Cumulative anthropogenic impacts on the world's oceans

Sara M. Maxwell

University of Washington, Bothell

Cumulative Impacts: Definition

‘The combined, incremental effects of human activity’

- US Environmental Protection Agency

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The sum of all impacts
on an ecosystem, habitat or population

Cumulative Impacts: 2020….

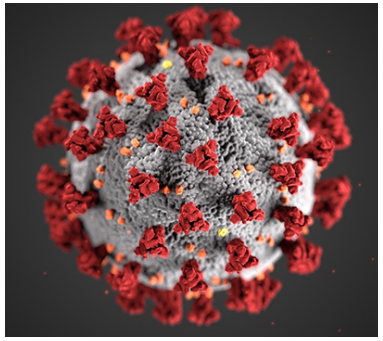
Cumulative Impacts: 2020….

January

Cumulative Impacts: 2020….

January

+



March

Cumulative Impacts: 2020….

January

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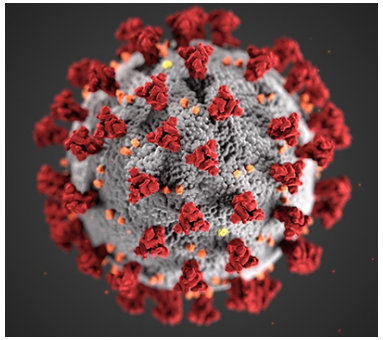

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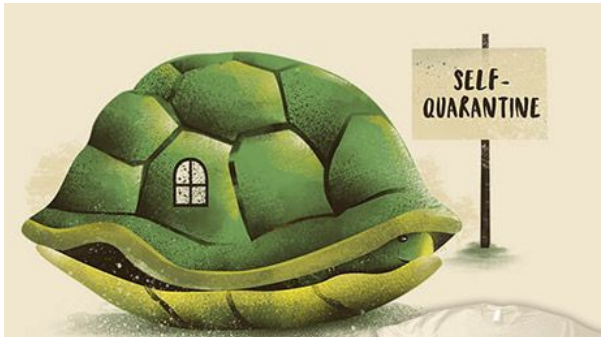

April / May

Cumulative Impacts: 2020….

January

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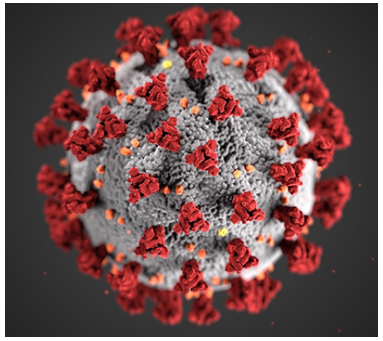

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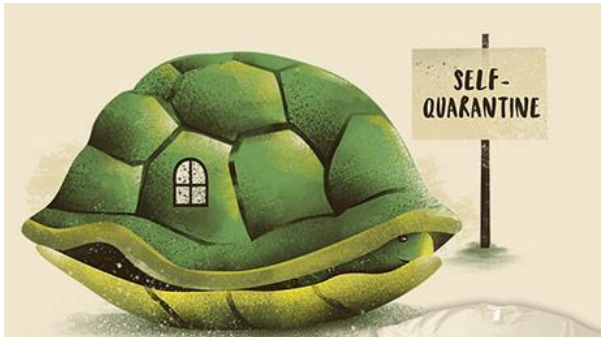

April / May

June

Cumulative Impacts: 2020….

January

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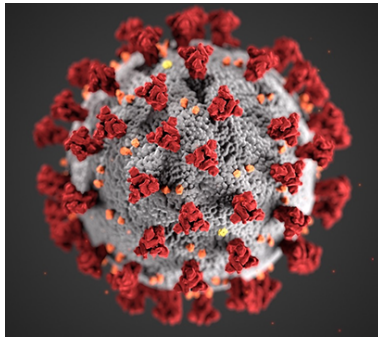

March

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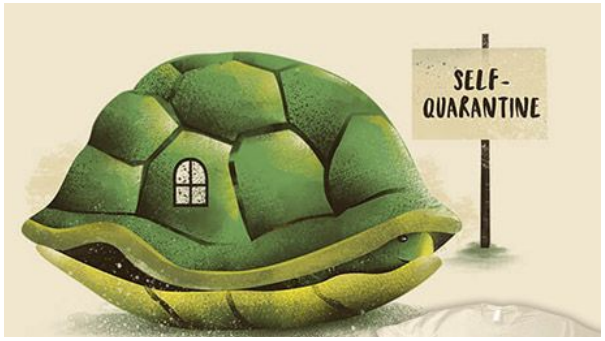

April / May

June

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Aug / Sep

Cumulative Impacts: 2020….

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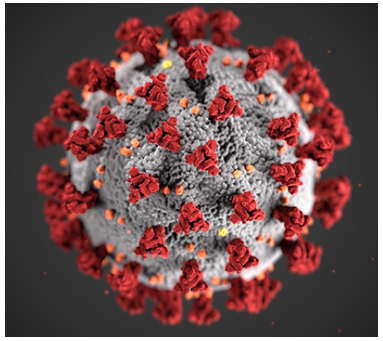

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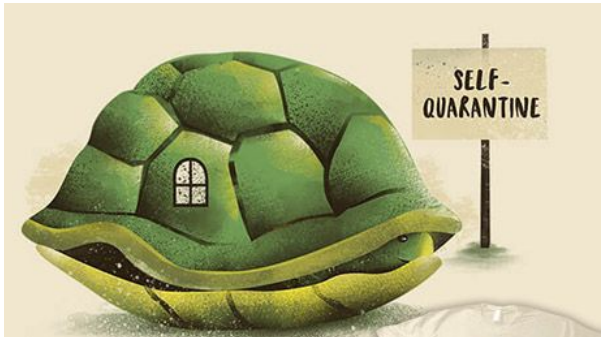

