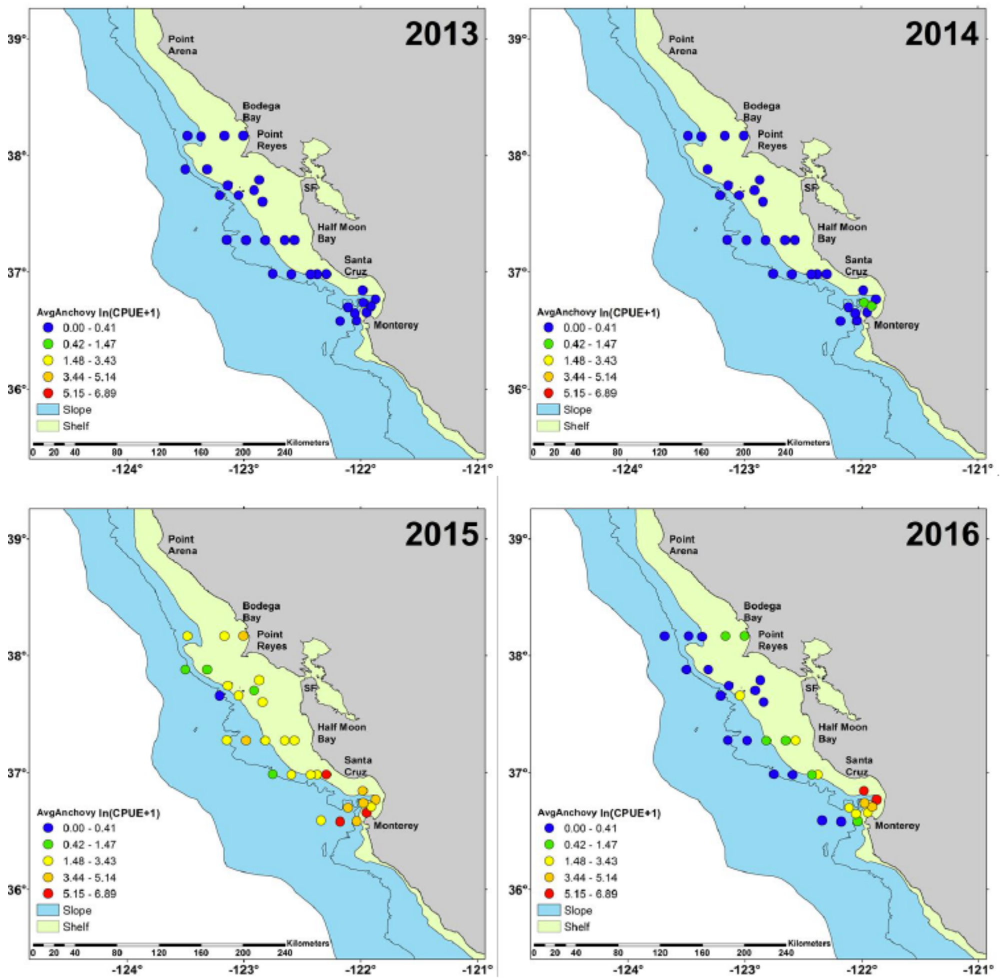
Low krill off shelf break & high concentration of anchovies on shelf

+ Humpback whale prey switching



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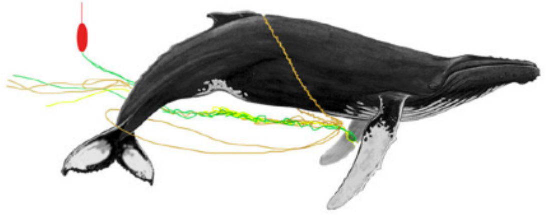

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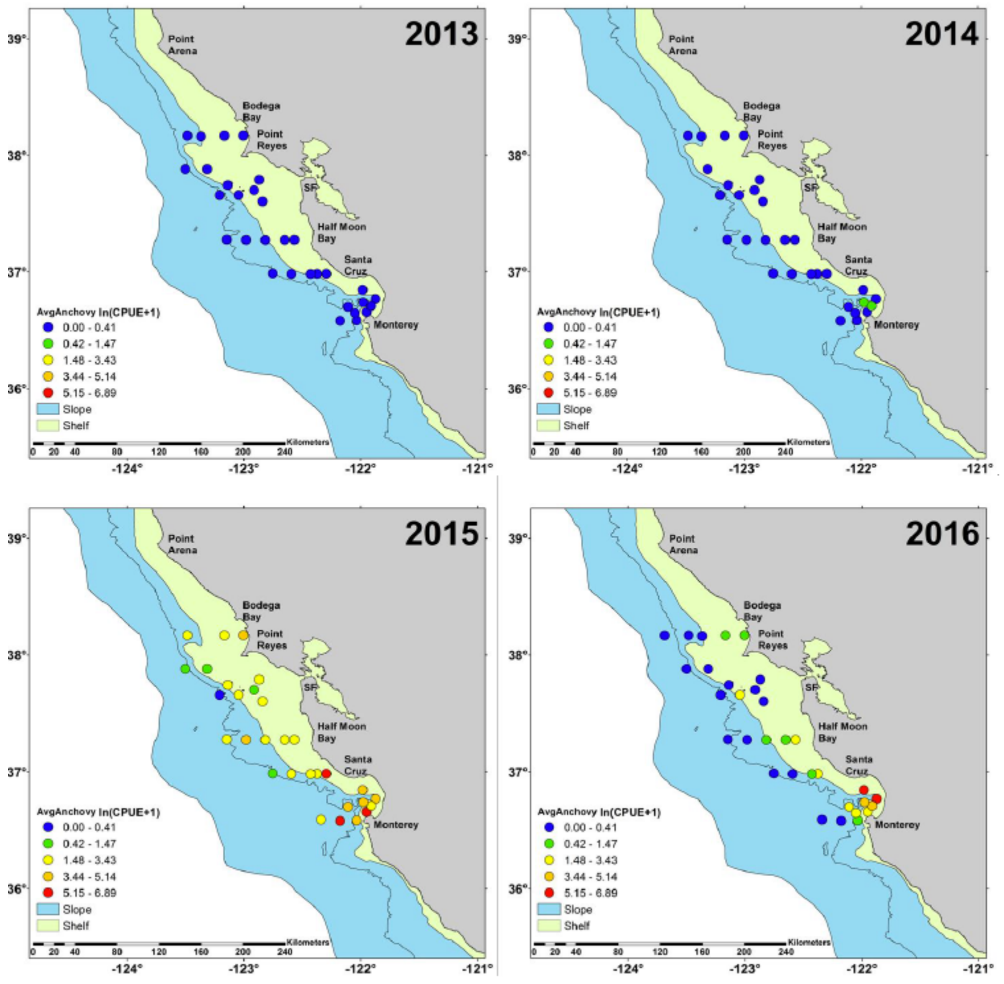
Recovering whale populations + Humpback whale prey switching



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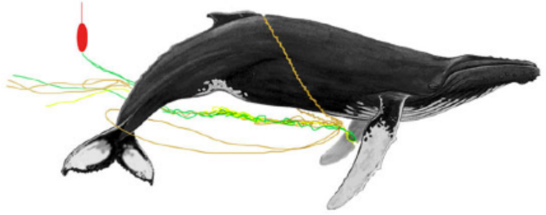
2015-16 Whale Entanglements



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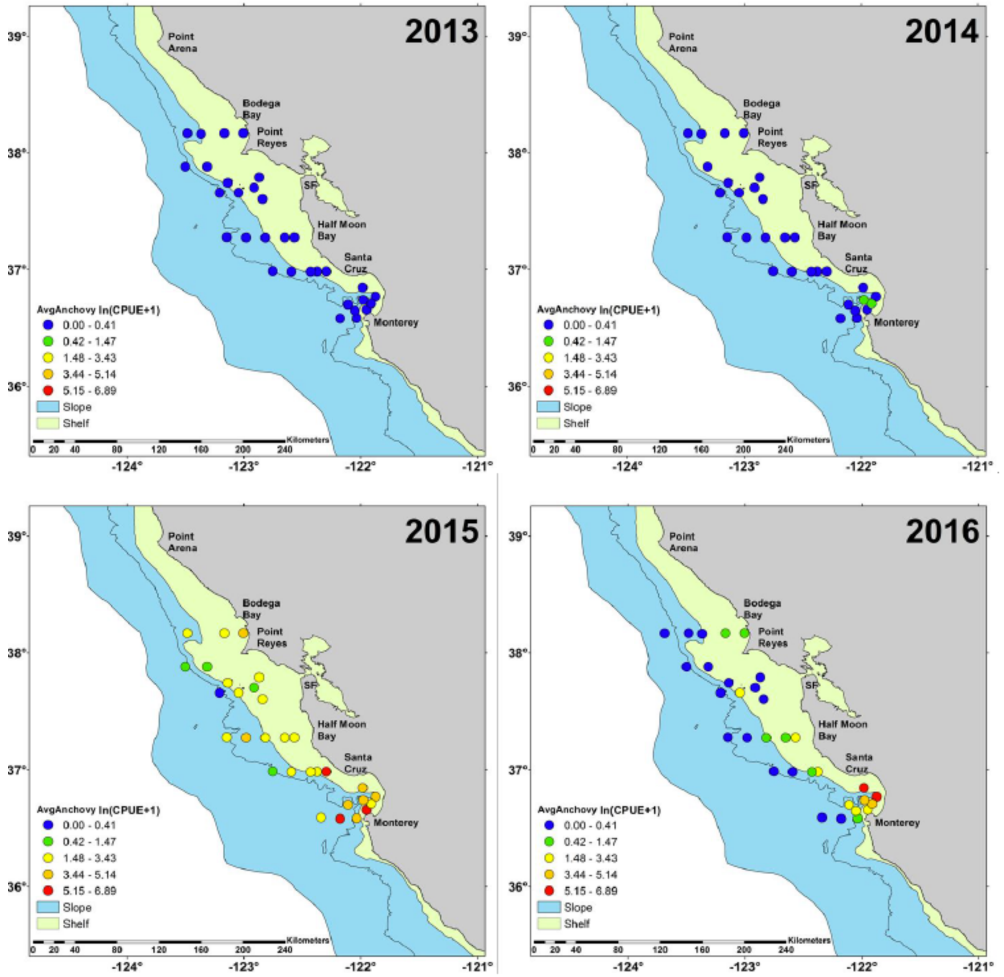

May-June Anchovy CPUE from trawls (Santora et al. 2020 *Nat Comm*)

End result: unusual time-space overlap of large numbers of foraging humpback whales and crab pots/lines

What do predators tell us?

Figure 1. Sampling methods and measurements of select predators: (a) collection of penguin chick morphometrics, (b) leatherback sea turtle (*Dermochelys coriacea*) with a satellite tag, (c) blue whale (*Balaenoptera musculus*) morphometrics via unmanned aircraft system, and (d) weight measurements of a female elephant seal (*Mirounga angustirostris*) carrying a biologging tag.

Marine top predators as climate and ecosystem sentinels

Elliott L Hazen[1,2*], Briana Abrahms[1], Stephanie Brodie[1,2], Gemma Carroll[1,2], Michael G Jacox[1,2,3], Matthew S Savoca[1,4], Kylie L Scales[5], William J Sydeman[6], and Steven J Bograd[1,2]

The rapid pace of environmental change in the Anthropocene necessitates the development of a new suite of tools for measuring ecosystem dynamics. Sentinel species can provide insight into ecosystem function, identify hidden risks to human health, and predict future change. As sentinels, marine apex (top) predators offer a unique perspective into ocean processes, given that they can move across ocean basins and amplify trophic information across multiple spatiotemporal scales. Because use of the terms "ecosystem sentinel" and "climate sentinel" has proliferated in the scientific literature, there is a need to identify the properties that make marine predators effective sentinels. We provide a clear definition of the term "sentinel", review the attributes of species identified as sentinels, and describe how a suite of such sentinels could strengthen our understanding and management of marine ecosystems. We contend that the use of marine predators as ecosystem sentinels will enable rapid response and adaptation to ecosystem variability and change.

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In an era of unprecedented environmental change, developing a suite of tools for ecosystem monitoring is critical. This need is particularly urgent in marine ecosystems, given the rapid, climate-driven changes in marine populations and communities (Poloczanska *et al.* 2013). Comprehensive monitoring in marine ecosystems presents a challenge due to difficulties inherent in observing the highly dynamic ocean environment at relevant timescales. Traditional ship-based surveys are expensive, autonomous floats and underwater vehicles are still sparsely distributed, and remote sensing fails to capture three-dimensional ocean structure. Furthermore, ecological monitoring in the open ocean is largely extractive and often involves lethal sampling of animal communities. In the undersampled marine realm, innovative and cost-effective tools that can rapidly assess ecosystem responses to environmental change are vital.

In a nutshell:

- Marine top predators are often conspicuous and wide ranging, and integrate information from the bottom to the top of the food web
- Such predators could act as "sentinels" of an ecosystem's response to climate variability and change
- We define the terms "climate sentinel" and "ecosystem sentinel", and describe the features of marine predators that would make them useful in these roles
- Choosing one or more appropriate sentinels can provide insight into ecosystem processes and help to manage changing ecosystems into the future

"Sentinel" species have been proposed as a means to provide information about unobserved components of the ecosystem (Zacharias and Roff 2001). Classic examples of sentinels include a domesticated variety of the canary (*Serinus canaria*), which was formerly used to monitor air quality in coal mines, and invertebrates, whose diversity has been used as an indicator of aquatic ecosystem health (Wilhm and Dorris 1968; Barry 2013). More recent studies show that vertebrate species can serve as sentinels of human health and environmental pollution (Bossart 2006; Smits and Fernie 2013), as well as coupled climate–ecosystem processes (Moore 2008). Useful sentinel species should integrate broader processes into rapidly interpretable metrics that reflect underlying ecosystem processes. Marine top predators (including certain species of predatory fish, seabirds, sea turtles, and marine mammals) have been proposed as ecosystem sentinels based on their conspicuous nature and capacity to indicate or respond to changes in ecosystem structure and function that would otherwise be difficult to observe directly (Figure 1; Bossart 2006; Boersma 2008; Moore 2008). Many marine top predators possess key characteristics of sentinel species, including (1) exhibiting clear responses to environmental variability or change (Sydeman *et al.* 2015; Fleming *et al.* 2016), (2) playing important roles in shaping marine food webs (Estes *et al.* 2016), and (3) indicating anthropogenic impacts on ecosystems (Sergio *et al.* 2008). Given these characteristics, there is a strong argument for using marine predators as ecosystem sentinels.

Despite the contemporary use of marine predators as sentinels (relevant examples are listed in WebTable 1), the absence of a standardized framework for identifying sentinel

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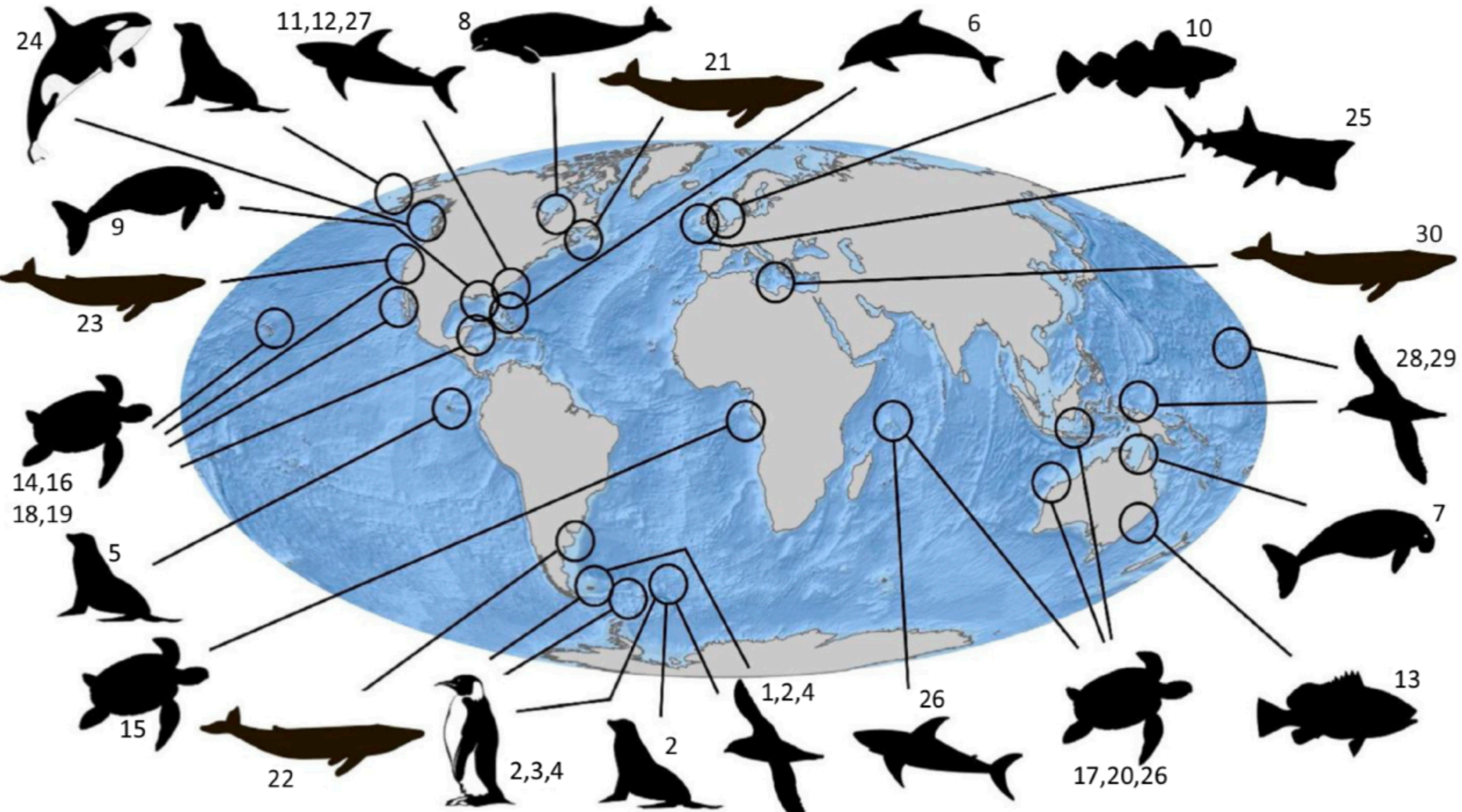
Tag data increasing in conservation



Trends in Ecology & Evolution

CellPress REVIEWS

Review

Translating Marine Animal Tracking Data into Conservation Policy and Management

Graeme C. Hays,[1,*] Helen Bailey,[2] Steven J. Bograd,[3] W. Don Bowen,[4] Claudio Campagna,[5] Ruth H. Carmichael,[6,7] Paolo Casale,[8] Andre Chiaradia,[9] Daniel P. Costa,[10] Eduardo Cuevas,[11,12] P.J. Nico de Bruyn,[13] Maria P. Dias,[14,15] Carlos M. Duarte,[16] Daniel C. Dunn,[17] Peter H. Dutton,[18] Nicole Esteban,[19] Ari Friedlaender,[10,20] Kimberly T. Goetz,[21] Brendan J. Godley,[22] Patrick N. Halpin,[17] Mark Hamann,[23] Neil Hammerschlag,[24] Robert Harcourt,[25] Autumn-Lynn Harrison,[26] Elliott L. Hazen,[3] Michelle R. Heupel,[27] Erich Hoyt,[28,35] Nicolas E. Humphries,[29] Connie Y. Kot,[17] James S.E. Lea,[30] Helene Marsh,[23] Sara M. Maxwell,[31] Clive R. McMahon,[25,32,33] Giuseppe Notarbartolo di Sciara,[34,35] Daniel M. Palacios,[36] Richard A. Phillips,[37] David Righton,[38,39] Gail Schofield,[40] Jeffrey A. Seminoff,[41] Colin A. Simpfendorfer,[23] David W. Sims,[29,42,43] Akinori Takahashi,[44] Michael J. Tetley,[35] Michele Thums,[45] Philip N. Trathan,[35] Stella Villegas-Amtmann,[10] Randall S. Wells,[46] Scott D. Whiting,[47] Natalie E. Wildermann,[48] and Ana M.M. Sequeira[49]

There have been efforts around the globe to track individuals of many marine species and assess their movements and distribution, with the putative goal of supporting their conservation and management. Determining whether, and how, tracking data have been successfully applied to address real-world conservation issues is, however, difficult. Here, we compile a broad range of case studies from diverse marine taxa to show how tracking data have helped inform conservation policy and management, including reductions in fisheries bycatch and vessel strikes, and the design and administration of marine protected areas and important habitats. Using these examples, we highlight pathways through which the past and future investment in collecting animal tracking data might be better used to achieve tangible conservation benefits.

Highlights

The value of animal tracking data to inform policy is illustrated by case studies from around the world and with a broad range of taxa.

Application of tracking data to policy and management can take various pathways, and engagement with stakeholders might often not be made by the original data collectors.

The impact of tracking data on policy and management can be improved if data collection and analyses target specific needs for management outcomes.

Early engagement among the data collectors and the stakeholders involved in policy development and implementation is important to help translate tracking data into conservation outcomes.

Tracking Data and Conservation Policy

The advent of reliable technology to track individual animals long-term (often >1 year), throughout marine and terrestrial environments, has produced a golden era for animal tracking studies [1,2]. In marine systems, long-term tracking is now routine for fish (e.g., bony fish, sharks, rays), birds (e.g., penguins, albatrosses, and shearwaters), mammals (e.g., seals, sirenians, dolphins, and whales), and reptiles (e.g., sea turtles). One driver behind growth in marine animal tracking studies is the need for distribution and movement data to inform conservation policy and management. In a recent literature review of 13 349 'movement ecology' papers published between 1990 and 2014, 35% ($n = 4672$ papers) mentioned 'conservation' [3]. However, the value of tracking data to inform policy is often presented as a 'given', yet not explicitly demonstrated [4]. For example, a review of the conservation impact of sea turtle tracking studies highlighted that of 369 papers published between 1982 and 2014 (supported by a questionnaire-based survey of 171 sea turtle researchers), there were only 12 instances where tracking findings led to clearly identifiable real-world changes in conservation practice, even though >120 papers identified conservation as a rationale for the work [5]. This suggests that either tracking and distribution data are not considered to be relevant or barriers exist which prevent their uptake by policy makers and managers, to the

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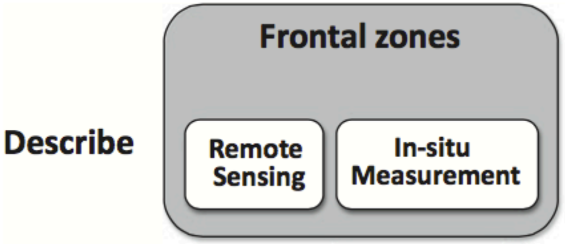
 https://doi.org/10.1016/j.tree.2019.01.009

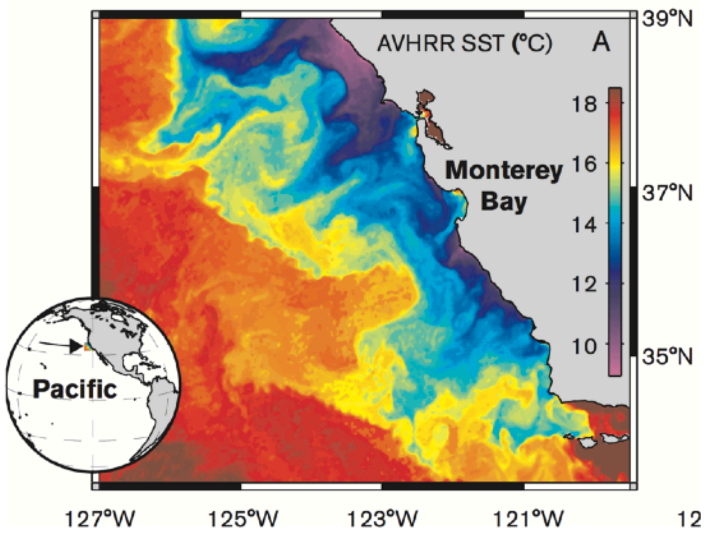
Dynamic Ocean Management

Management that changes in space and time, at scales relevant for animal movement and human use.

Hobday et al. 2014, Lewison et al. 2015, Maxwell et al. 2015, Hazen et al. 2018

Dynamic Ocean Management





Ryan et al. 2005

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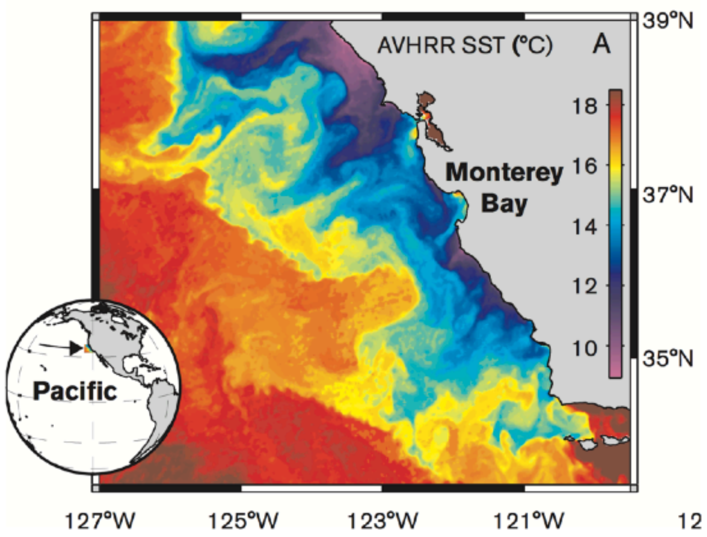

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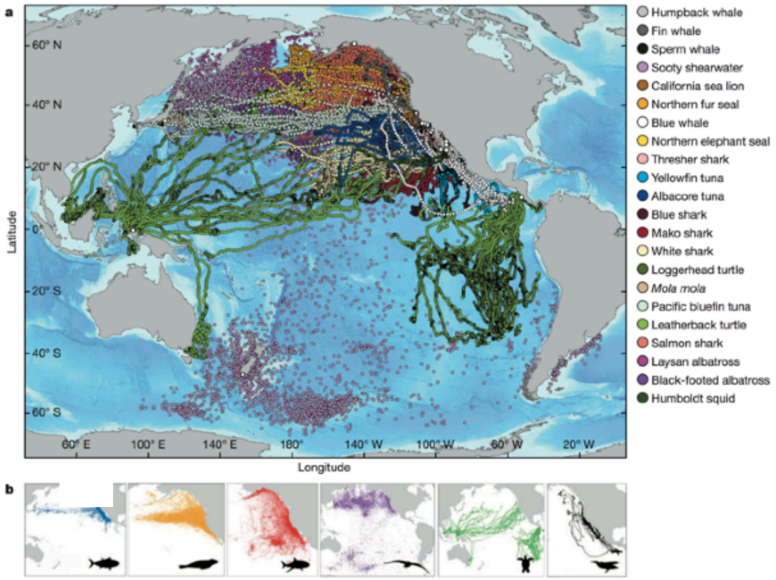

Block et al. 2011

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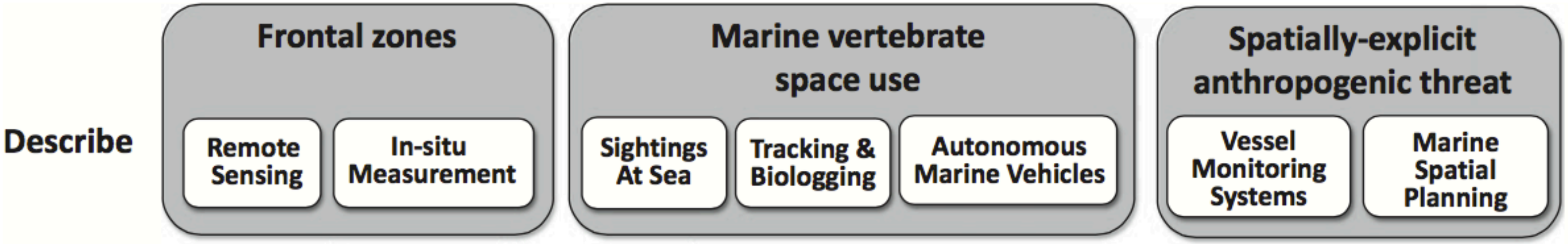
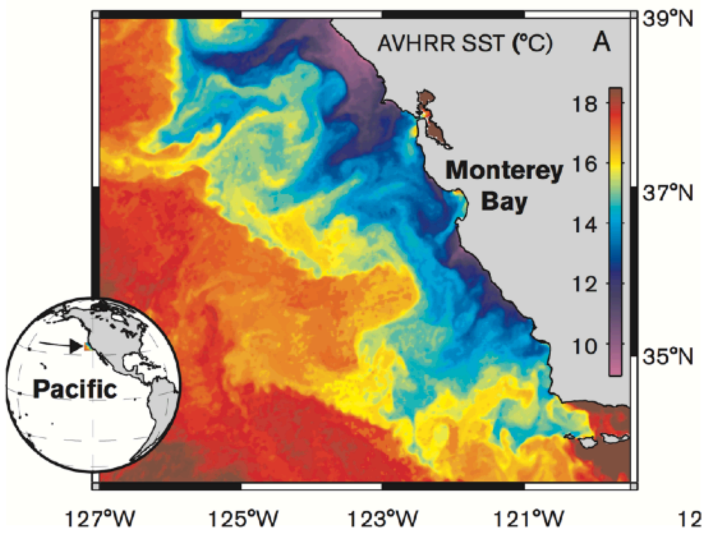
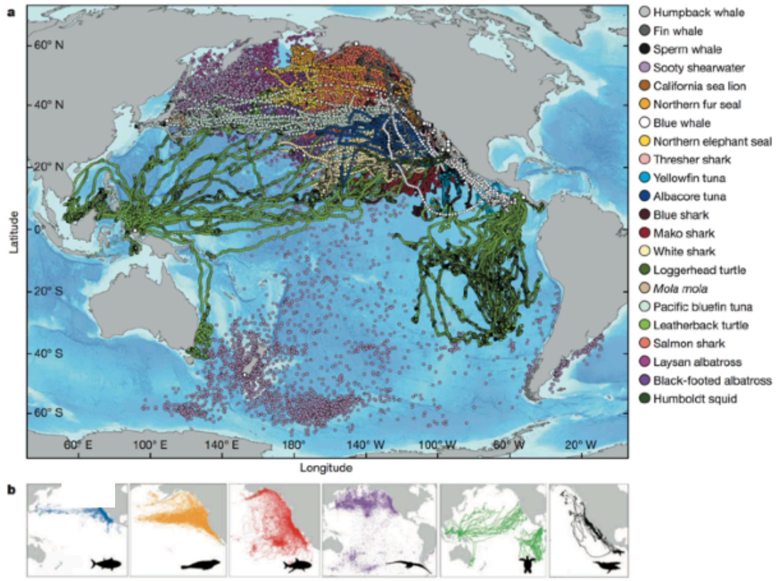
Dynamic Ocean Management

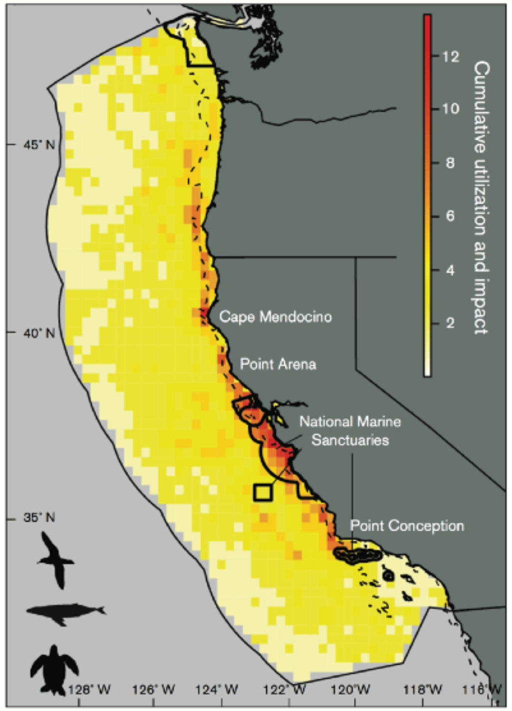




Ryan et al. 2005



Block et al. 2011

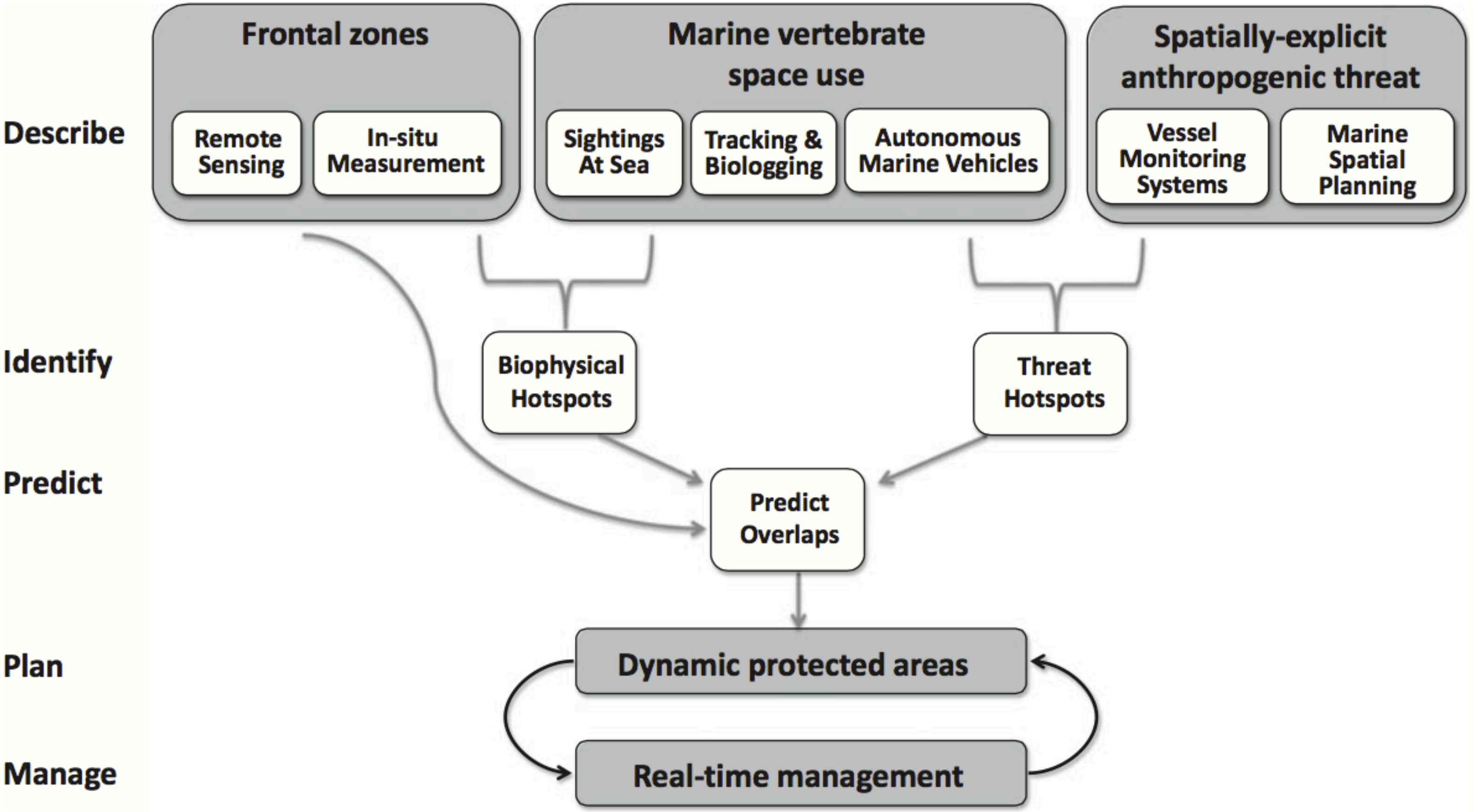


Maxwell et al. 2013

Management that changes in space and time, at scales relevant for animal movement and human use.

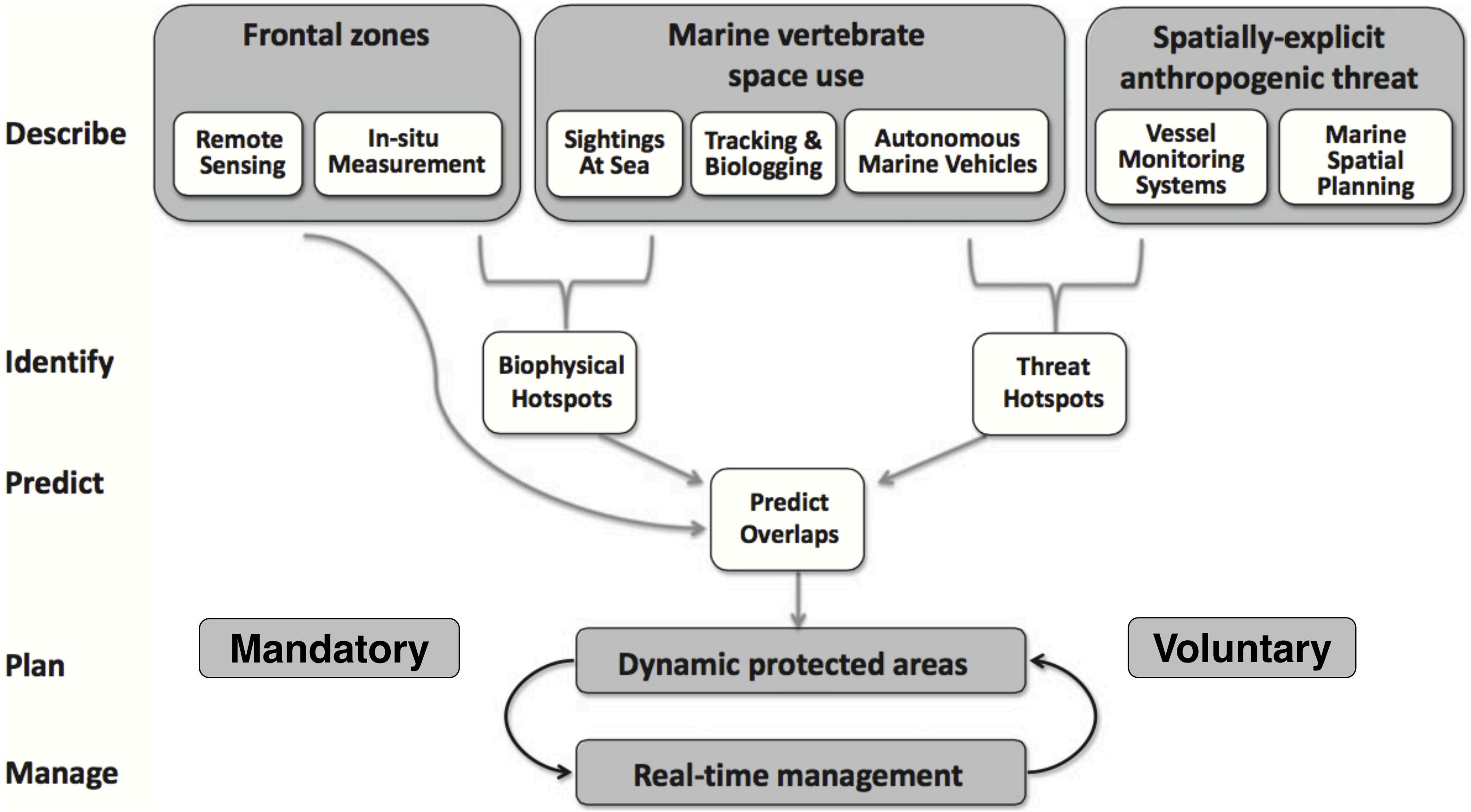
Hobday et al. 2014, Lewison et al. 2015, Maxwell et al. 2015, Hazen et al. 2018

Dynamic Ocean Management



Scales et al. 2014 J Appl Ecol

Dynamic Ocean Management



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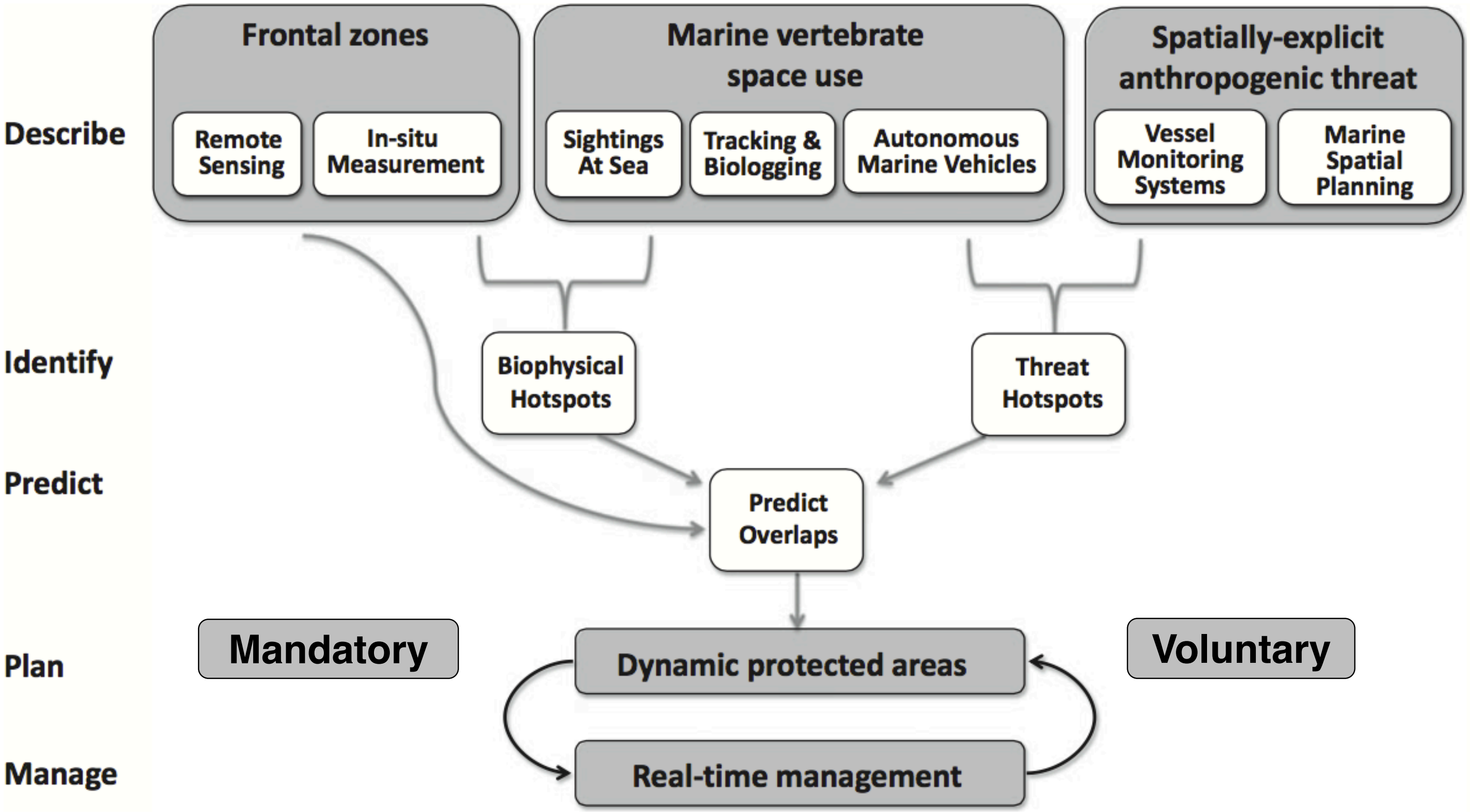
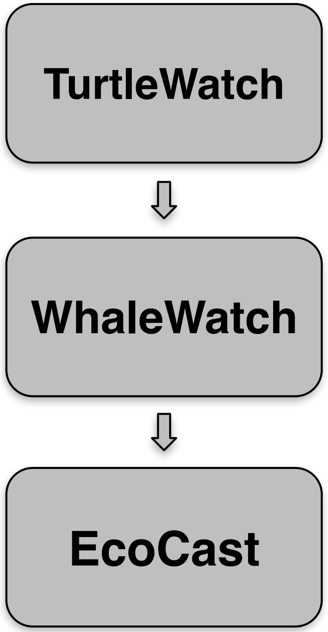
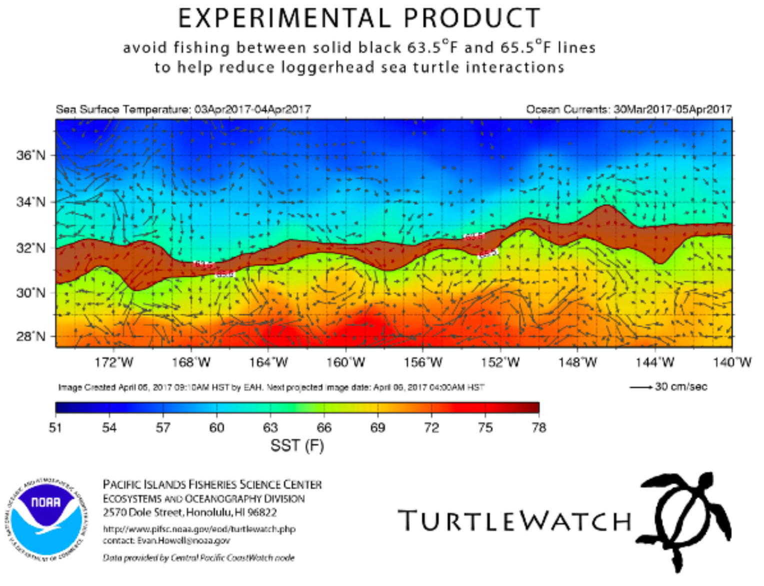




Scales et al. 2014 J Appl Ecol

TurtleWatch

Voluntary,
yet effective



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ENDANGERED SPECIES RESEARCH
Endang Species Res

Printed December 2008
Published online July 1, 2008

Contribution to the Theme Section 'Fisheries bycatch: problems and solutions'

OPEN ACCESS

TurtleWatch: a tool to aid in the bycatch reduction of loggerhead turtles *Caretta caretta* in the Hawaii-based pelagic longline fishery

Evan A. Howell[1,*], Donald R. Kobayashi[1,2], Denise M. Parker[1,3], George H. Balazs[1], Jeffrey J. Polovina[1]

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ABSTRACT: Operational longline fishery characteristics, bycatch information, and loggerhead turtle satellite tracks were all used in conjunction with remotely sensed sea surface temperature data to identify the environmental area where the majority of loggerhead turtle bycatch occurred in the Hawaii-based longline fishery during 1994 to 2006. In the first quarter of each calendar year from 1994 to 2006, the majority of shallow longline sets and associated loggerhead turtle bycatch were above 28° N, which corresponds to the area near the North Pacific Subtropical Frontal Zone. Based on the thermal ranges of bycatch, sets and the satellite-tagged turtles, it was recommended that shallow sets should only be deployed in waters south of the 18.5°C (~65.5°F) isotherm to decrease loggerhead turtle bycatch. This recommendation formed the basis for the TurtleWatch tool, a map providing up-to-date information about the thermal habitat of loggerhead sea turtles in the Pacific Ocean north of the Hawaiin Islands. TurtleWatch was released to fishers and managers in electronic and paper formats on December 26, 2006, to assist in decision making during the first quarter of 2007. Fishery information from 2007 was later compared with data for the years 2005 to 2006 to assess the response of the fishery to TurtleWatch. The observed fleet movement during the first quarter of 2007 was to the north of the 18.5°C (~65.5°F) isotherm (i.e. in the area recommended for avoidance by the TurtleWatch product) with increased effort and lower bycatch rates. We discuss possible reasons for this decrease in turtle bycatch north of the frontal zone together with future research directions which may lead to refinement of the TurtleWatch product.

