

A Global Map of Human Impacts on Marine Ecosystems*

A Preview for the Arctic?

Ben Halpern, Shaun Walbridge, Kimberly Selkoe, Carrie Kappel, Fiorenza Micheli, Caterina D'Agrosa, John Bruno, Kenneth Casey, Colin Ebert, Helen Fox, Rod Fujita, Dennis Heinemann, Hunter Lenihan, Elizabeth Madin, Matthew Perry, Elizabeth Selig, Mark Spalding, Robert Steneck, Reg Watson

*Science, 15 Feb 2008, 319: 948-952

The Inexhaustible Ocean



Perhaps Not So Inexhaustible

2003

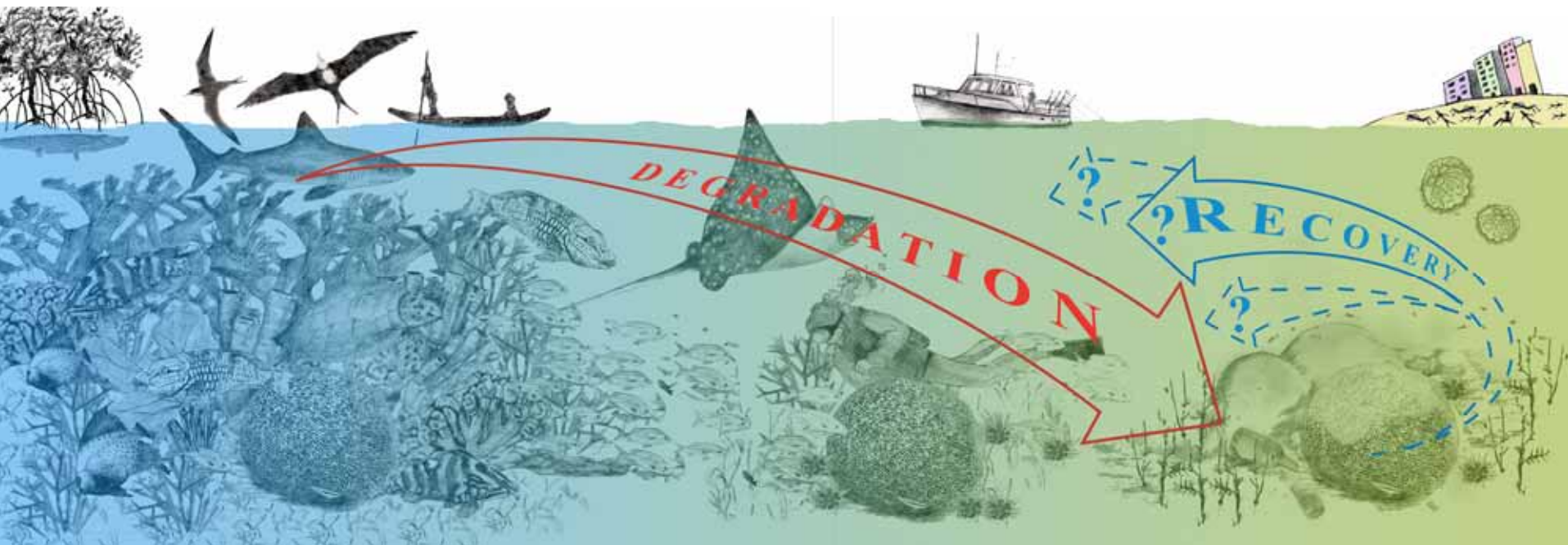
Are U.S. Coral Reefs on the Slippery Slope to Slime?

J. M. Pandolfi,^{1*} J. B. C. Jackson,^{3,4} N. Baron,⁵ R. H. Bradbury,⁶ H. M. Guzman,⁴ T. P. Hughes,⁷ C. V. Kappel,⁸ F. Micheli,⁸ J. C. Ogden,⁹ H. P. Possingham,² E. Sala³

2006

Impacts of Biodiversity Loss on Ocean Ecosystem Services

Boris Worm,^{1*} Edward B. Barbier,² Nicola Beaumont,³ J. Emmett Duffy,⁴ Carl Folke,^{5,6} Benjamin S. Halpern,⁷ Jeremy B. C. Jackson,^{8,9} Heike K. Lotze,¹ Fiorenza Micheli,¹⁰ Stephen R. Palumbi,¹⁰ Enric Sala,⁸ Kimberley A. Selkoe,⁷ John J. Stachowicz,¹¹ Reg Watson¹²



We have long dealt with impacts one at a time, but impacts are cumulative



**Overfishing
+
Sewage
+
Warming/Bleaching
↓
Phase shift
to algal dominance**

The Global Map of Human Impacts

GOALS

- **Map multiple anthropogenic impacts on 20 marine ecosystems types**
 - **Create global picture of relative cumulative impacts**
 - **Establish an impacts baseline**
- **Identify regions most in need of relief and most in need of protection**

17 Different Stressors Mapped

- 6 Commercial & Artisanal Fishing**
- 3 Land-based Pollution**
- 3 Climate Change (temp, pH, UV)**
- 1 Ocean-based Pollution**
- 1 Commercial Shipping**
- 1 Benthic Structures (oil rigs)**
- 1 Species Invasions**
- 1 Direct Human Damage (trampling)**

Vulnerability of Ecosystems to Stressors

Five Criteria:

- Spatial scale
- Frequency
- Functional impact
- Resistance
- Recovery time

**Vulnerability
Weight**

*Every ecosystem-by-stressor combination
assessed with a survey of experts*

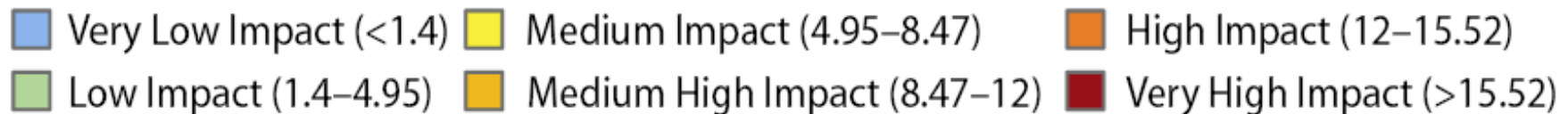
(Halpern et al. 2007 Conservation Biology)

Cumulative Impact Scores*

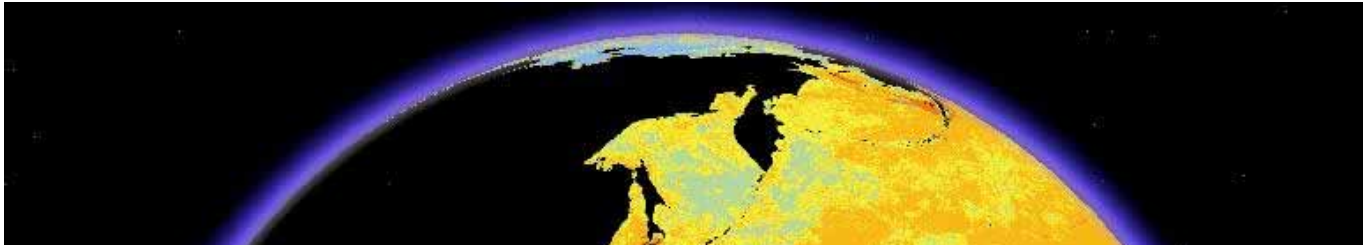
Sum within each 1km² pixel across all ecosystem types of log-transformed and standardized stressor values weighted by vulnerability

41% of the ocean subject to medium to very high impact

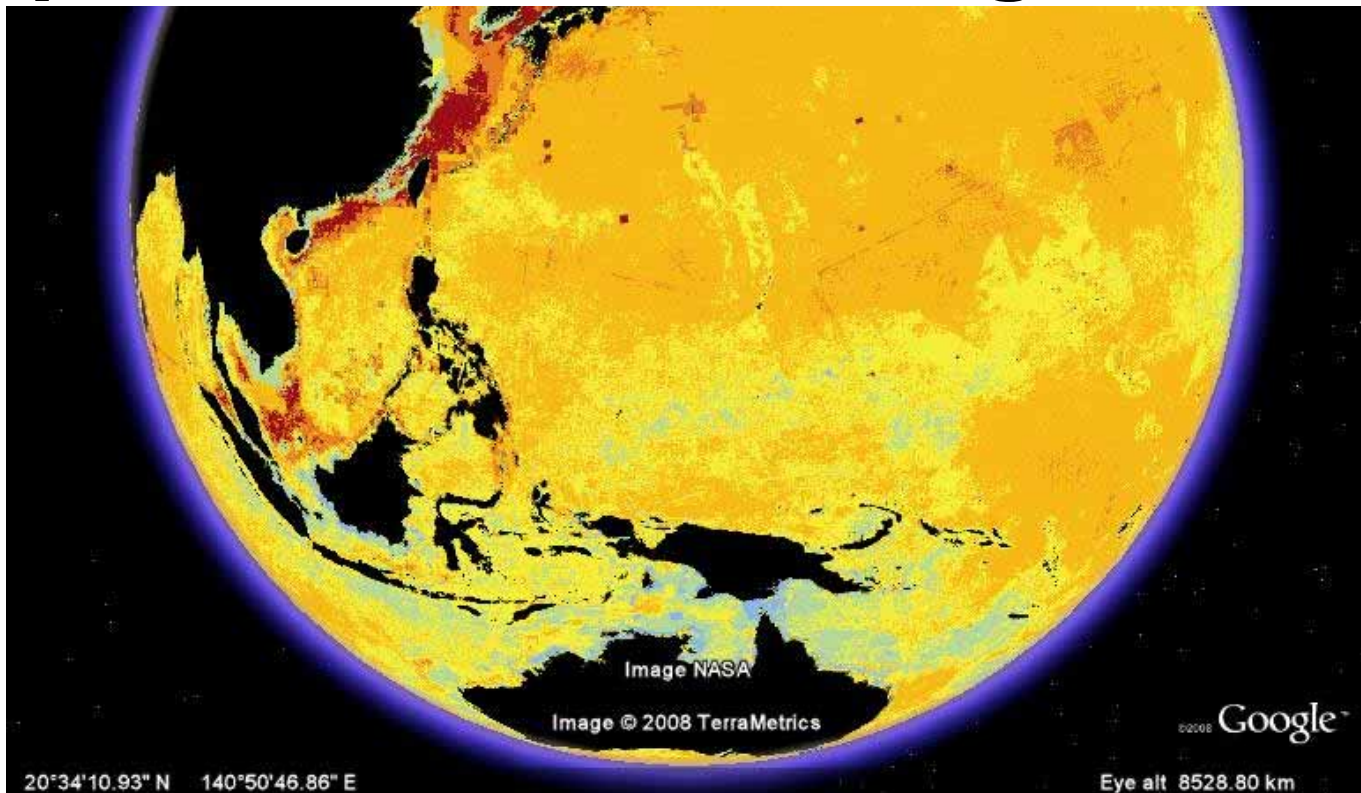
Less than 4% subject to very low impact









* vulnerability-weighted sum across all stressors and ecosystems for each 1km² pixel