April / May

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+

Aug / Sep

+

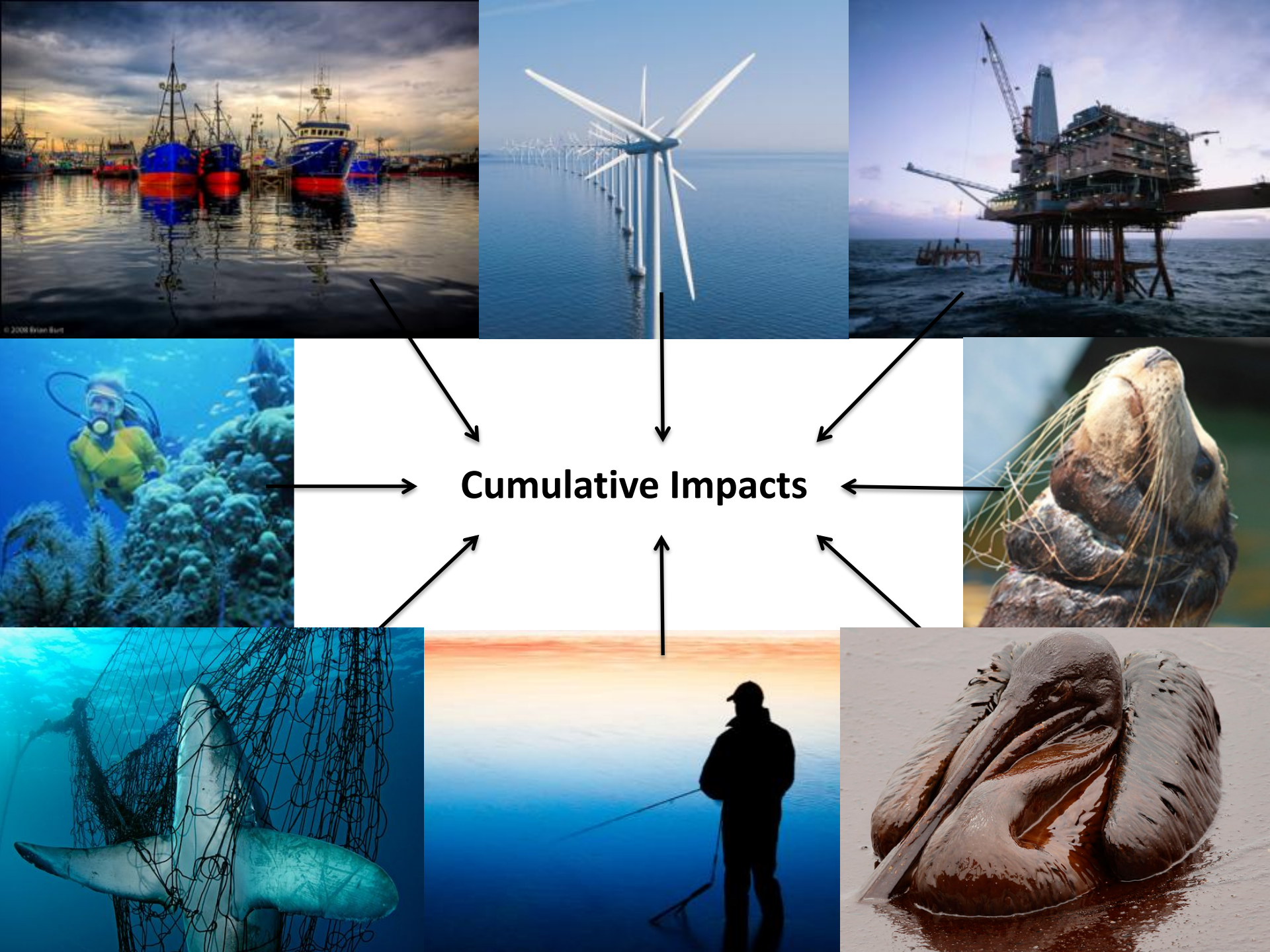
DECISION 2020

Oct / Nov

Cumulative Impacts: 2020….

Cumulative Impacts from Offshore Wind Energy

- Collision with turbines
- Noise from turbine construction, operation or maintenance
- Pollution from vessels or maintenance/operation of turbines
- Habitat alteration or destruction
- Impacts from electromagnetic fields
- Potential entanglement resulting from turbine components
- Displacement from habitats or other behavioral responses


Cumulative Impacts

Cumulative Impacts to Seabirds

Displacement

Cumulative Impacts to Seabirds

Displacement

+

Resource Competition

Cumulative Impacts to Seabirds

Displacement

+

Resource Competition

+

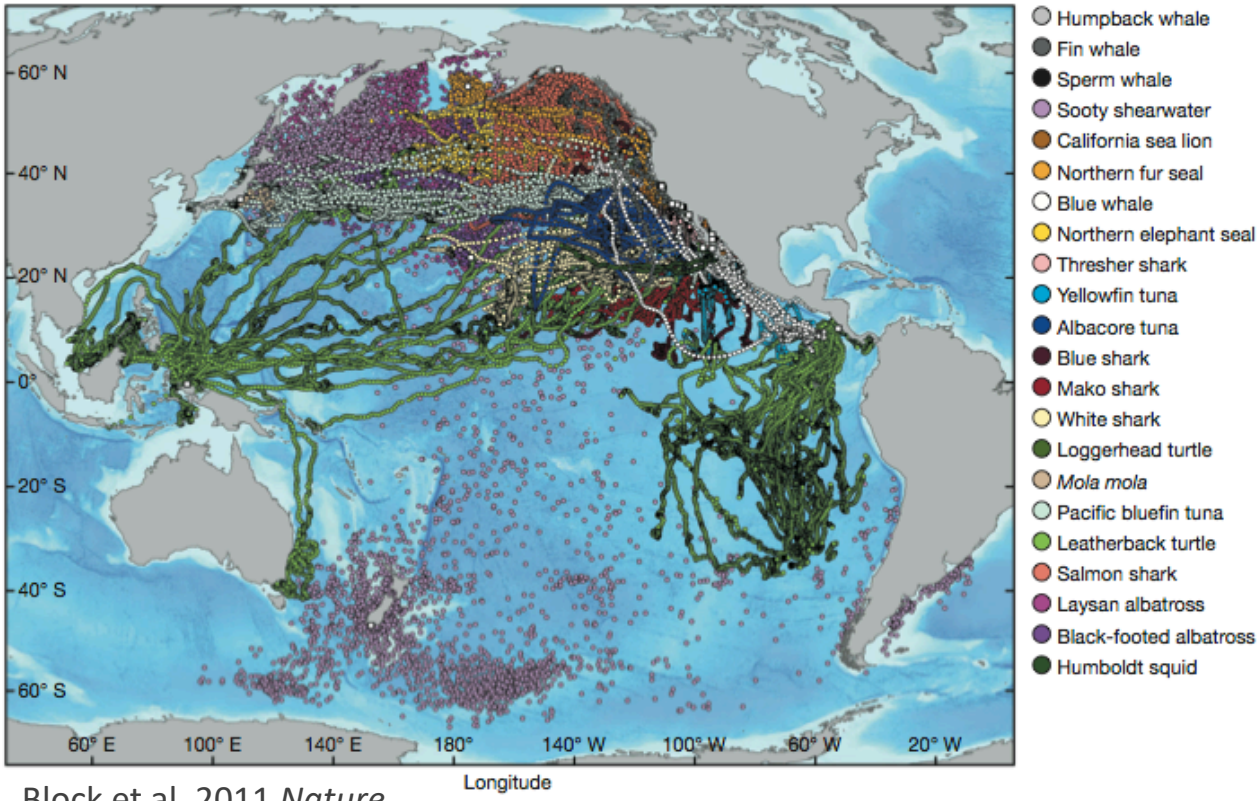
Sea Level Rise

=

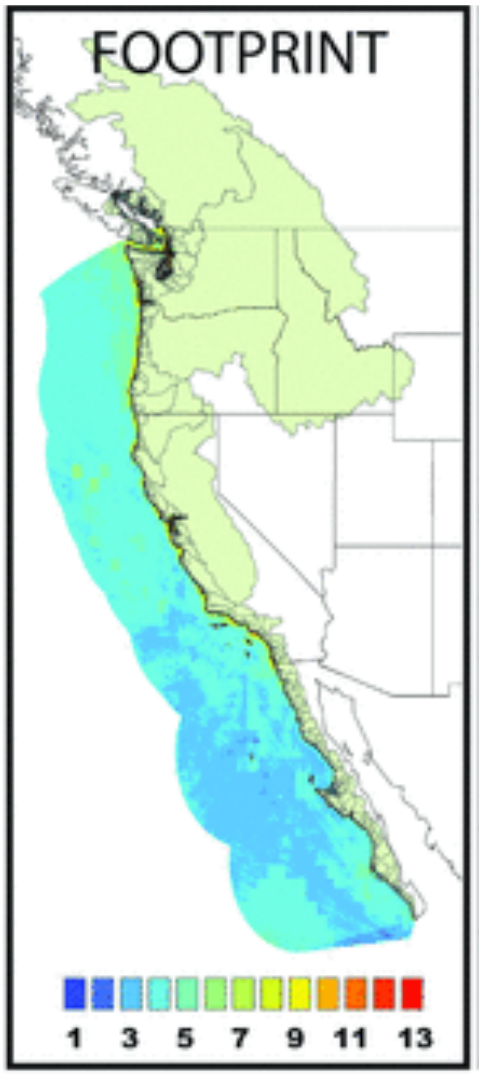
Cumulative Impacts

How do we determine cumulative impacts?