KEY WORDS: Loggerhead turtles · Bycatch · Remote-sensing · Sea surface temperature · Longline fishery · Transition zone · Swordfish

INTRODUCTION

The interactions of sea turtles with high seas fisheries are a global concern, with fisheries bycatch implicated as one of several factors in the population decline of many sea turtle species, including the loggerhead turtle *Caretta caretta* (Hatase et al. 2002, Hays et al. 2003, Peckham et al. 2007). The loggerhead is a circumglobal sea turtle species (Dodd 1988) that undergoes a series of ontogenetic shifts during its life cycle, with stages occupying a series of habitats that include nesting beach, oceanic, and neritic areas (Bjorndal 2003). In the North Pacific, loggerhead nesting beaches are only found in Japan, where, during the last half of the 20th century a substantial decline (50 to 90%) in the size of the annual loggerhead nesting population at nesting beaches was reported (Kamezaki et al. 2003). The importance of the oceanic stage to juvenile loggerheads was hypothesized first by Carr (1987) with recent work by Polovina et al. (2006) reporting that specific pelagic regions, such as the Kuroshio Extension Bifurcation Region of the North

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TurtleWatch

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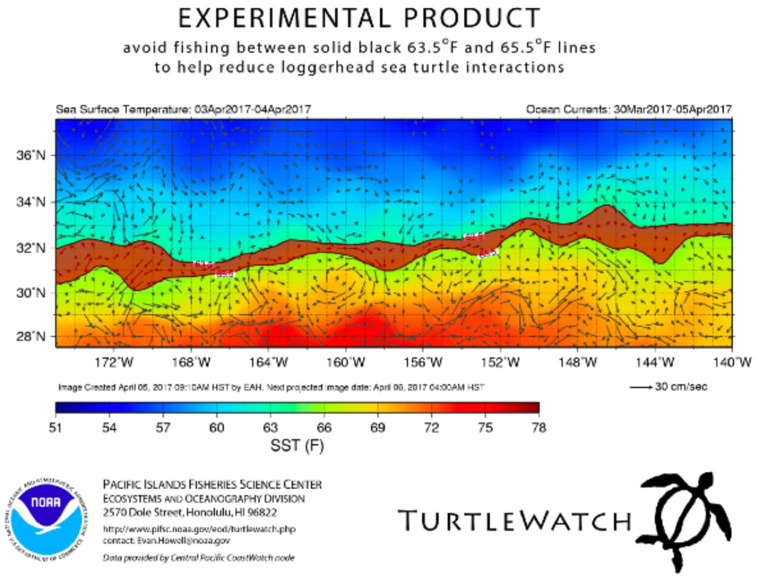

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[2]Department of Environmental Sciences, University of Technology, Sydney, Broadway, New South Wales 2007, Australia

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FISHERIES OCEANOGRAPHY

FISHERIES OCEANOGRAPHY *Fish. Oceanogr.* 24:1, 57–68, 2015

Enhancing the TurtleWatch product for leatherback sea turtles, a dynamic habitat model for ecosystem-based management

EVAN A. HOWELL,[1,*] AIMEE HOOVER,[2,4] SCOTT R. BENSON,[3] HELEN BAILEY,[4] JEFFREY J. POLOVINA,[1] JEFFREY A. SEMINOFF[5] AND PETER H. DUTTON[5]

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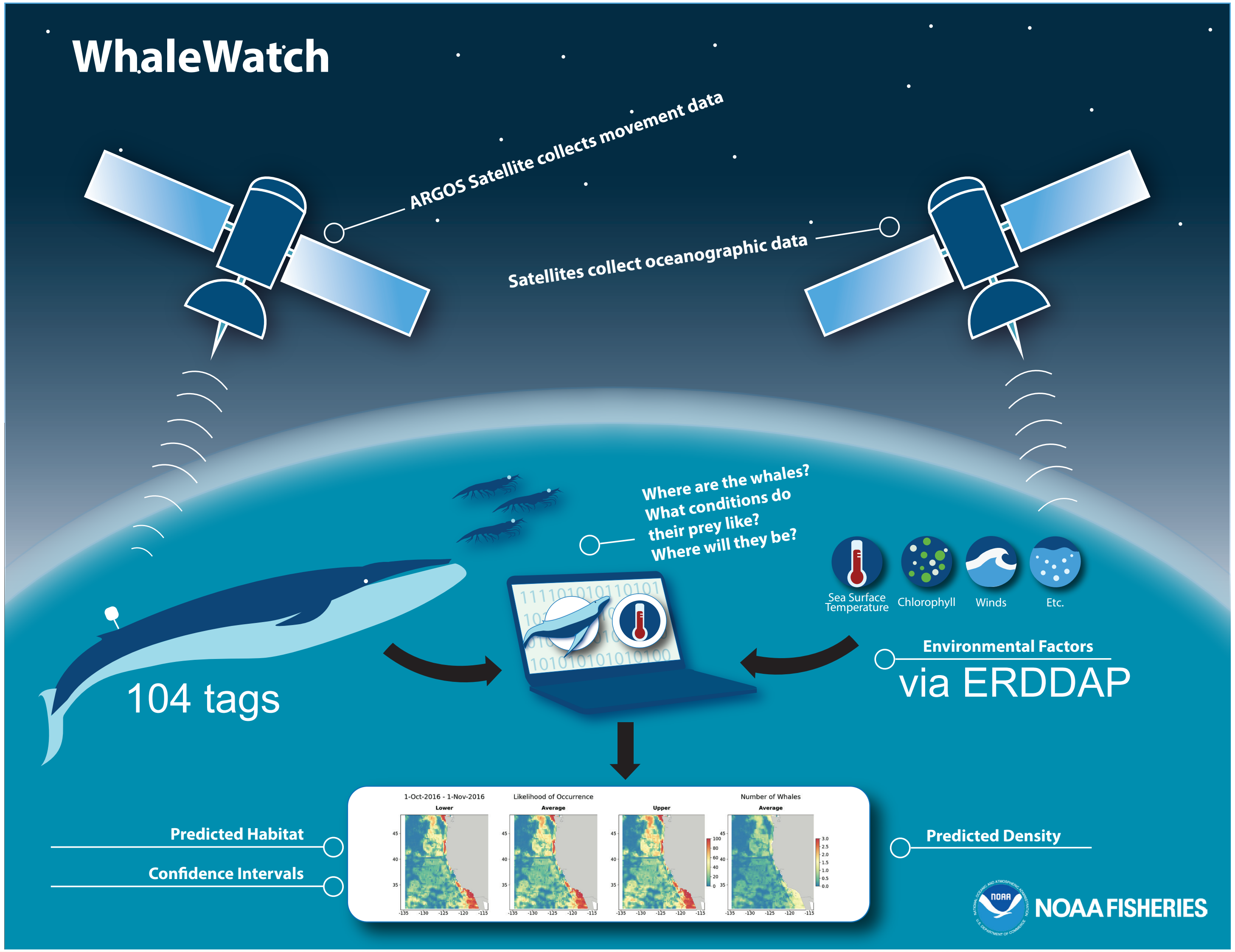
ABSTRACT

centered at 17.2° and 22.9°C, occupied by leatherbacks on fishing grounds of the Hawaii-based swordfish fishery. This new information was used to expand the TurtleWatch product to provide managers and industry near real-time habitat information for both loggerheads and leatherbacks. The updated TurtleWatch product provides a tool for dynamic management of the Hawaii-based shallow-set fishery to aid in the bycatch reduction of both species. Updating the management strategy to dynamically adapt to shifts in multi-species habitat use through time is a step towards an ecosystem-based approach to fisheries management in pelagic ecosystems.

Key words: Central North Pacific, dynamic management, fisheries, leatherback sea turtles, sea surface temperature, swordfish

WhaleWatch: Near real-time models for dynamic management of blue whales in the North Pacific

WHALEWATCH



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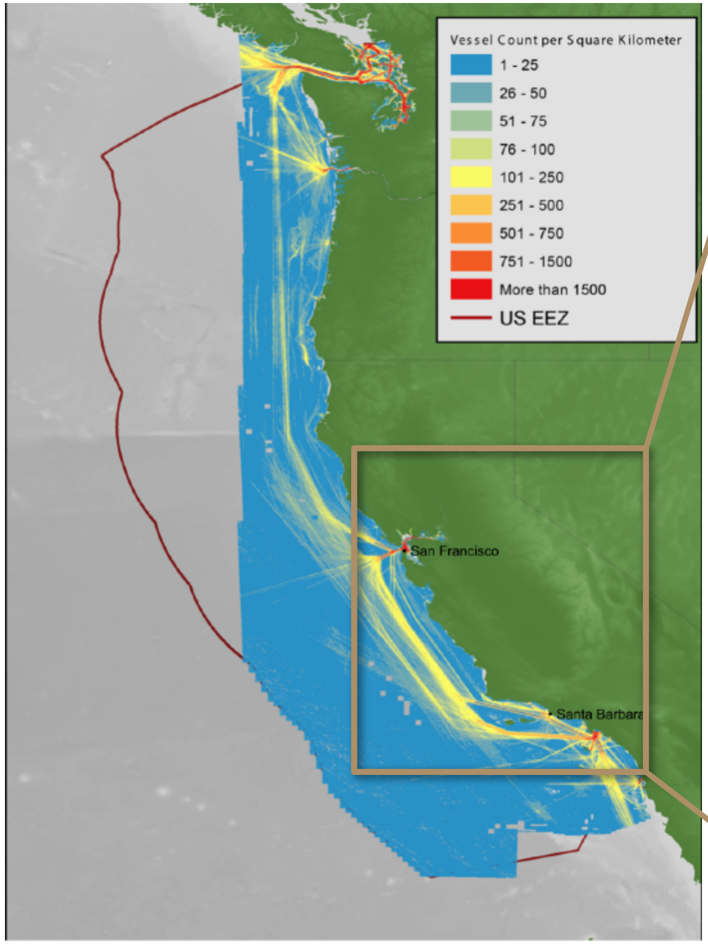
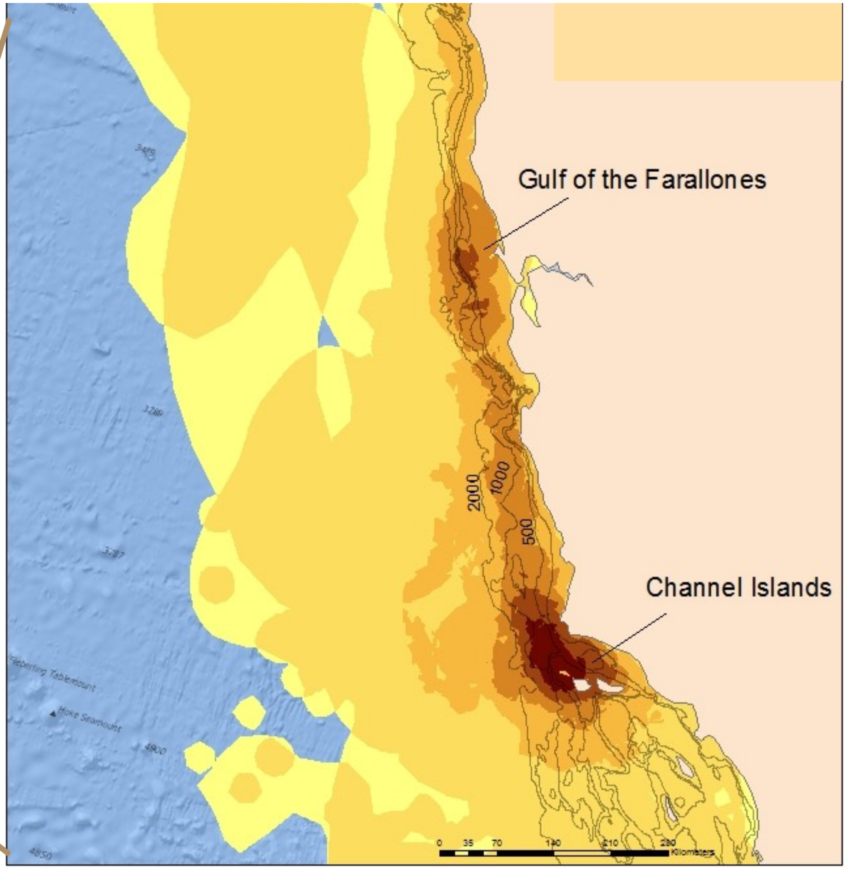
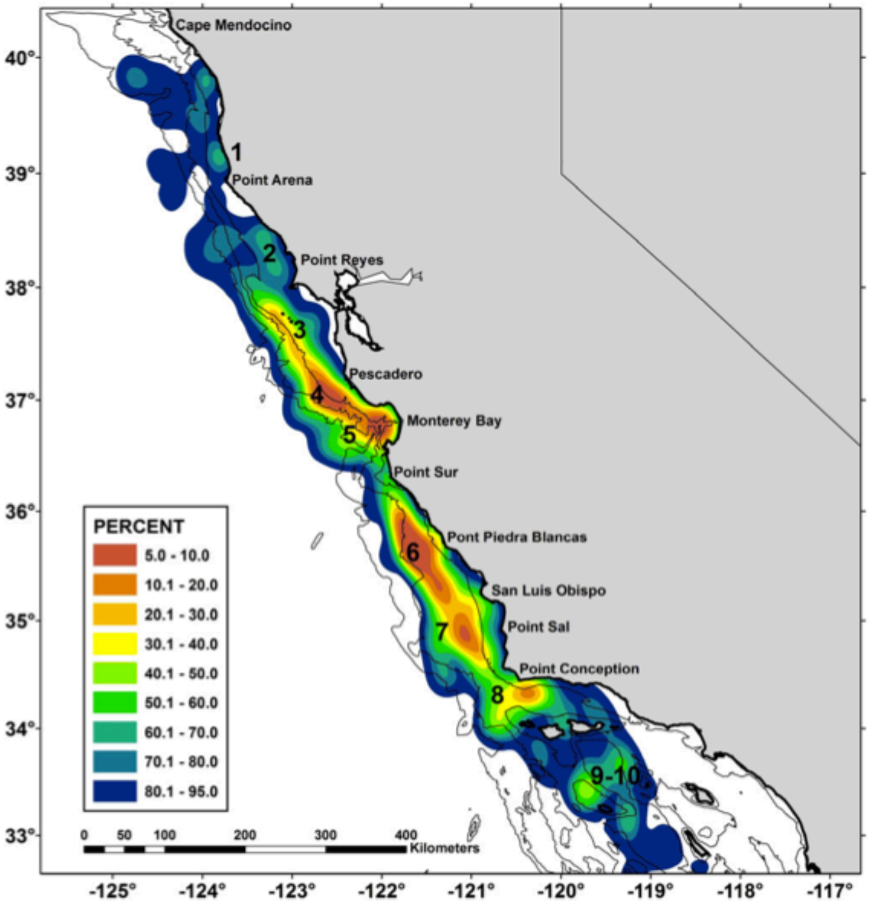
Krill and blue whale hotspots





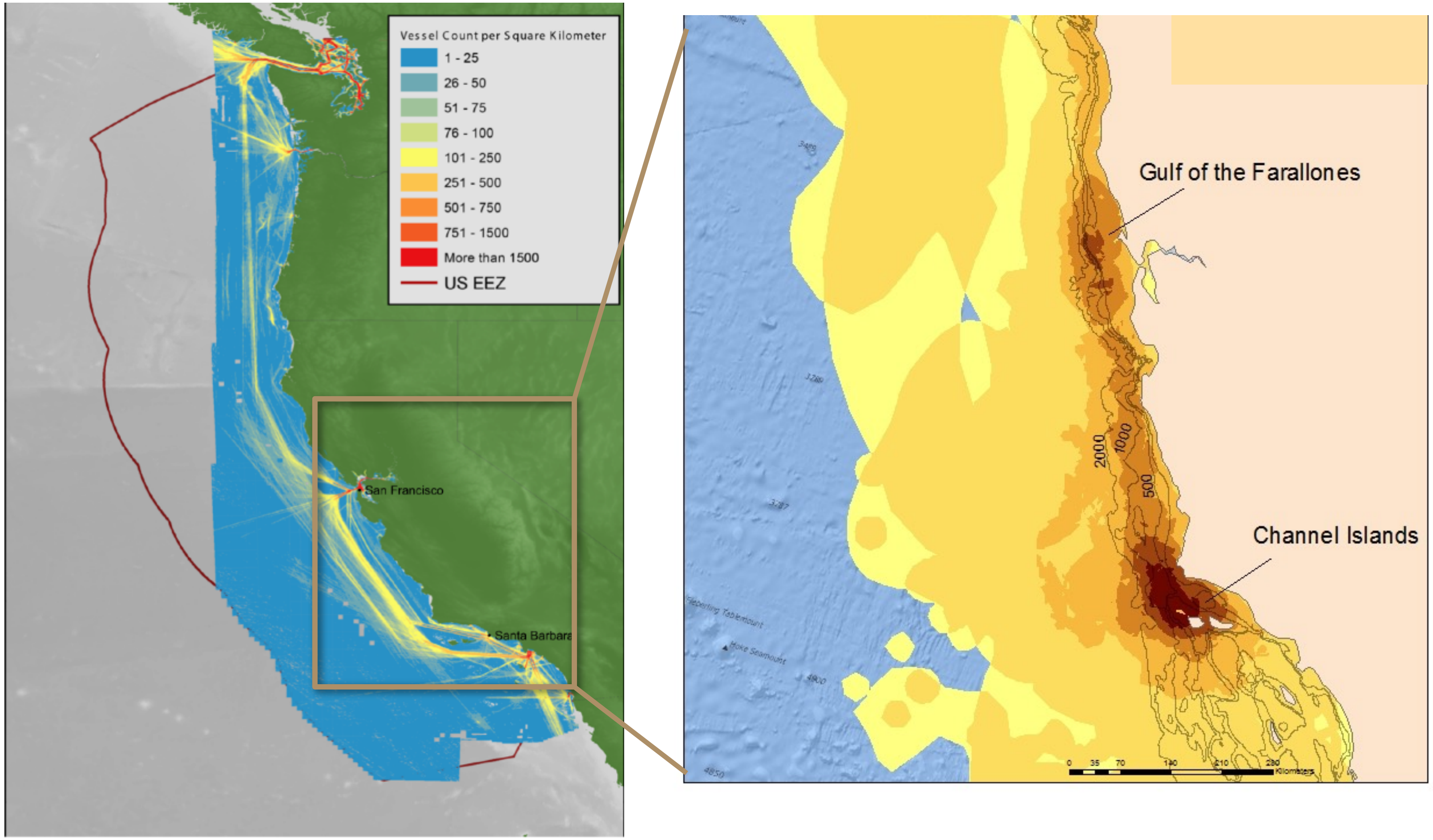


Hazen et al. 2016 *JAE*

Blue whales have similar hotspots (1994-2008). From Irvine et al. 2014

Krill utilization distributions during May-June 2004-2009. From Santora et al. 2011.

Shipping and blue whale hotspots



Hazen et al. 2016 *JAE*

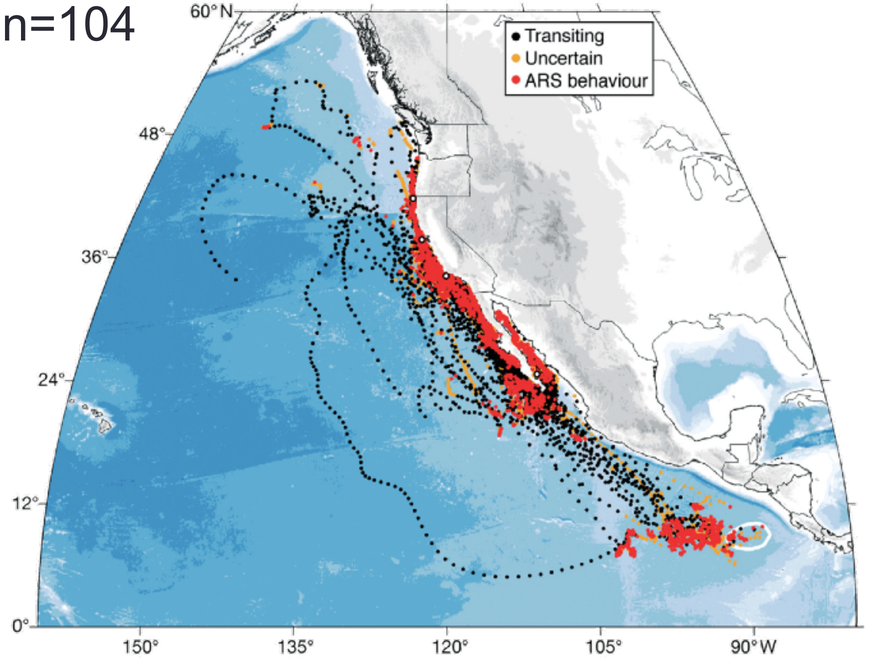
Blue whales have similar hotspots (1994-2008). From Irvine et al. 2014

- High spatial overlap between shipping intensity and blue whale hotspots
- Opportunity for finer temporal management?

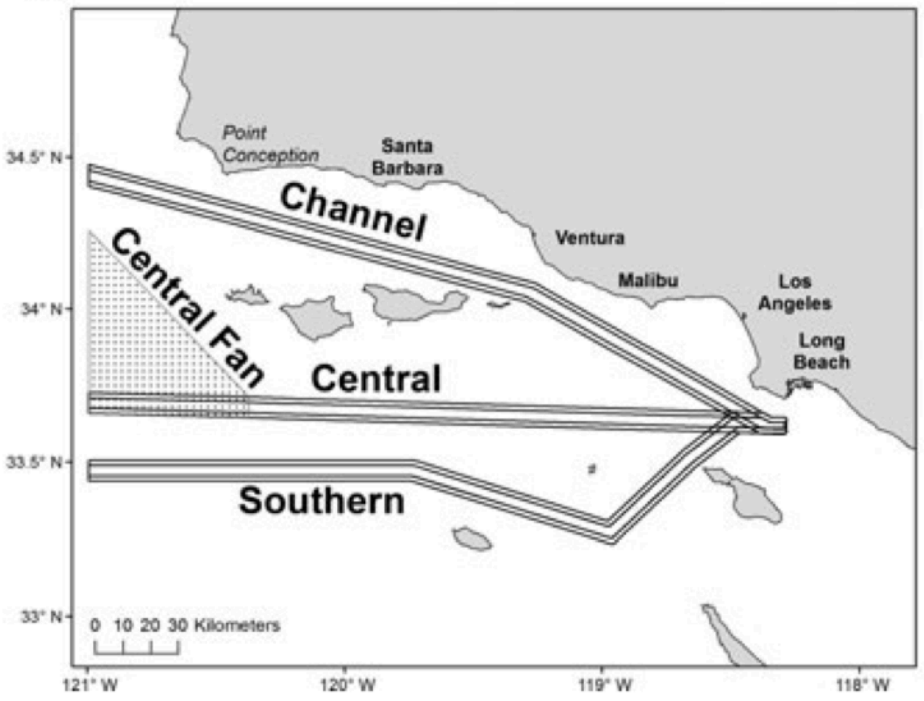
Objective

- Use satellite telemetry and remotely-sensed oceanographic data to develop near-real time (8-day to monthly) habitat models for blue whales in the California Current System.
- This can assist management efforts to mitigate against human impacts, such as ship strikes for the entire year.

n=104

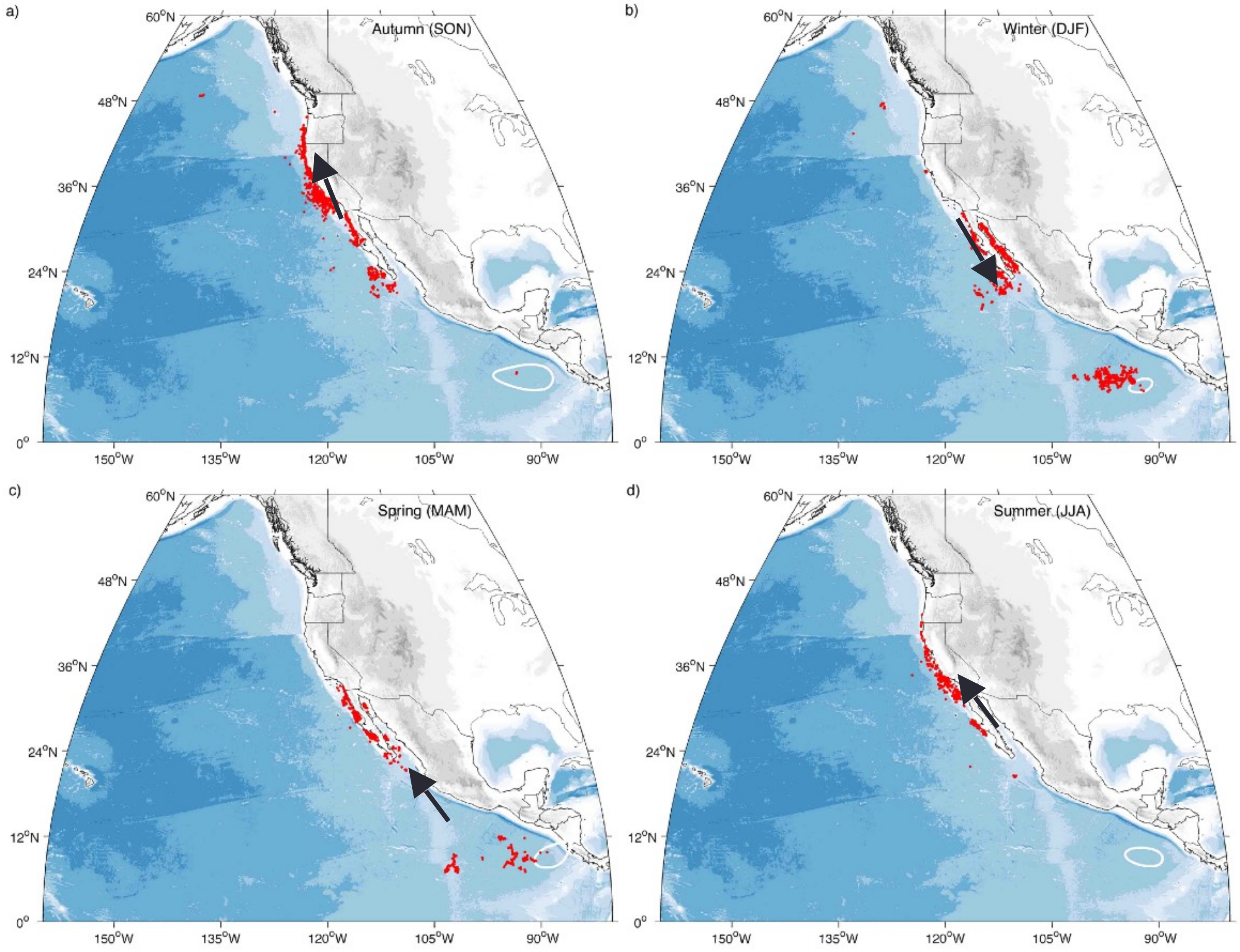


Bailey et al. 2009

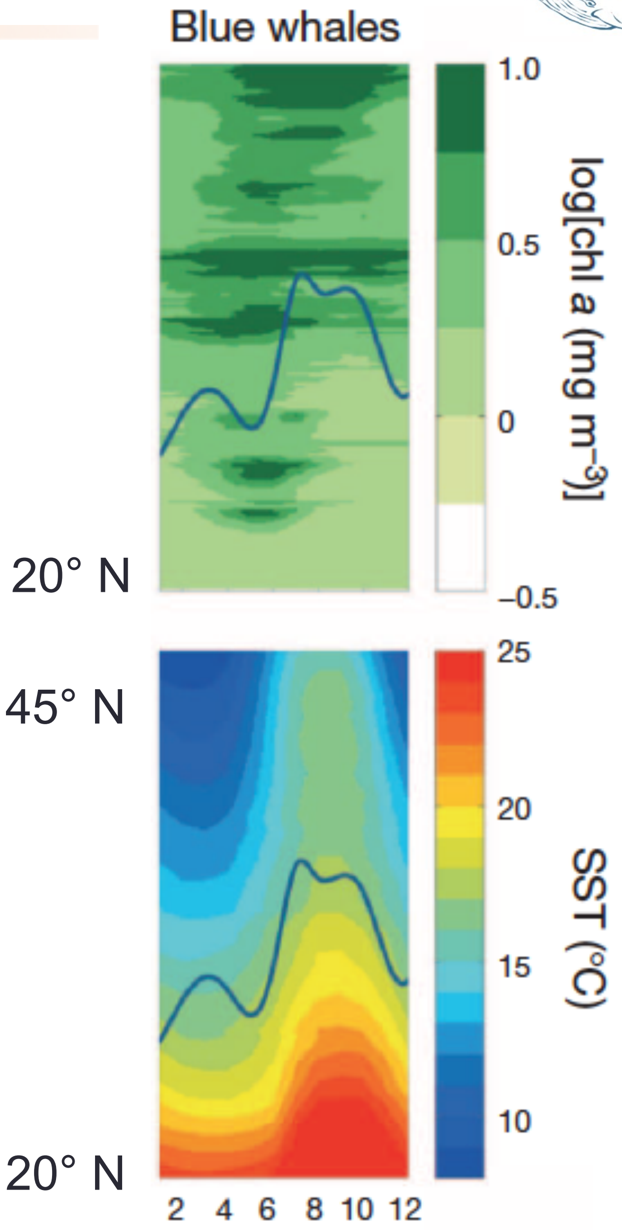


Redfern et al. 2013

Seasonal movement



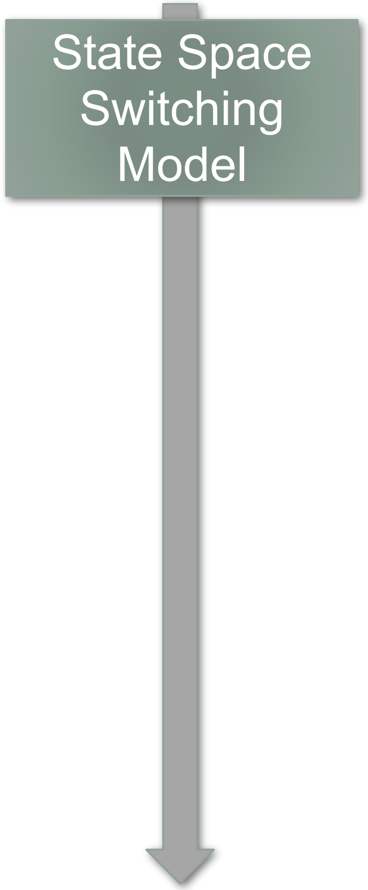
Bailey et al. 2009

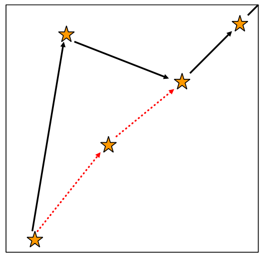


Block et al. 2011

Approach

1. Apply a state-space model to provide regularized daily positions from whale satellite telemetry data

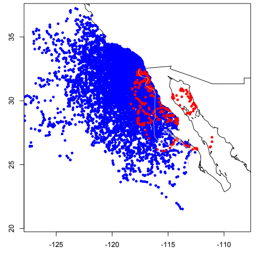


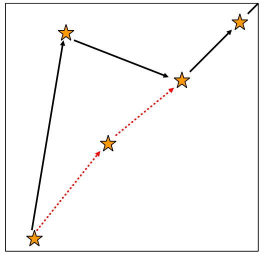


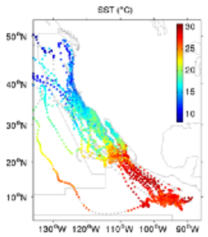
Hazen et al. 2017

Approach

1. Apply a state-space model to provide regularized daily positions from whale satellite telemetry data
2. Extract environmental data at the time and location of each whale position and pseudo-absence



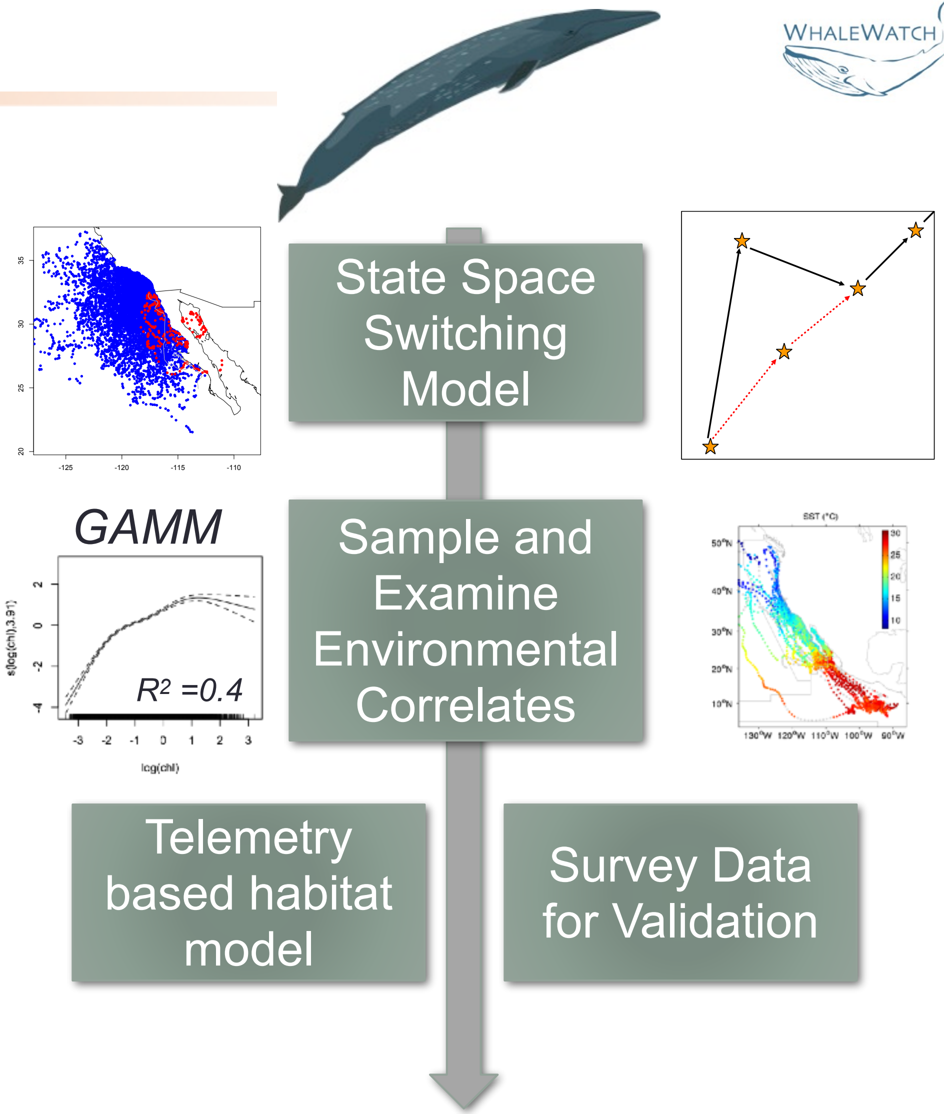




Hazen et al. 2017

Approach

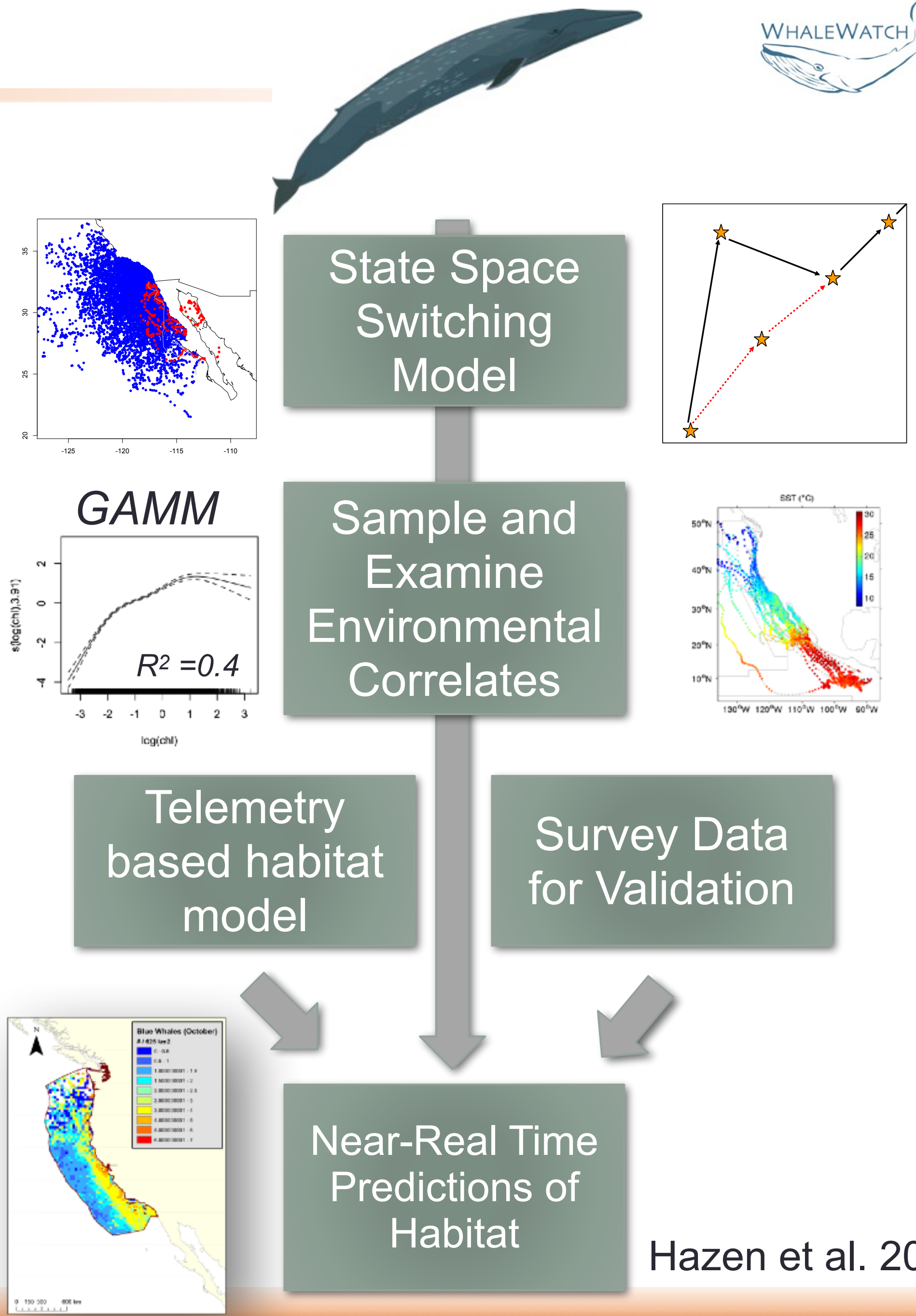
1. Apply a state-space model to provide regularized daily positions from whale satellite telemetry data
2. Extract environmental data at the time and location of each whale position and pseudo-absence
3. Develop habitat preference models using Generalized Additive Mixed Models & Boosted Regression Trees