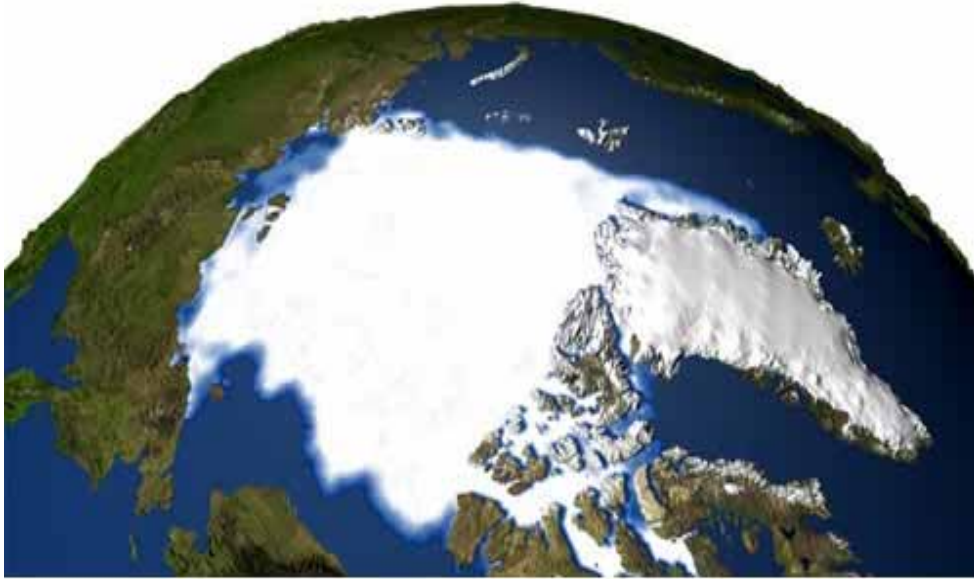


Adaptation ⇔ Recovering Resilience

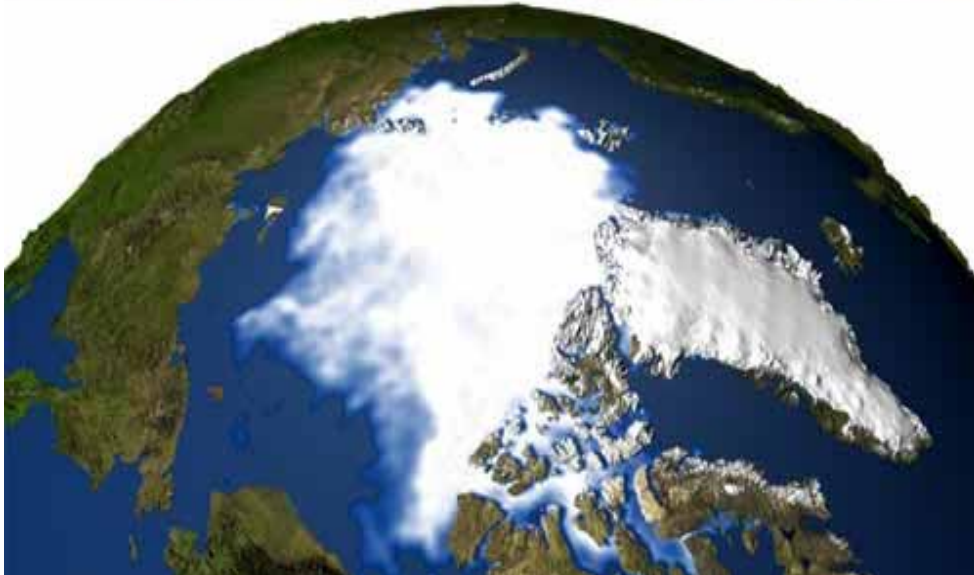


- | | | |
|-----------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
|  Very Low Impact (<1.4) |  Medium Impact (4.95–8.47) |  High Impact (12–15.52) |
|  Low Impact (1.4–4.95) |  Medium High Impact (8.47–12) |  Very High Impact (>15.52) |