Cumulative Impacts on Mobile Marine Species



Block et al. 2011 *Nature*



Halpern et al. 2009 *Conservation Letters*

685 individuals from 8 species

Blue whales
(*Balenoptera musculus*)
n = 51; 2004 – 2007

Humpback whales
(*Megaptera novaengliae*)
n = 15; 2004 – 2005

California sea lions
(*Zalophus californianus*)
n = 111; 2003 – 2008

Northern elephant seal
(*Mirounga angustirostris*)
n = 244; 2003 – 2008

Laysan albatrosses
(*Phoebastria immutablilis*)
n = 33; 2003, 2005

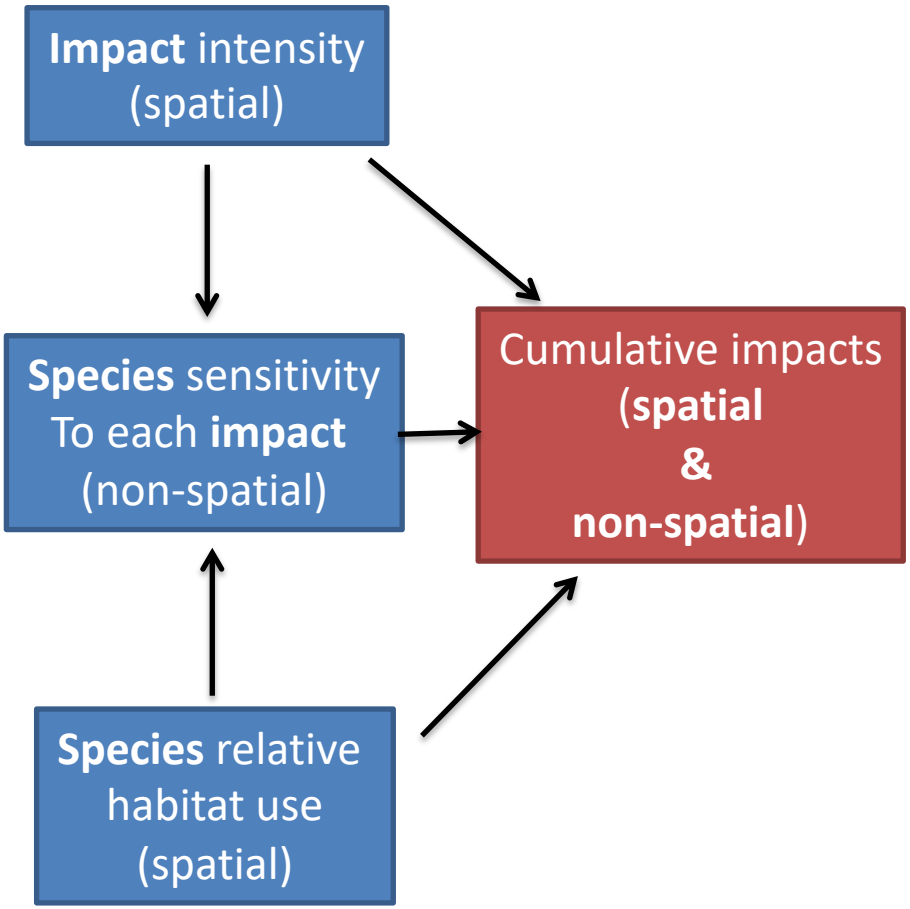
Black-footed albatrosses
(*Phoebastria nigripes*)
n = 72; 2003 – 2007

Sooty shearwaters
(*Puffinus griseus*)
n = 25; 2005 – 2006

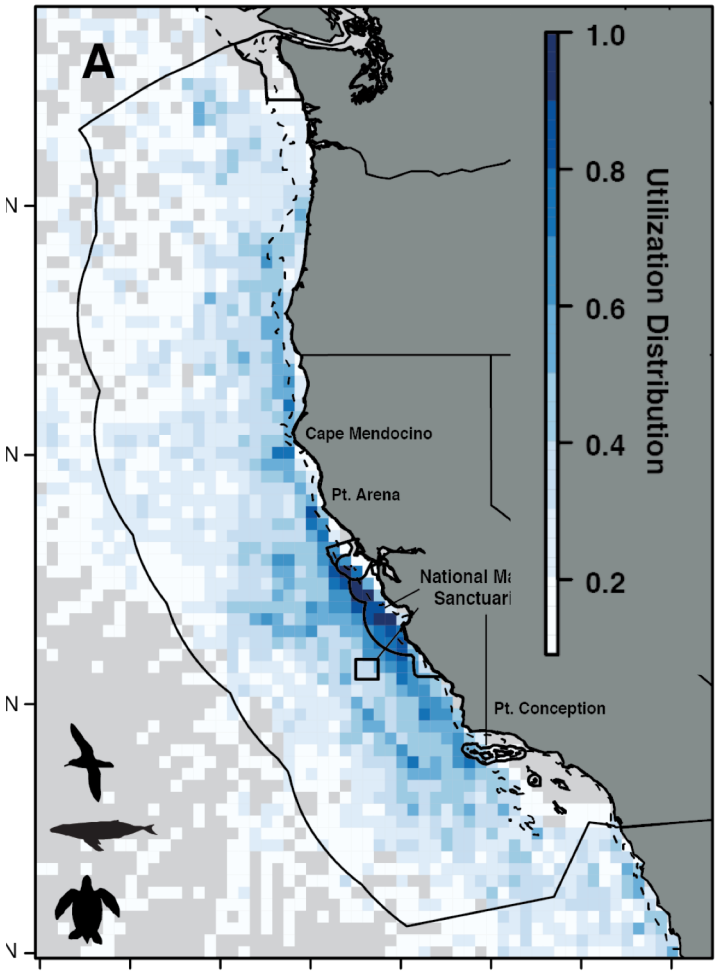
Leatherback sea turtles
(*Dermochelys olivacea*)
n = 18; 2004 – 2008

Managing for Cumulative Impacts

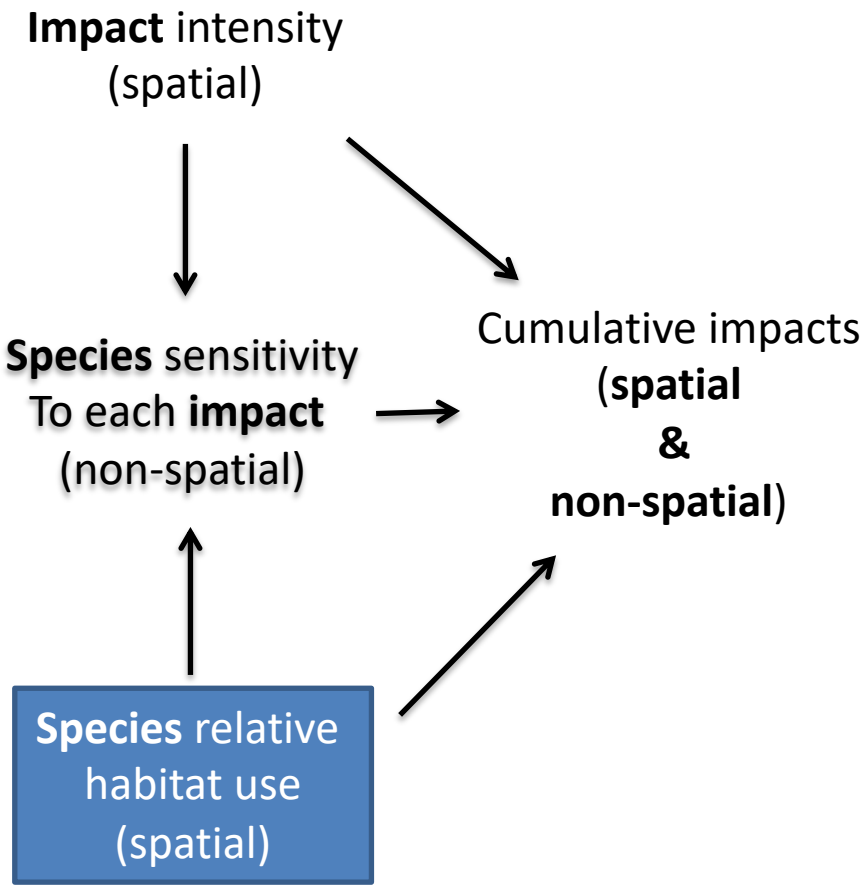
Quantitative, spatial framework for cumulative impacts