Hazen et al. 2017

Approach

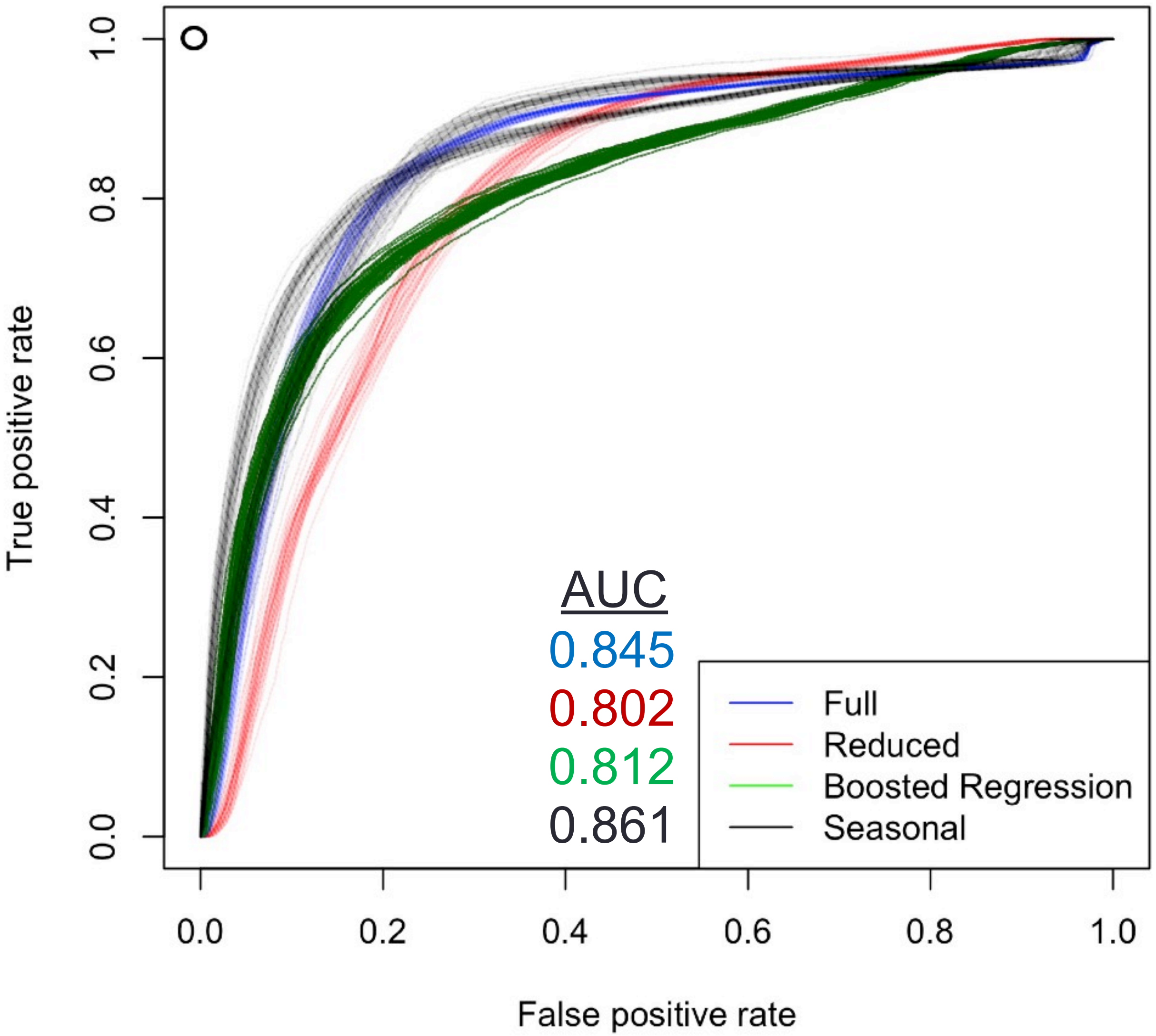
1. Apply a state-space model to provide regularized daily positions from whale satellite telemetry data
2. Extract environmental data at the time and location of each whale position and pseudo-absence
3. Develop habitat preference models using Generalized Additive Mixed Models & Boosted Regression Trees
4. Develop a tool predicting whale densities (e.g. Aarts et al. 2008) based on the current environmental conditions



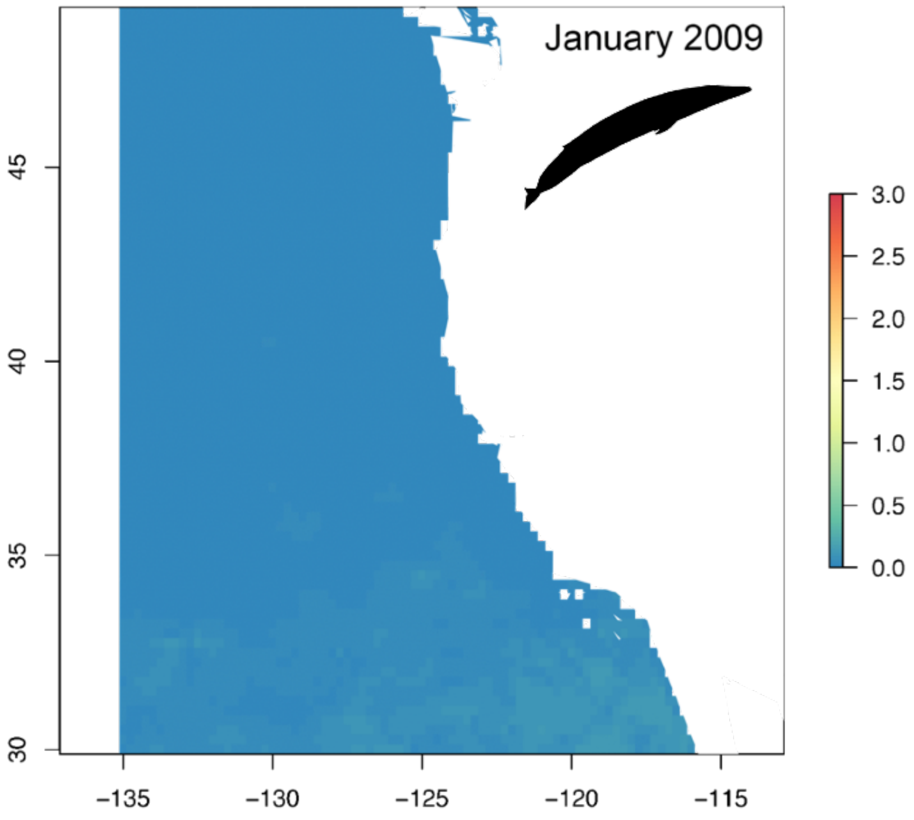
Hazen et al. 2017

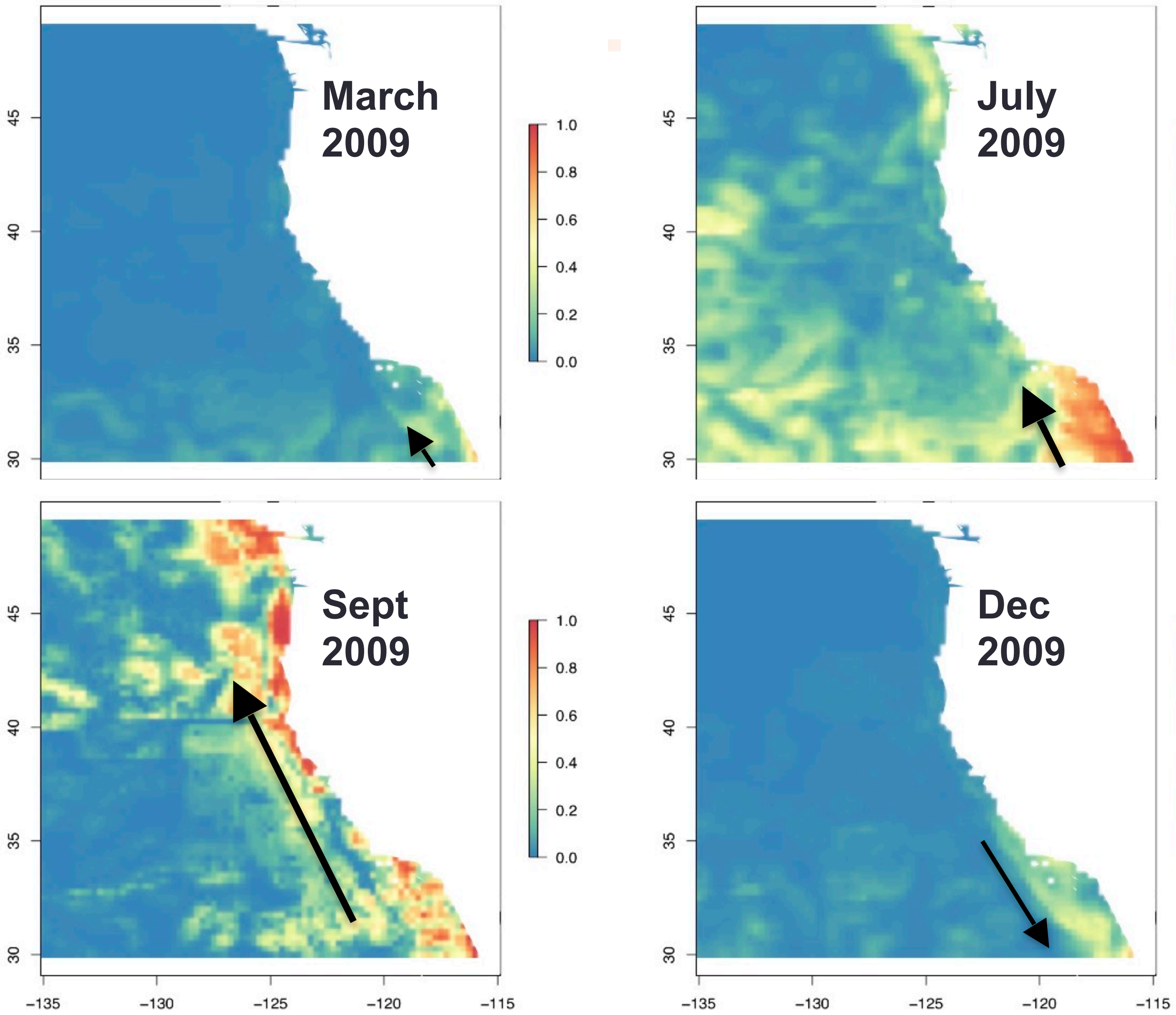
Model fit & evaluation

- Full model
  - SST + log(Chl) + Bathymetry + SSH SD + Bathy SD
- Reduced
  - SST + Bathymetry
- Seasonal v. Full
- Boosted Regression Trees - Full



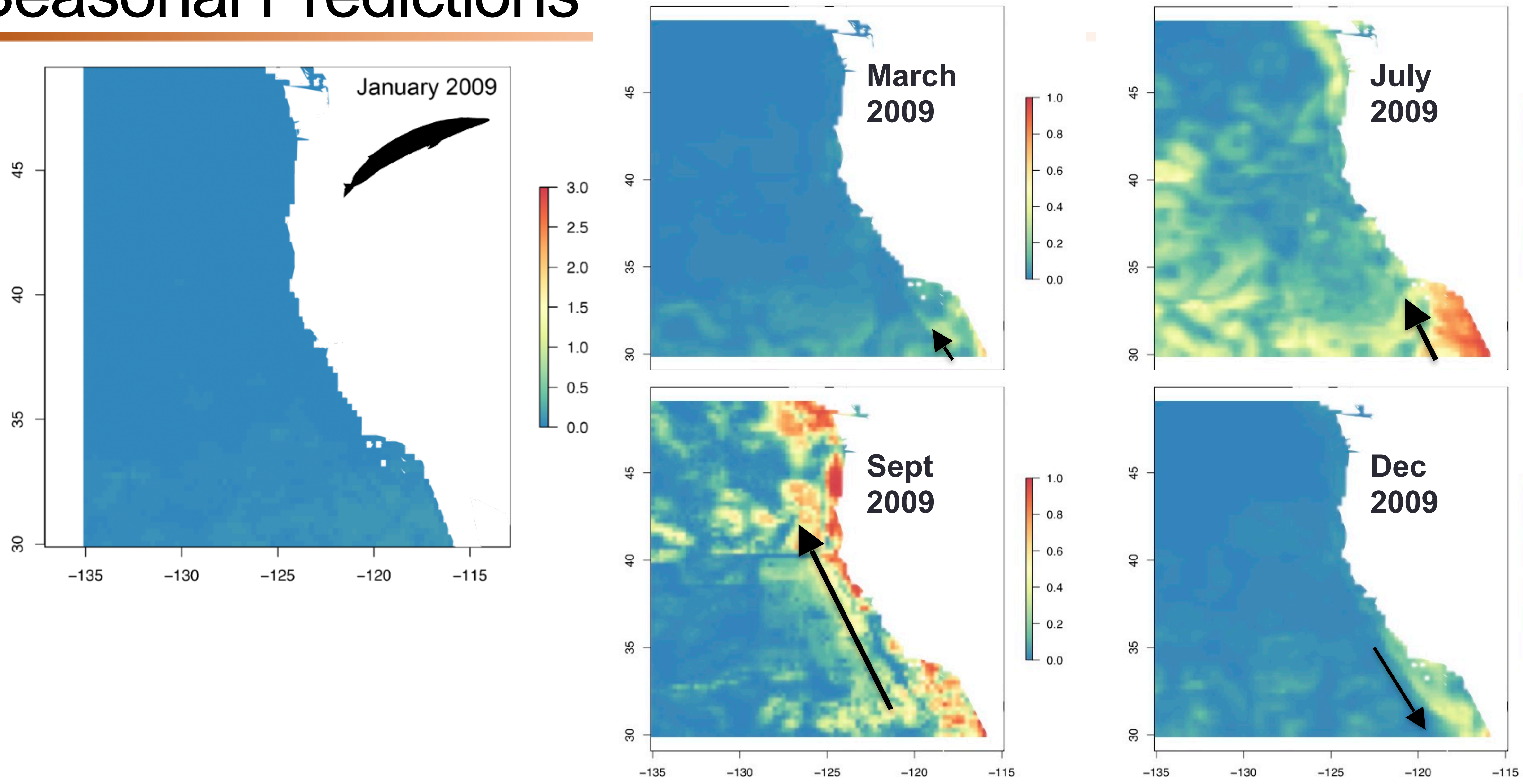
Seasonal Predictions





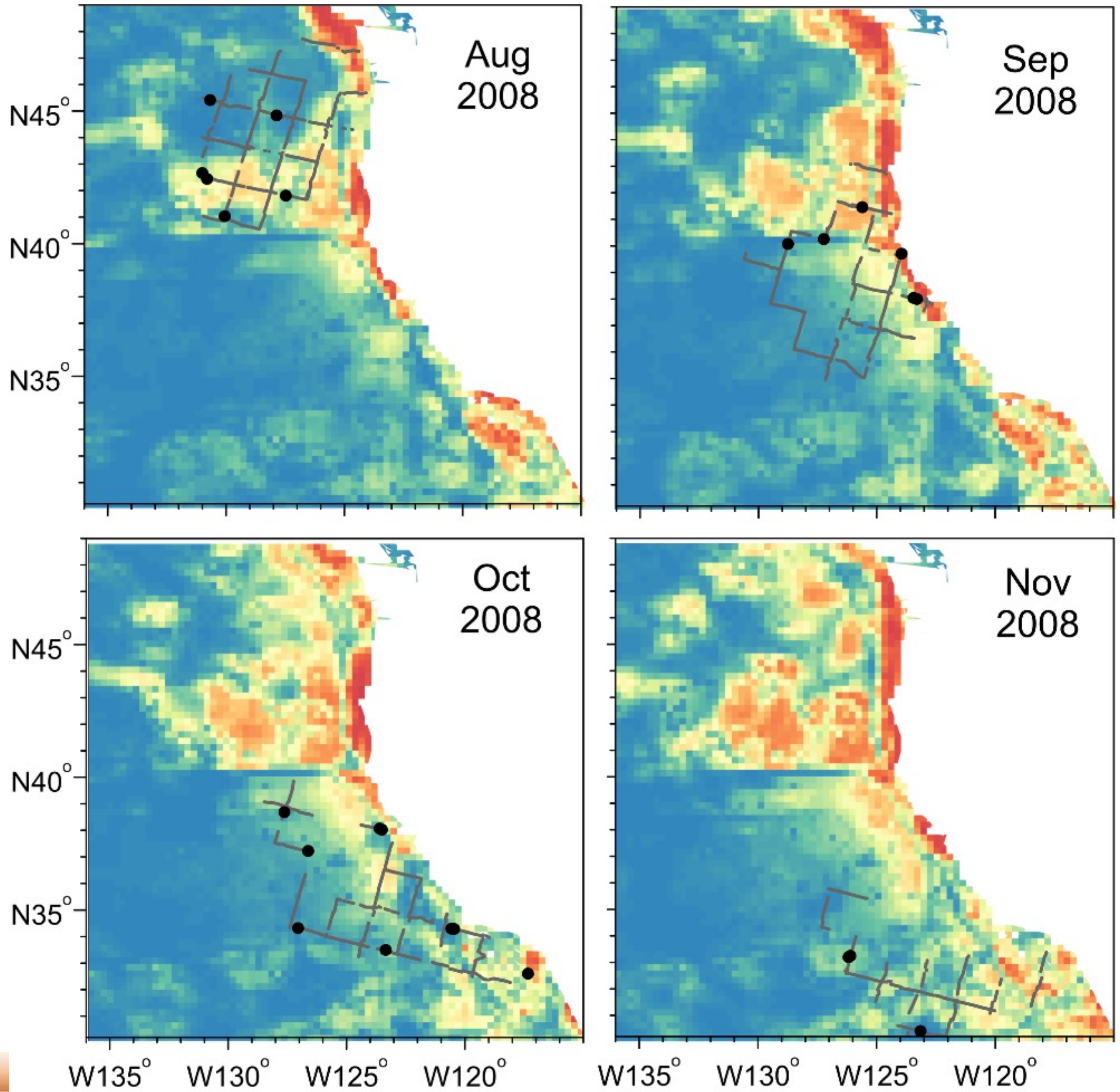
Hazen et al. 2017 J. Appl. Ecol

Seasonal Predictions



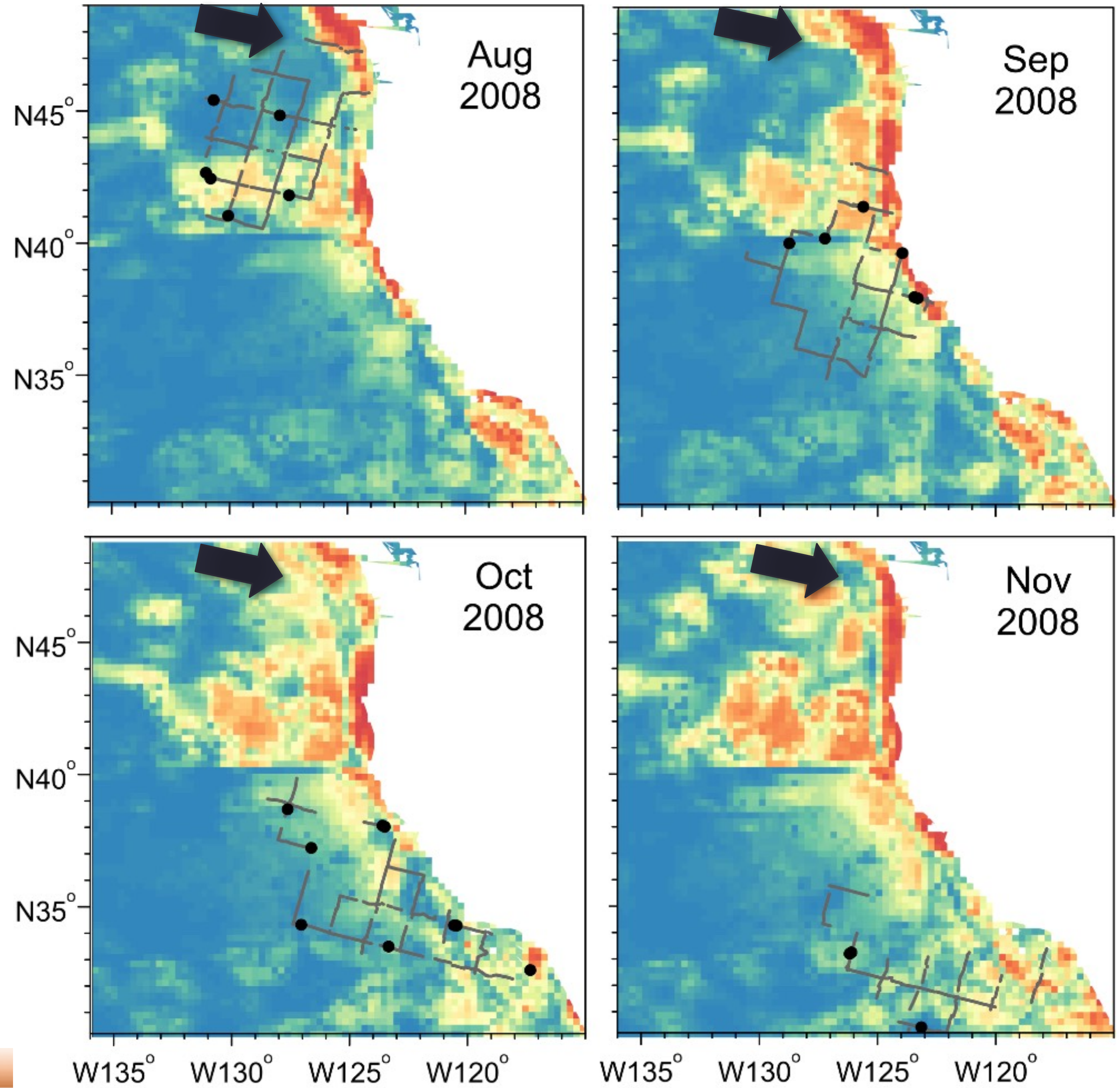
Hazen et al. 2017 J. Appl. Ecol

Comparison with sightings



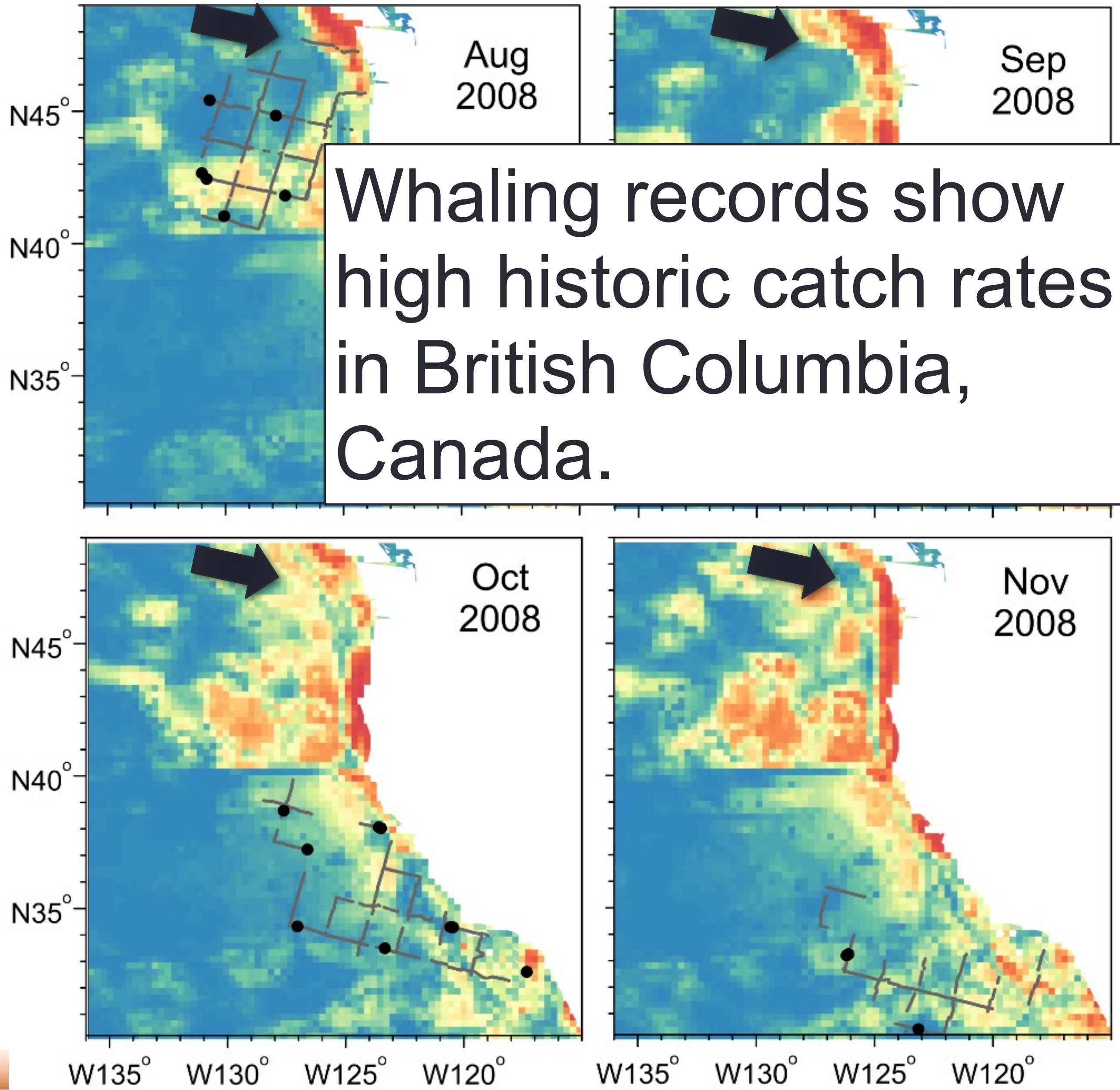
Hazen et al. 2017 J Appl Ecol

Comparison with sightings

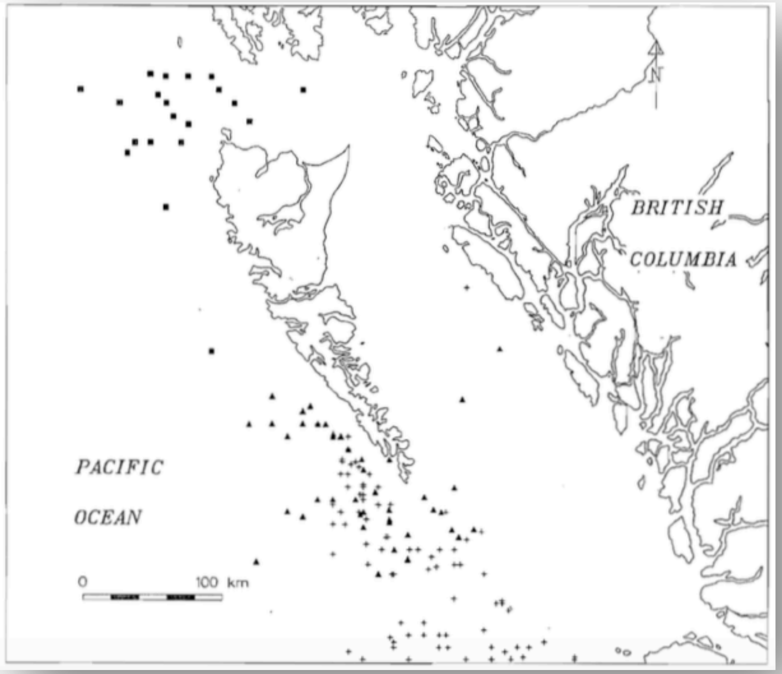


Hazen et al. 2017 J Appl Ecol

Comparison with sightings



Whaling records show high historic catch rates in British Columbia, Canada.

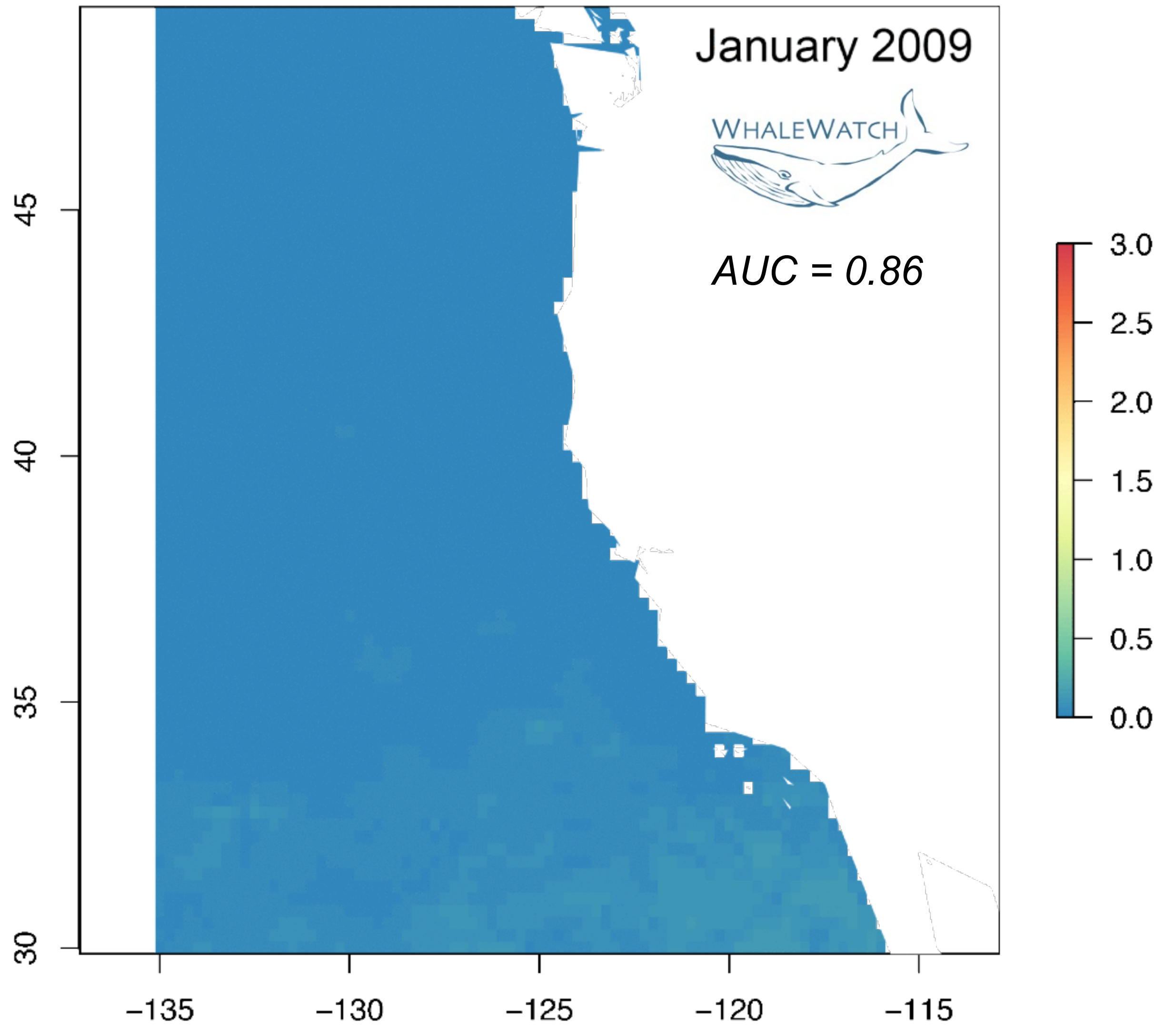


Nichol and Heise 1992

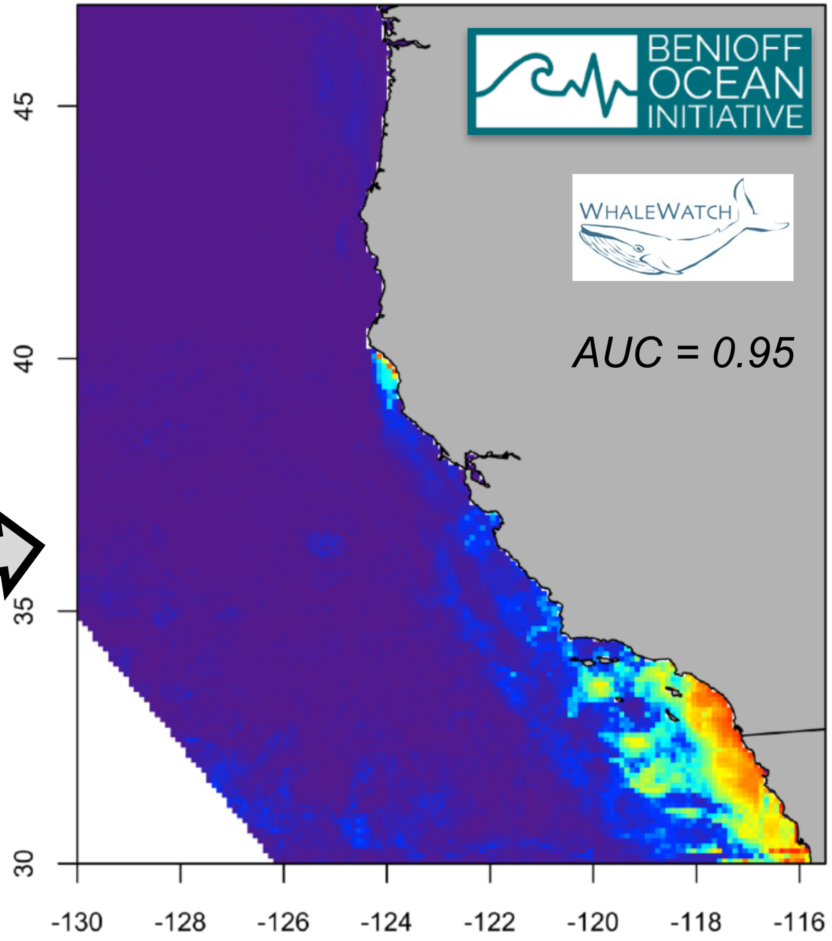
Hazen et al. 2017 J Appl Ecol

WhaleWatch 1.0 to 2.0

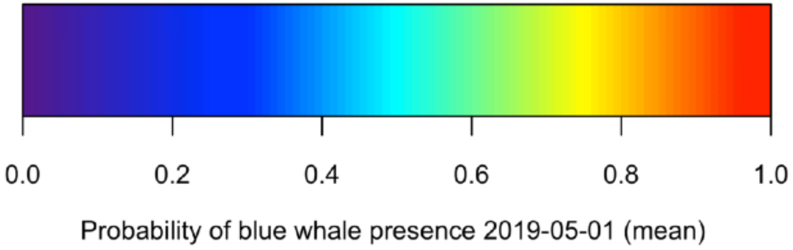
https://coastwatch.pfeg.noaa.gov/projects/whalewatch2/



Hazen et al. 2017 J. Appl. Ecol



Abrahms et al. 2019 Div. Dist.



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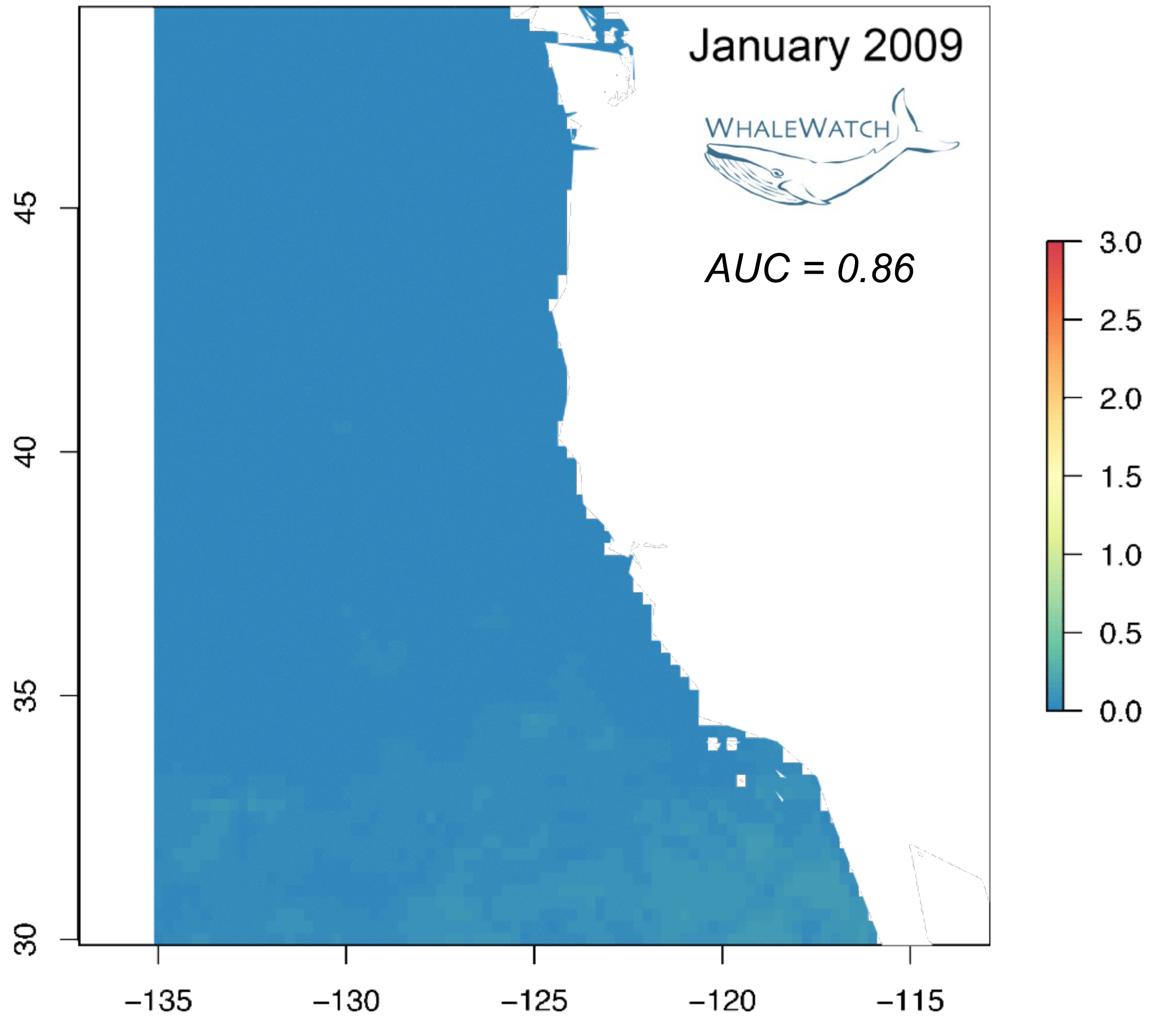
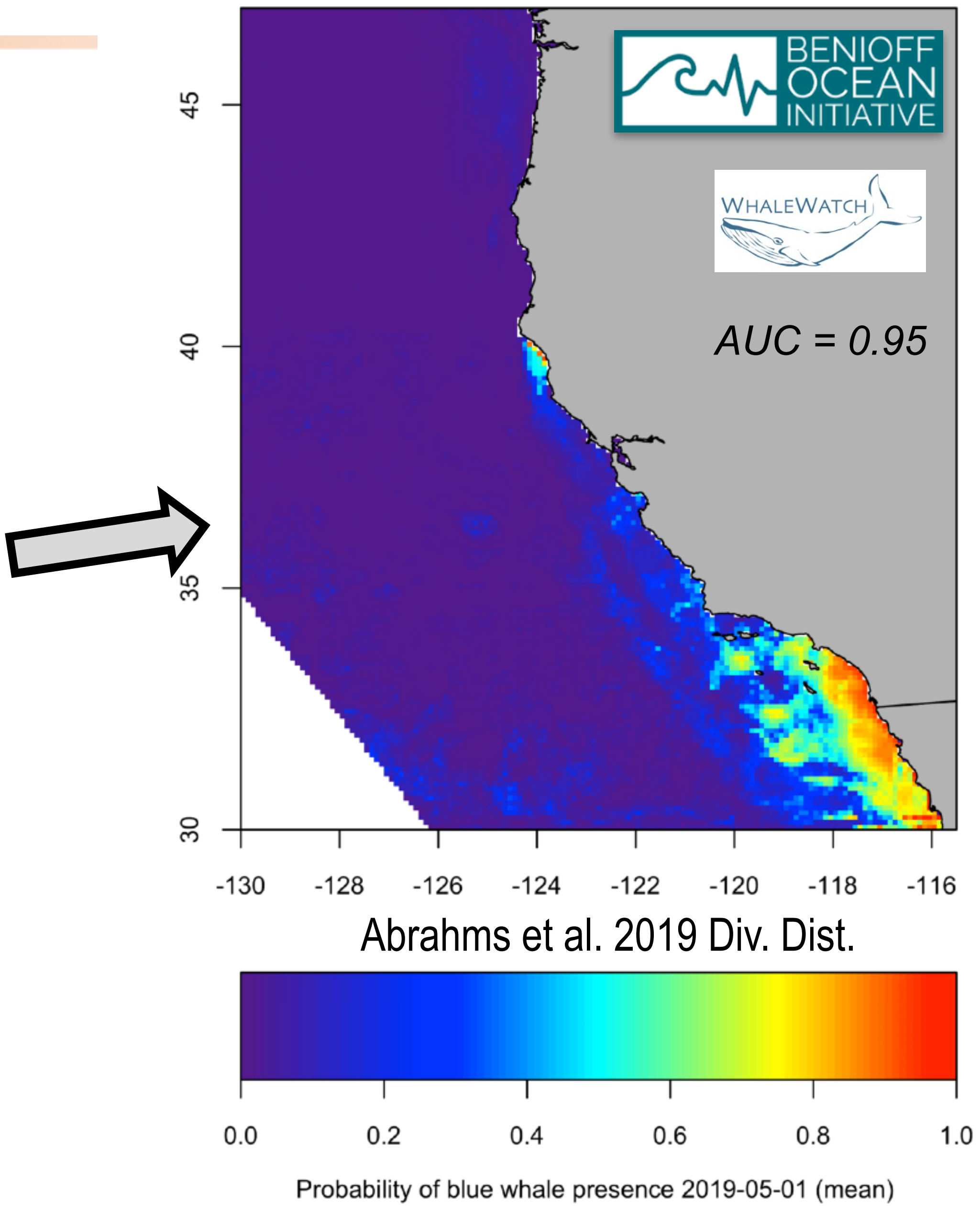


Hazen et al. 2017 J. Appl. Ecol



Abrahms et al. 2019 Div. Dist.