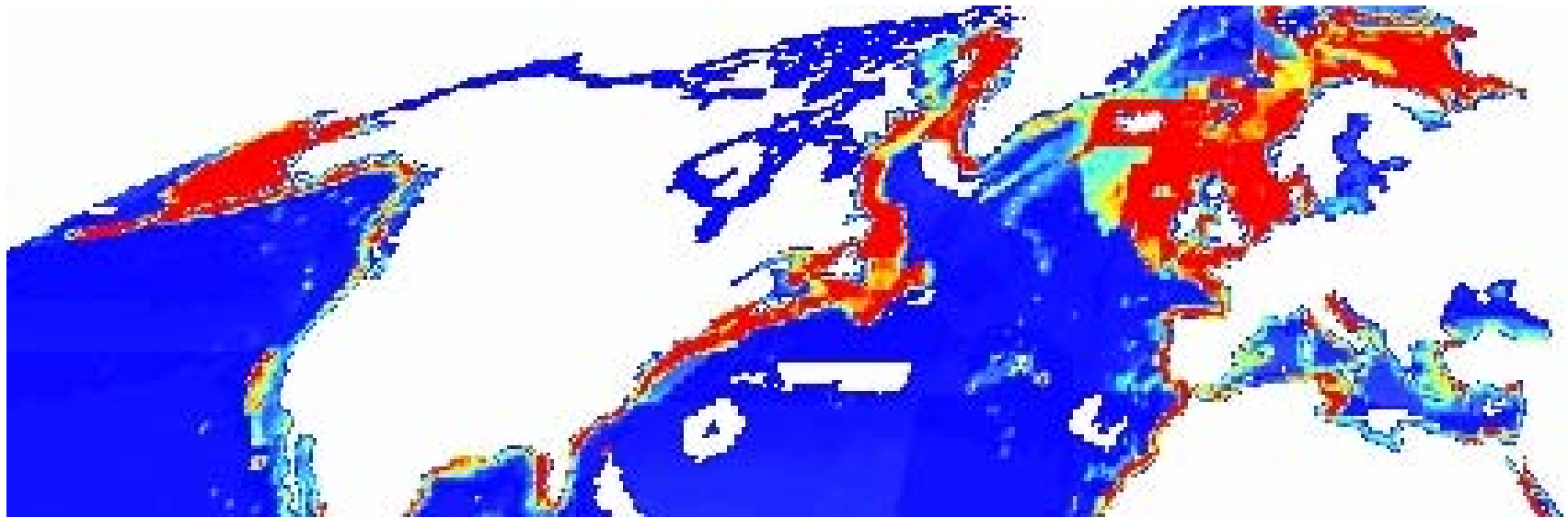
Arctic One of Least Impacted Areas



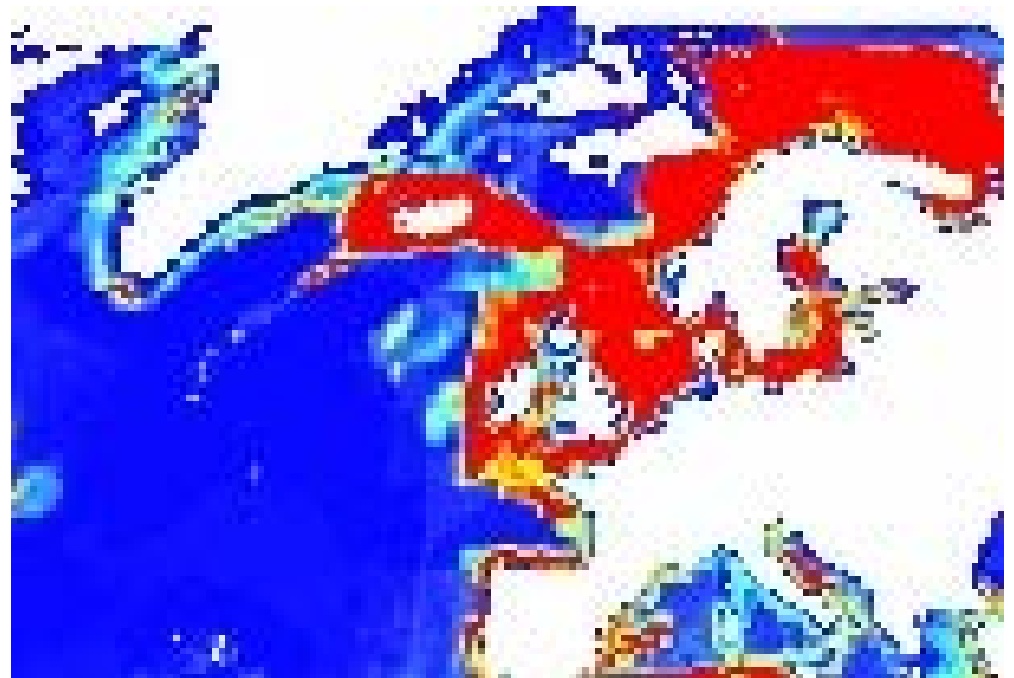
- Ice prevents access
- Light commercial fishing
- Some artisanal fishing
- Few humans or settlements
- Relatively little pollution
- Little ship traffic



But, warming and acidification are or will have their impact on the Arctic, and sea ice loss is opening the Arctic to surrounding threats