Relative Habitat Use



Maxwell et al. 2013 *Nature Communications*



Animal utilization greater along coastlines vs. offshore

Welch's *t*-test: $t_{281} = 11.0$, $p < 0.001$

Impact Intensity

24 drivers:
Halpern et al. 2009 (*Conservation Letters*)

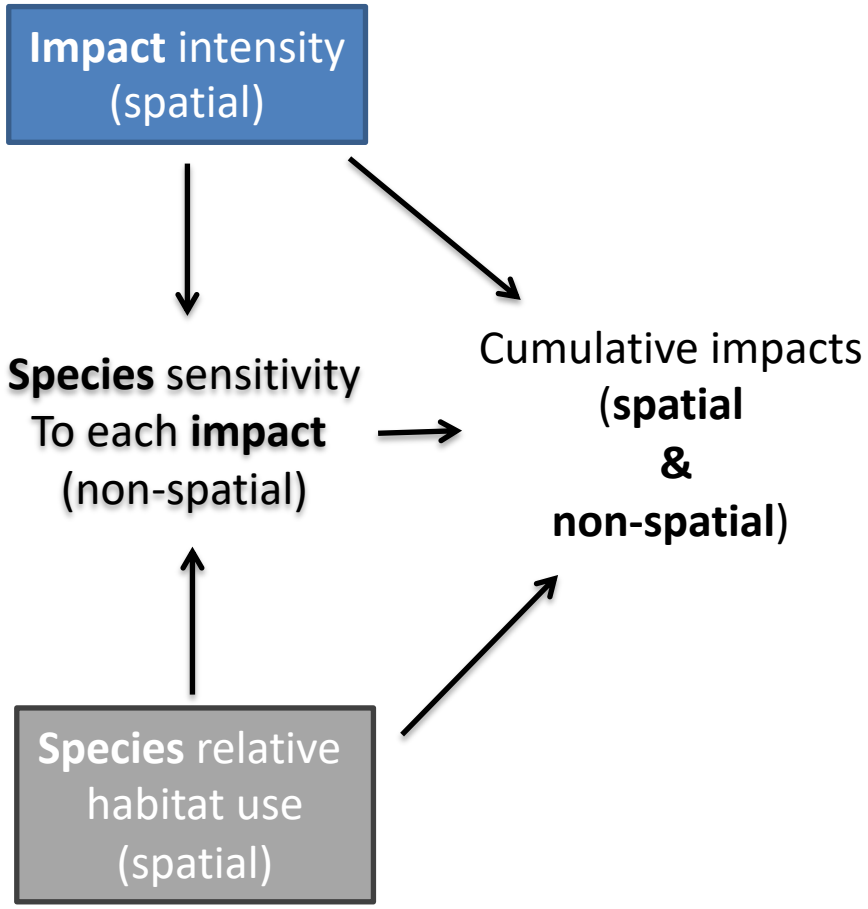
Climate: UV radiation, ocean acidification

Pollution: ocean pollution, organic and inorganic pollution, nutrient deposition, coastal waste

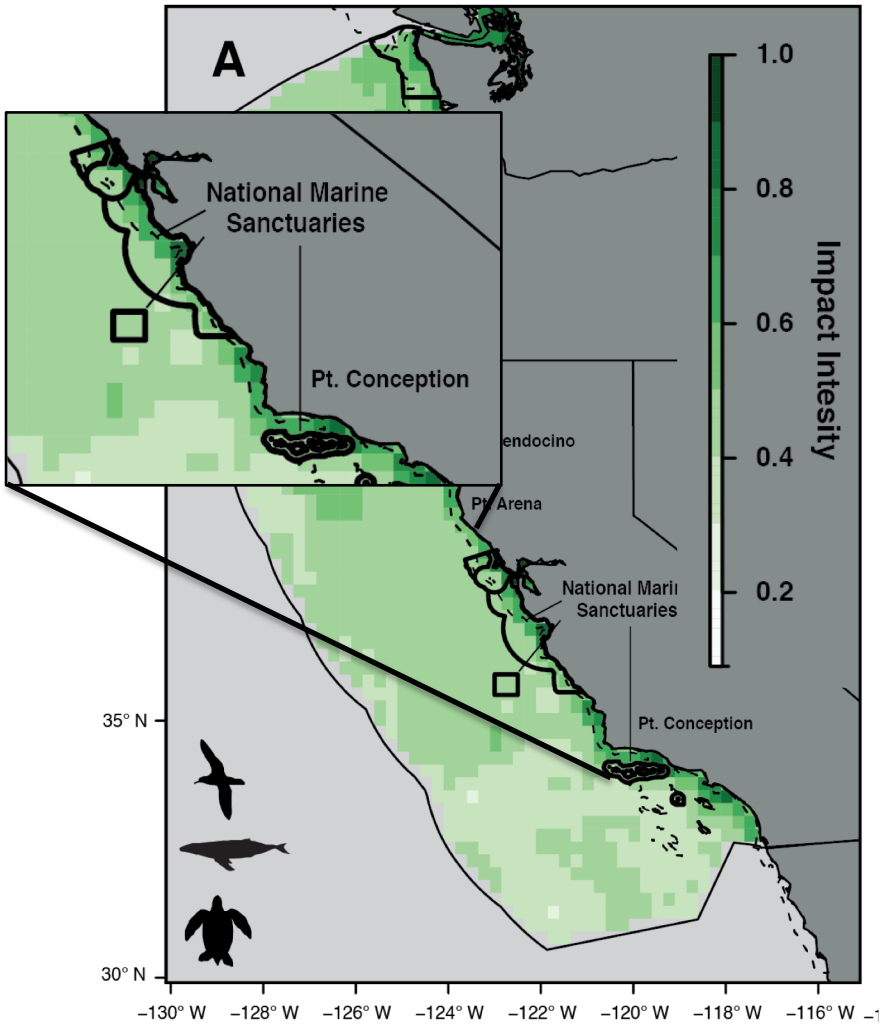
Shipping: shipping lanes, invasive species

Fishing: pelagic, demersal, high and low bycatch, destructive and non-destructive

Coastal: beach access, ocean engineering, fish farming, power plants, sediment runoff



Impact Intensity



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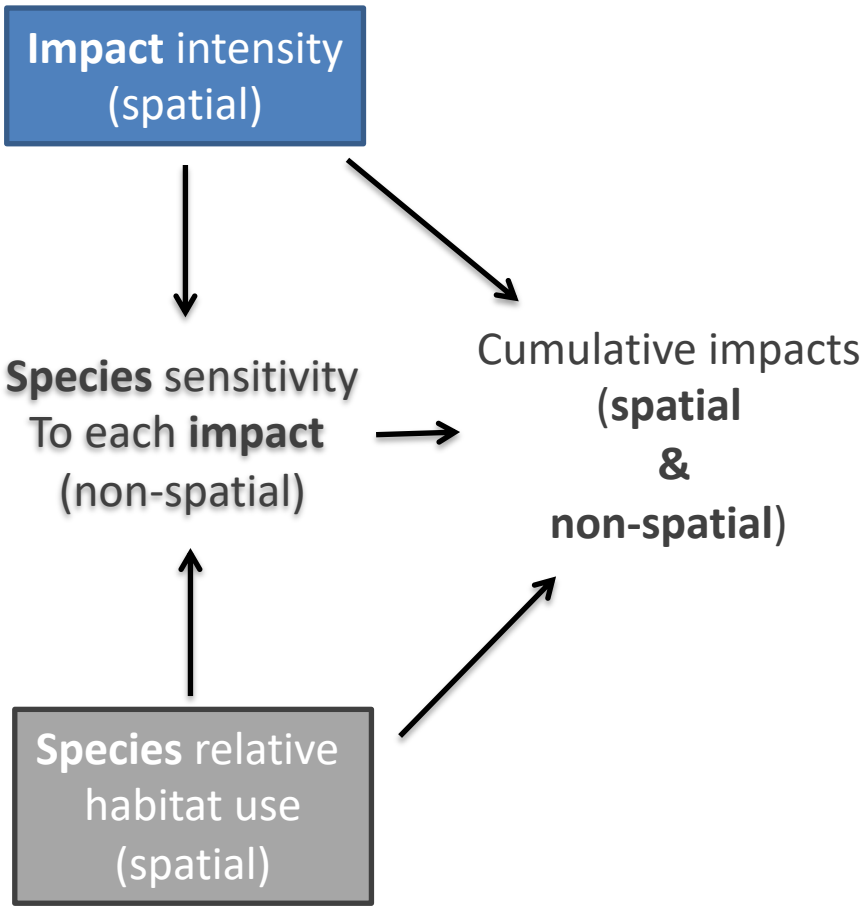