WhaleWatch 2.0 to WhaleSafe

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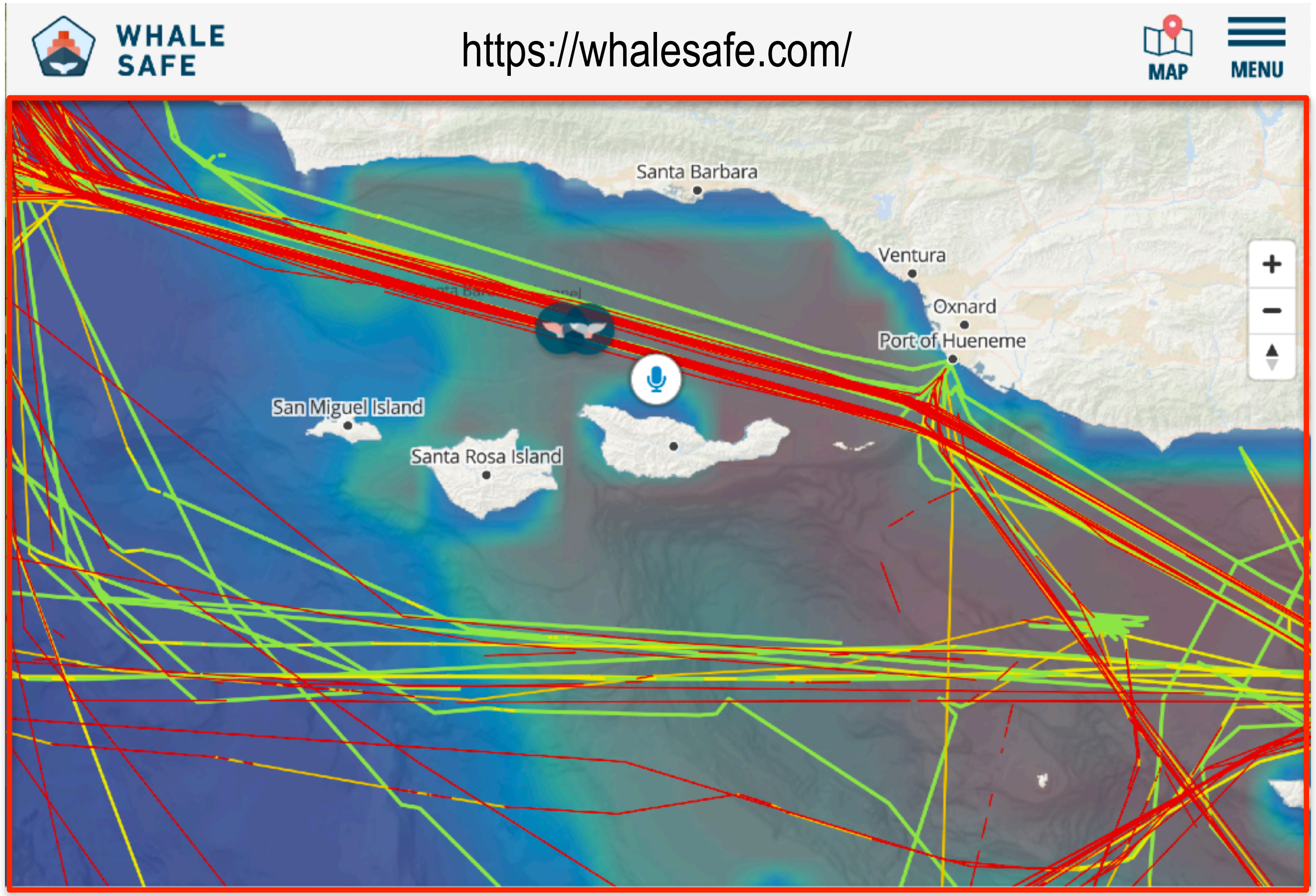

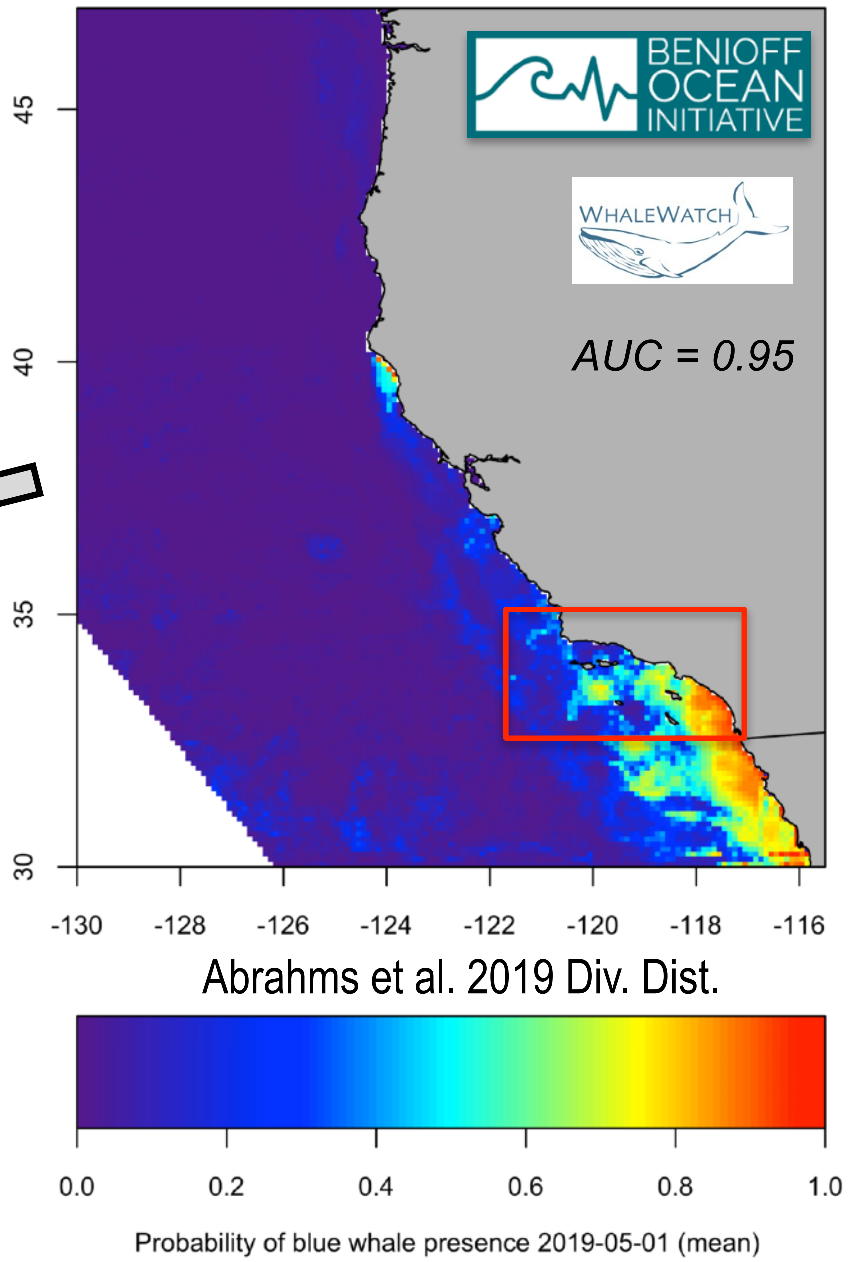

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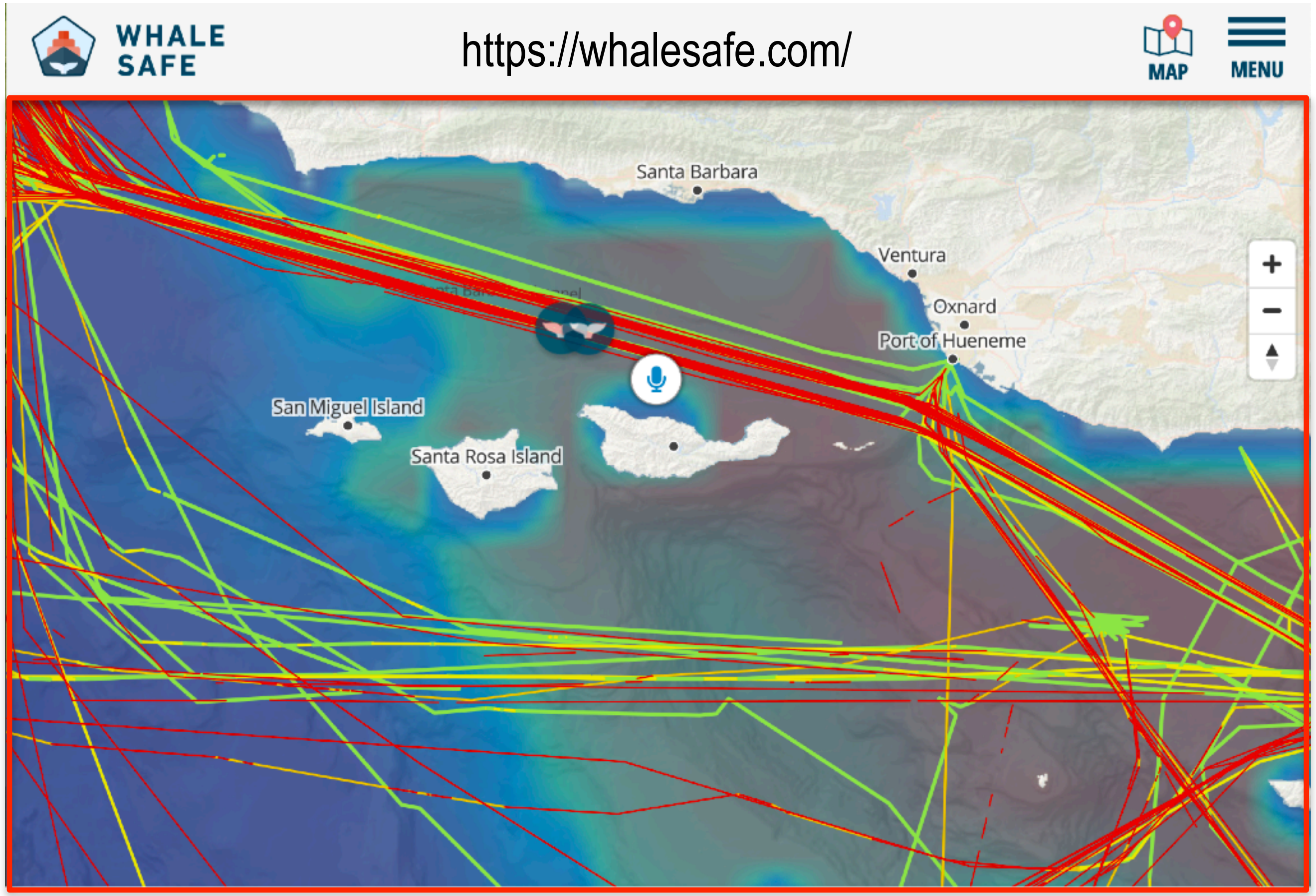
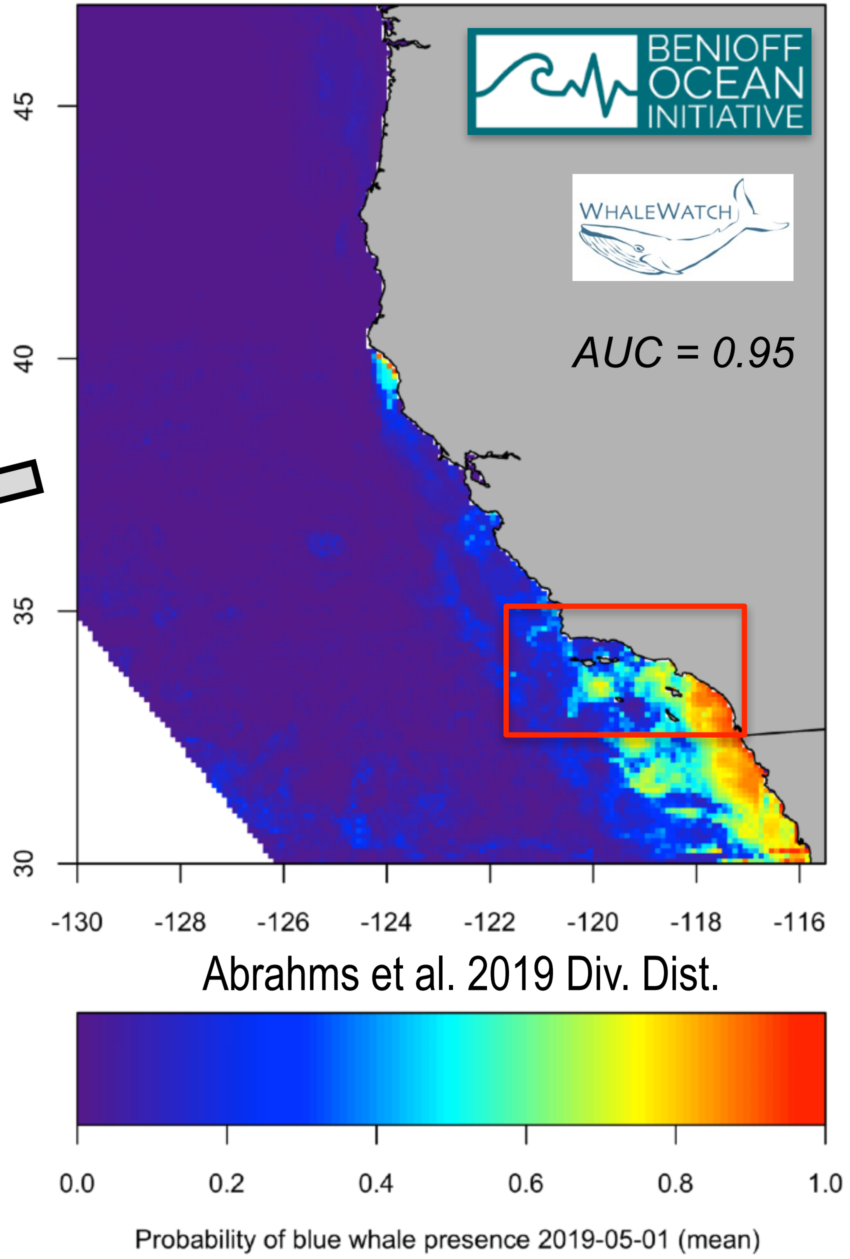
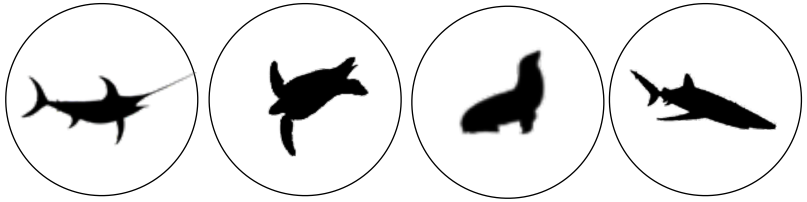




Abrahms et al. 2019 Div. Dist.

EcoCast

An Eco-informatic Tool for Fisheries Sustainability



NOAA COASTWATCH WEST COAST REGIONAL NODE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SCIENCE ADVANCES | RESEARCH ARTICLE

ECOLOGY

A dynamic ocean management tool to reduce bycatch and support sustainable fisheries

Elliott L. Hazen,[1,2,3]* Kylie L. Scales,[2,4] Sara M. Maxwell,[5] Dana K. Briscoe,[2] Heather Welch,[2] Steven J. Bograd,[1,2] Helen Bailey,[6] Scott R. Benson,[1,7] Tomo Eguchi,[1] Heidi Dewar,[1] Suzy Kohin,[1] Daniel P. Costa,[2] Larry B. Crowder,[8] Rebecca L. Lewison[9]

Seafood is an essential source of protein for more than 3 billion people worldwide, yet bycatch of threatened species in capture fisheries remains a major impediment to fisheries sustainability. Management measures designed to reduce bycatch often result in significant economic losses and even fisheries closures. Static spatial management approaches can also be rendered ineffective by environmental variability and climate change, as productive habitats shift and introduce new interactions between human activities and protected species. We introduce a new multispecies and dynamic approach that uses daily satellite data to track ocean features and aligns scales of management, species movement, and fisheries. To accomplish this, we create species distribution models for one target species and three bycatch-sensitive species using both satellite telemetry and fisheries observer data. We then integrate species-specific probabilities of occurrence into a single predictive surface, weighing the contribution of each species by management concern. We find that dynamic closures could be 2 to 10 times smaller than existing static closures while still providing adequate protection of endangered nontarget species. Our results highlight the opportunity to implement near real-time management strategies that would both support economically viable fisheries and meet mandated conservation objectives in the face of changing ocean conditions. With recent advances in eco-informatics, dynamic management provides a new climate-ready approach to support sustainable fisheries.

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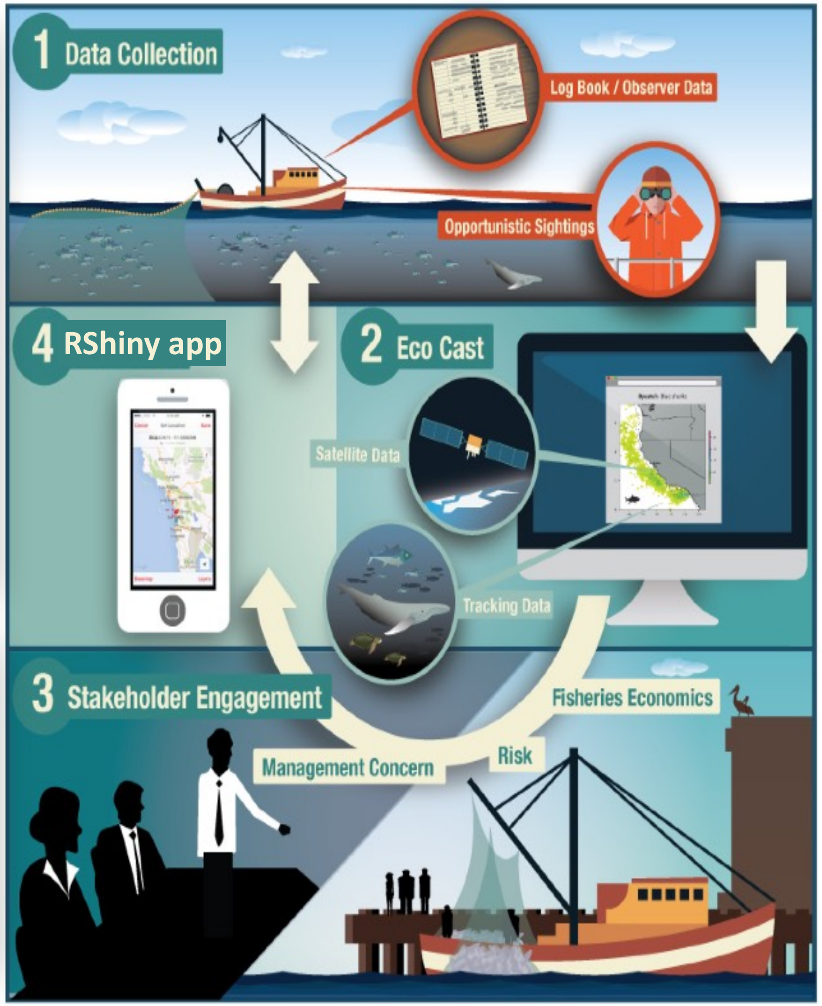
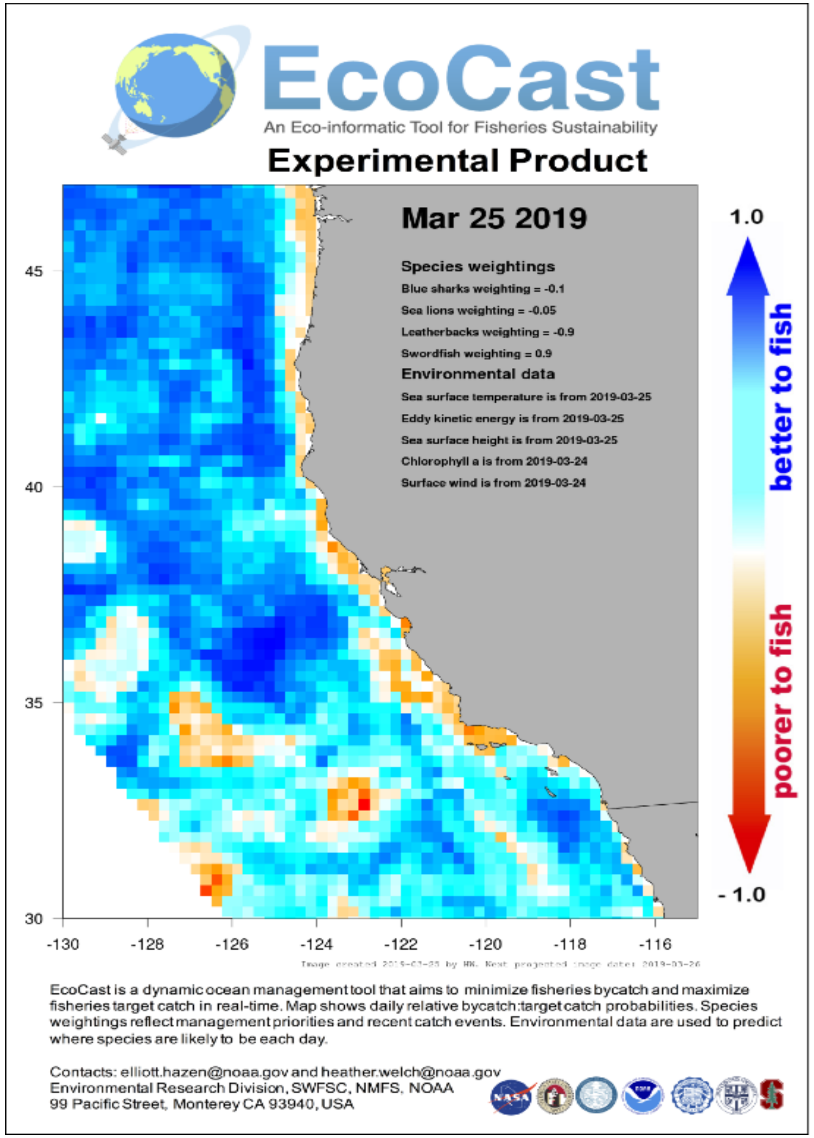
RESEARCH ARTICLE
Journal of Applied Ecology

Practical considerations for operationalizing dynamic management tools

Heather Welch[1,2] | Elliott L. Hazen[1] | Steven J. Bograd[1] | Michael G. Jacox[1] | Stephanie Brodie[1,2] | Dale Robinson[1,2] | Kylie L. Scales[3] | Lynn Dewitt[2] | Rebecca Lewison[4]



Drew Briscoe

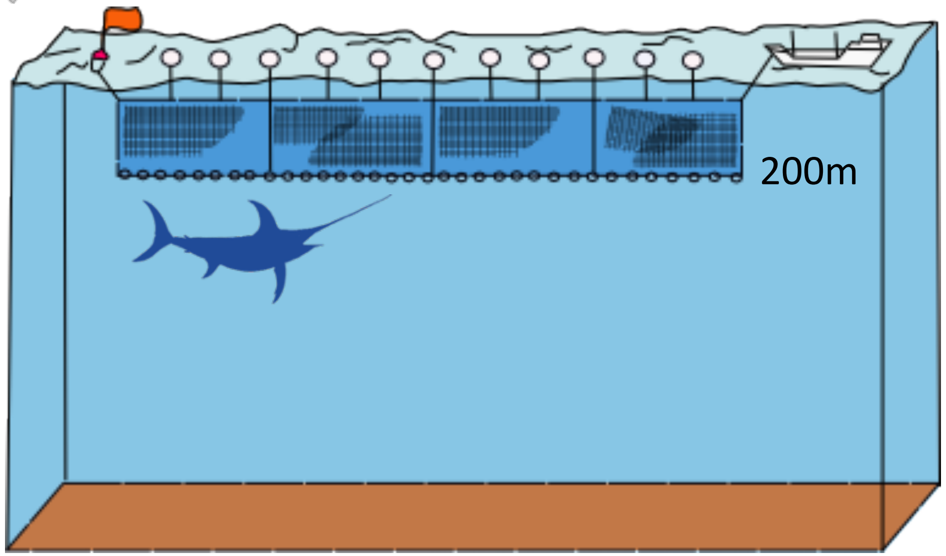


https://coastwatch.pfeg.noaa.gov/ecocast/

@Heather_M_Welch

EcoCast

An Eco-informatic Tool for Fisheries Sustainability



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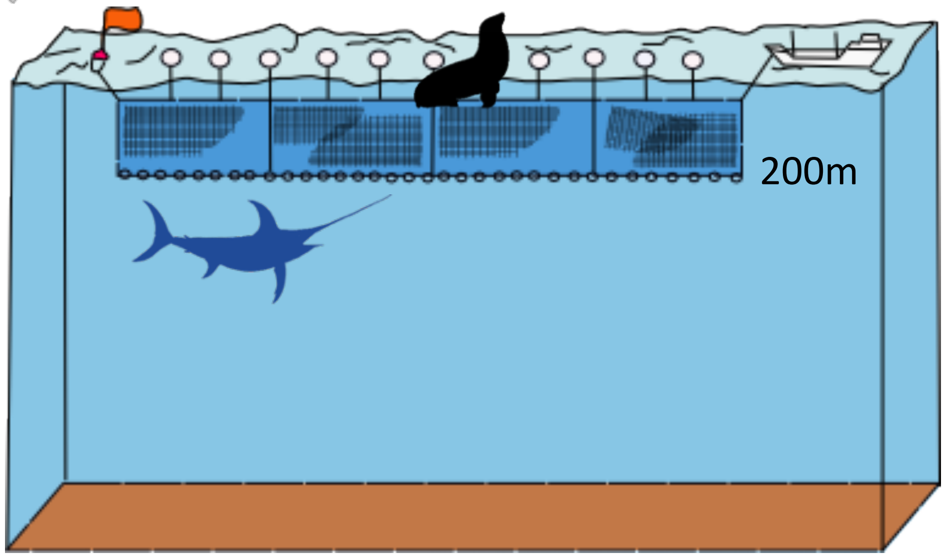

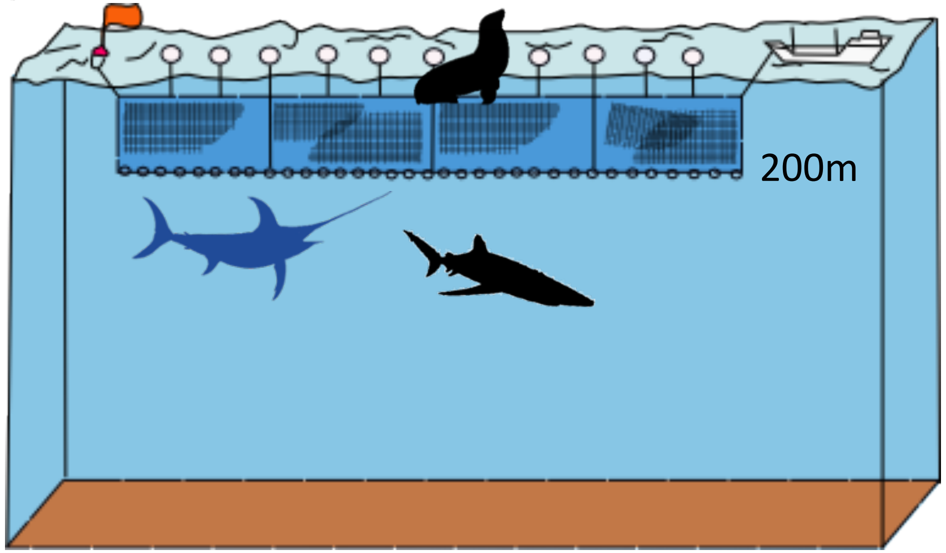
200m

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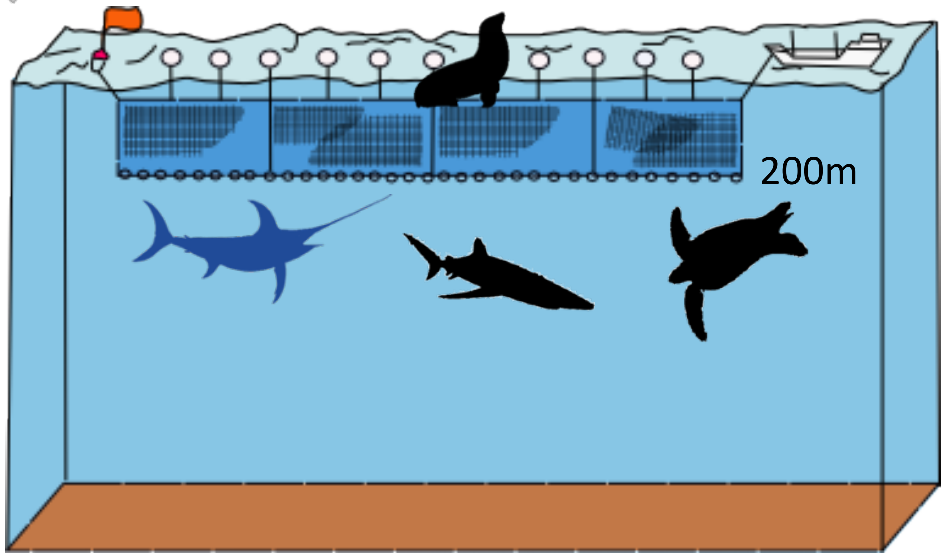

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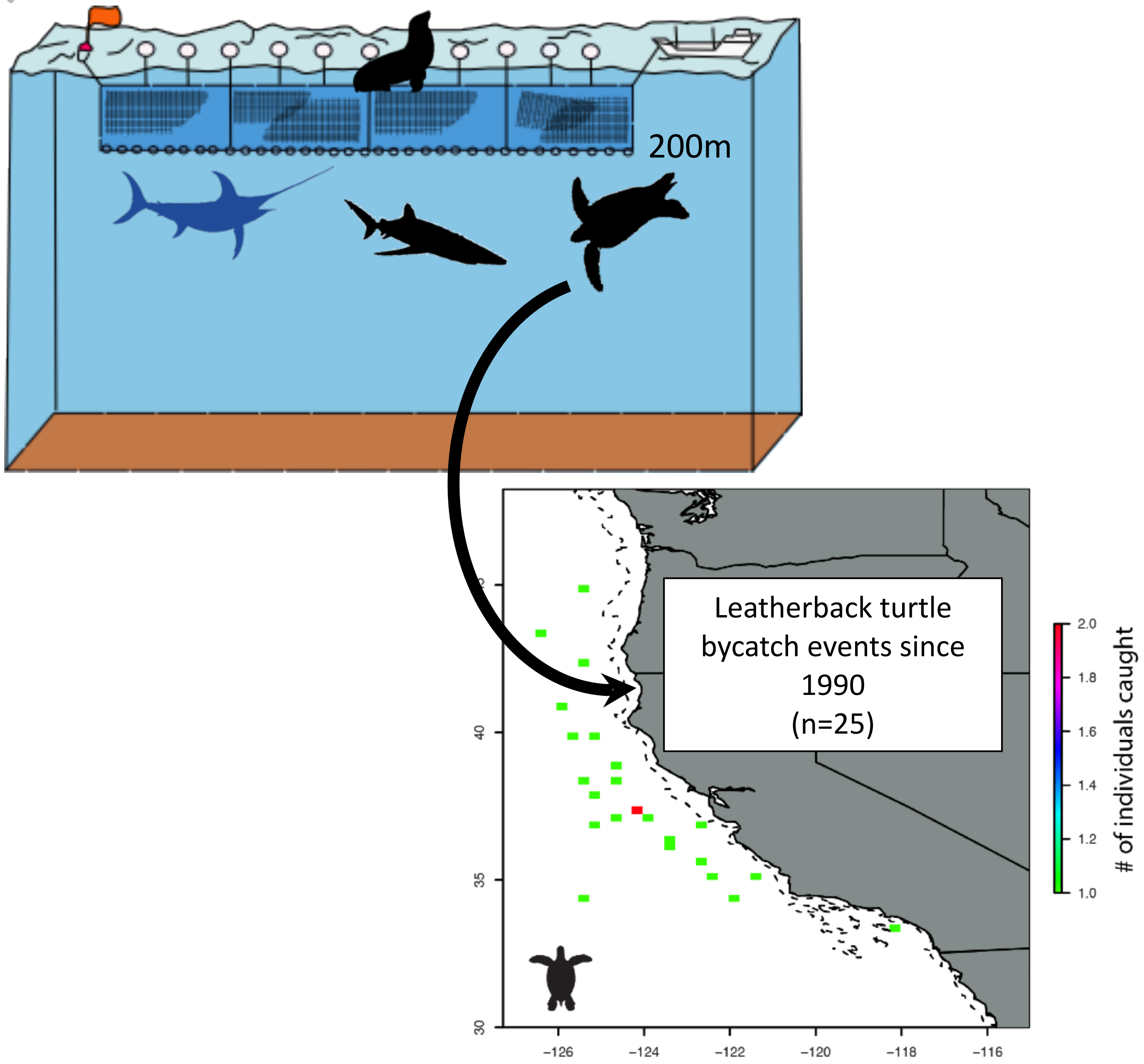

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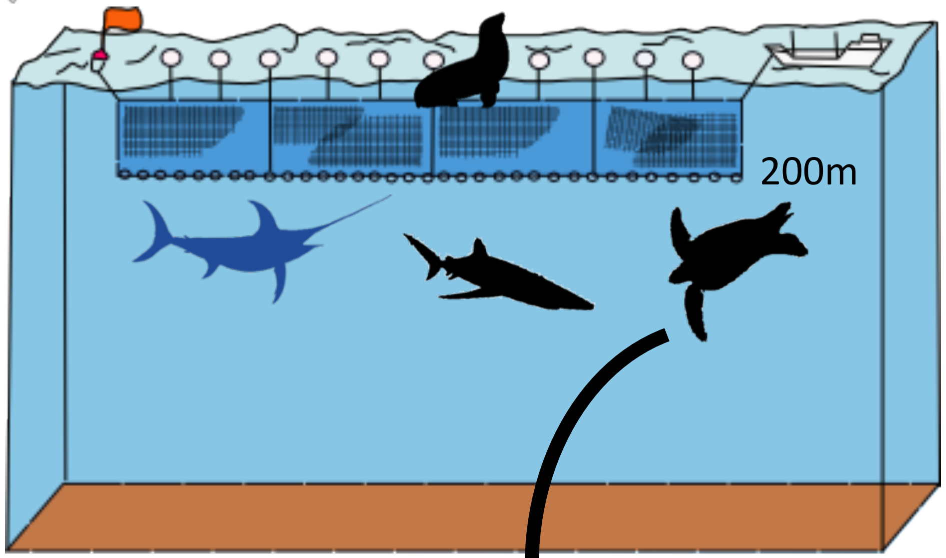

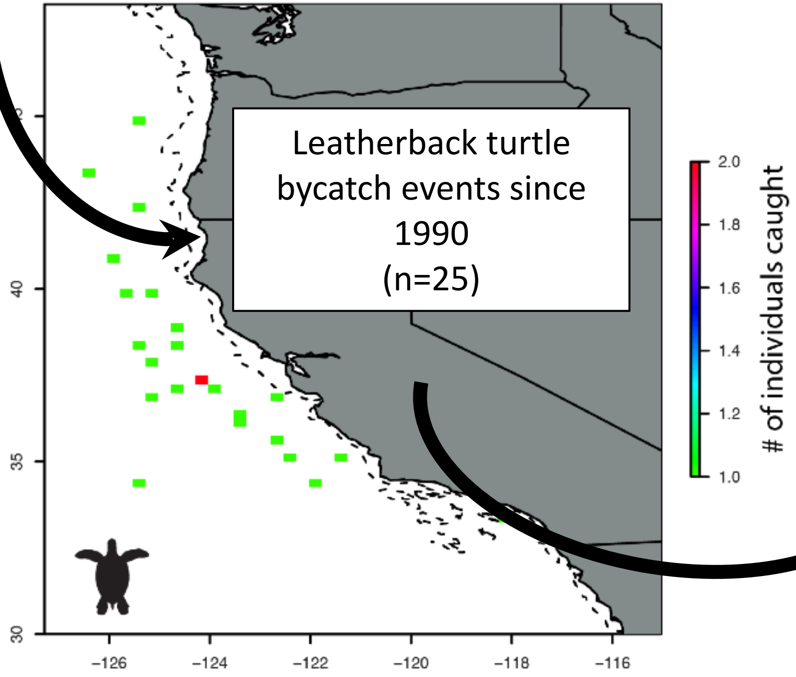

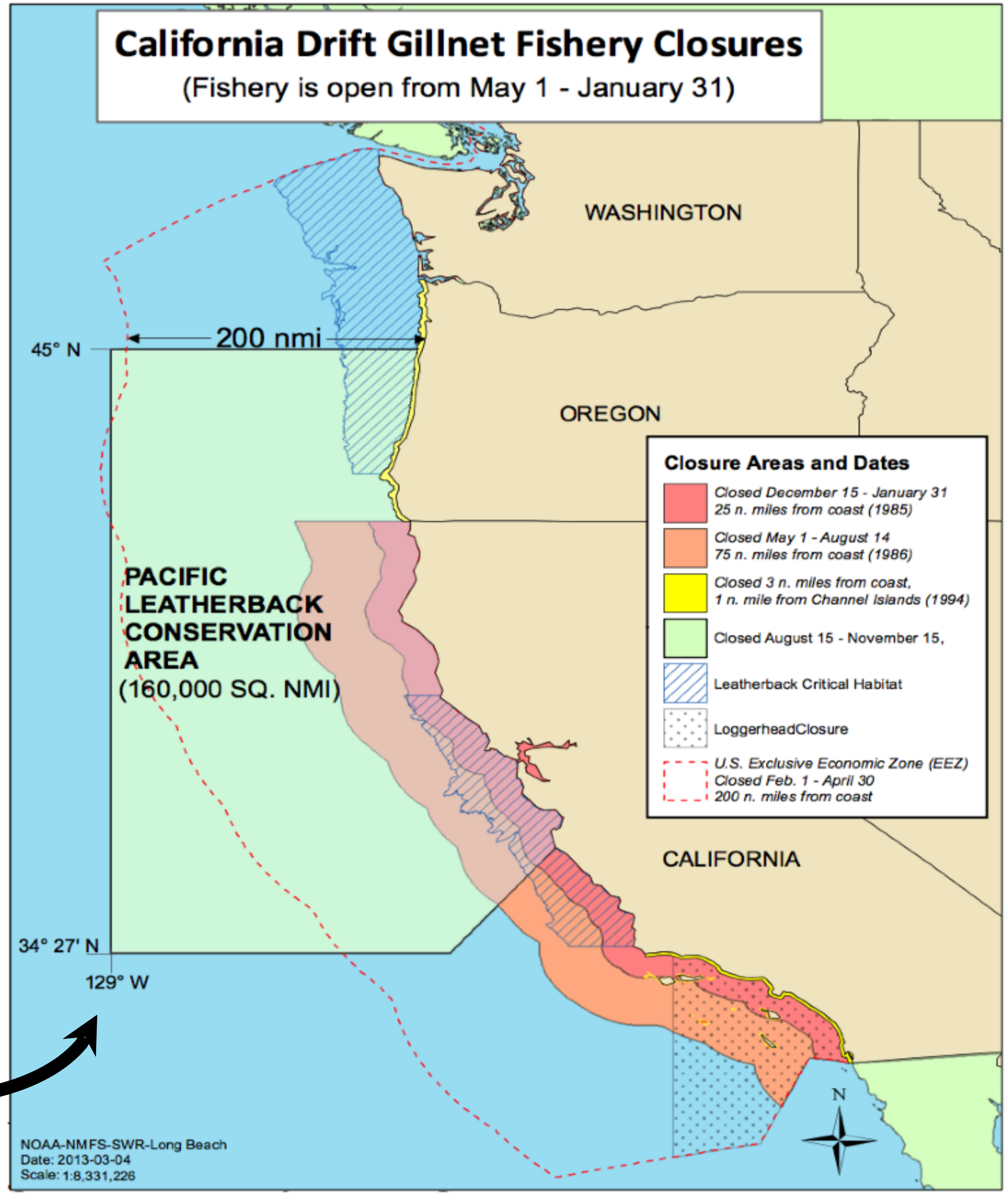

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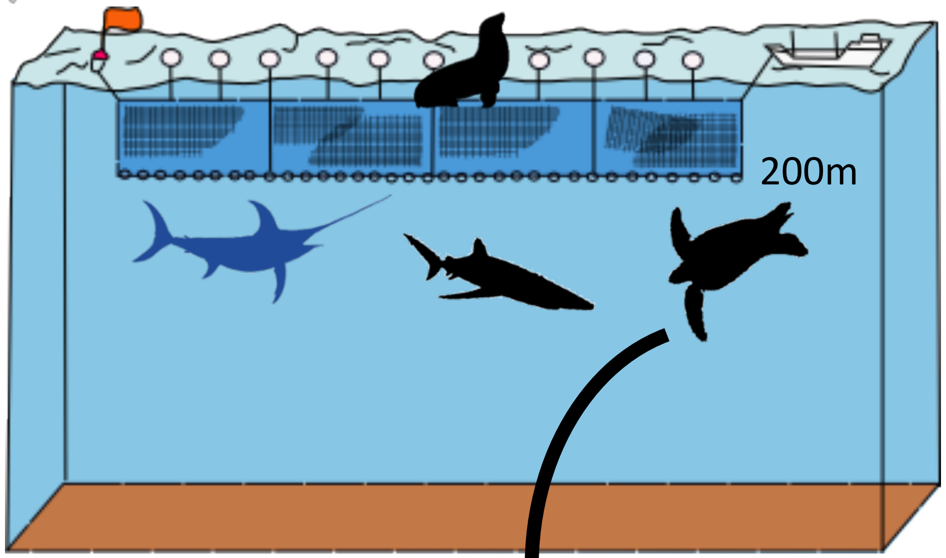
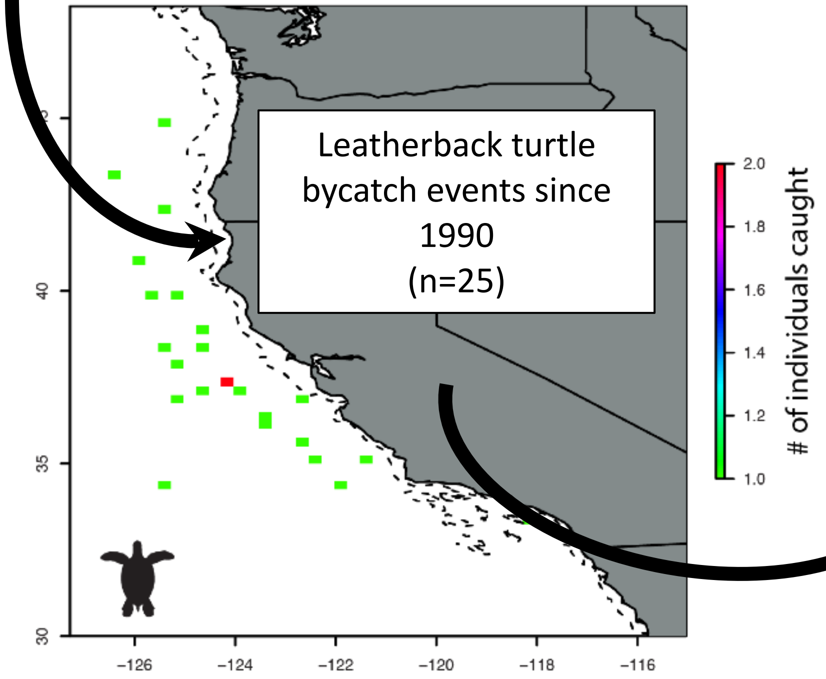
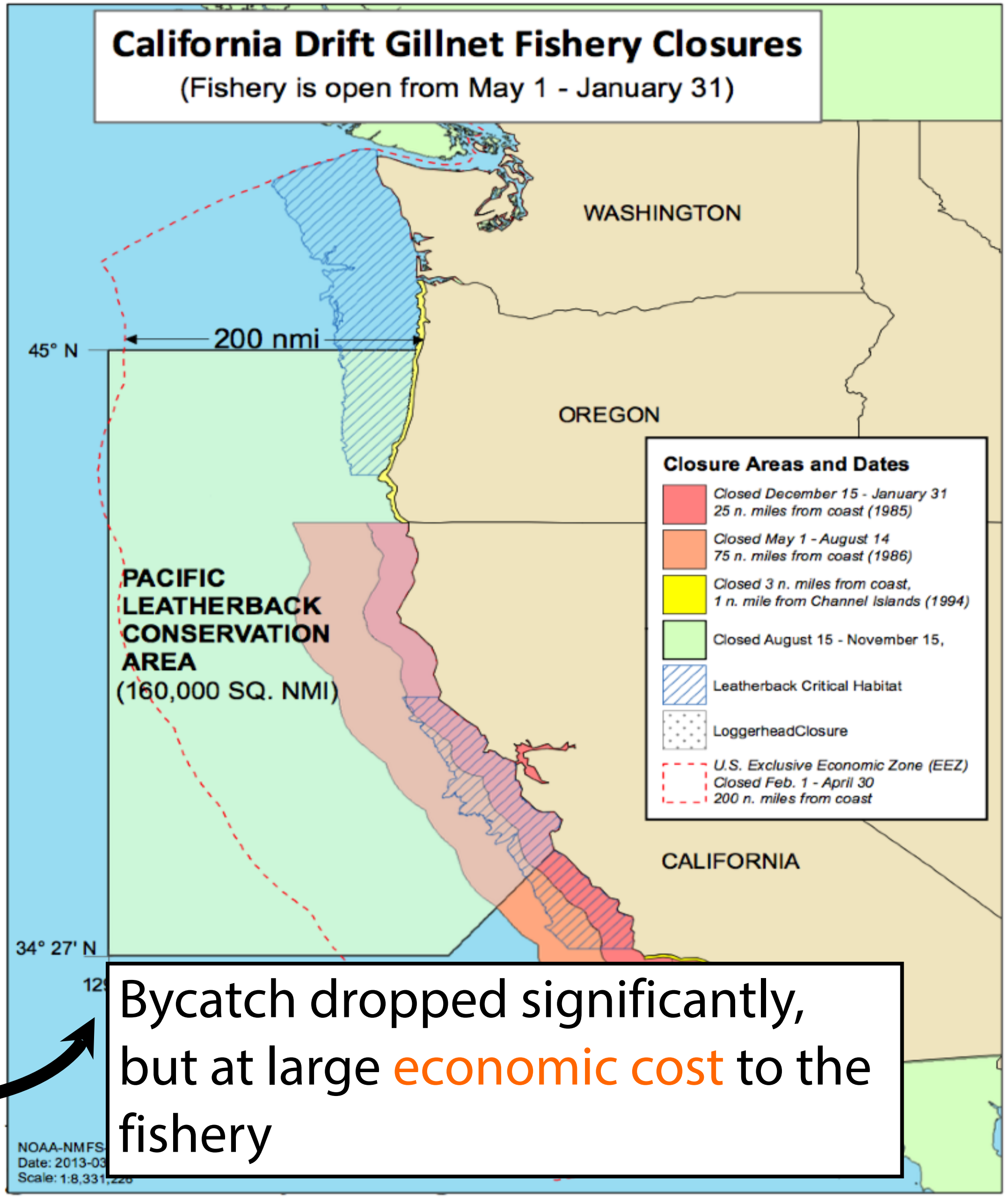