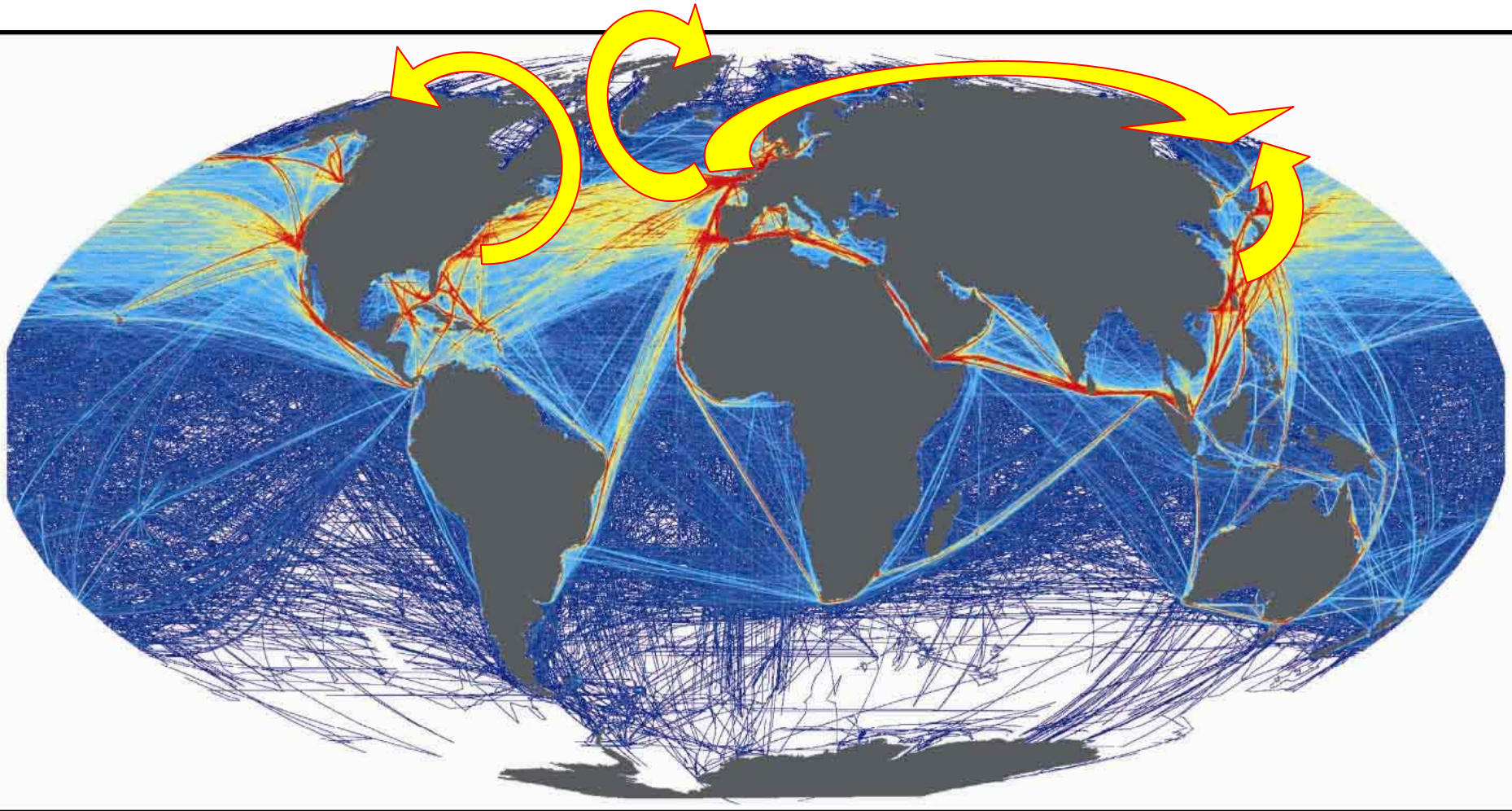
**Destructive
Demersal
Fishing**



**High
Bycatch
Pelagic
Fishing**

Commercial shipping and pollution

New Routes and New Risks



Oil and Gas Development



- Prospective areas for oil and gas, and known reserves
- Oil production
- Gas production
- Mining site

Implications

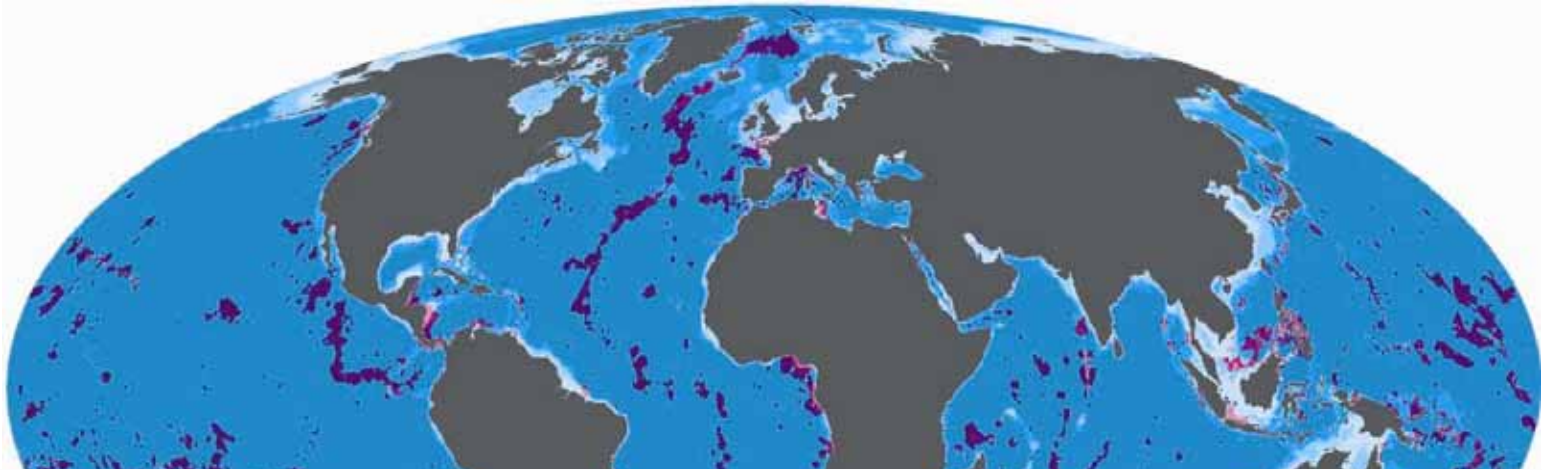
- Climate change impacts should be clearer
- Lack of knowledge high \Rightarrow Research critical to successful management
- Monitoring necessary
- Adaptation \Rightarrow Preserving resilience
- Opportunity to employ EBM from start
 - Precautionary Approach
 - Area-based
 - Adaptive
 - Resilience-based
 - Climate change-based



"HOW ON EARTH DO WE TURN IT OFF?"