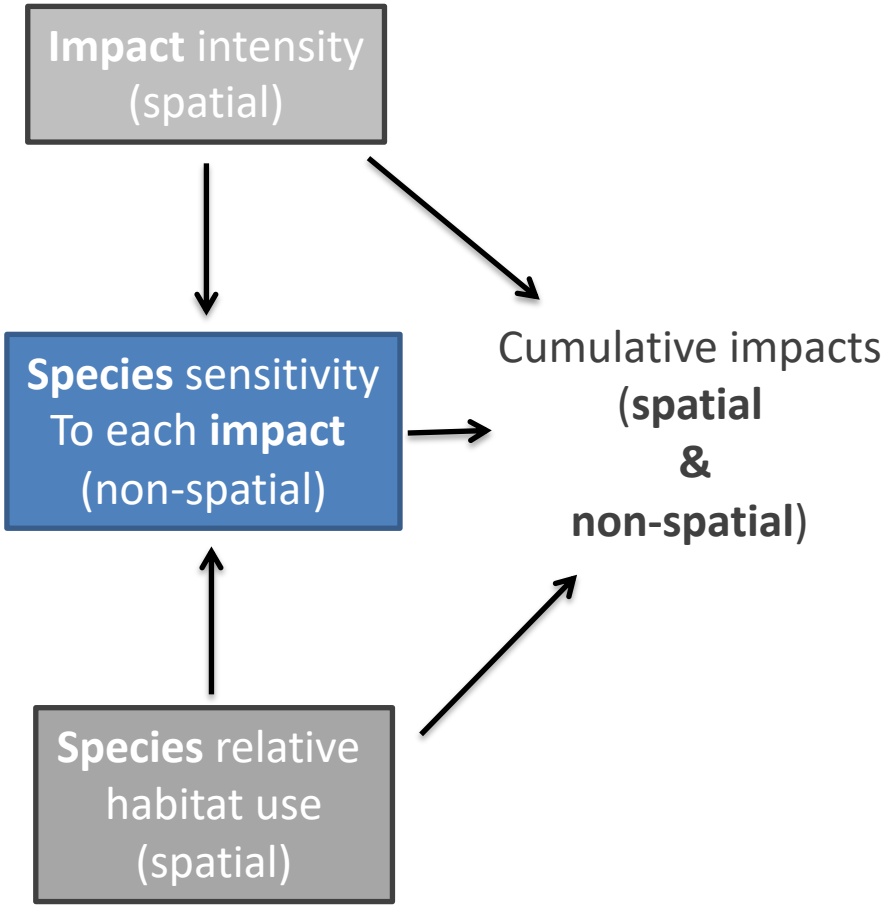
Human impacts greater along coastlines vs. offshore

Welch's *t*-test: $t_{298} = 17.29$, $p < 0.001$

Species Sensitivity to Impacts

192 Sensitivity Scores
(24 drivers x 8 species)
which considers
6 vulnerability measures

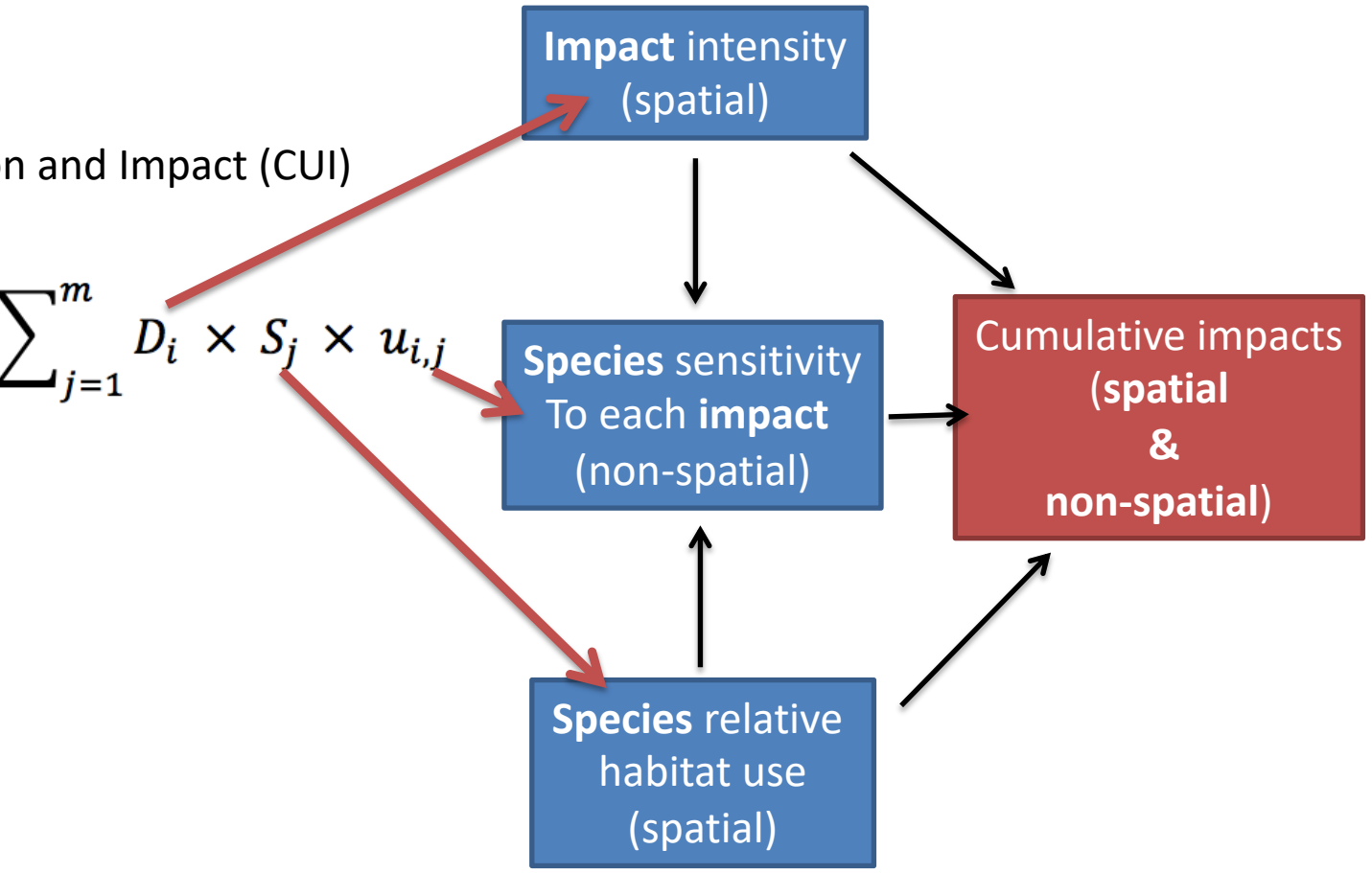
1. Frequency
2. Direct vs. indirect impact
3. Resistance (likelihood of mortality)
4. Recovery time of individual
5. Reproductive impacts
6. Population effects