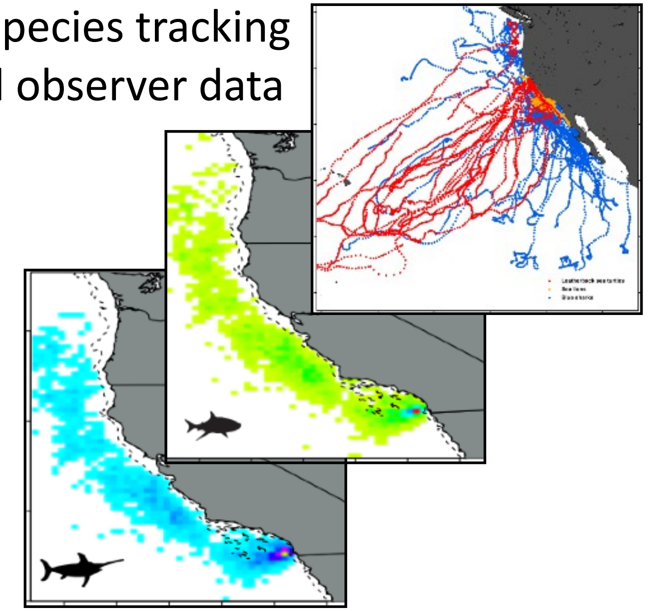


Leatherback turtle bycatch events since 1990 (n=25)



Bycatch dropped significantly, but at large economic cost to the fishery

1. Species tracking and observer data



Hazen et al. 2018 *Science Advances*

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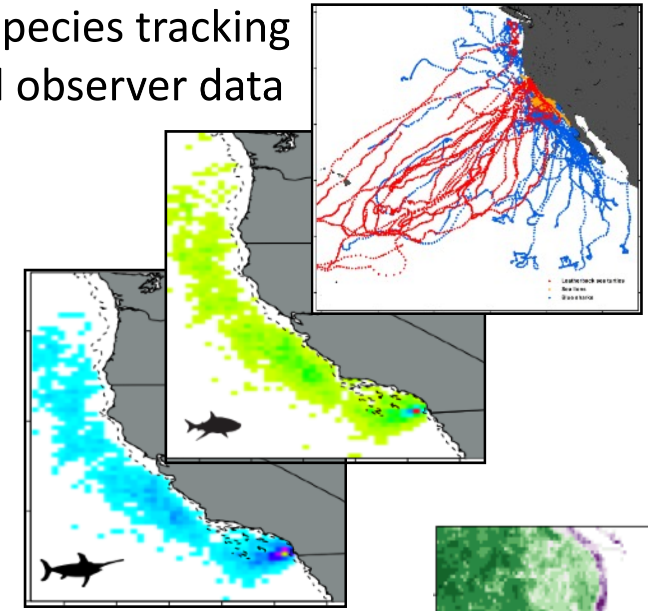

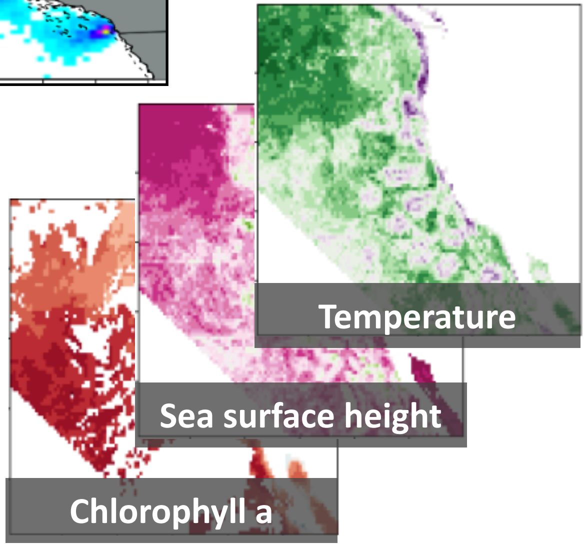

2. Environmental data from satellites

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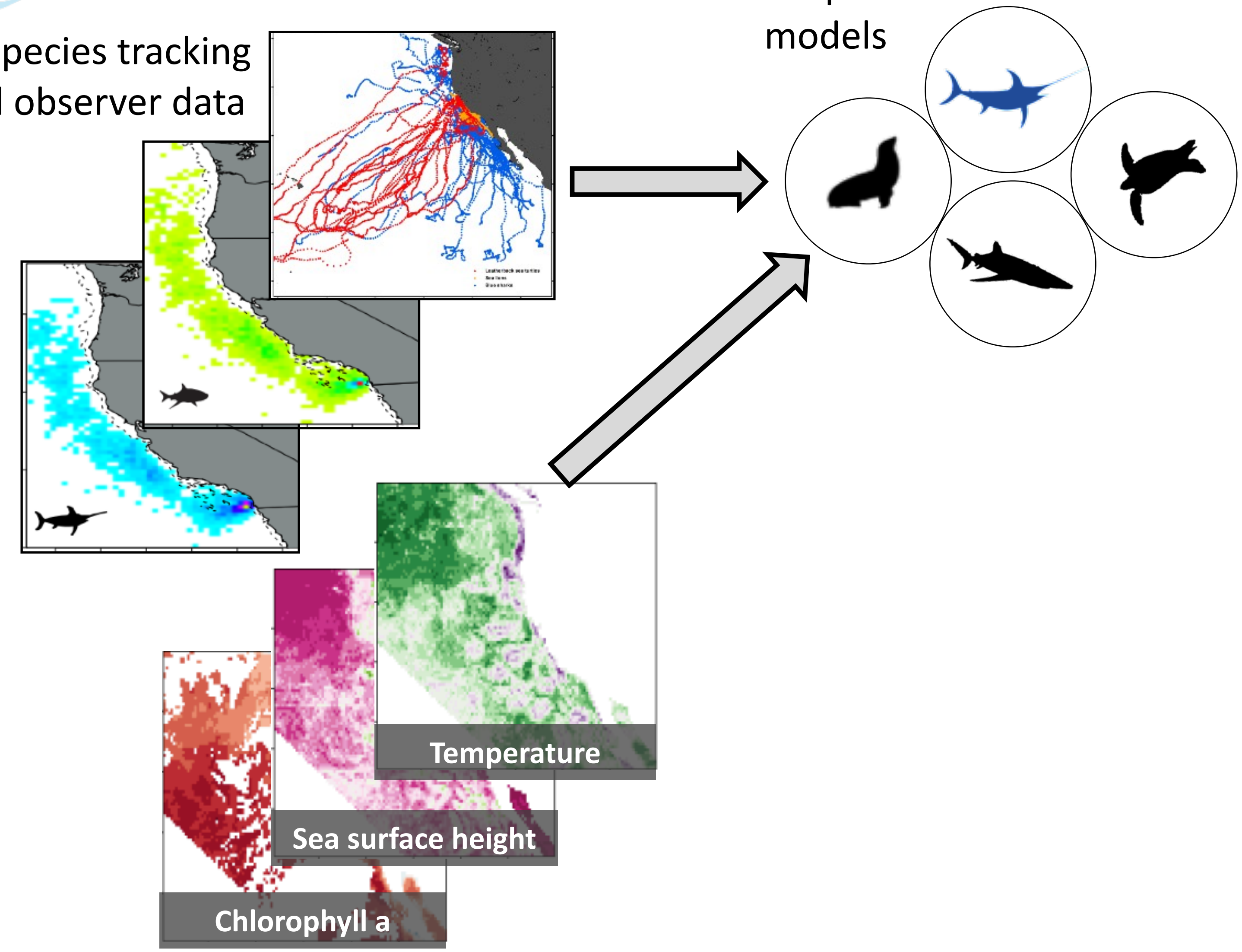

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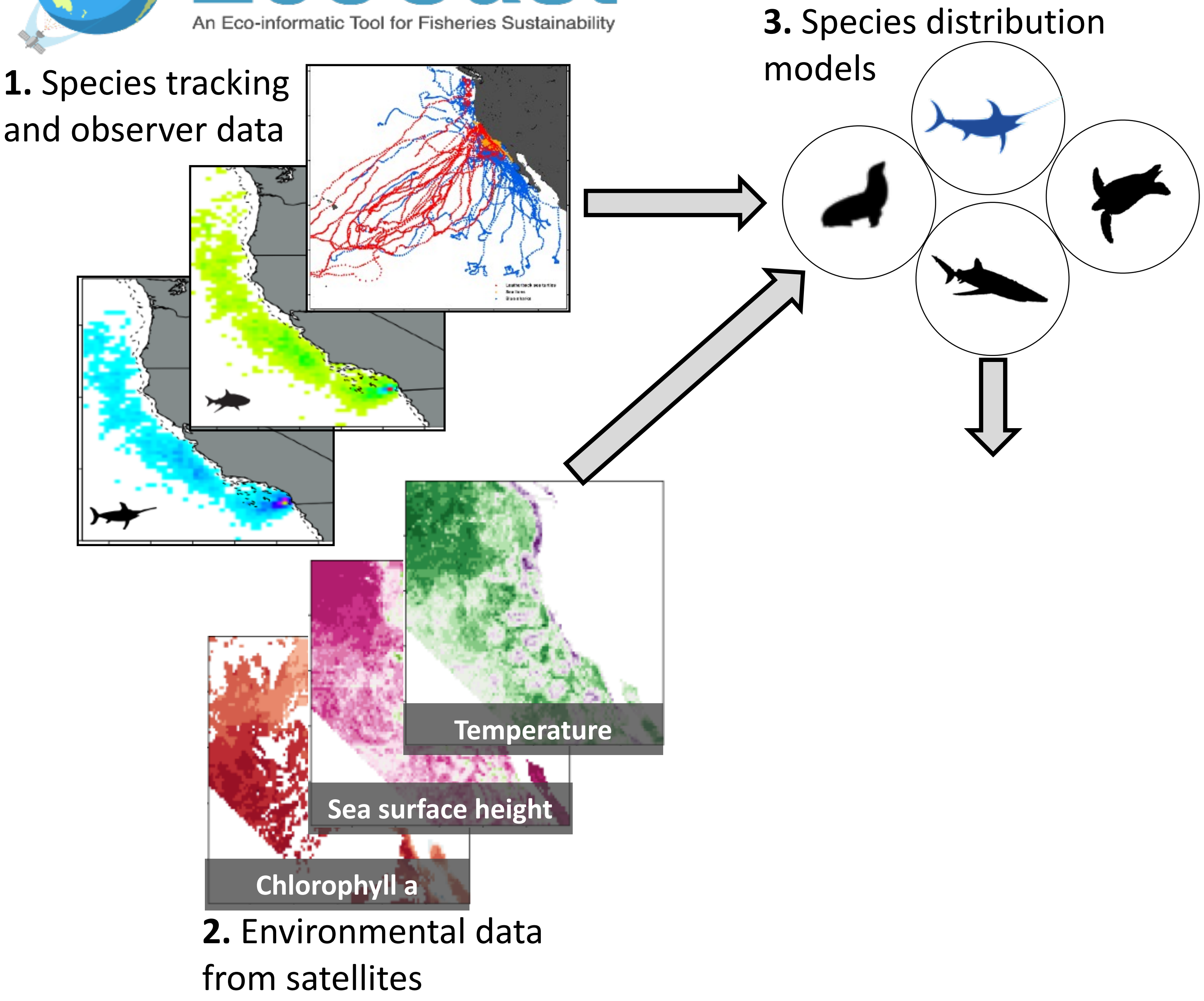
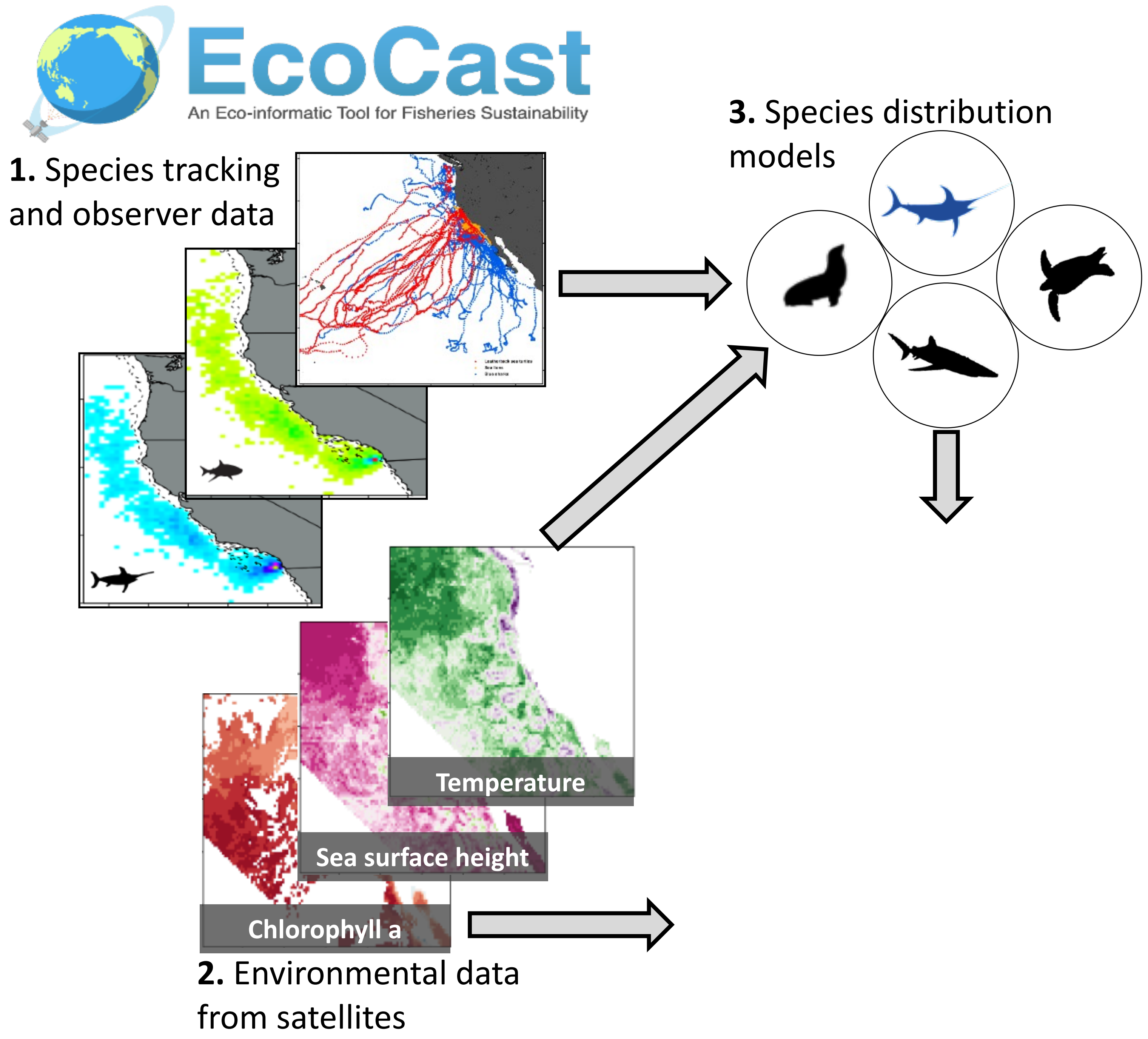
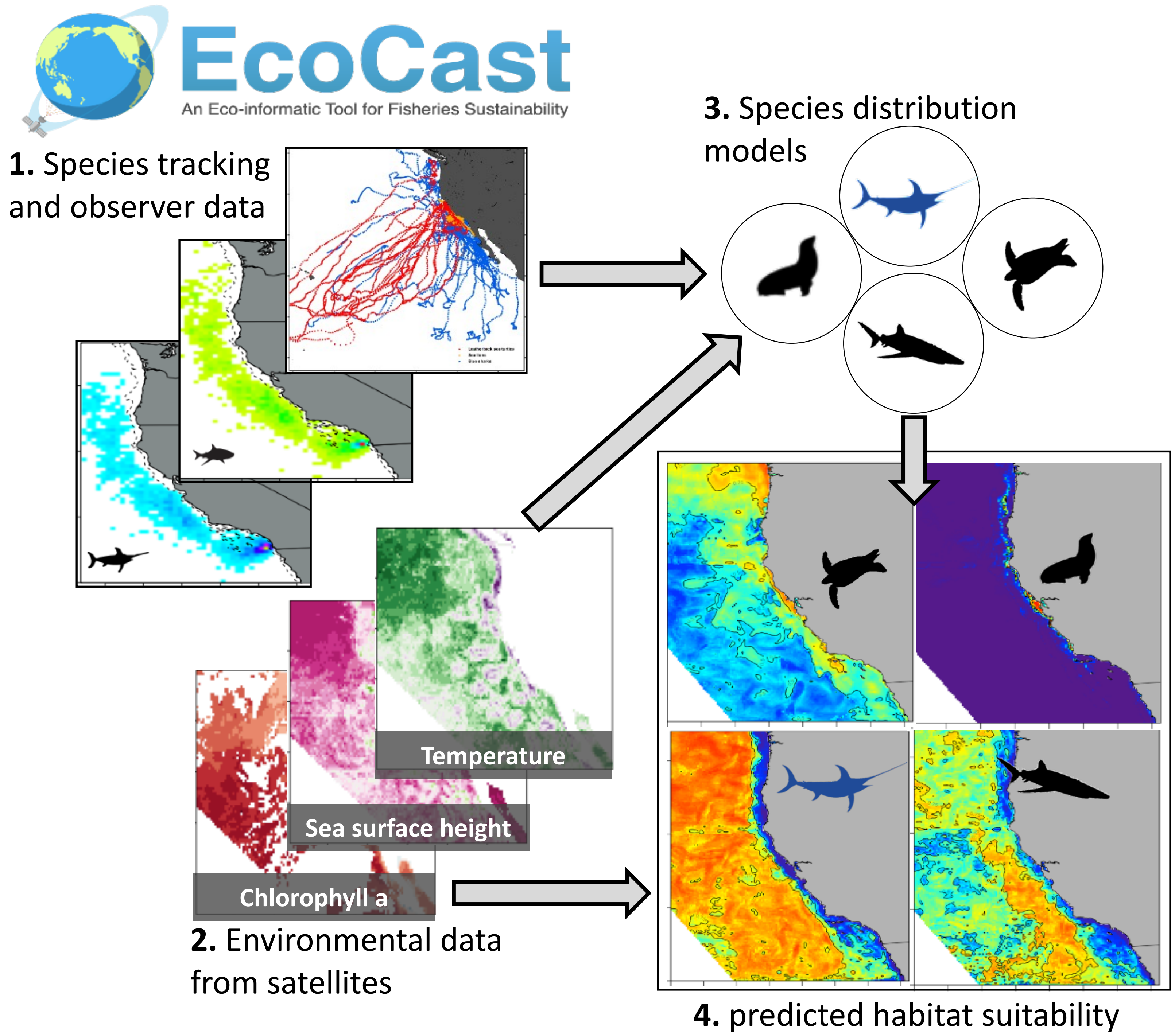


Hazen et al. 2018 *Science Advances*



Hazen et al. 2018 *Science Advances*



Hazen et al. 2018 *Science Advances*

EcoCast
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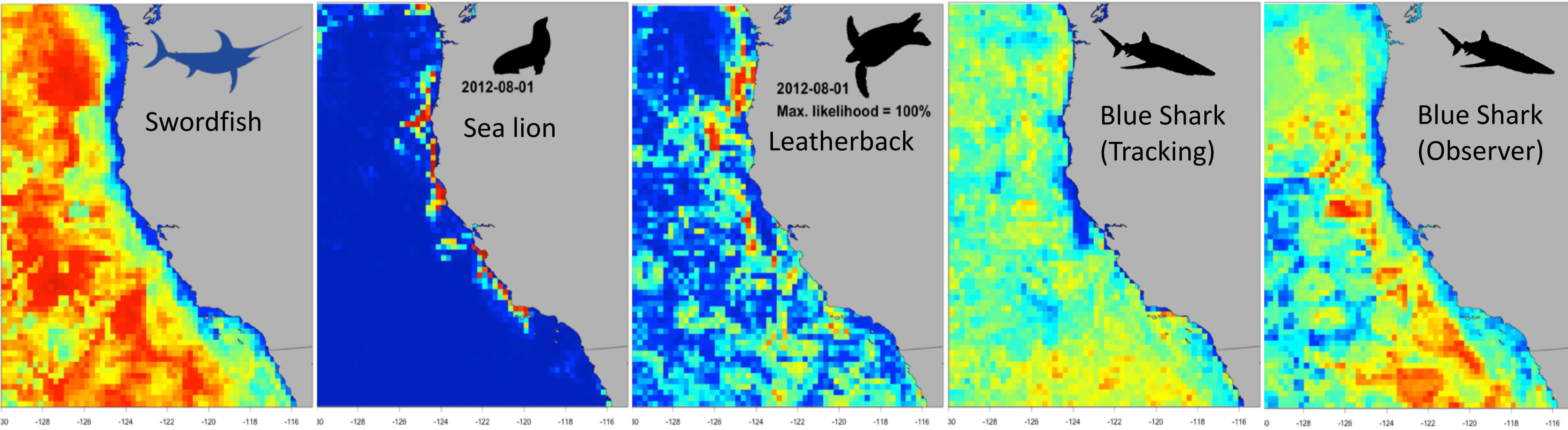
Individual species predictions



Hazen et al. 2018 *Science Advances*

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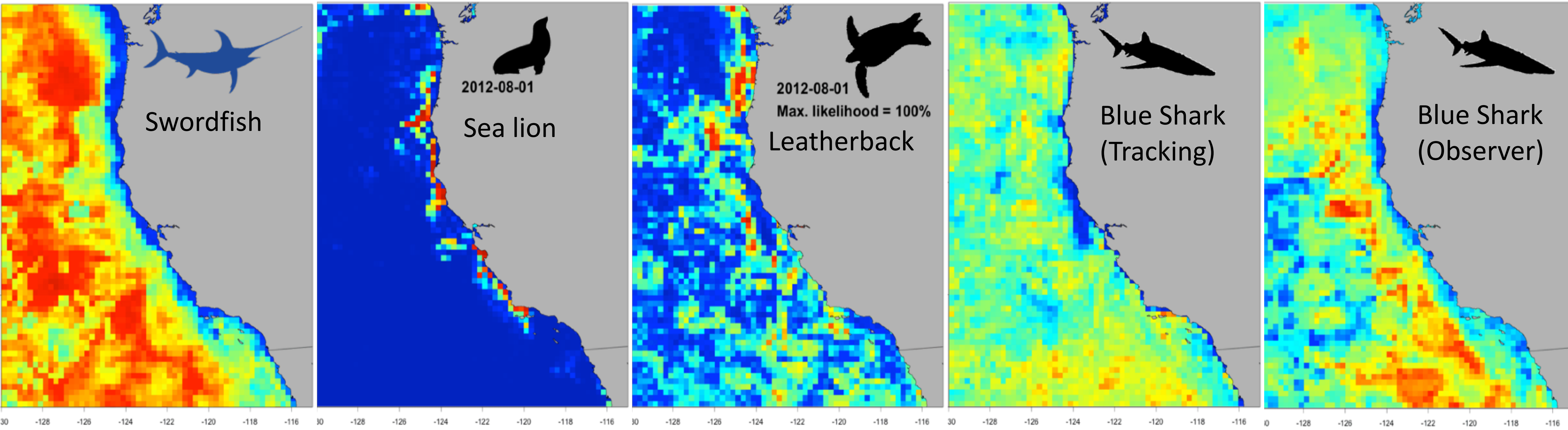

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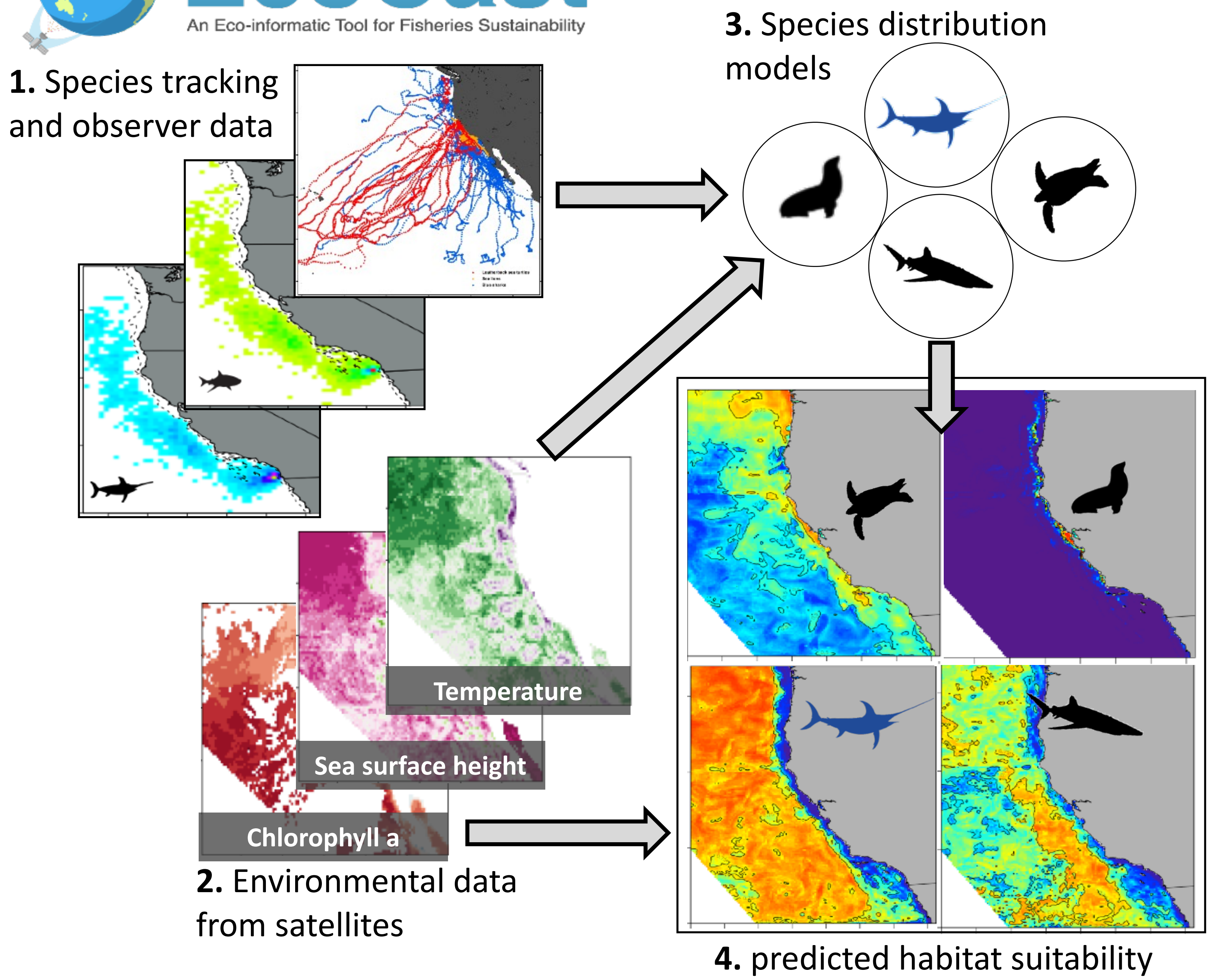
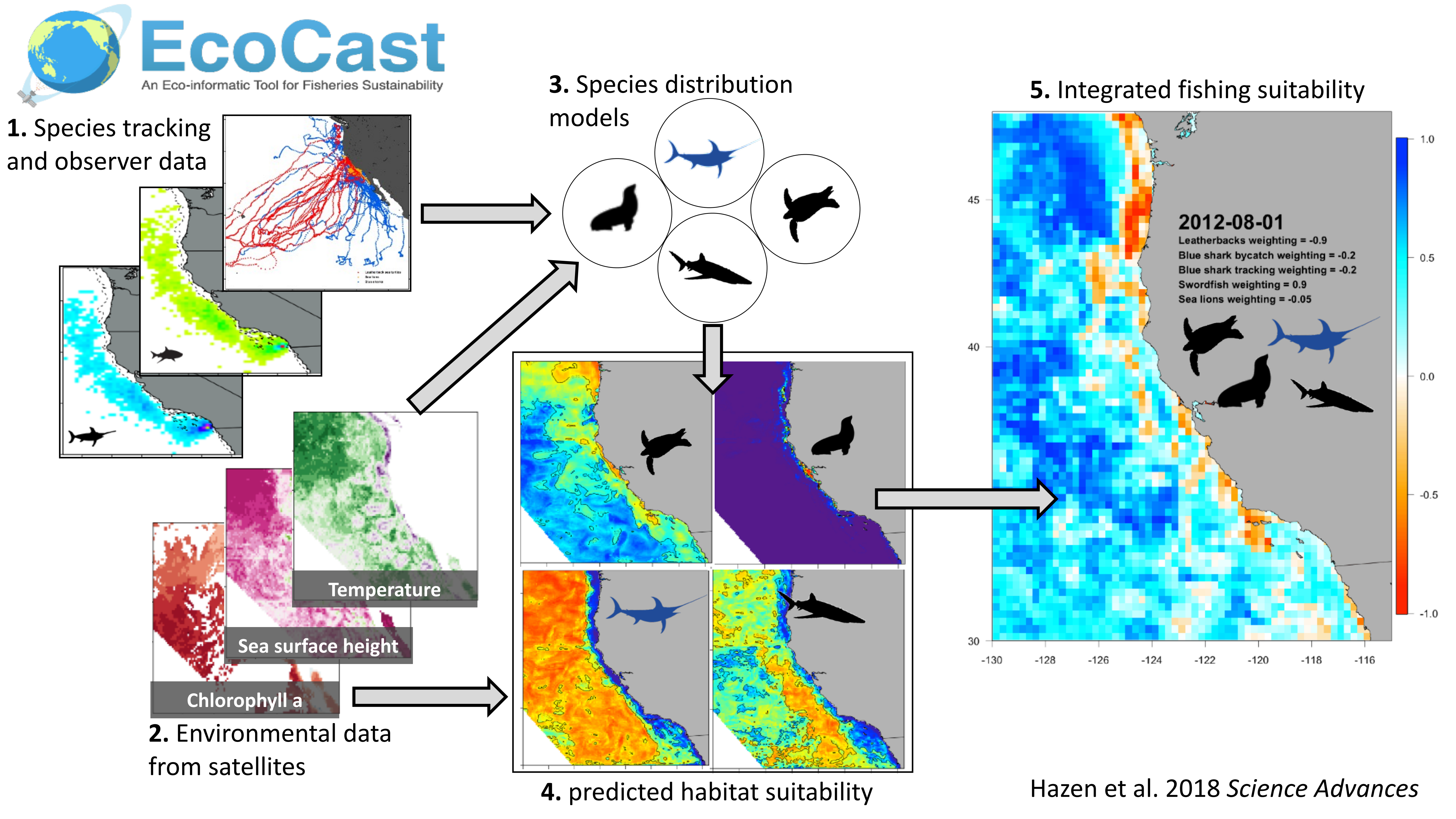
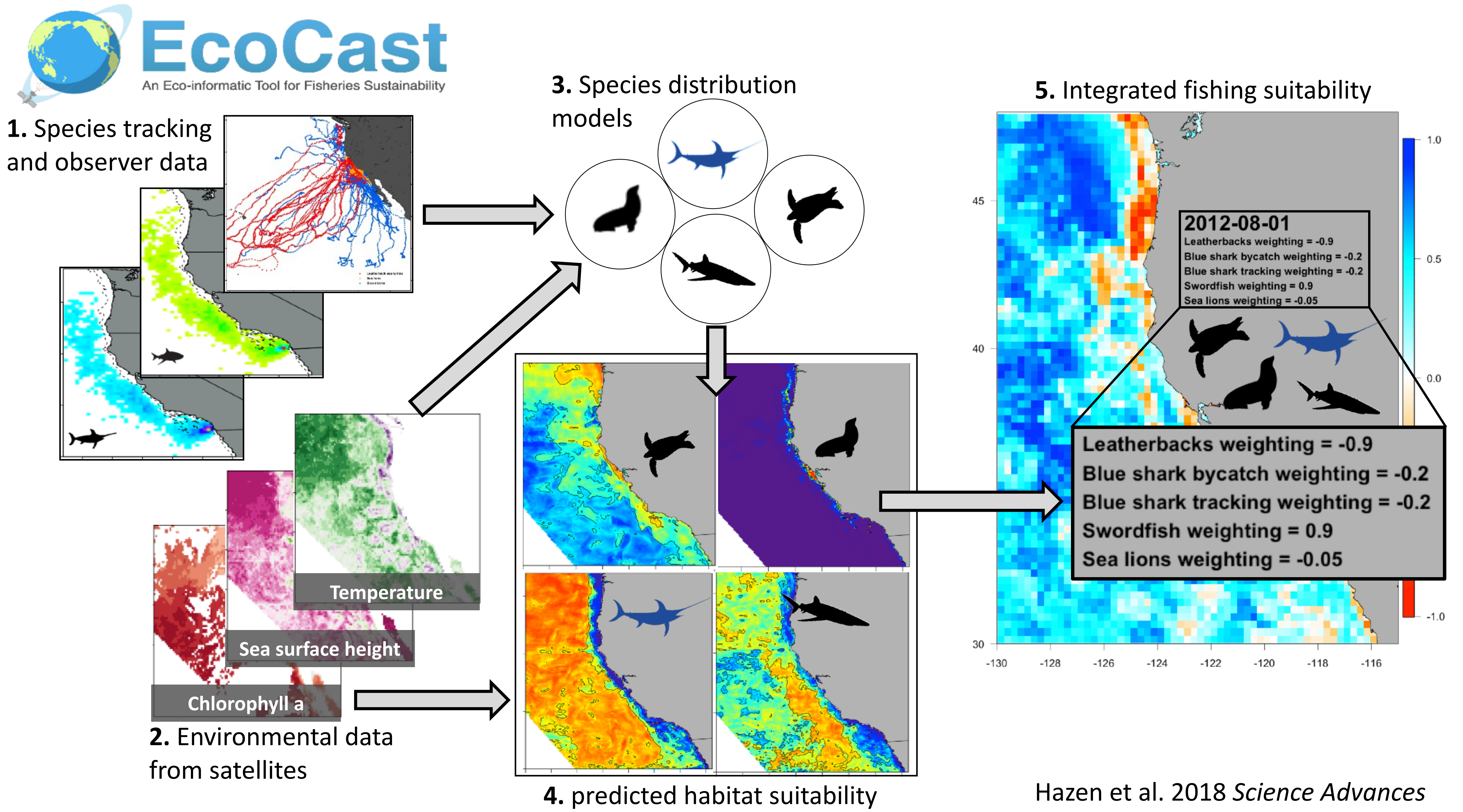


Hazen et al. 2018 *Science Advances*

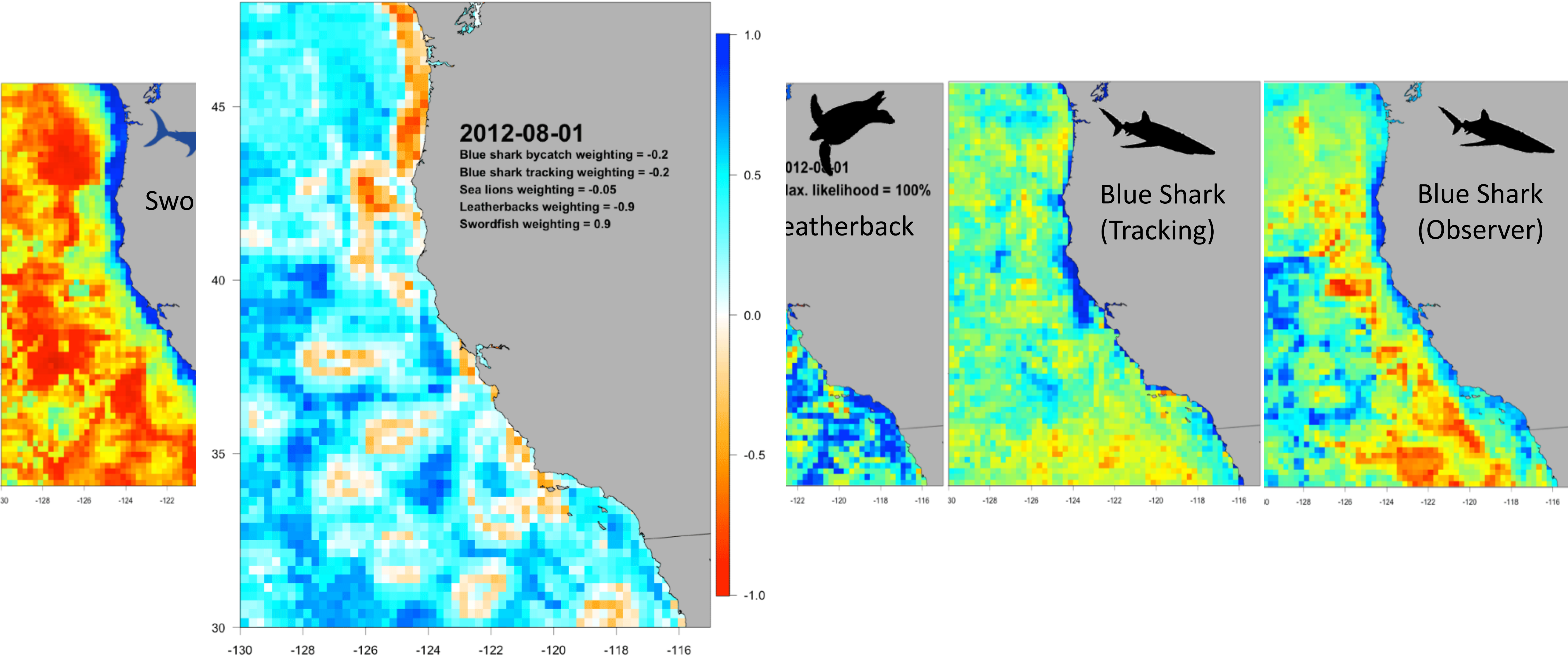


EcoCast
An Eco-informatic Tool for Fisheries Sustainability
1. Species tracking and observer data
2. Environmental data from satellites
Temperature
Sea surface height
Chlorophyll a
3. Species distribution models
4. predicted habitat suitability
5. Integrated fishing suitability
2012-08-01
Leatherbacks weighting = -0.9
Blue shark bycatch weighting = -0.2
Blue shark tracking weighting = -0.2
Swordfish weighting = 0.9
Sea lions weighting = -0.05
Hazen et al. 2018 Science Advances