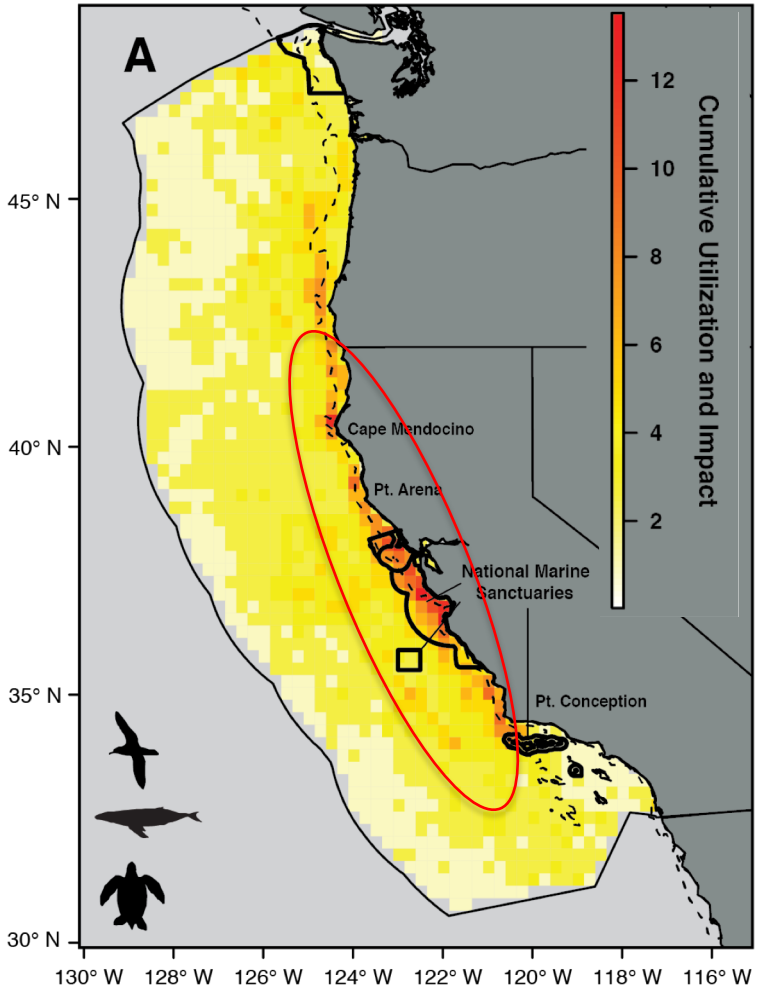
Species Sensitivity to Impacts

Cumulative Utilization and Impact (CUI)

$$CUI = \sum_{i=1}^{n} \sum_{j=1}^{m} D_i \times S_j \times u_{i,j}$$



Results: Cumulative Impacts



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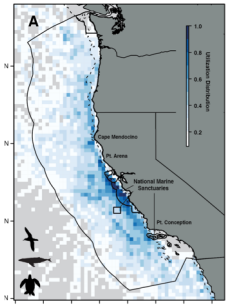
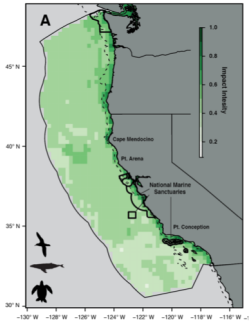
$$CUI = \sum_{i=1}^{n} \sum_{j=1}^{m} D_i \times S_j \times u_{i,j}$$



192 Vulnerability Scores

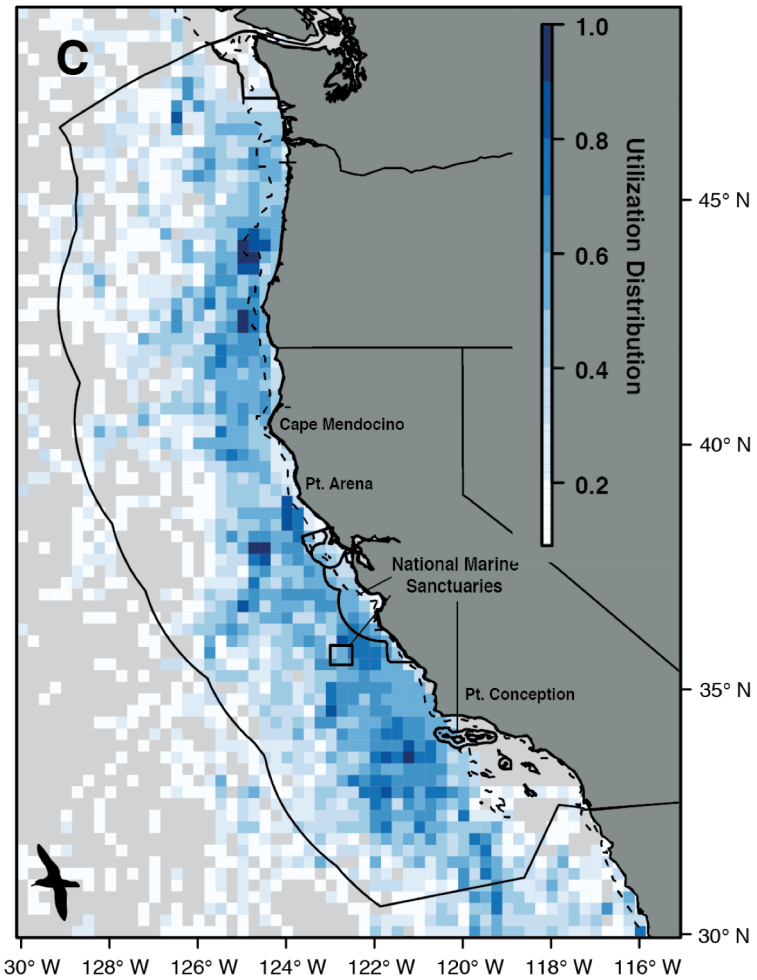


Cumulative impacts greater along coastlines vs. offshore

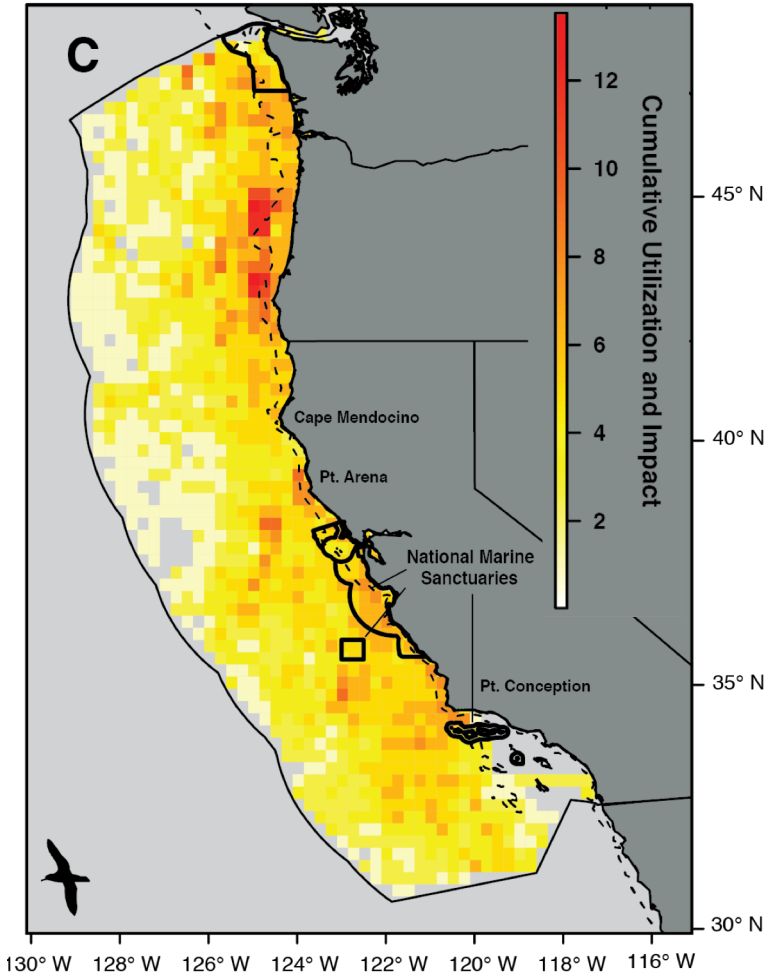
Welch's t-test: $t_{243} = 7.64$, $p < 0.001$