Hazen et al. 2018 *Science Advances*

Integrated species predictions



Hazen et al. 2018 *Science Advances*

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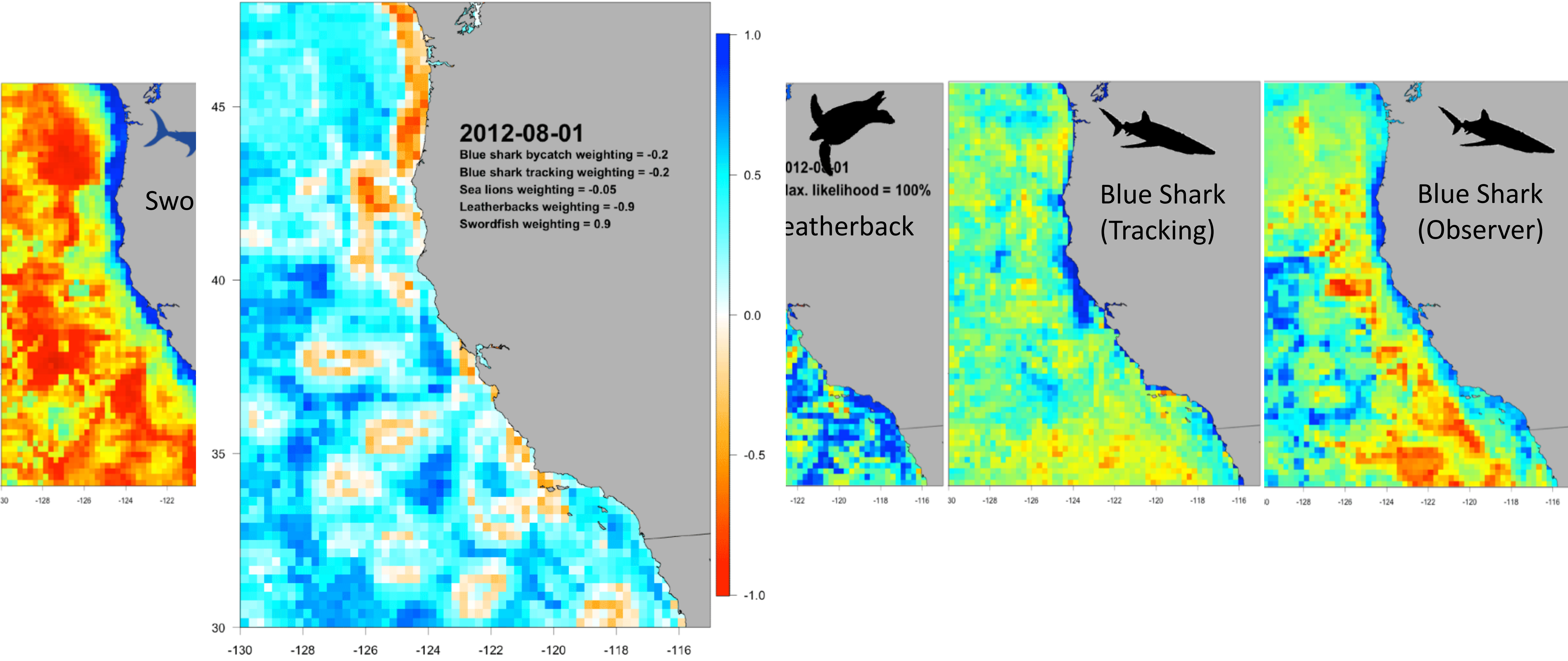

Hazen et al. 2018 *Science Advances*

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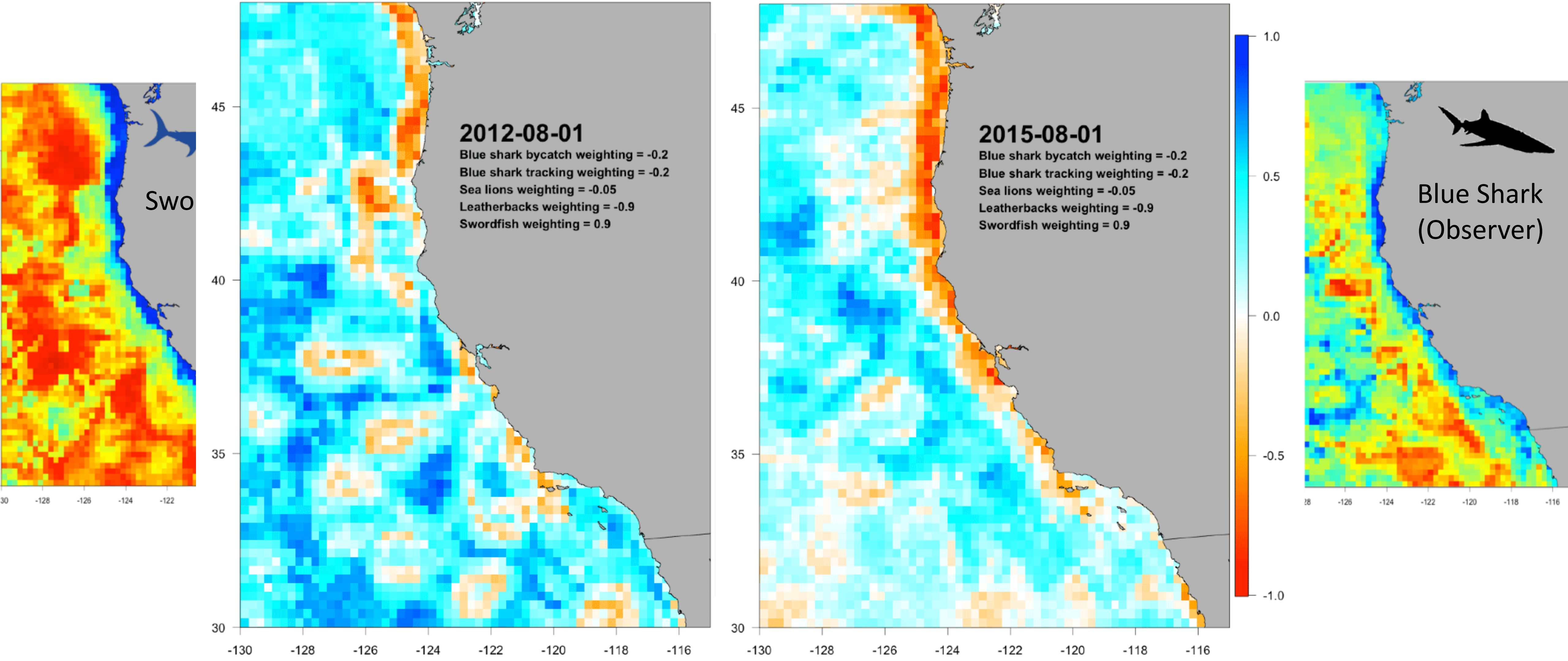

Hazen et al. 2018 *Science Advances*

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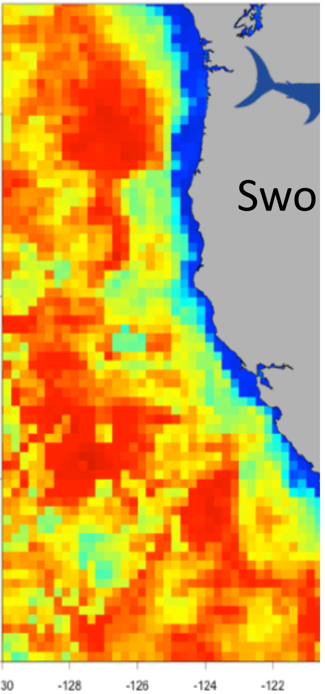
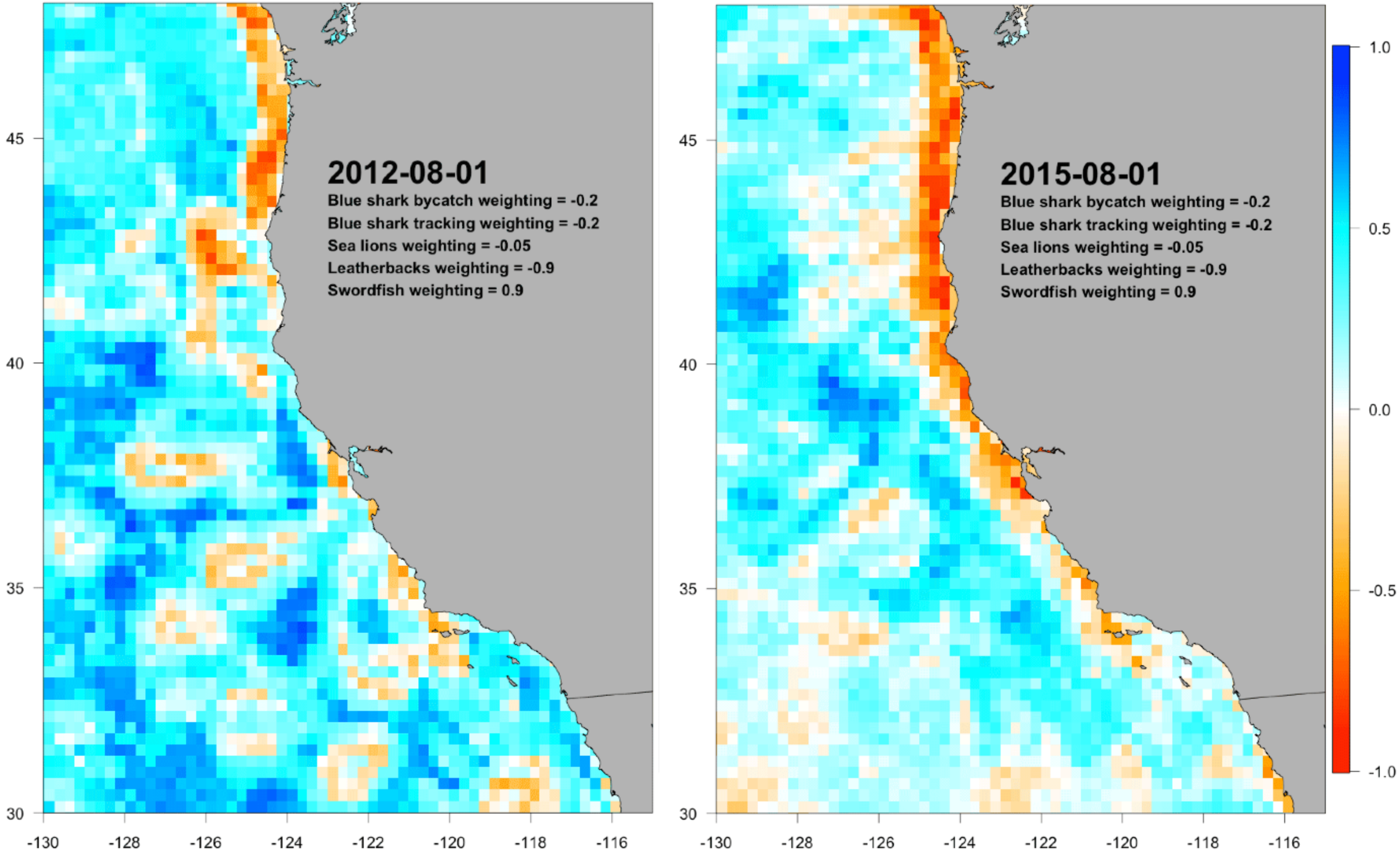
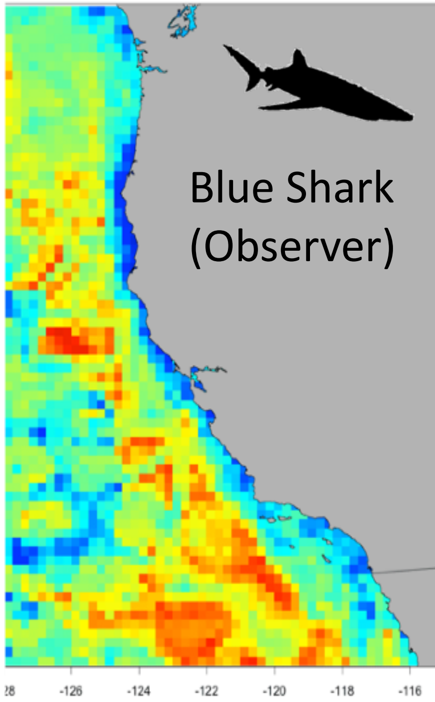
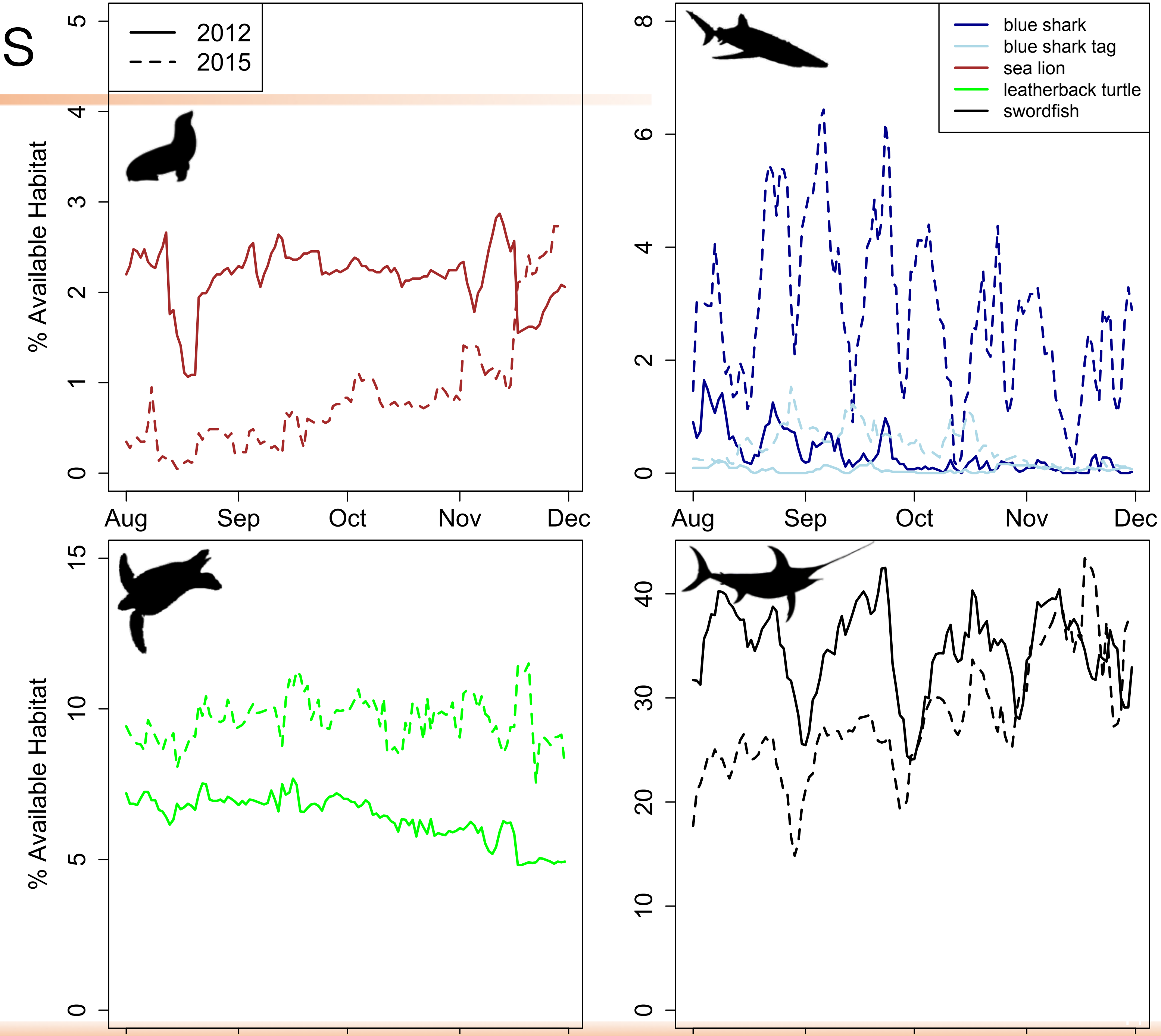






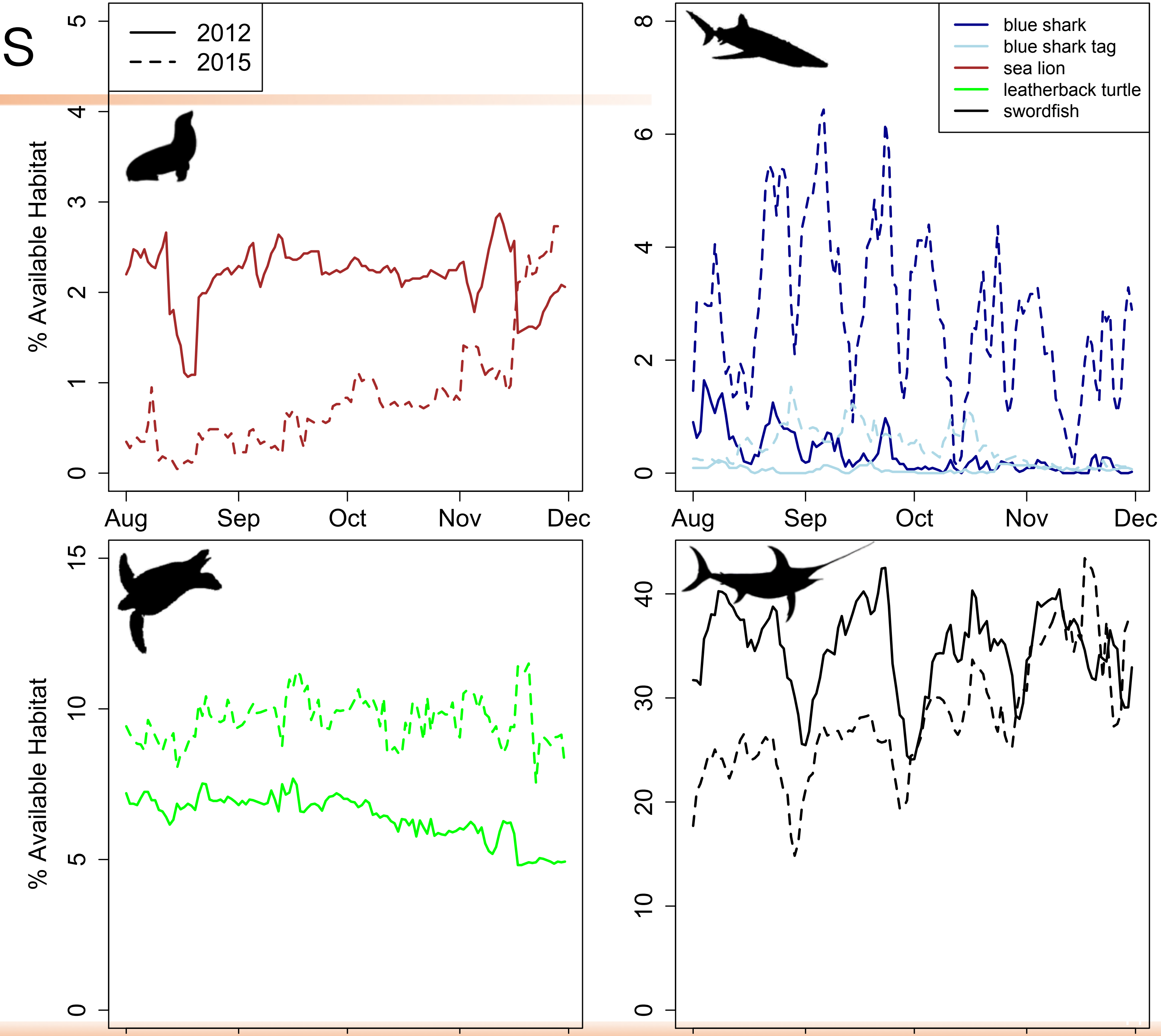
Hazen et al. 2018 *Science Advances*

Predicted ENSO effects



Predicted ENSO effects

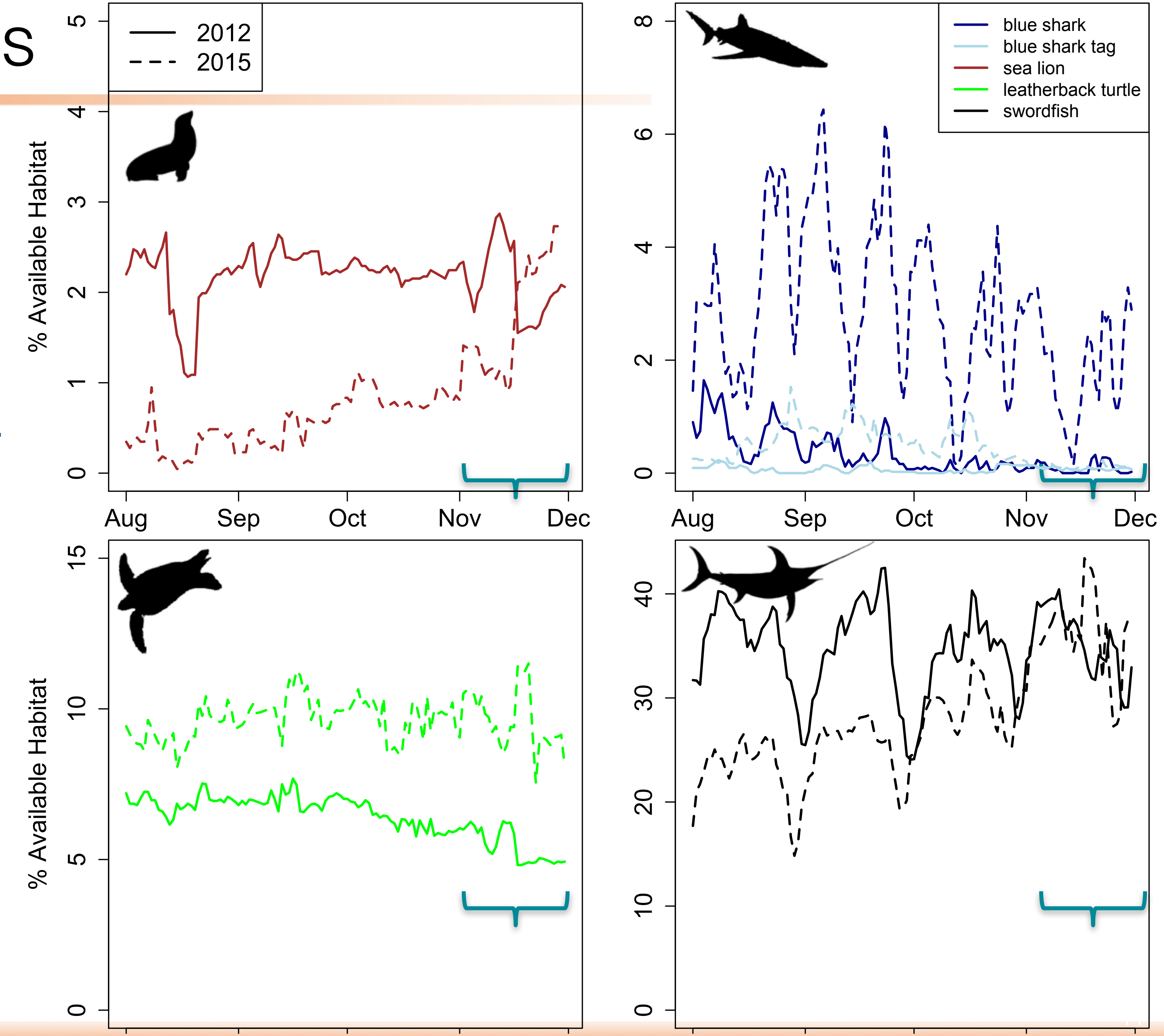
1. We can turn predictions into a time series to create indicators.



Predicted ENSO effects

1. We can turn predictions into a time series to create indicators.

2. Fishing late in the year (Nov-Dec) in 2015 may have been optimal (except for sea lions).

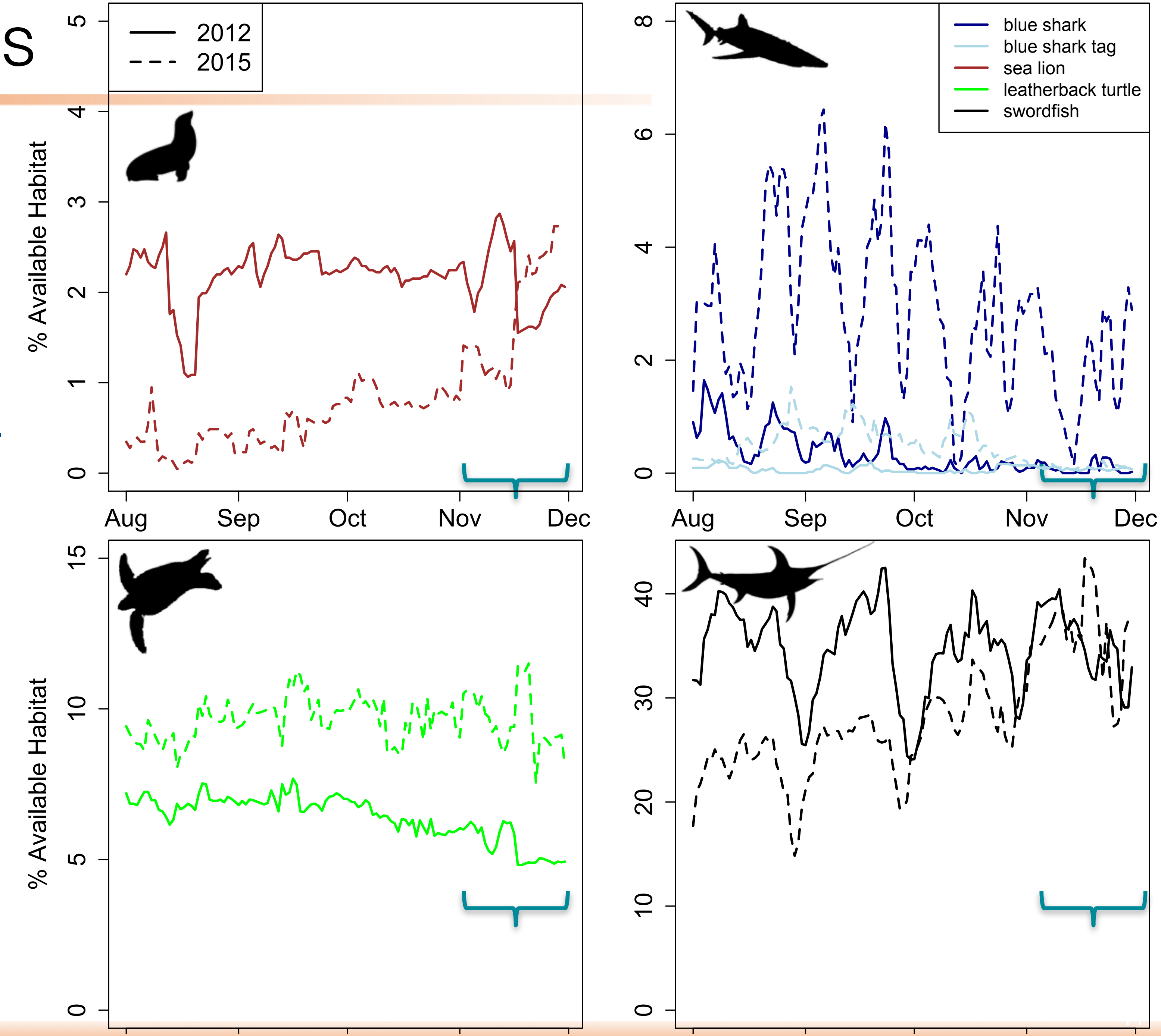


Predicted ENSO effects

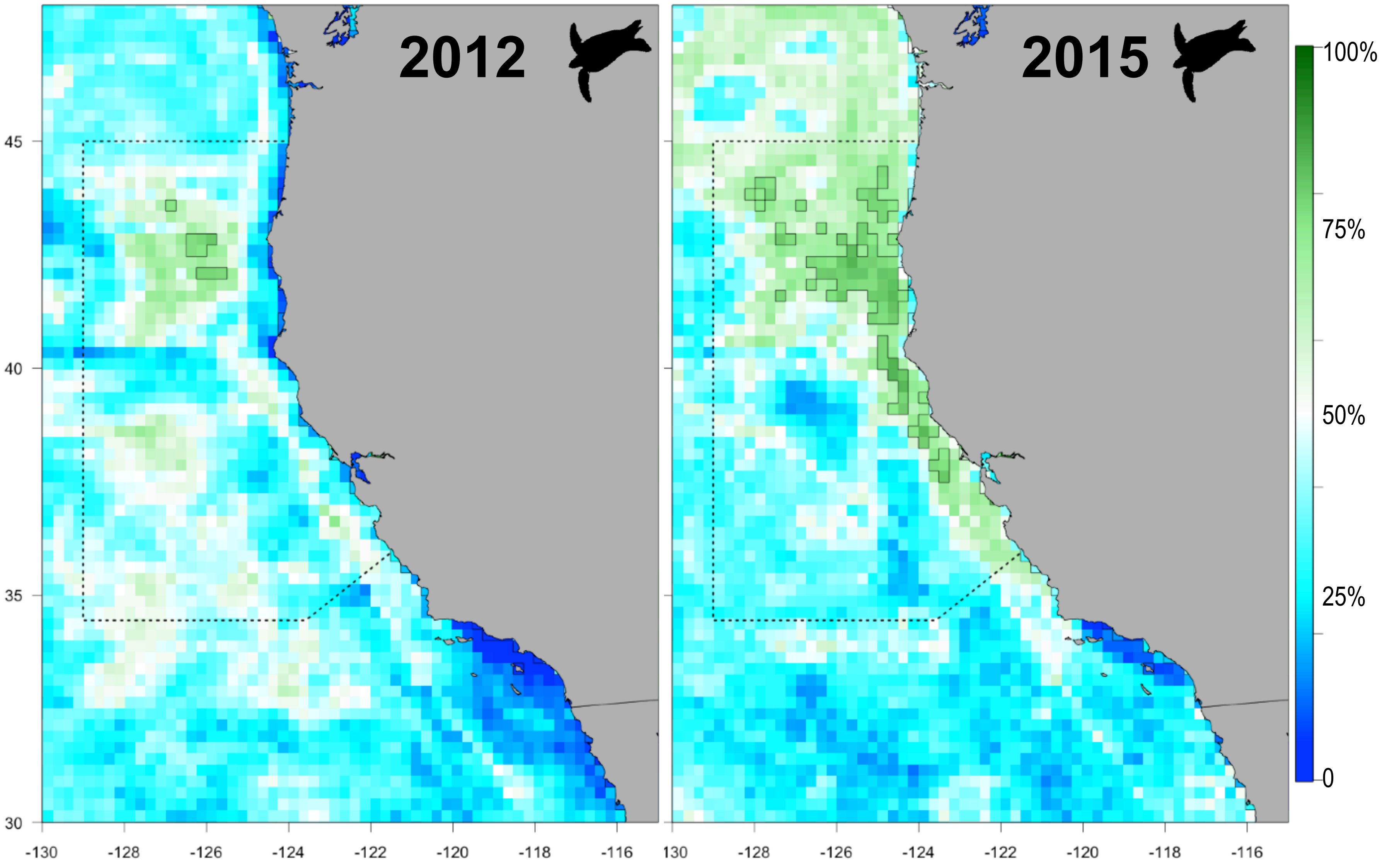
1. We can turn predictions into a time series to create indicators.

2. Fishing late in the year (Nov-Dec) in 2015 may have been optimal (except for sea lions).

3. Highlights the difficulty in managing across “normal” and “unusual” years.

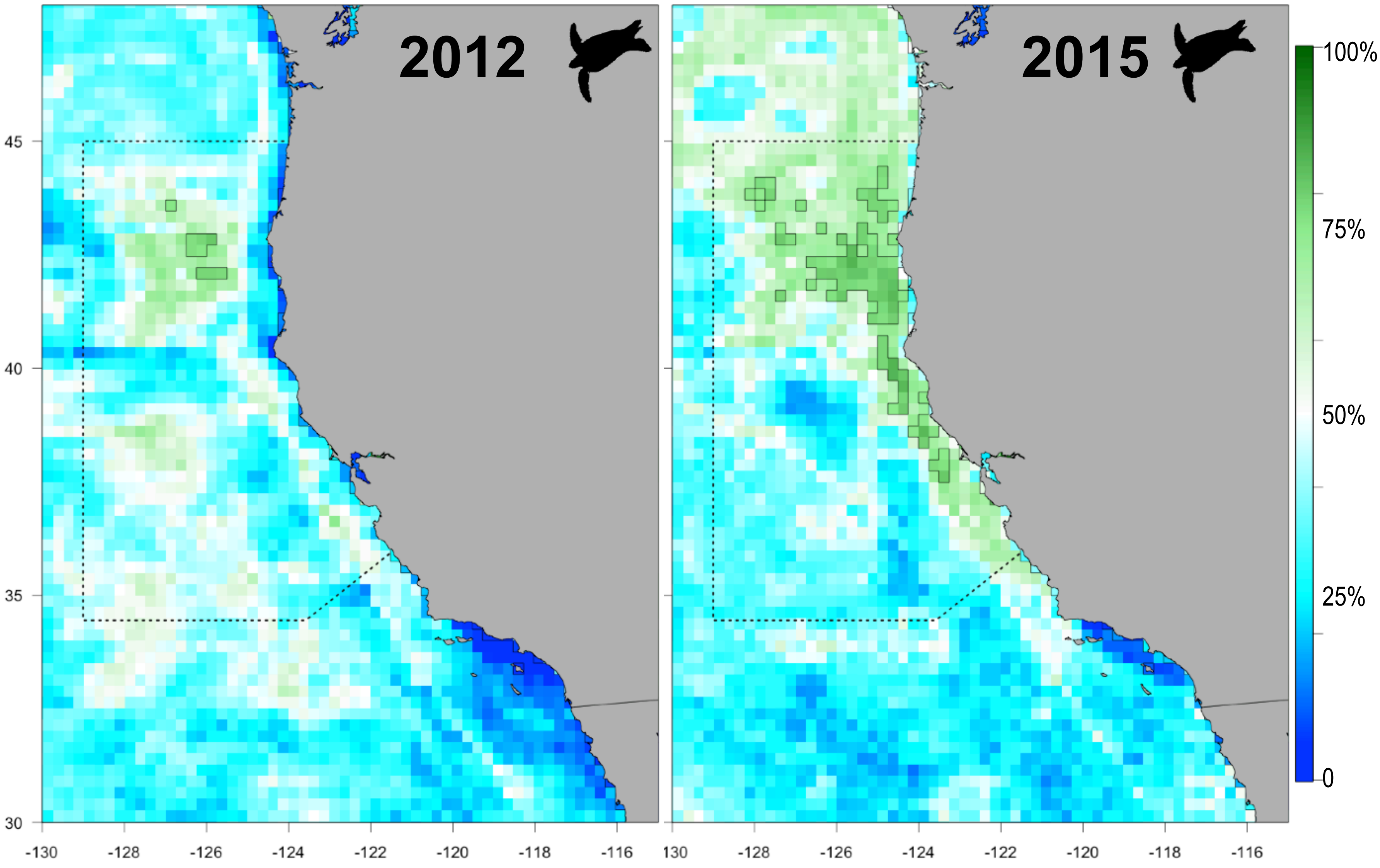


EcoCast predictions - California Drift Gillnet Fishery



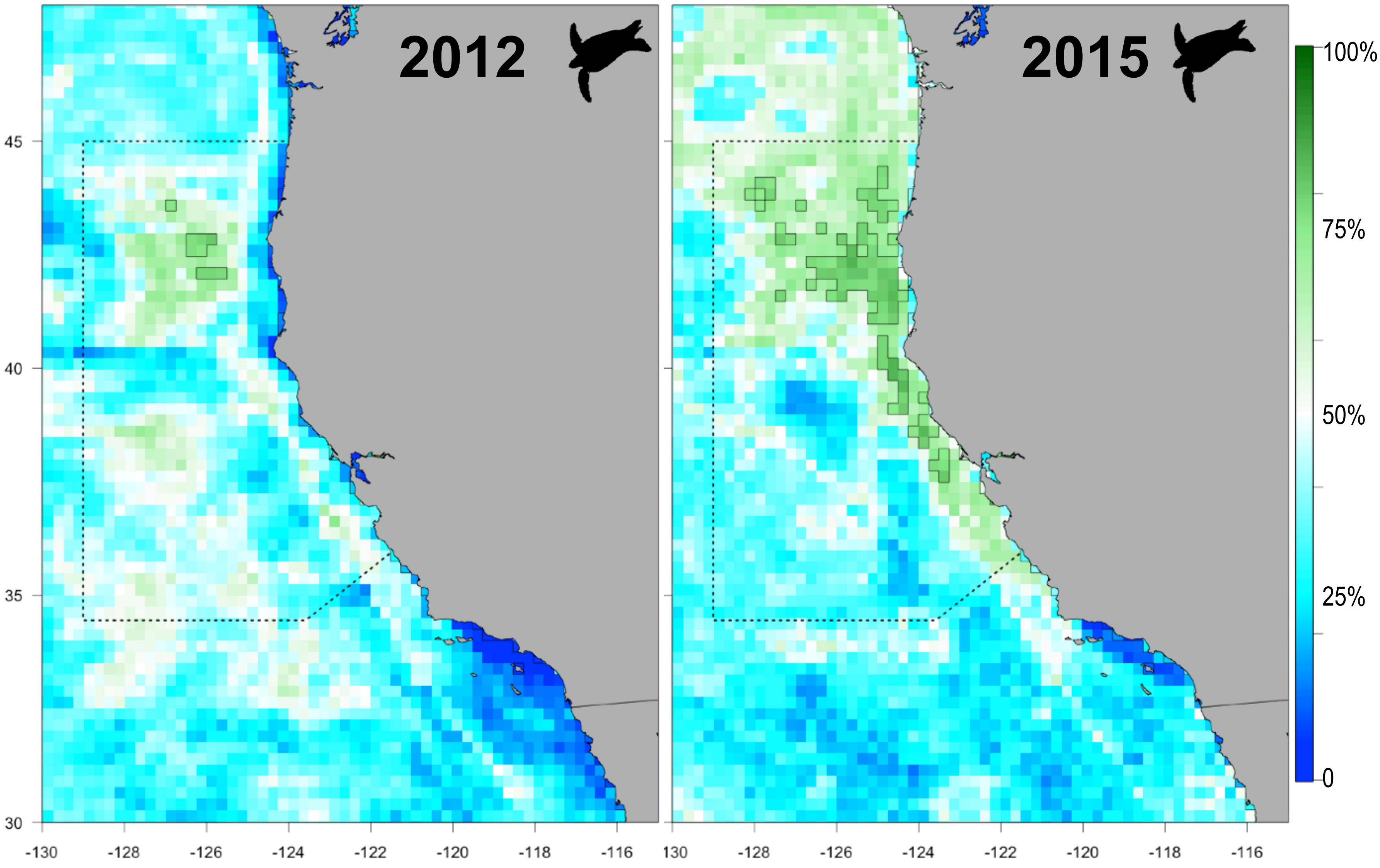
EcoCast predictions - California Drift Gillnet Fishery

- Z = Percentage of days that were predicted to be leatherback habitat



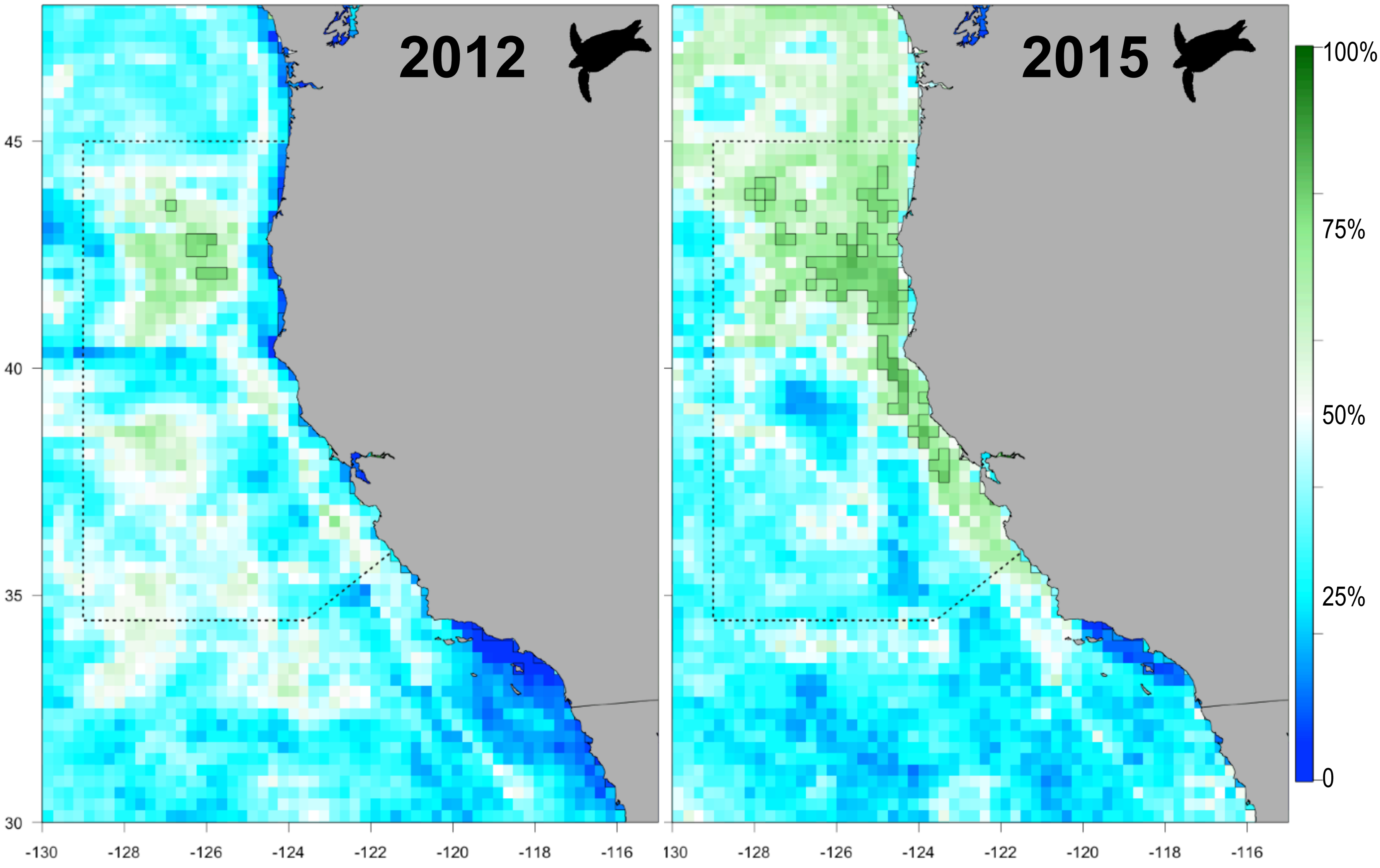
EcoCast predictions - California Drift Gillnet Fishery

- Z = Percentage of days that were predicted to be leatherback habitat
- PLCA captures > 80% of habitat in “normal” year but less in a warm, El Niño year.