Results: Cumulative Utilization & Impact

Maxwell et al. 2013 *Nature Communications*



50% of core habitat OFF shelf



81.2% of core cumulative impacts ON shelf

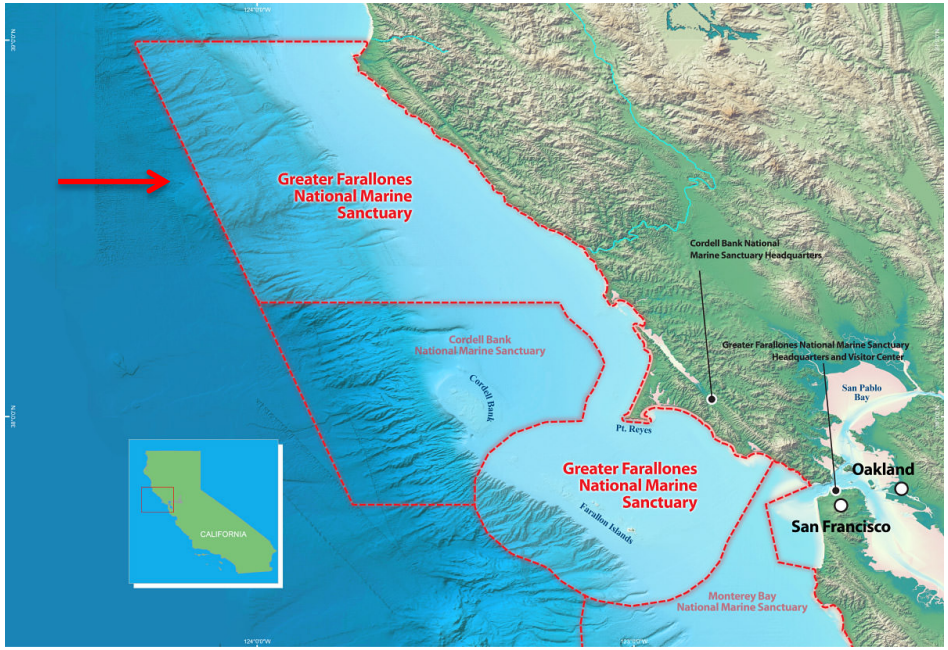
Need to know distribution of both habitat *AND* stressors

Expansion of Sanctuaries

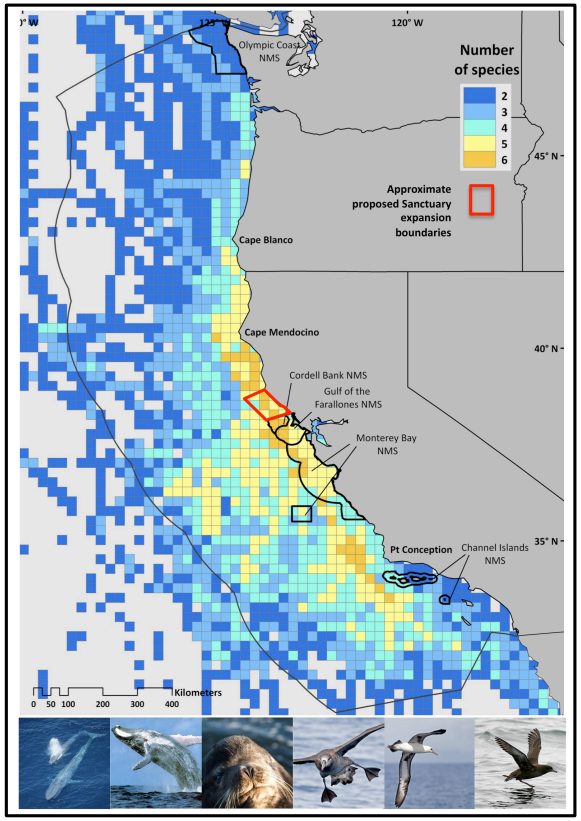
Proposed expansion of Cordell Bank & Gulf of the Farallones Sanctuaries to Pt Arena

→ Greater Farallones National Marine Sanctuary

(March 2015)



Proposed Sanctuary Expansion: Range Inclusion for Species of Concern



Distribution of **blue whales, humpback whales, California sea lions, black-footed albatrosses, Laysan albatrosses and sooty shearwaters.** All species distribution along the US West Coast (2003-2008) represented by number of species per grid cell; grid cells are 0.25°. National Marine Sanctuaries are outlined in white; 1000 m bathymetric contour is outlined in black; US Exclusive Economic Zone is outlined in grey. Gaps occur between Cape Blanco and Cordell Bank National Marine Sanctuaries, between the Channel Islands and Monterey Bay Sanctuaries, as well as offshore. The approximate boundaries of the proposed Sanctuary expansion are outlined in red.

Contact: Sara Maxwell (smaxwell@ucsc.edu) or Dan Costa (costa@biology.ucsc.edu).

TOPP Tagging Of Pacific Pelagics

CENSUS OF MARINE LIFE

US Senate Bill: HR 1187 (2012)

Cumulative Impacts to Seabirds

1. Impacts are not necessarily additive

Cumulative Impacts to Seabirds

1. Impacts are not necessarily additive

Displacement

+

Resource Competition

+

Sea Level Rise

=

Cumulative Impacts

Cumulative Impacts Considerations

1. Impacts are not necessarily additive

Displacement

X

Resource Competition

+

Sea Level Rise^2

=

Cumulative Impacts

Cumulative Impacts to Considerations

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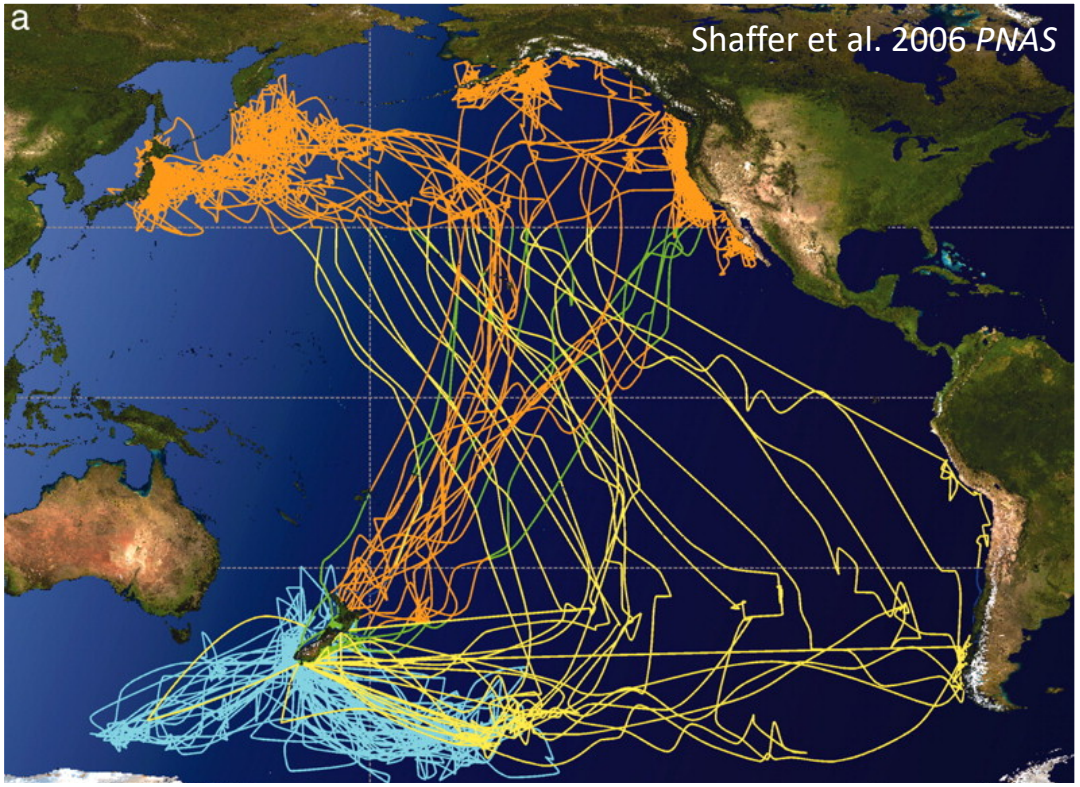
2. Impacts occur anywhere in time - past, present and/or future