EcoCast predictions - California Drift Gillnet Fishery

- Z = Percentage of days that were predicted to be leatherback habitat
- PLCA captures > 80% of habitat in “normal” year but less in a warm, El Niño year.
- A tool to evaluate efficacy (and timing) of seasonal closures



EcoCast
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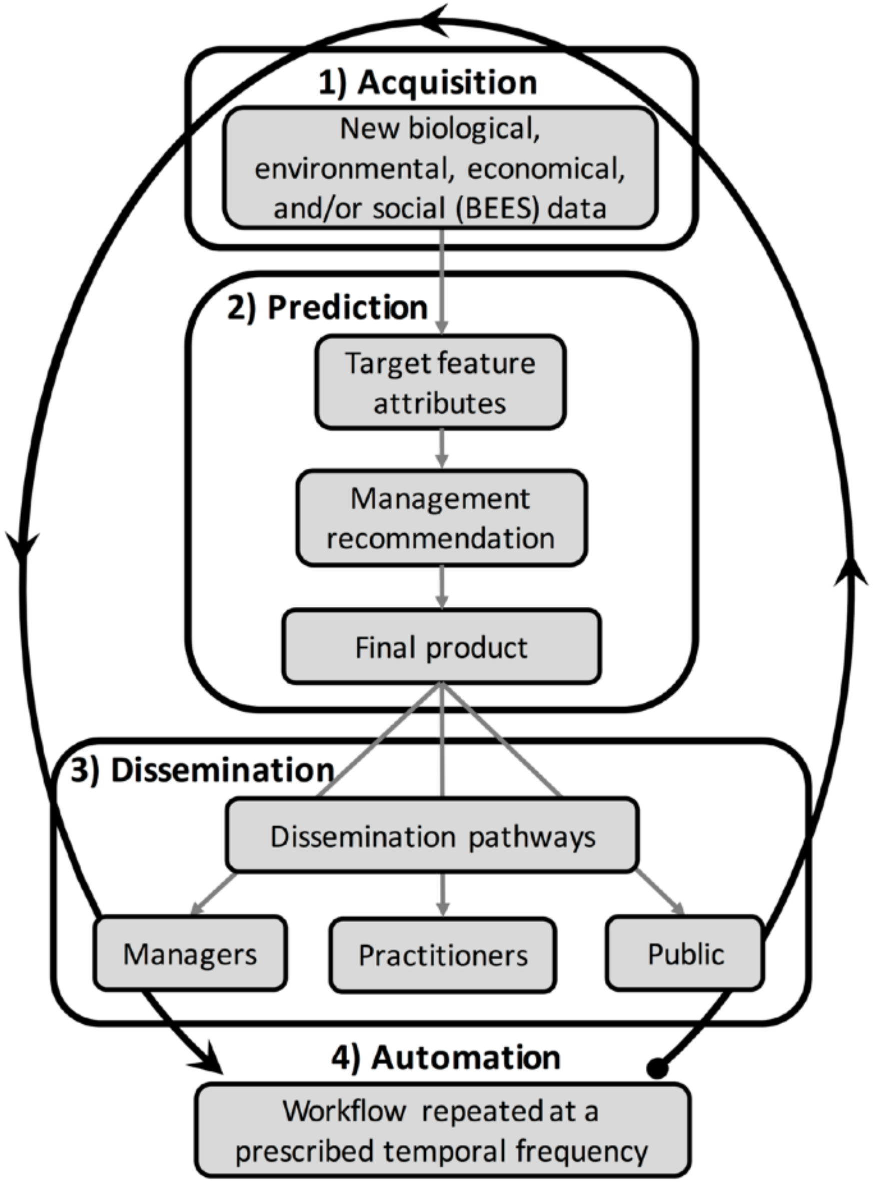
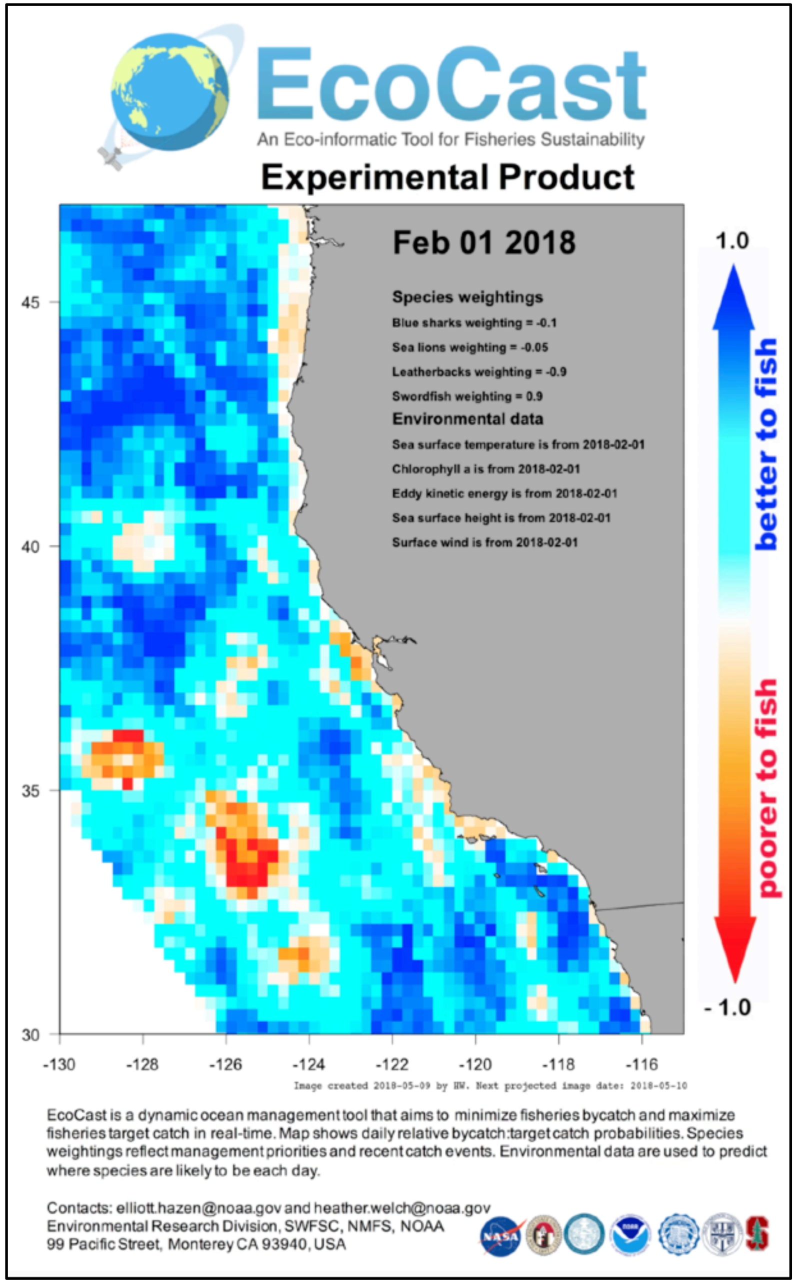
Tool operationalization



Welch et al. 2018 *JAE*

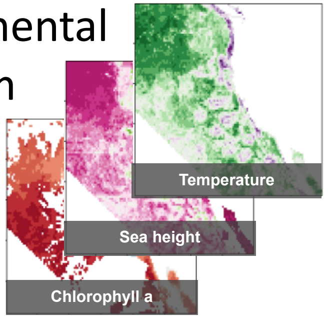


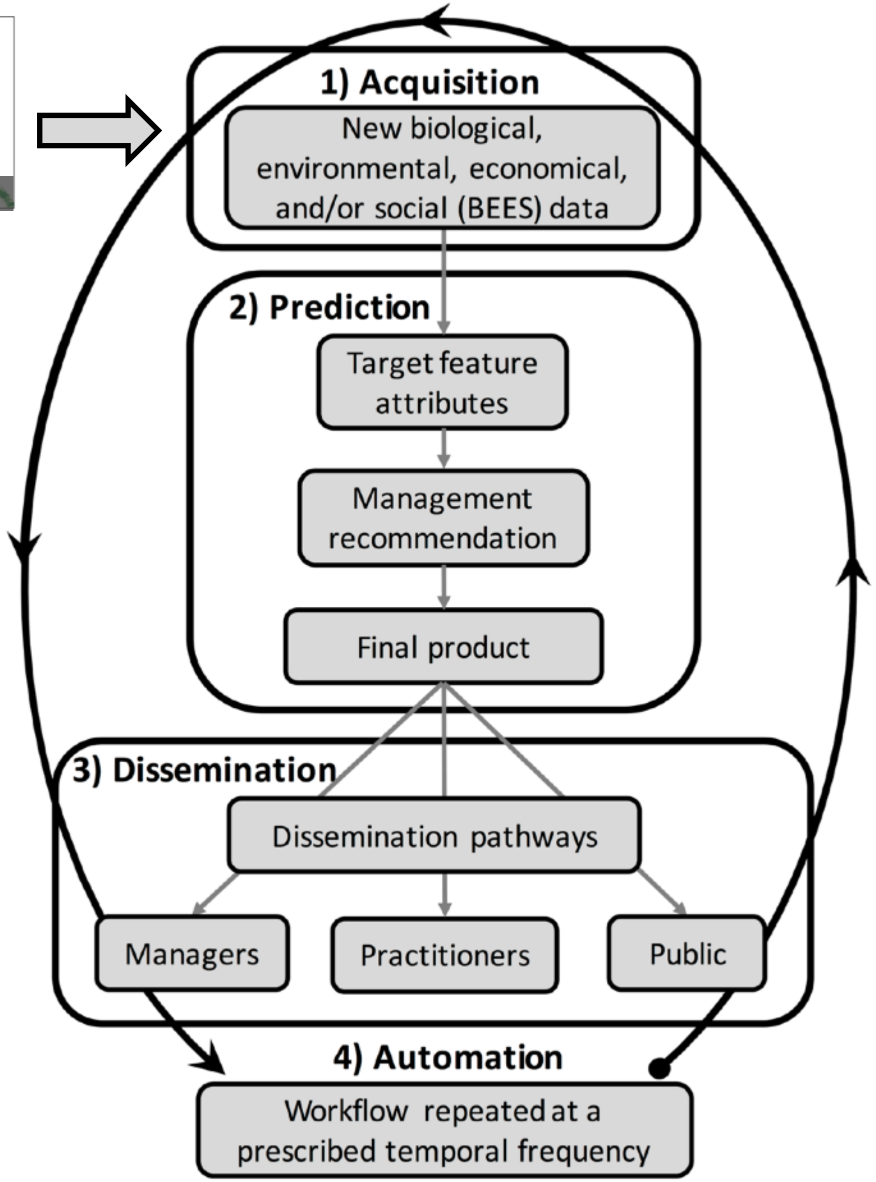
EcoCast

An Eco-informatic Tool for Fisheries Sustainability

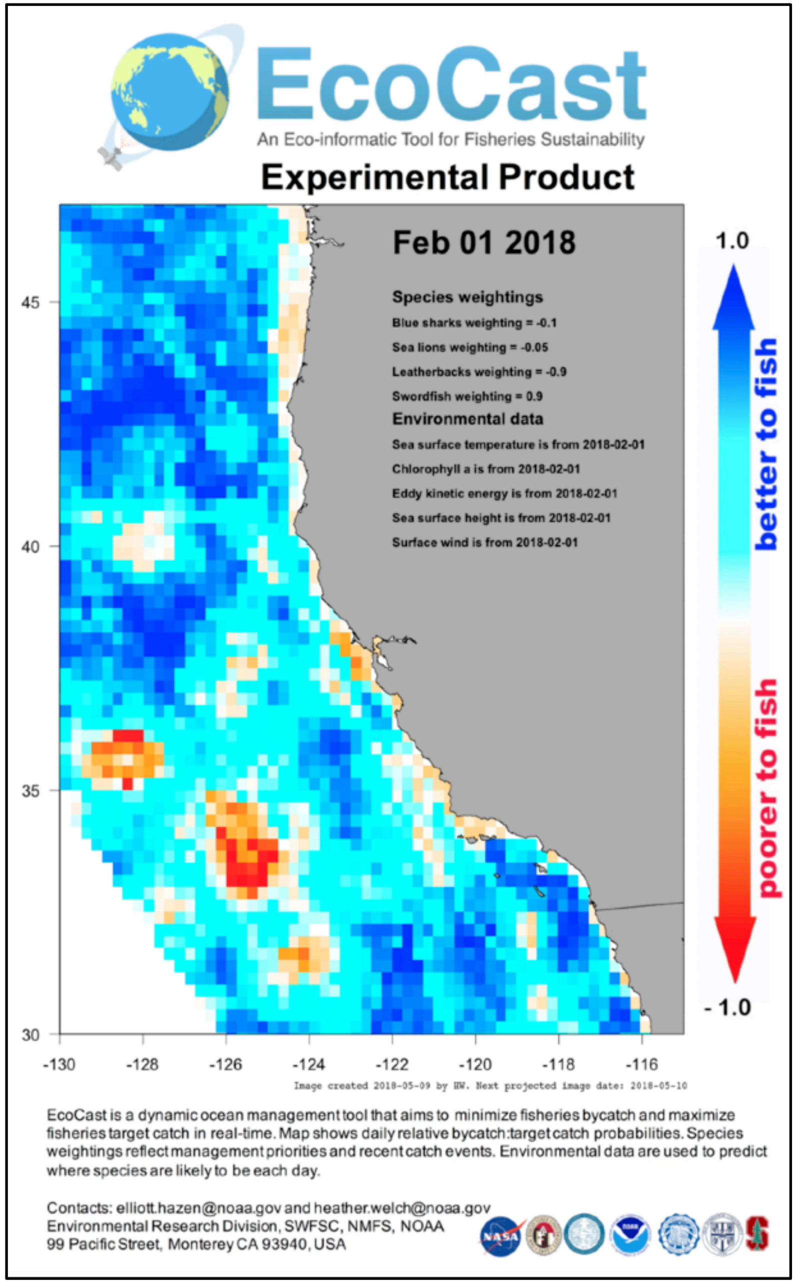
Tool operationalization

Environmental data from satellites





Welch et al. 2018 *JAE*



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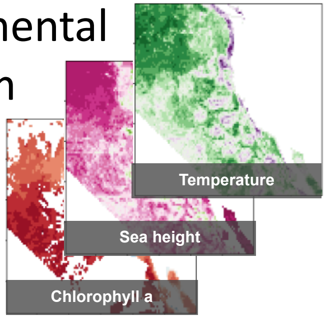
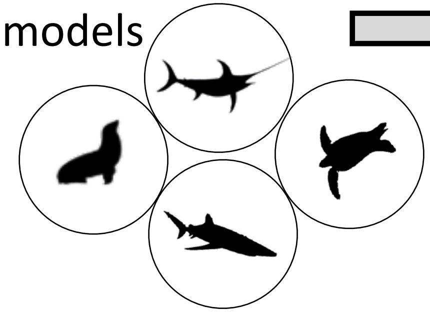
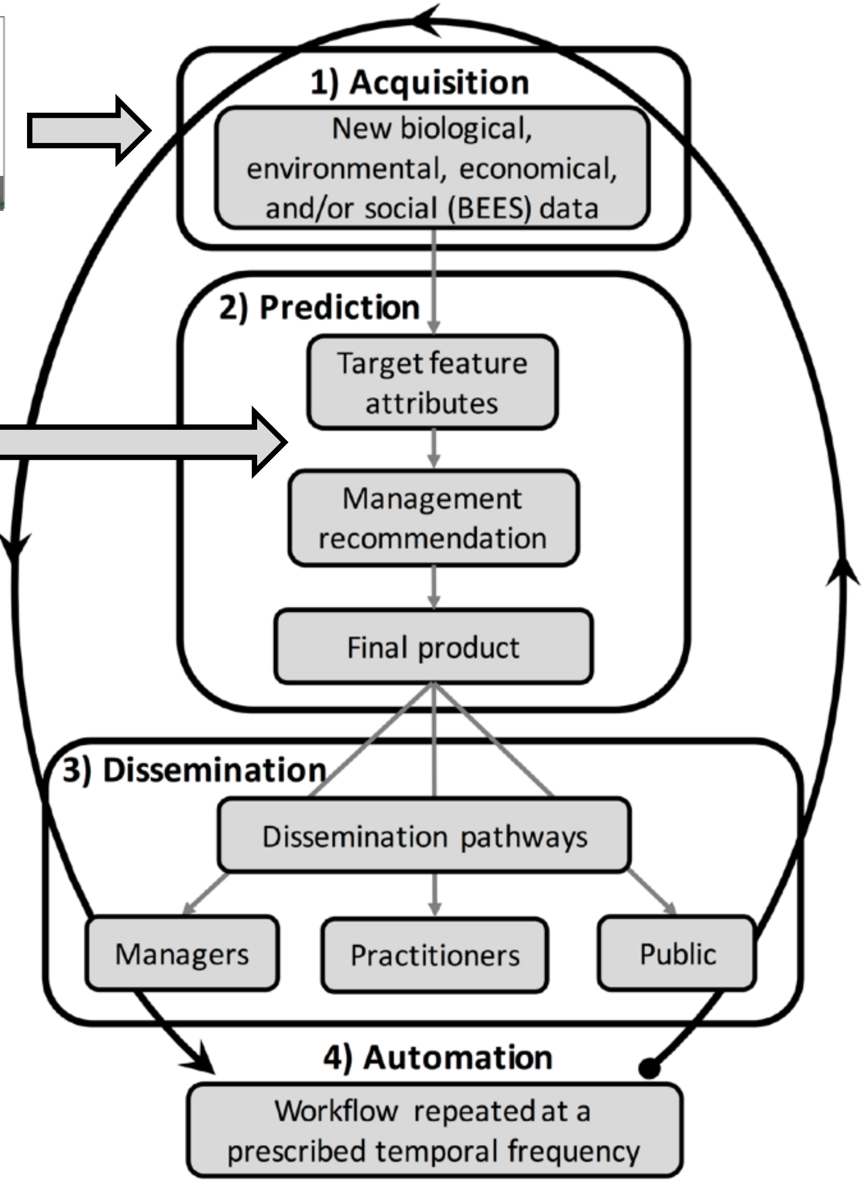


Species distribution models





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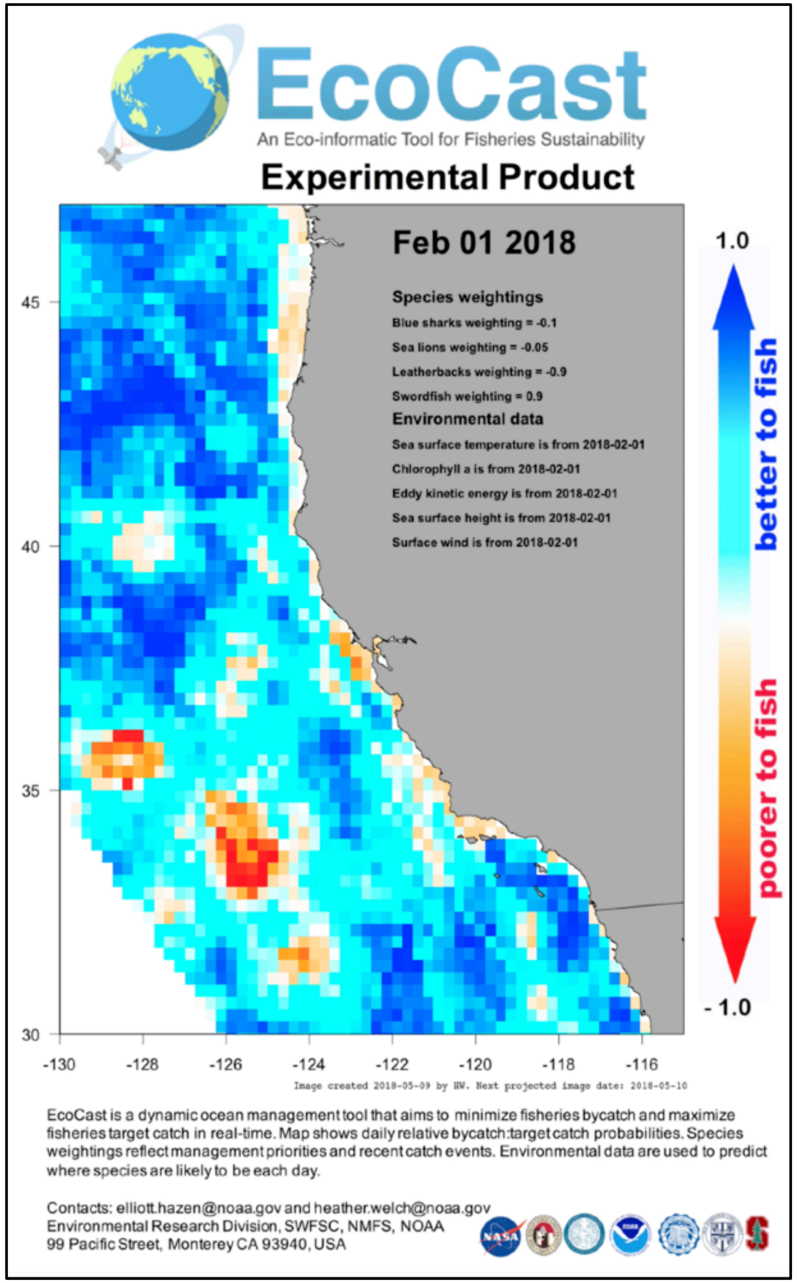

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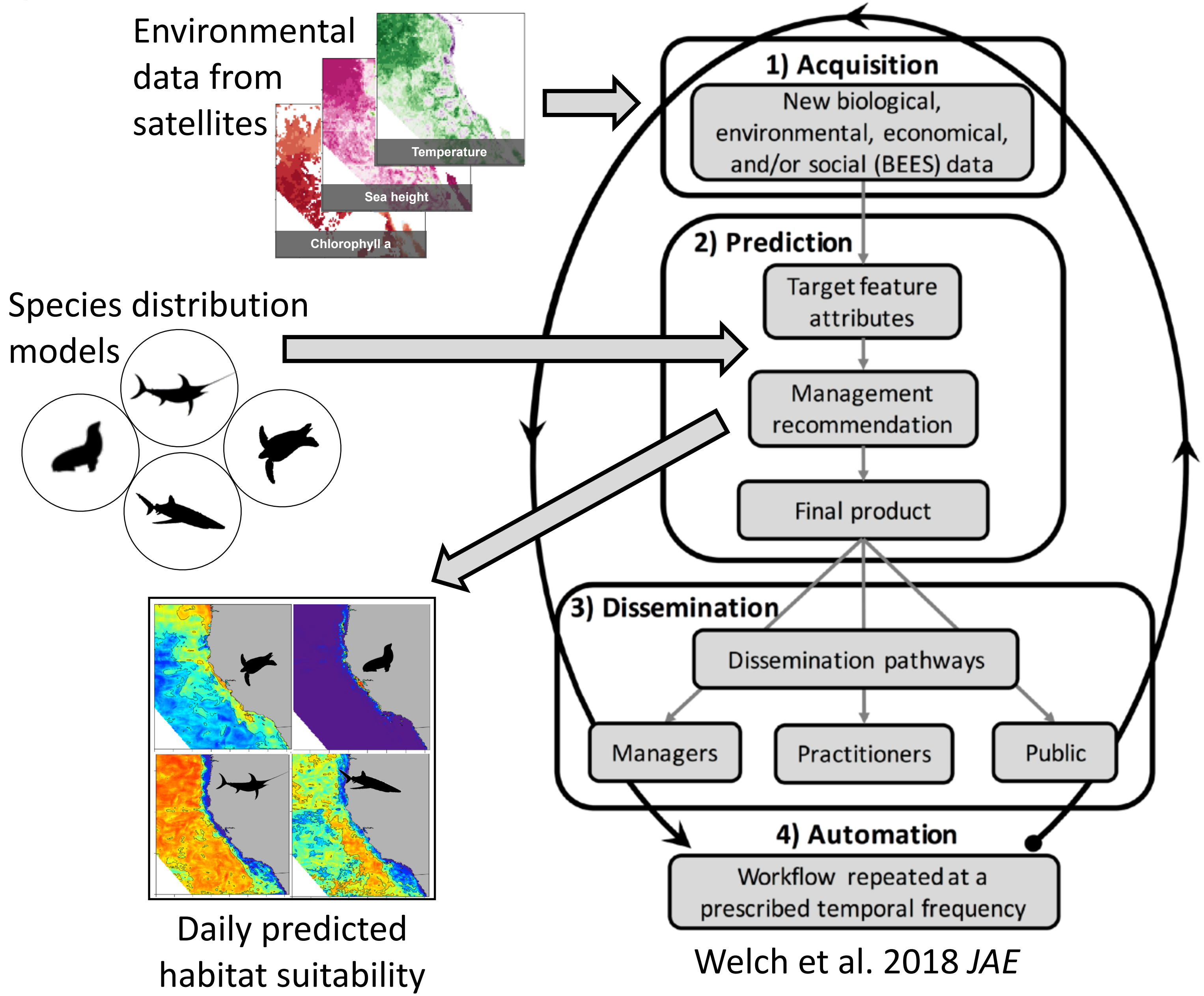

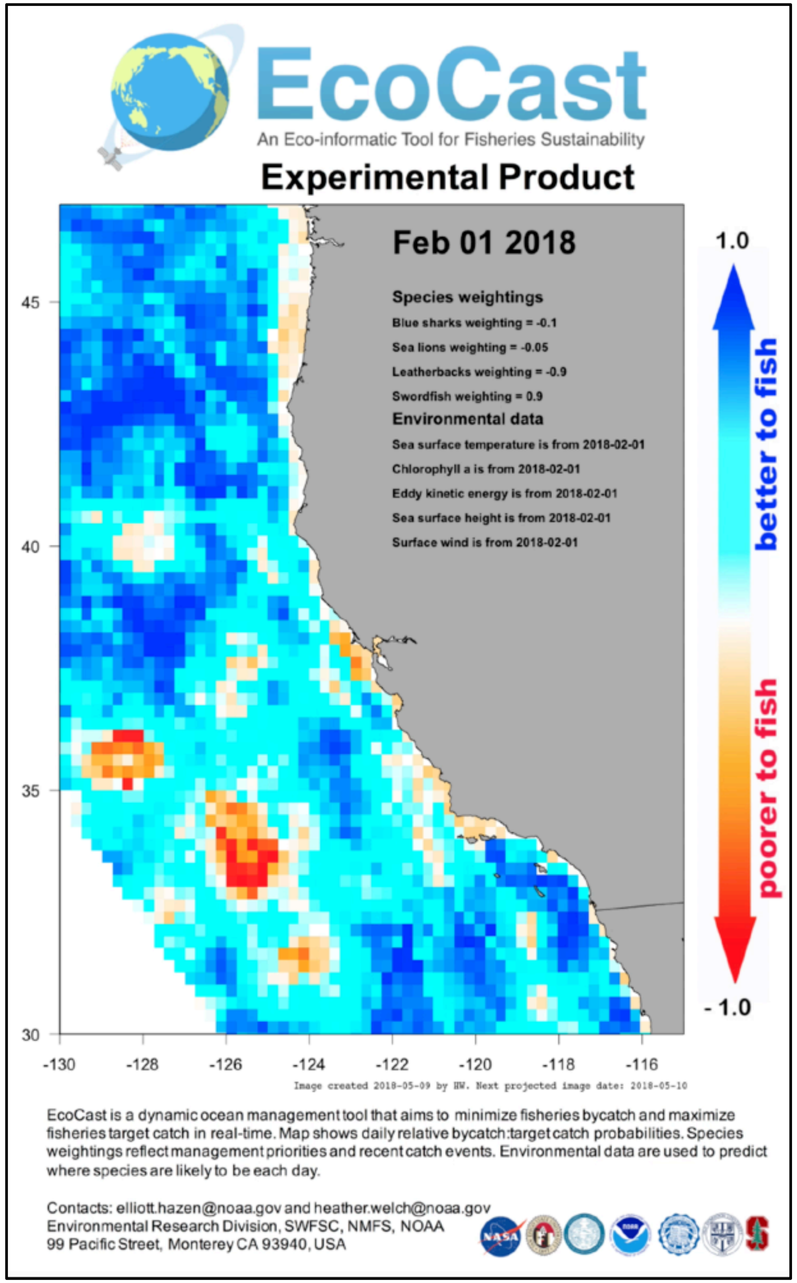

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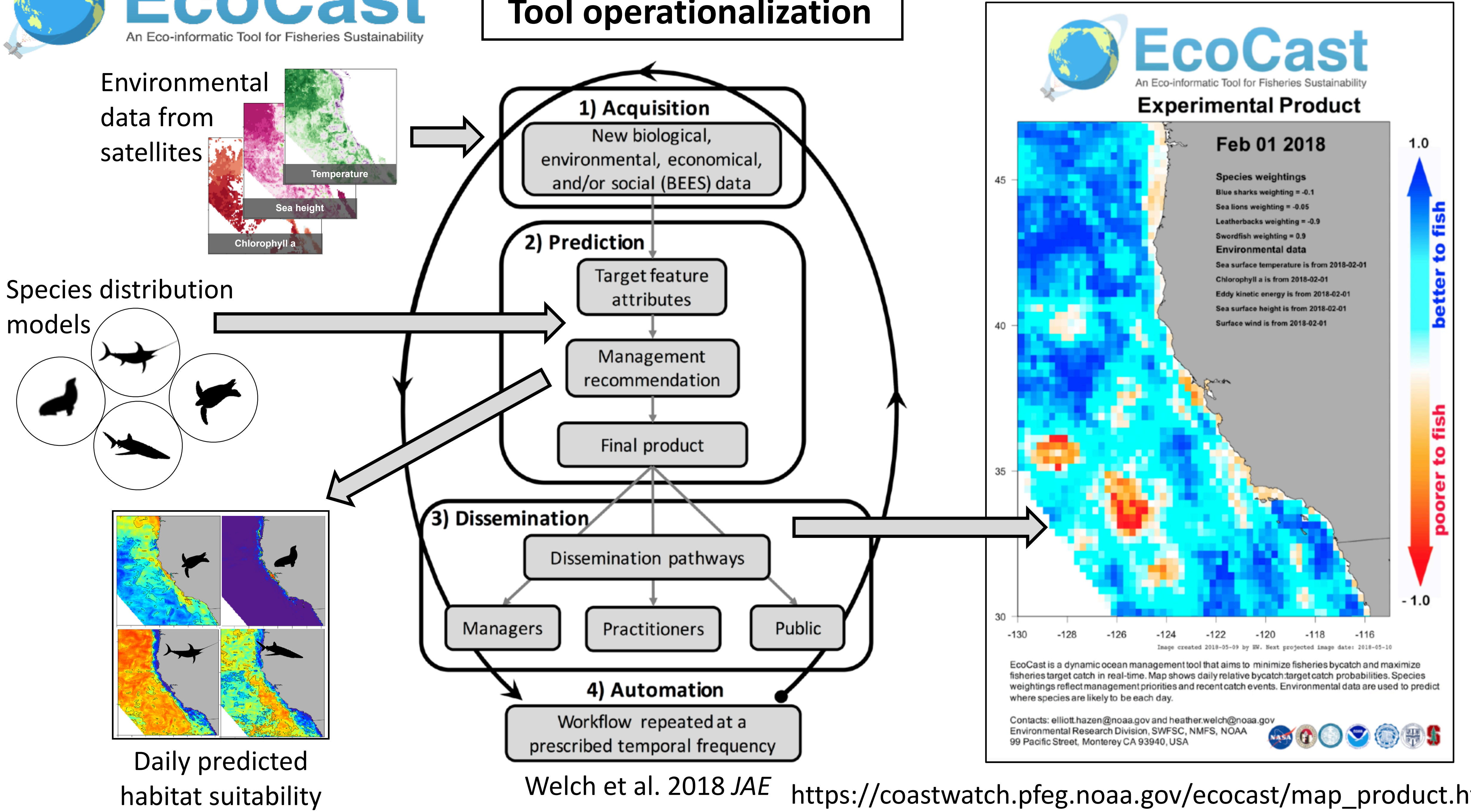


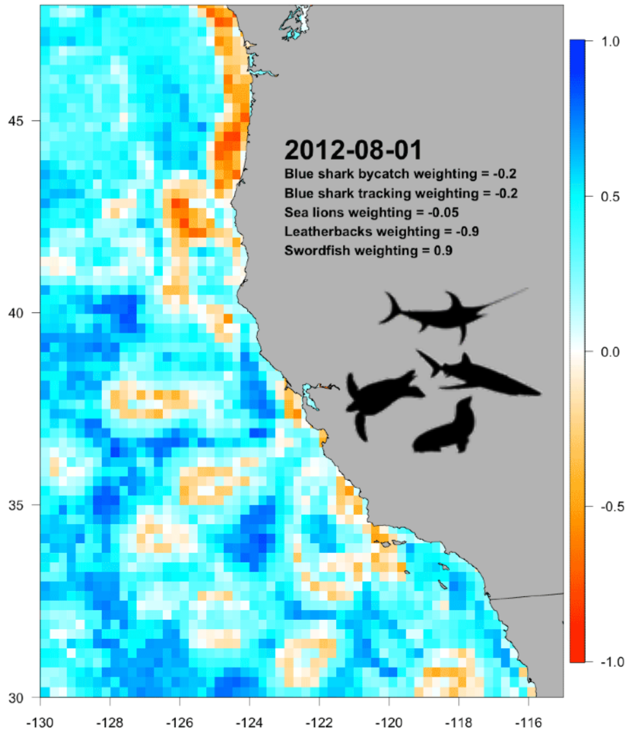
Welch et al. 2018 *JAE*

https://coastwatch.pfeg.noaa.gov/ecocast/map_product.html

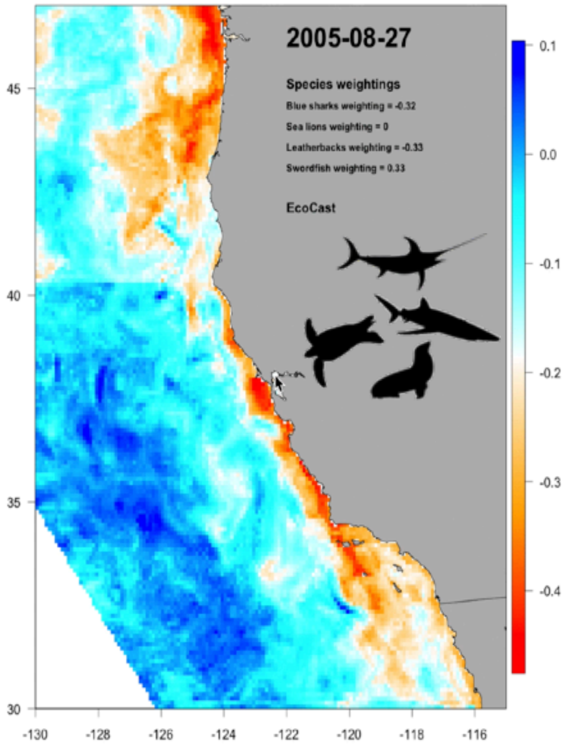
EcoCast
An Eco-informatic Tool for Fisheries Sustainability

Next Steps

Switch to regional ocean model driven predictions



Satellite predictions



Regional ocean model predictions

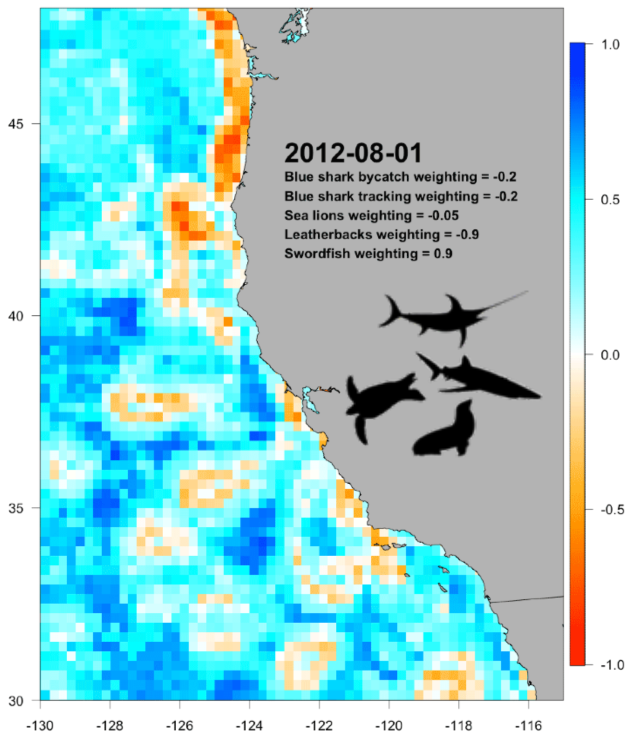
Brodie, S. et al. 2018. Integrating dynamic subsurface habitat metrics into species distribution models. *Frontiers in Marine Science.*

Welch, H. et al. 2019. Decision support tools for dynamic management. *Conservation Biology.*

EcoCast Next Steps

An Eco-informatic Tool for Fisheries Sustainability

Switch to regional ocean model driven predictions



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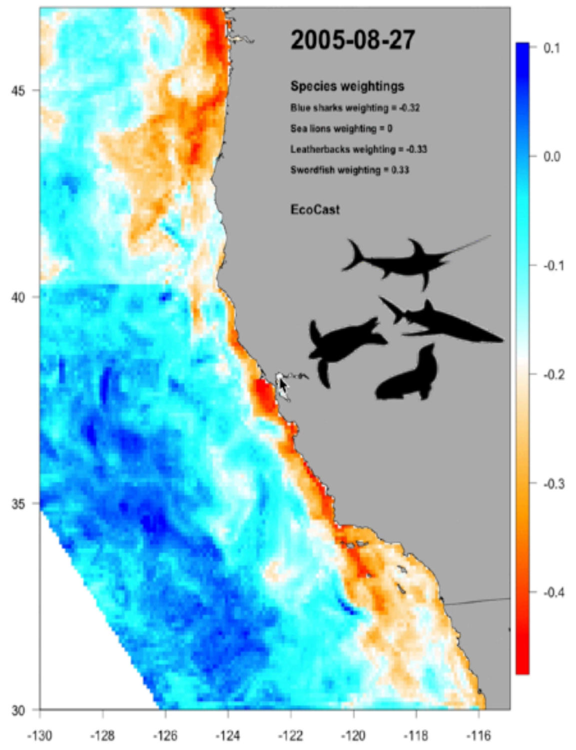

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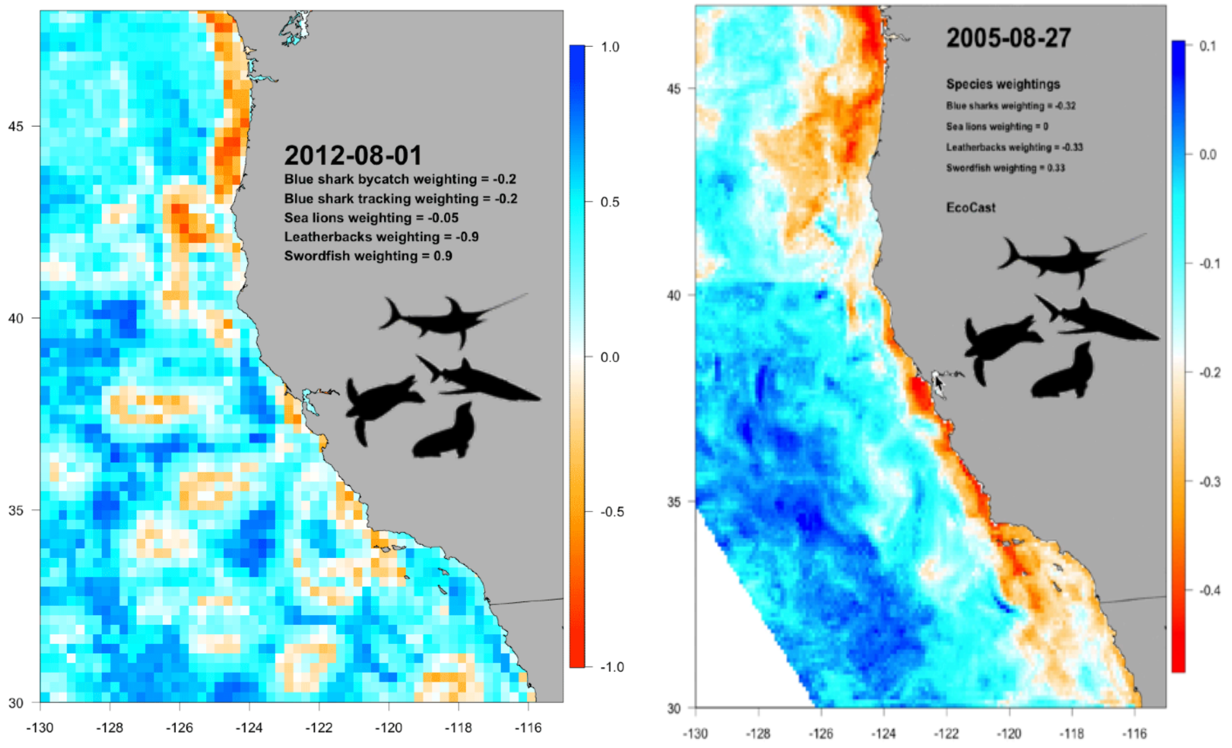

Satellite predictions | Regional ocean model predictions

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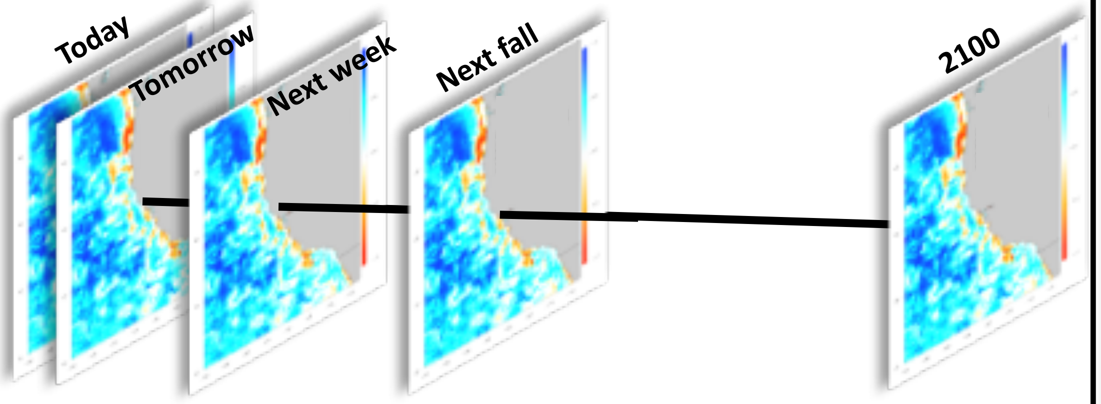
Expand from nowcasts to seasonal forecasts and climate projections

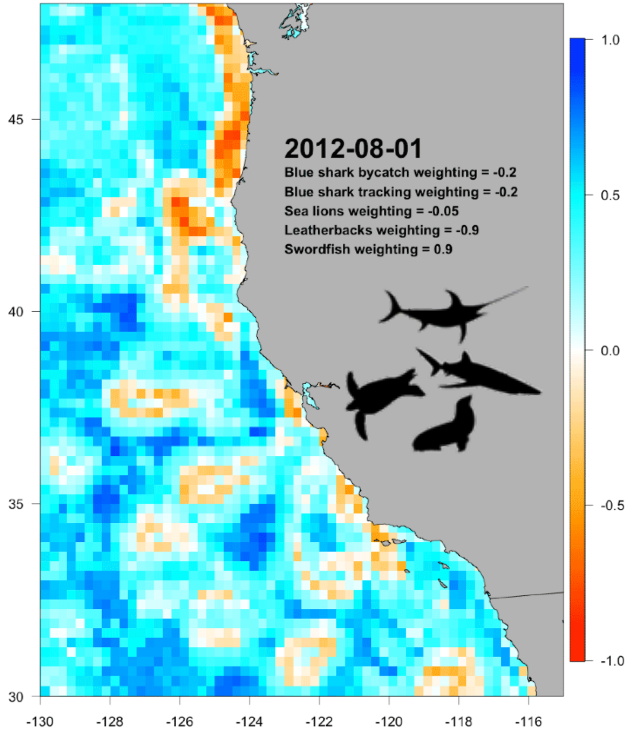


For more on the FutureSeas project see https://futureseas.github.io/

EcoCast Next Steps

An Eco-informatic Tool for Fisheries Sustainability

Switch to regional ocean model driven predictions



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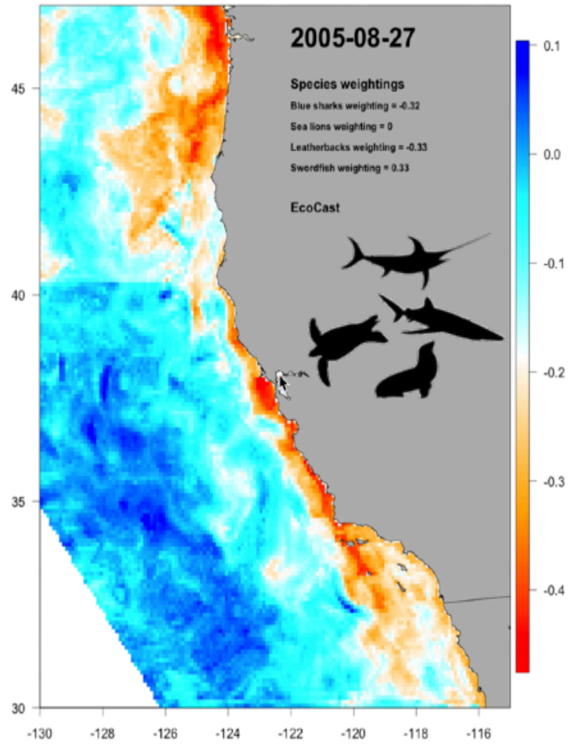

Regional ocean model predictions

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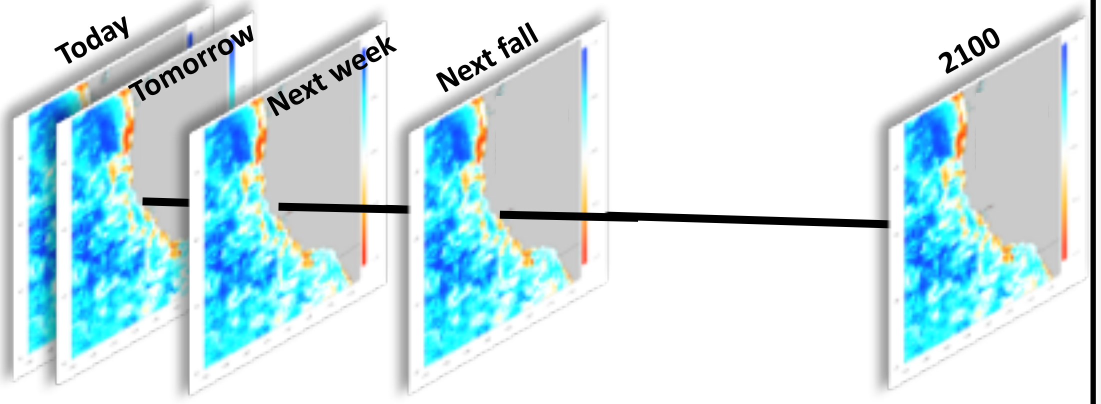

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Incorporate additional bycatch species such as marine mammals using additional sources of data

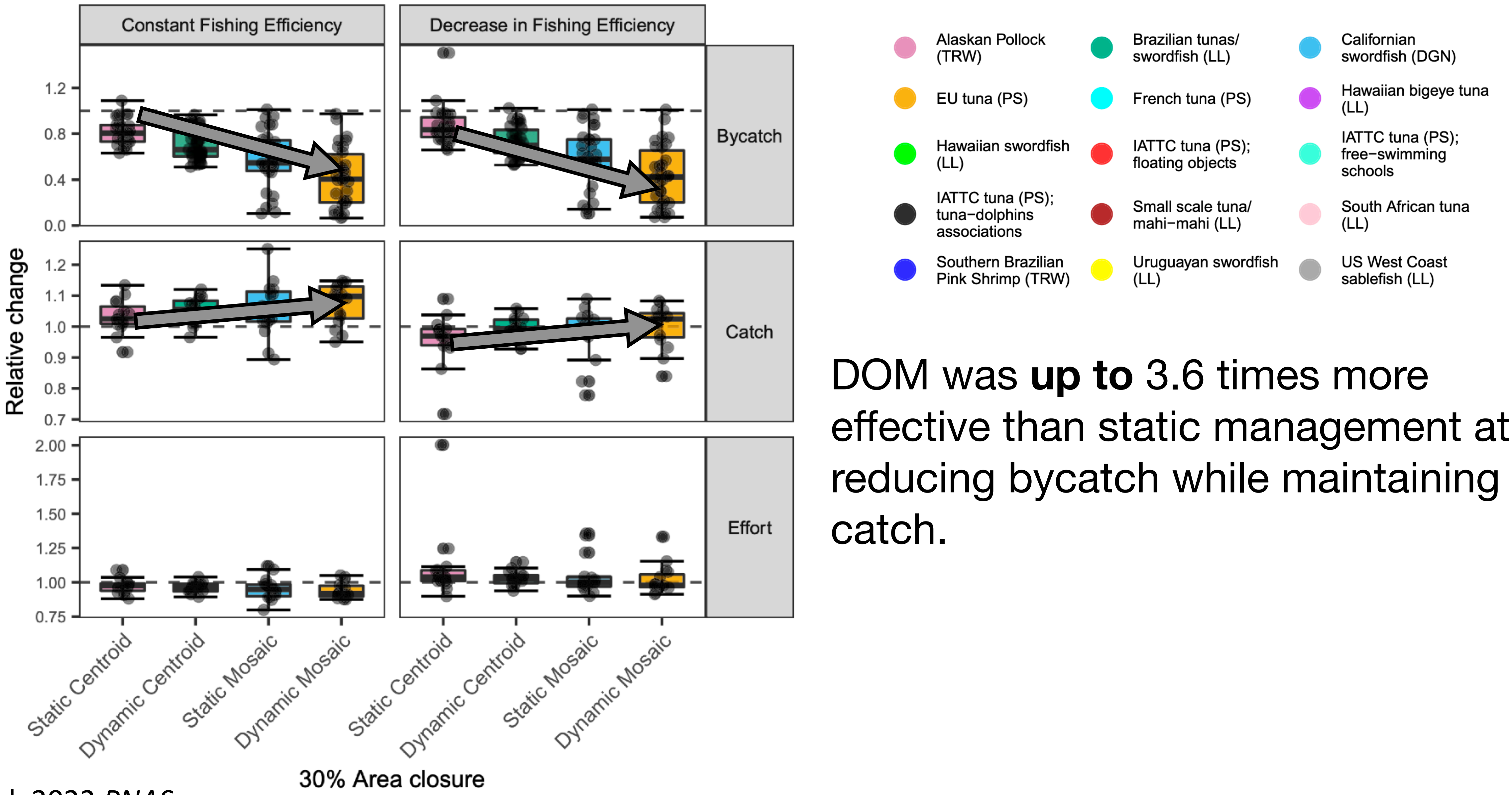
Becker, E. et al. 2020. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. *Ecology and Evolution*

DOM Meta-analysis of 15 global fisheries

- Alaskan Pollock (TRW)
- Brazilian tunas/ swordfish (LL)
- Californian swordfish (DGN)
- EU tuna (PS)
- French tuna (PS)
- Hawaiian bigeye tuna (LL)
- Hawaiian swordfish (LL)
- IATTC tuna (PS); floating objects
- IATTC tuna (PS); free−swimming schools
- IATTC tuna (PS); tuna−dolphins associations
- Small scale tuna/ mahi−mahi (LL)
- South African tuna (LL)
- Southern Brazilian Pink Shrimp (TRW)
- Uruguayan swordfish (LL)
- US West Coast sablefish (LL)

Pons et al. 2022 *PNAS*

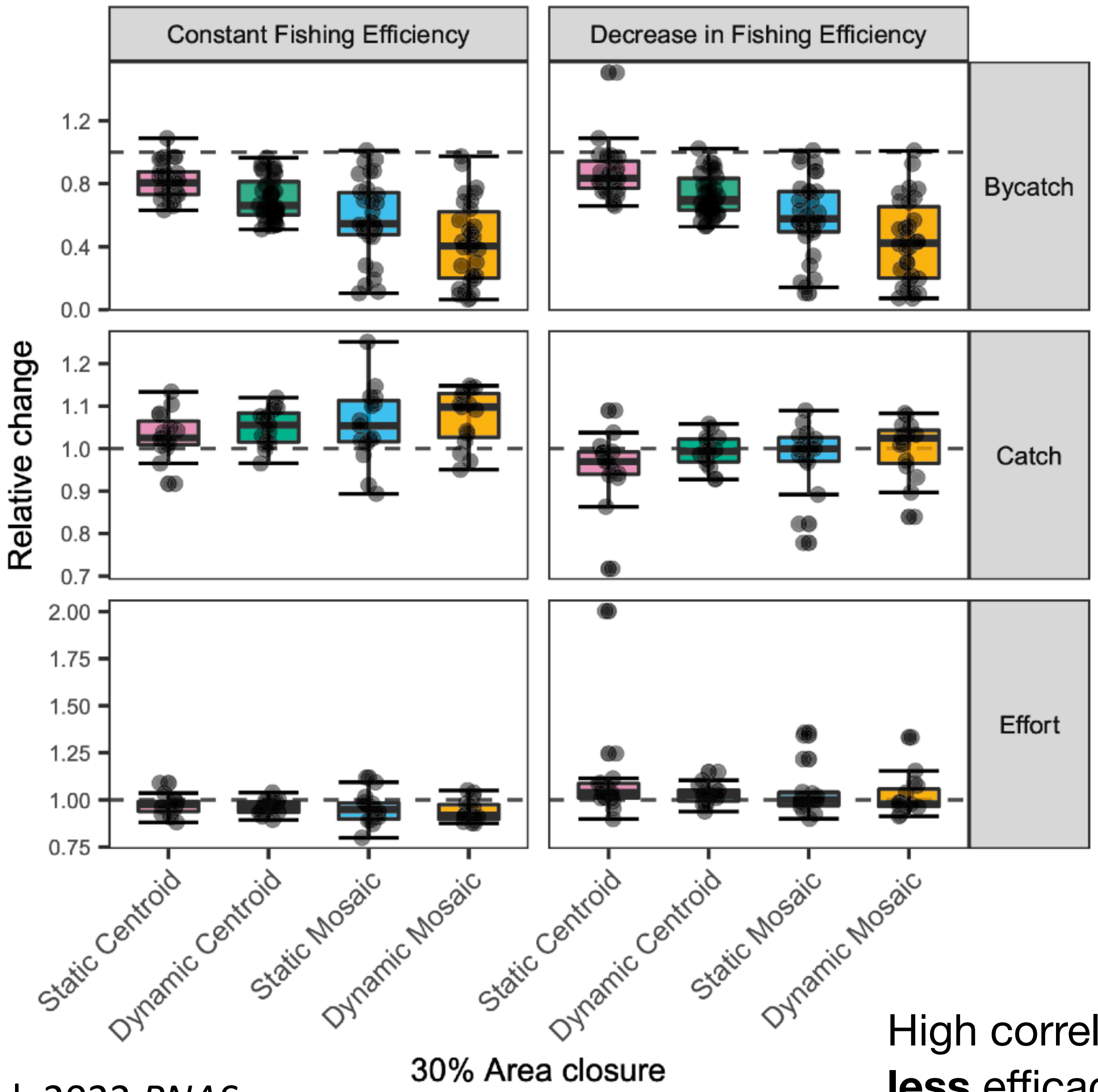
DOM Meta-analysis of 15 global fisheries

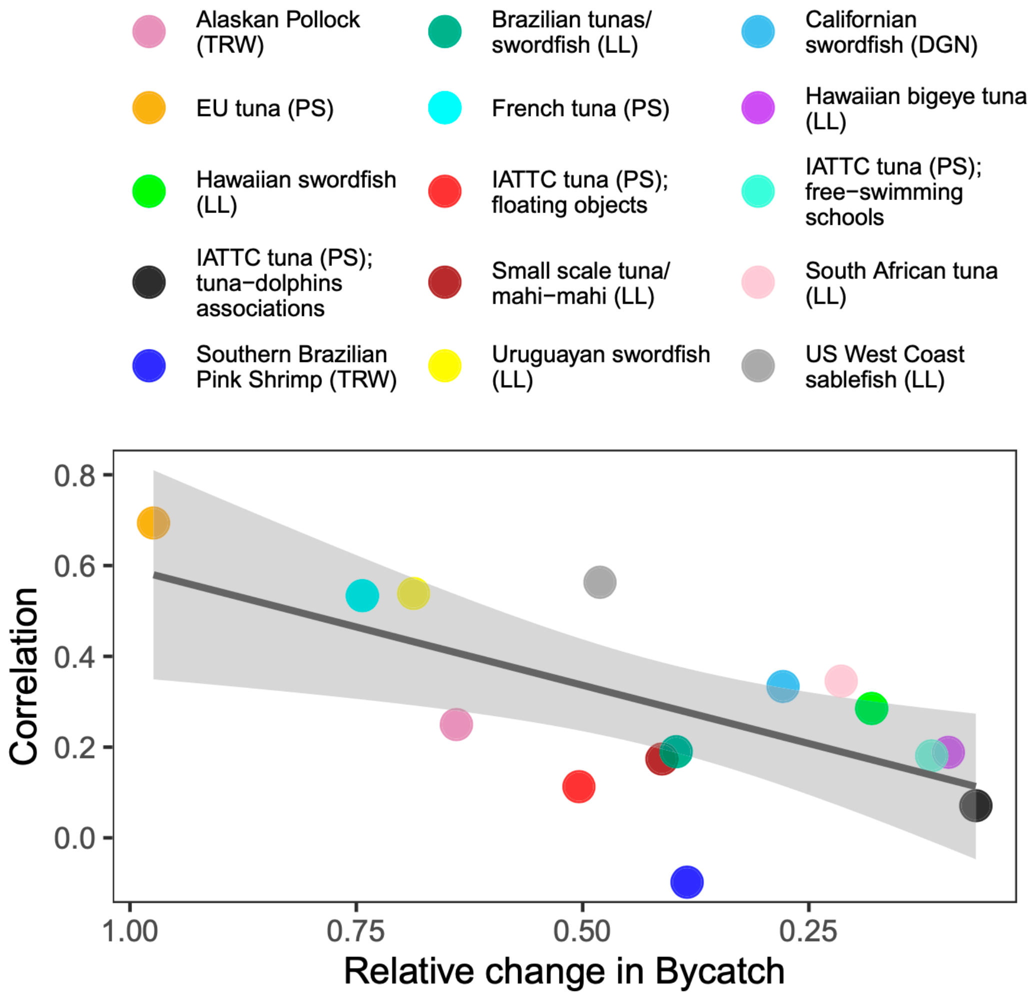


DOM was **up to** 3.6 times more effective than static management at reducing bycatch while maintaining catch.

Pons et al. 2022 *PNAS*

DOM Meta-analysis of 15 global fisheries





High correlation between target catch and bycatch resulted in **less** efficacy of Dynamic Ocean Management approaches.

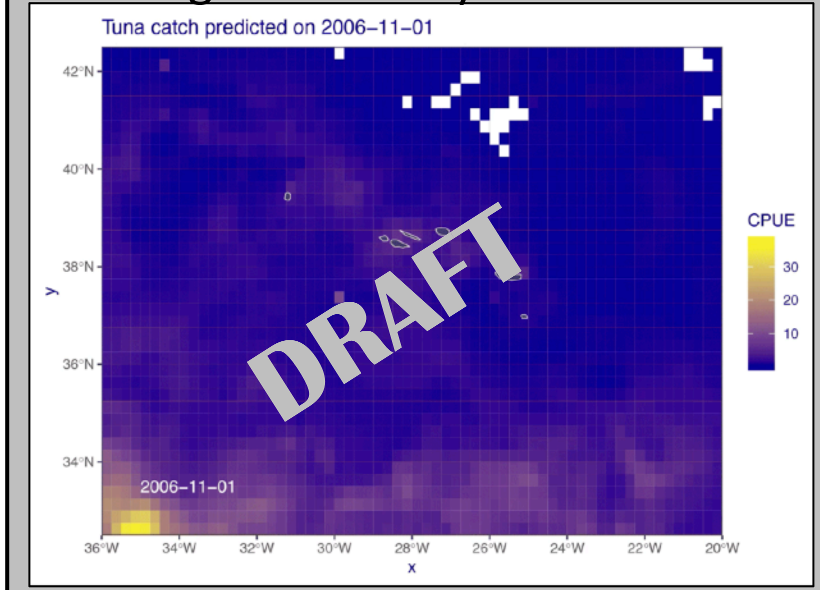
Pons et al. 2022 *PNAS*

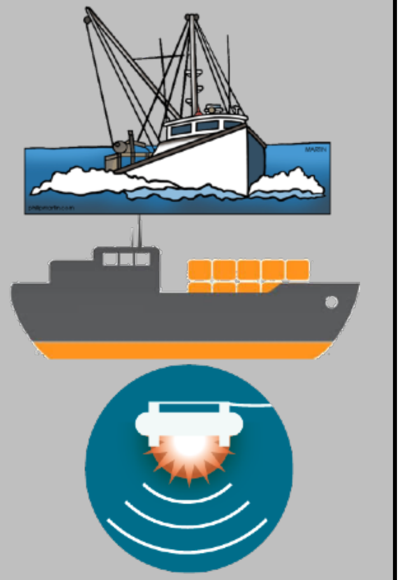
Future Directions

EcoCast — An Eco-informatic Tool for Fisheries Sustainability

EcoCast as a framework for other dynamic ocean management tools

Tool to promote a sustainable blue economy while reducing biodiversity risks in real-time





Future Directions

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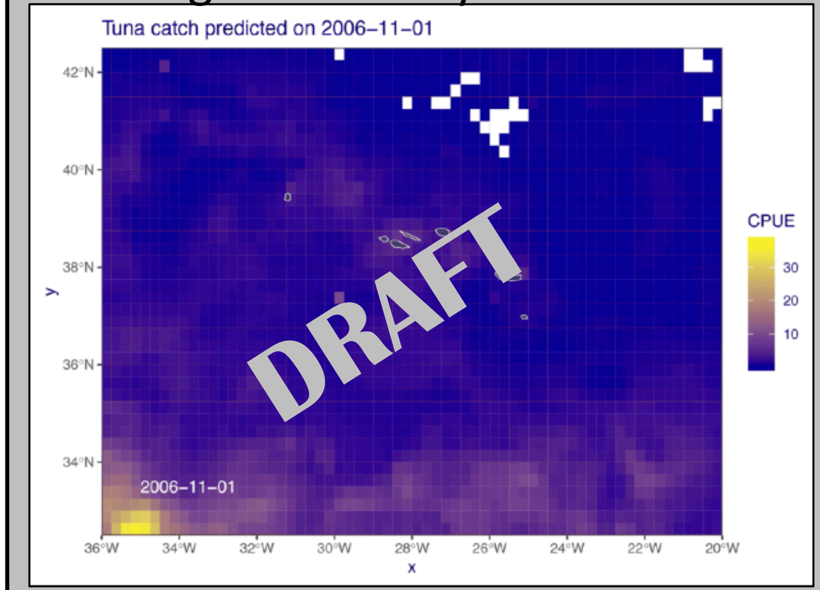
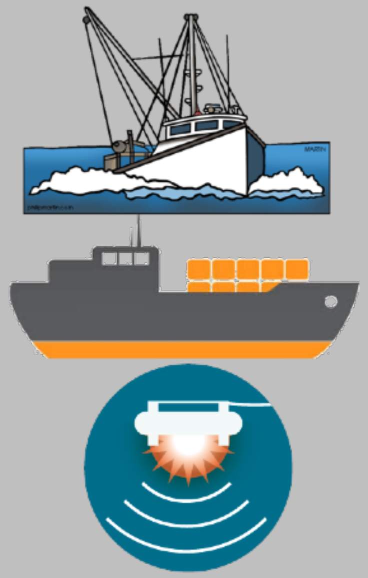
EcoCast as a framework for other dynamic ocean management tools

Açores Cast

Tool to promote a sustainable blue economy while reducing biodiversity risks in real-time





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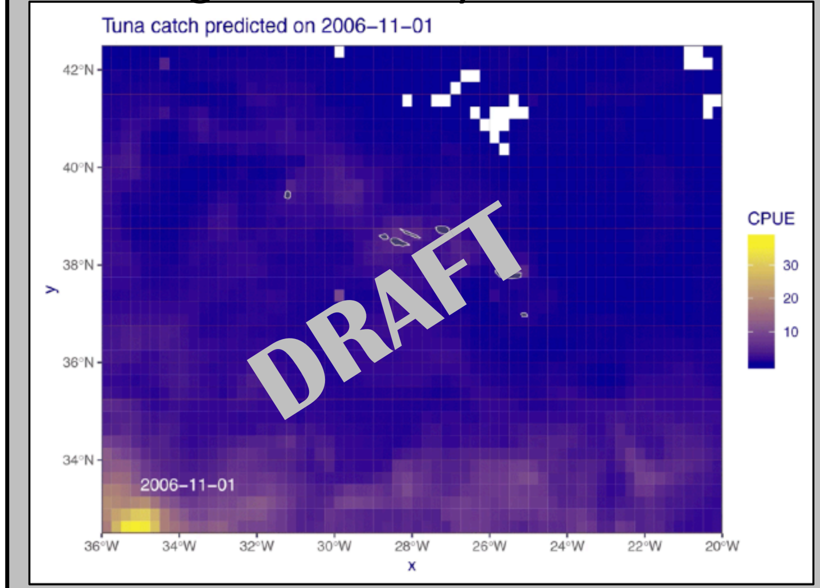
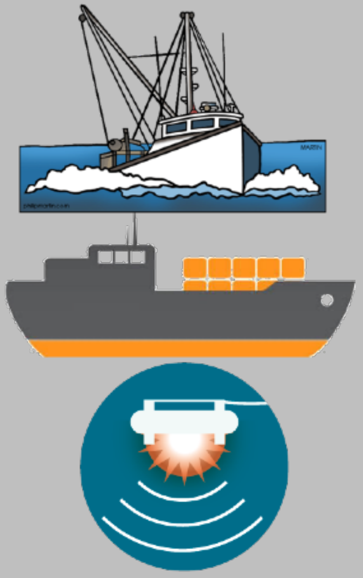
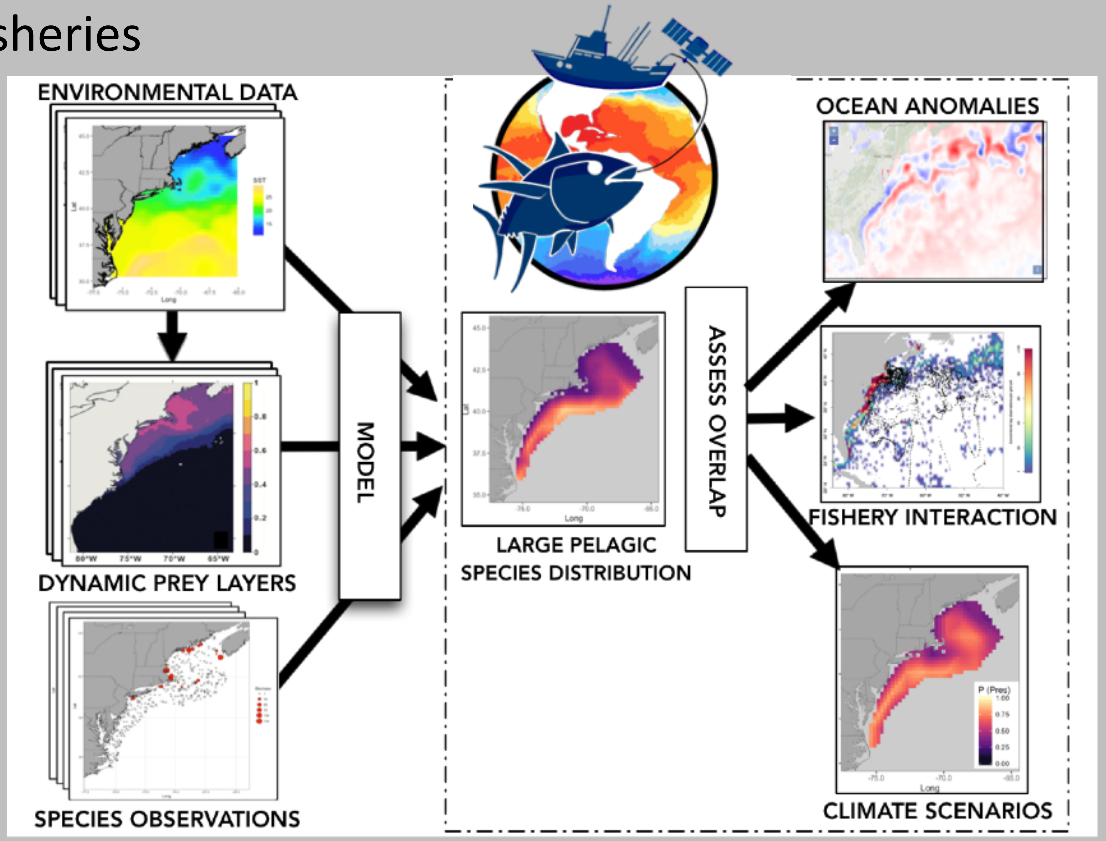




Fisheries Climate Toolkit (FaCeT)

Supporting climate-ready, resilient and sustainable fisheries



Led by Rebecca Lewison, Kathy Mills, and Cam Braun

Future Directions

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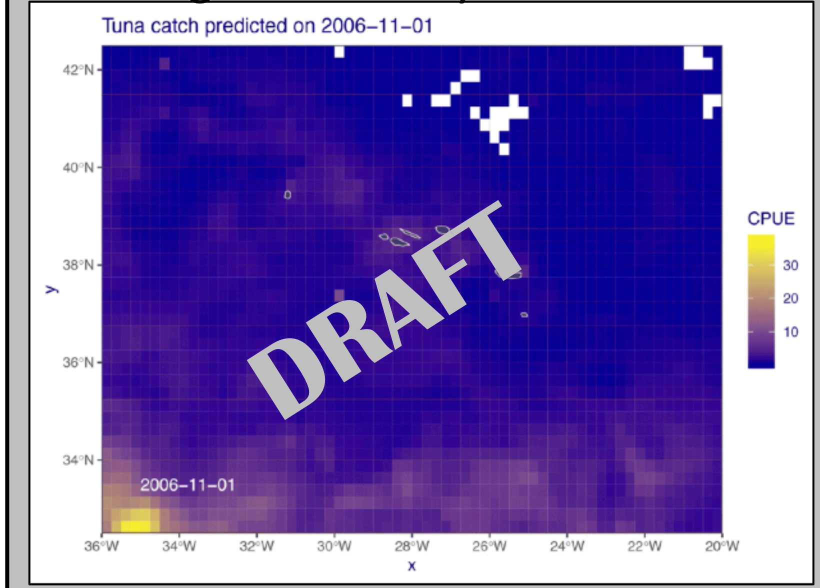

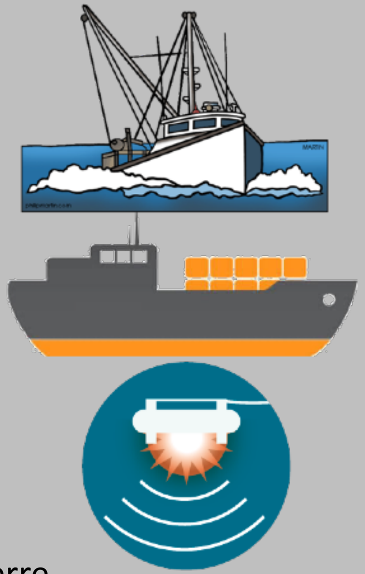

Led by Mónica Silva, Pedro Afonso, and Fred Vanderperre

Fisheries Climate Toolkit (FaCeT)

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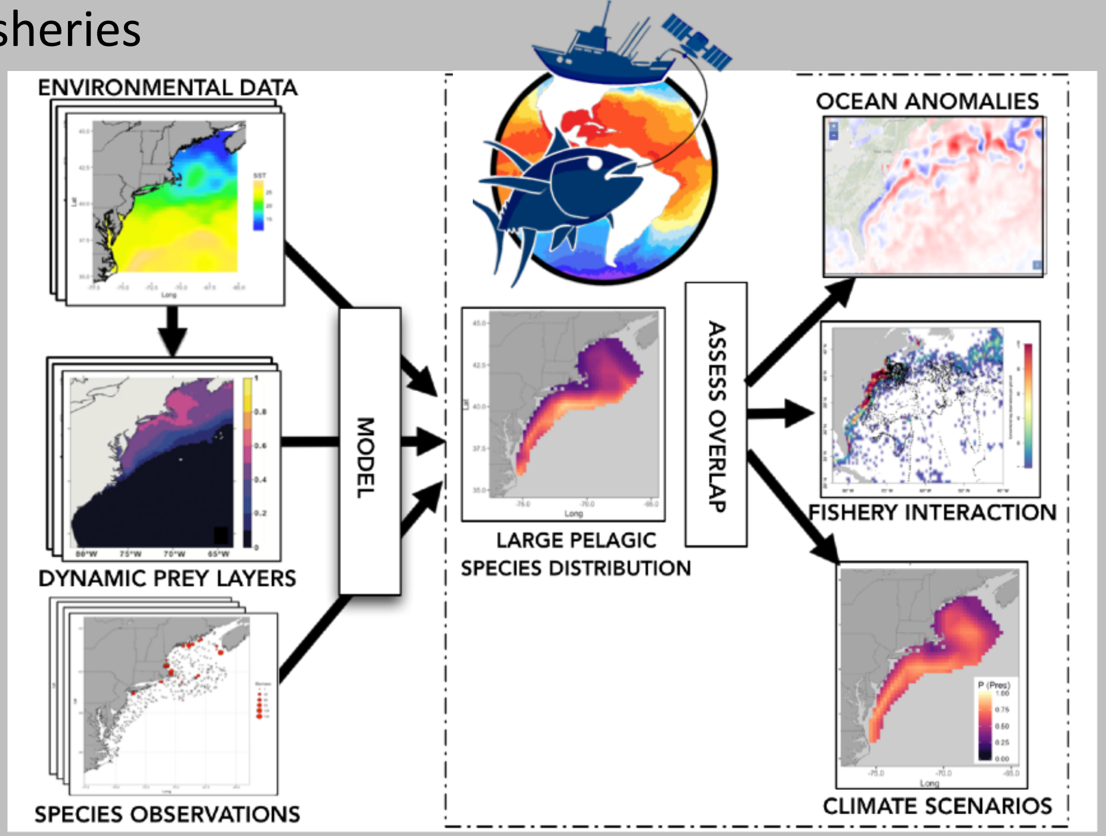
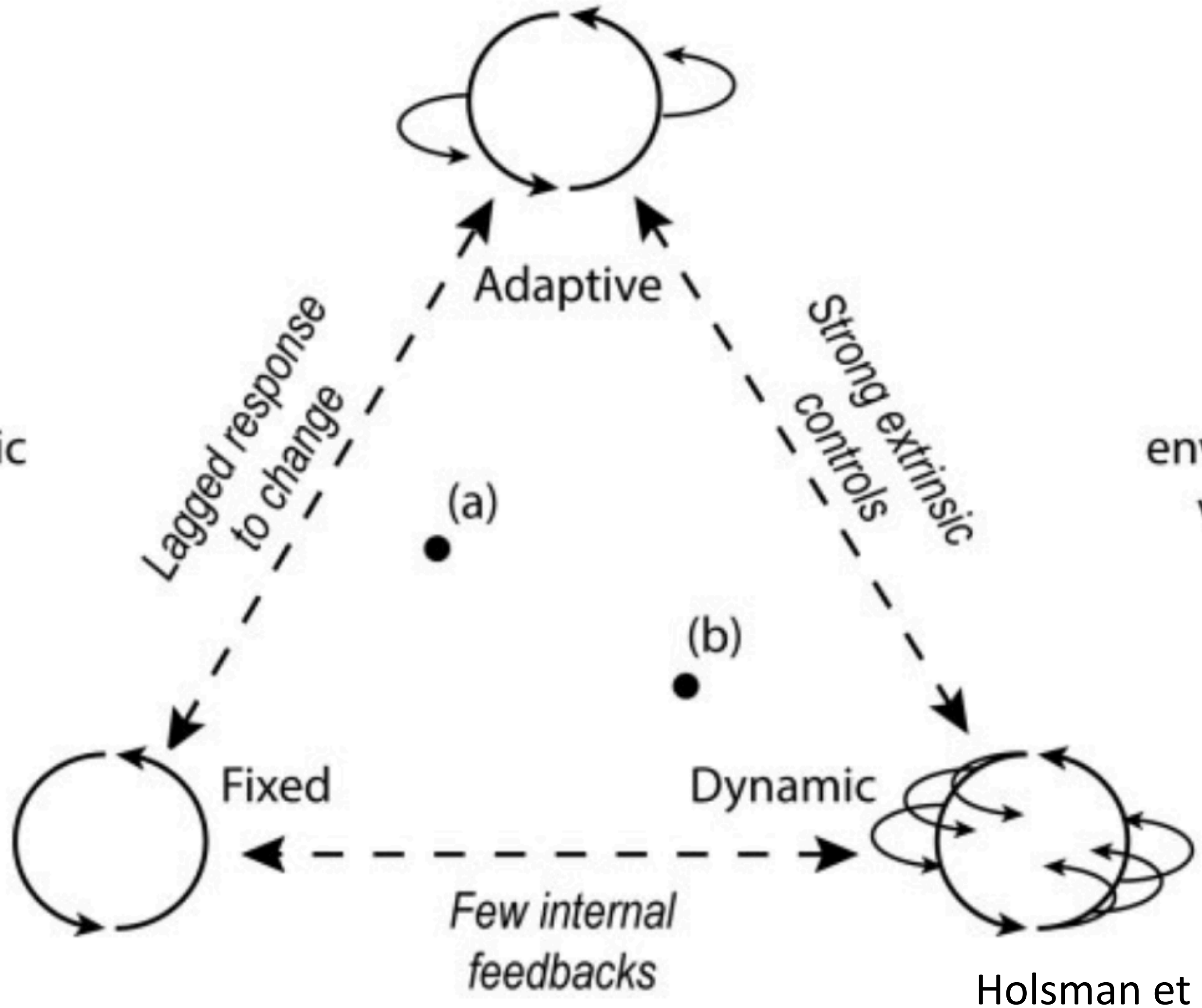


Led by Rebecca Lewison, Kathy Mills, and Cam Braun

Conclusions

- We need a **portfolio** of integrated scales of management

high
socio-economic
variability



high
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Holsman et al. 2019 *ICES JMS*

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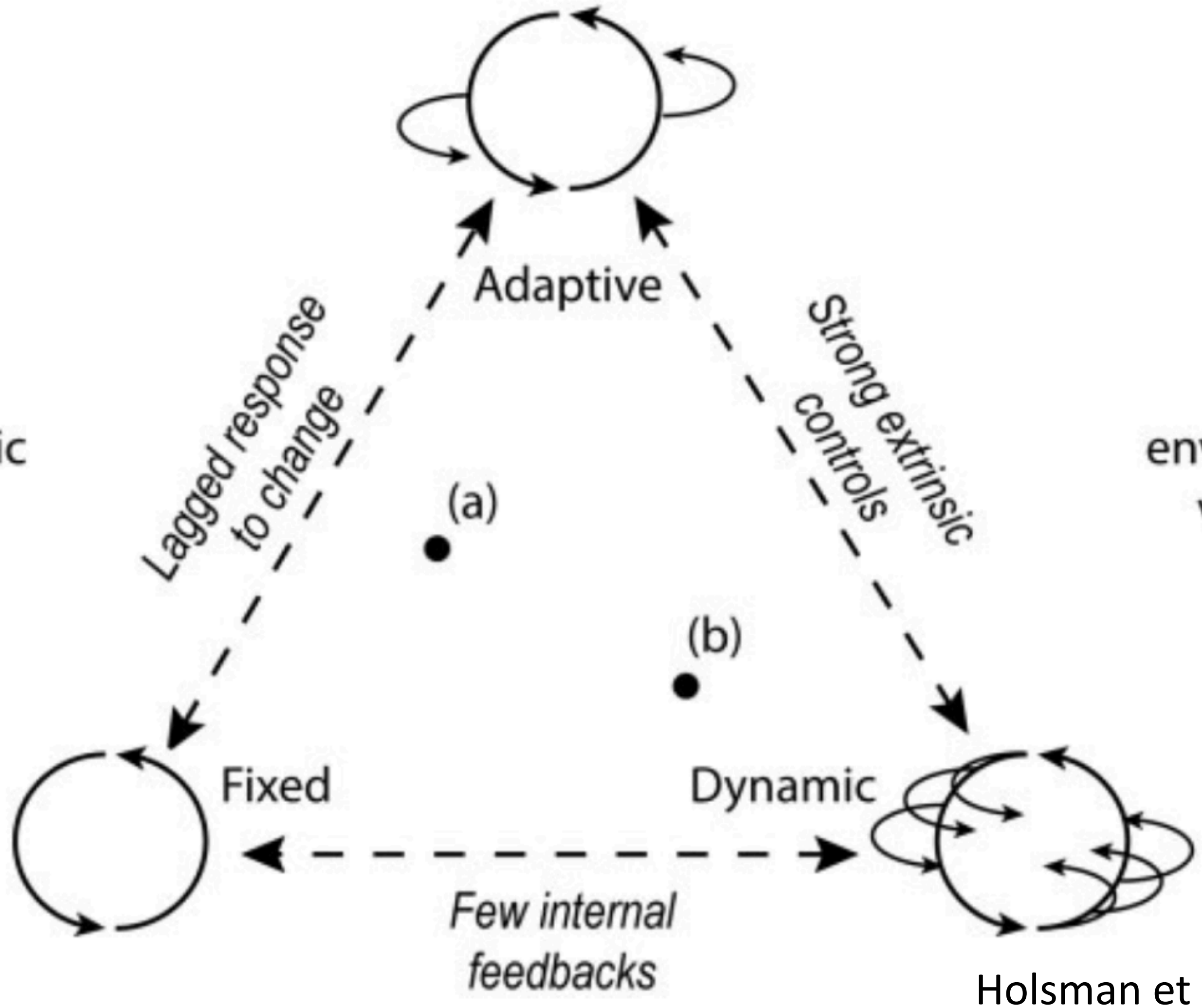

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Conclusions

- We need a **portfolio** of integrated scales of management
- Multi-species models offer the ability to serve as a **win-win**, and EcoCast can be adjusted dynamically and adaptively.
- Dynamic ocean management offers a **climate-ready** management approach and a better match with ecological processes **AND** human activities in space and time.

BBC

NOAA NMML

NOAA SWFSC

Southwest Fisheries Science Center, NOAA Fisheries Service

Research → Operationalize → Maintain → Update → Compare → Assess → Forecast

Resources

Websites

WhaleWatch 2.0 website:
https://coastwatch.pfeg.noaa.gov/projects/whalewatch2/

EcoCast website:
https://coastwatch.pfeg.noaa.gov/ecocast/

Latest EcoCast image:
https://oceanview.pfeg.noaa.gov/ecocast/output/latest_week/latest.png

Download EcoCast data:
https://coastwatch.pfeg.noaa.gov/erddap/griddap/ecocast.graph

Papers

Hazen et al. 2021. Where did they not go? Considerations for generating pseudo-absences for telemetry-based habitat models. *Movement Ecology.*

Hazen et al. 2018. A dynamic ocean management tool to reduce bycatch and support sustainable fisheries. *Science Advances.*

Welch et al. 2018. Practical considerations for operationalizing dynamic management tools. *Journal of Applied Ecology.*

Welch et al. 2019. Decision support tools for dynamic management. *Conservation Biology.*

GitHub Code

Research: https://github.com/elhazen/PA-paper

https://github.com/elhazen/EcoCast-SciAdv

Operationalize: https://github.com/HeatherWelch/EcoCast_Operationalization

Compare: https://github.com/HeatherWelch/Decision-support-tools-for-dynamic-management

Elliott Hazen (elliott.hazen@noaa.gov) @elhazen

In collaboration with B. Abrahms, H. Bailey, E. Becker, S.R. Benson, D.K. Briscoe, S. Brodie, D.P. Costa, L.B. Crowder, H. Dewar, L. Dewitt, C.A. Edwards, T. Eguchi, K. Forney, E. Howell, A. Hoover, L. Irvine, M.G. Jacox, S. Kohin, B.L. Lewison, B. Mate, S.M. Maxwell, B. Muhling, D. Palacios, D. Robinson, K.L. Scales, J. Smith, S. Stohs, J. Sweeney, D. Tommasi, H. Welch, C. Wilson, S.J. Bograd