Cumulative Impacts to Considerations

1. Impacts are not necessarily additive
2. Impacts occur anywhere in time - past, present and/or future
3. Impacts occur across time AND space



Cumulative Impacts to Considerations

1. Impacts are not necessarily additive
2. Impacts occur anywhere in time - past, present and/or future
3. Impacts occur across time AND space
4. Some impacts will have population-level consequences

Cumulative Impacts to Considerations

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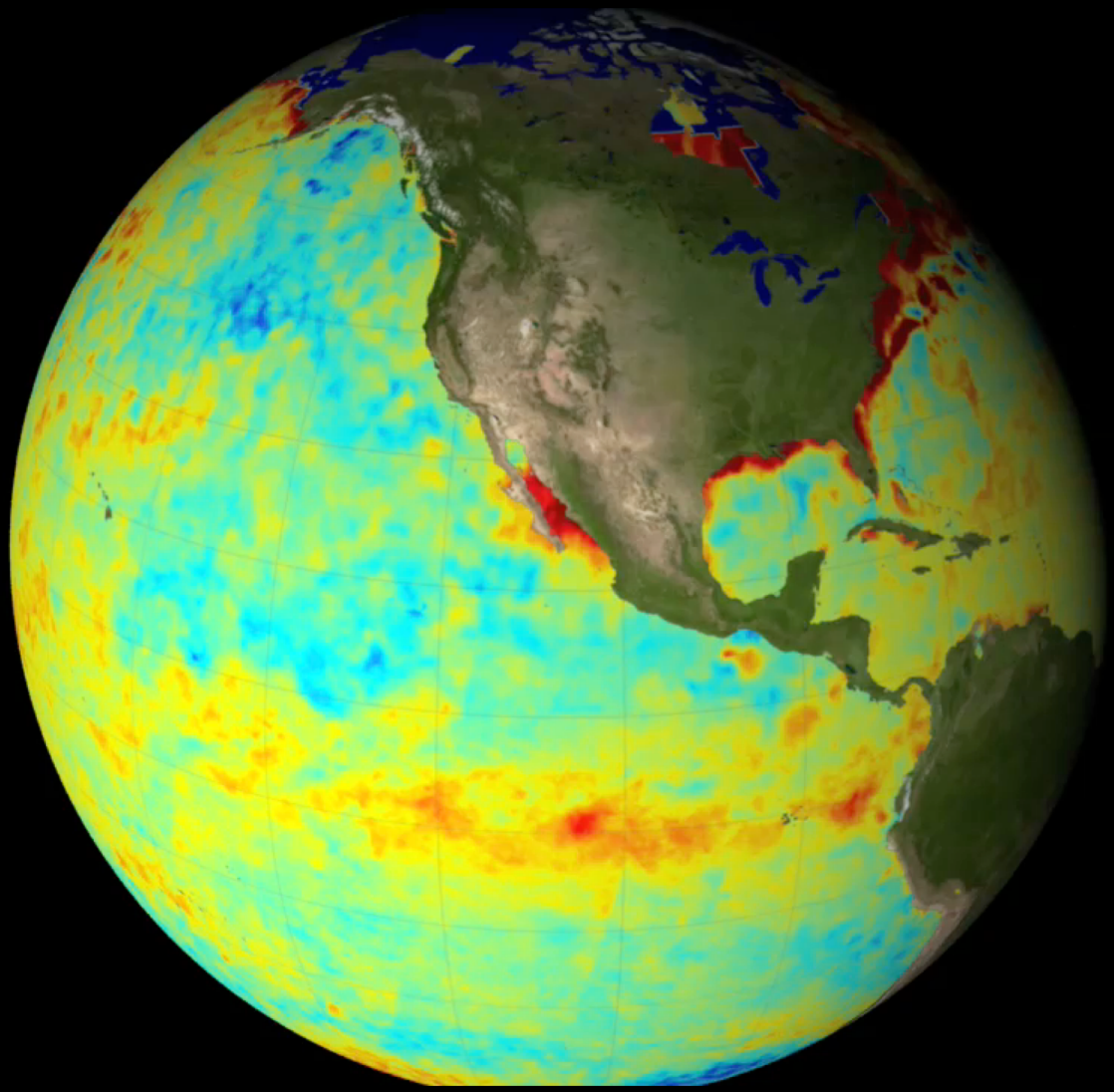
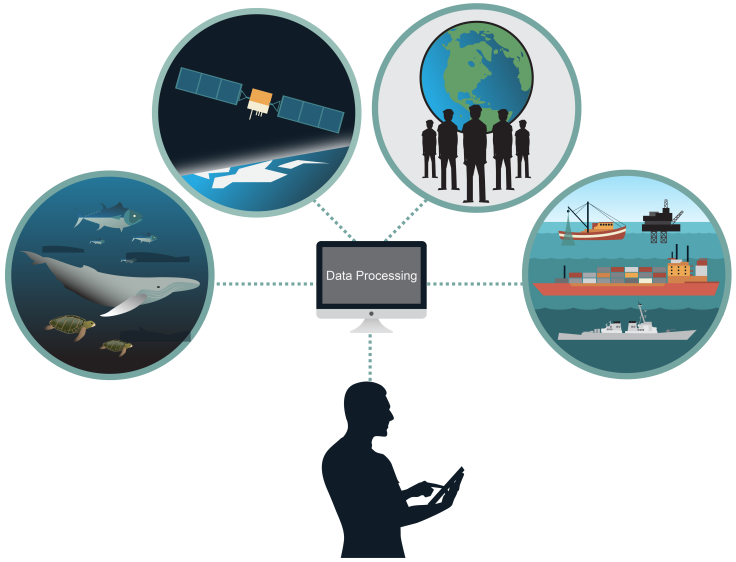
2. Impacts occur anywhere in time - past, present and/or future
3. Impacts occur across time AND space
4. Some impacts will have population-level consequences
5. Oceans are dynamic ecosystems

Oceans are dynamic ecosystems



Credit: NOAA

Dynamic Ocean Management



- Management that **changes in space and time**
- in response to the shifting nature of the ocean and its users
- based on the integration of new biological, oceanographic, social and/or economic data
- **in near real-time**

Maxwell et al (2015) *Marine Policy*

Sectoral approaches:

Fisheries:

- Howell et al 2015 *Fisheries Oceanography*;
- Hazen et al 2018 *Science Advances*,

Shipping

- WhaleAlert

Multi-Sectoral approaches:

Mobile MPAs:

- Maxwell et al 2020 *Science*

Thank you!

BOTHELL

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http://maxwelllab.weebly.com/

Funders:
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