© MATSON
STYLING: BOB DE GROOT
caglecartoons.com

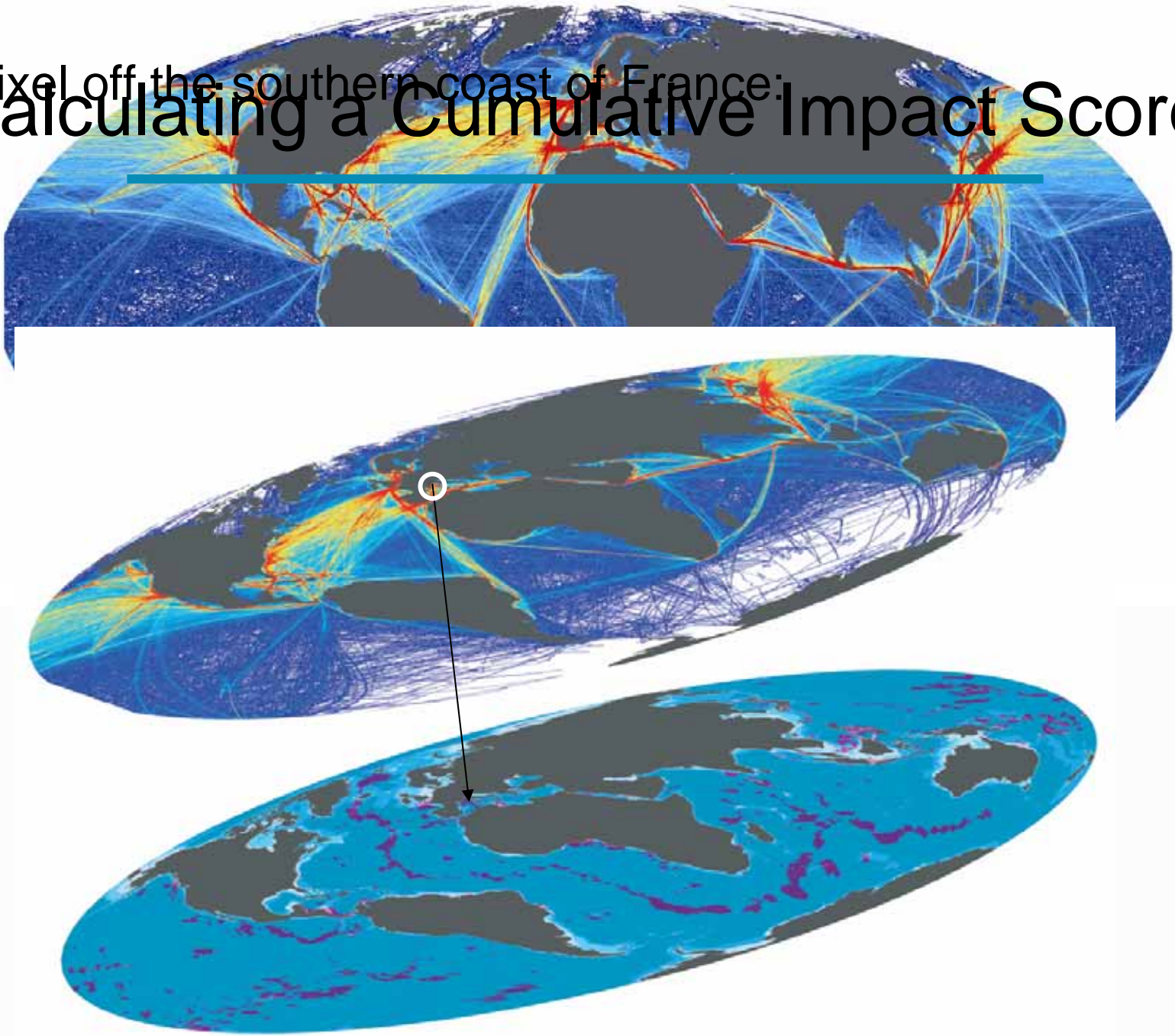
Calculating a Cumulative Impact Score



Composite map of 20 ecosystem types

A pixel off the southern coast of France:

Calculating a Cumulative Impact Score



Shipping load:

96

(percentile)

Vulnerability weight:

x

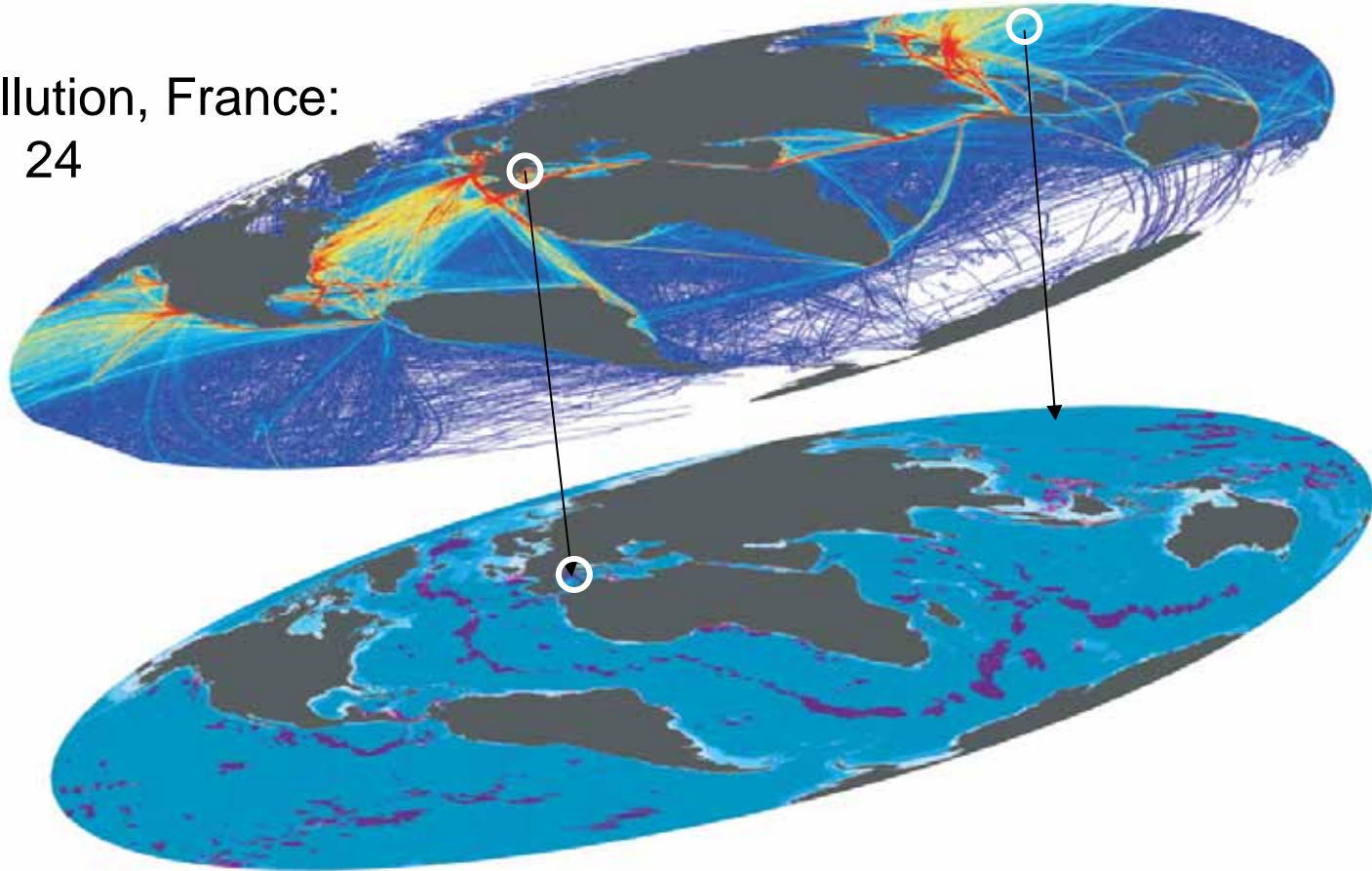
0.25

(shipping in shelf waters)

A pixel in the Pacific: = 24

Ship pollution, France:

24



Shipping load:

28

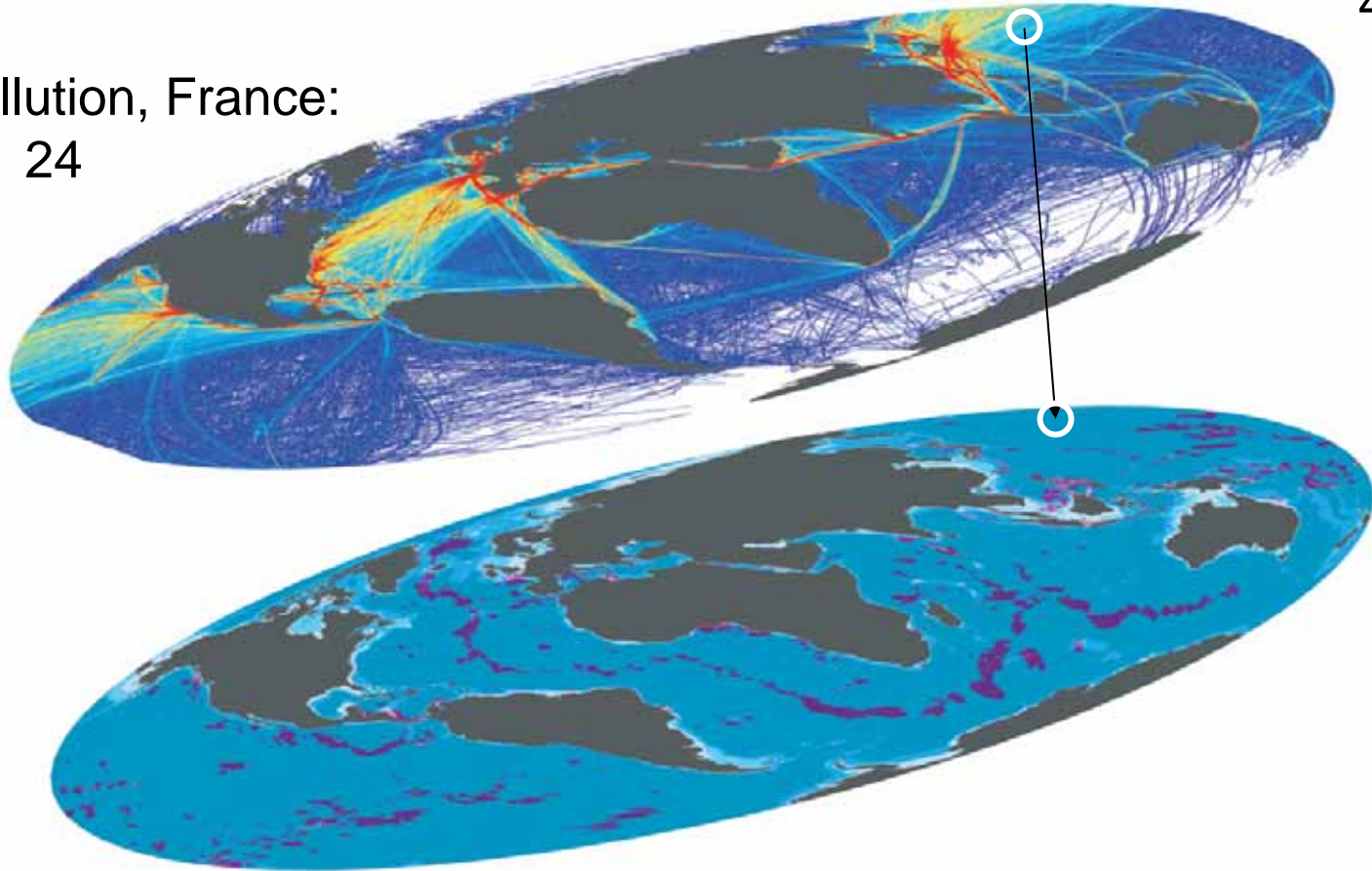
Vulnerability weight:

0.15

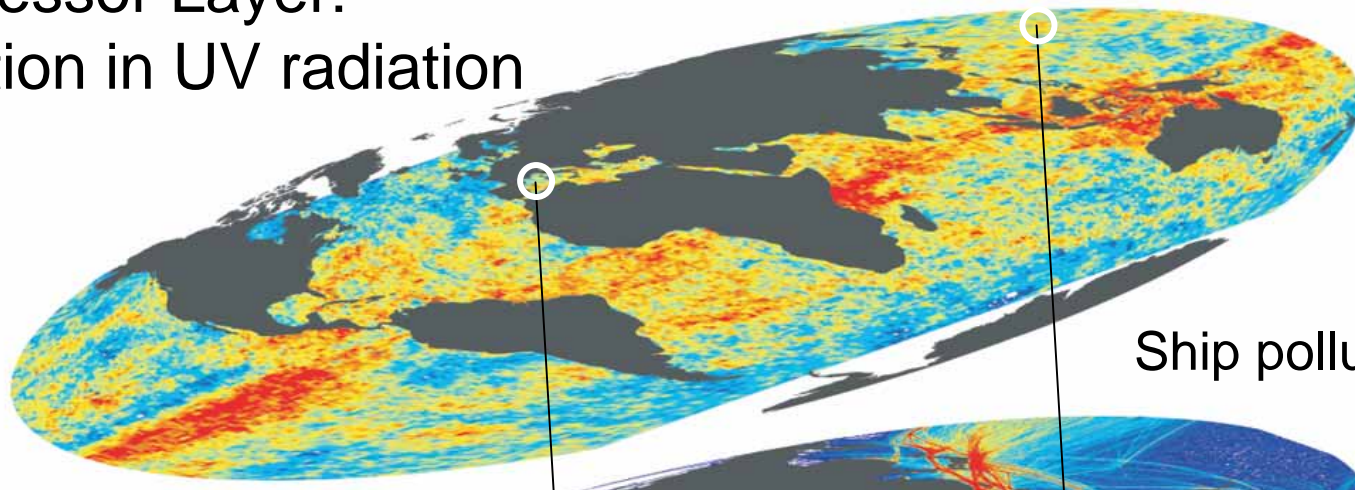
\times = 4
A pixel in the Pacific:
(shipping in pelagic waters)

Ship pollution, Pacific:
4

Ship pollution, France:
24

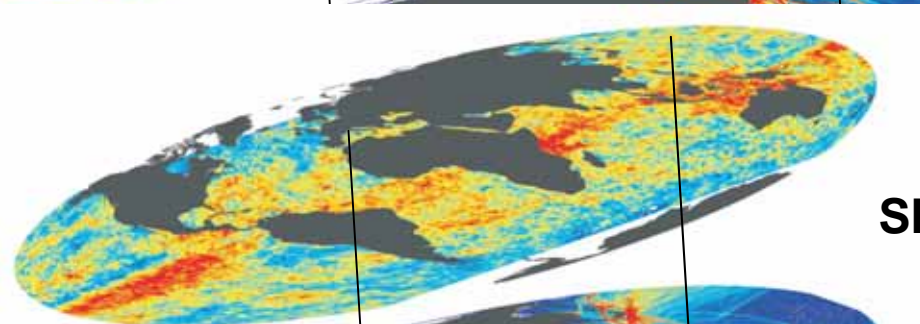
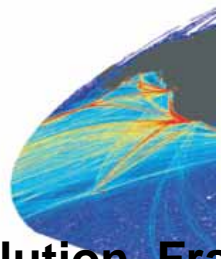


2nd stressor Layer:
Elevation in UV radiation



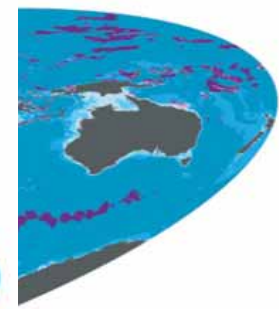
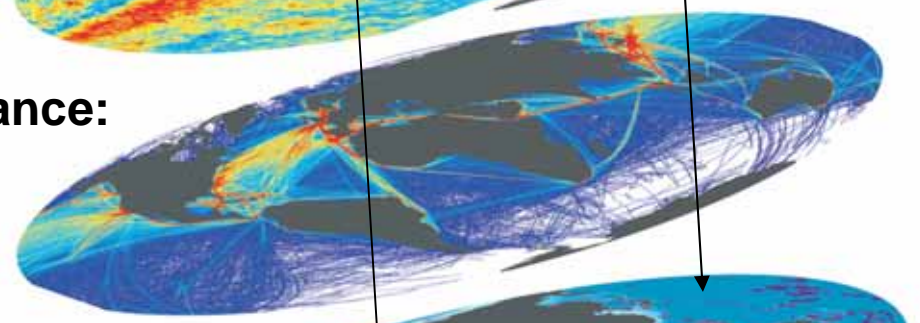
Ship pollution, Pacific:
4

Ship pollution, Fr
24



Ship pollution, Pacific:
4

Ship pollution, France:
24



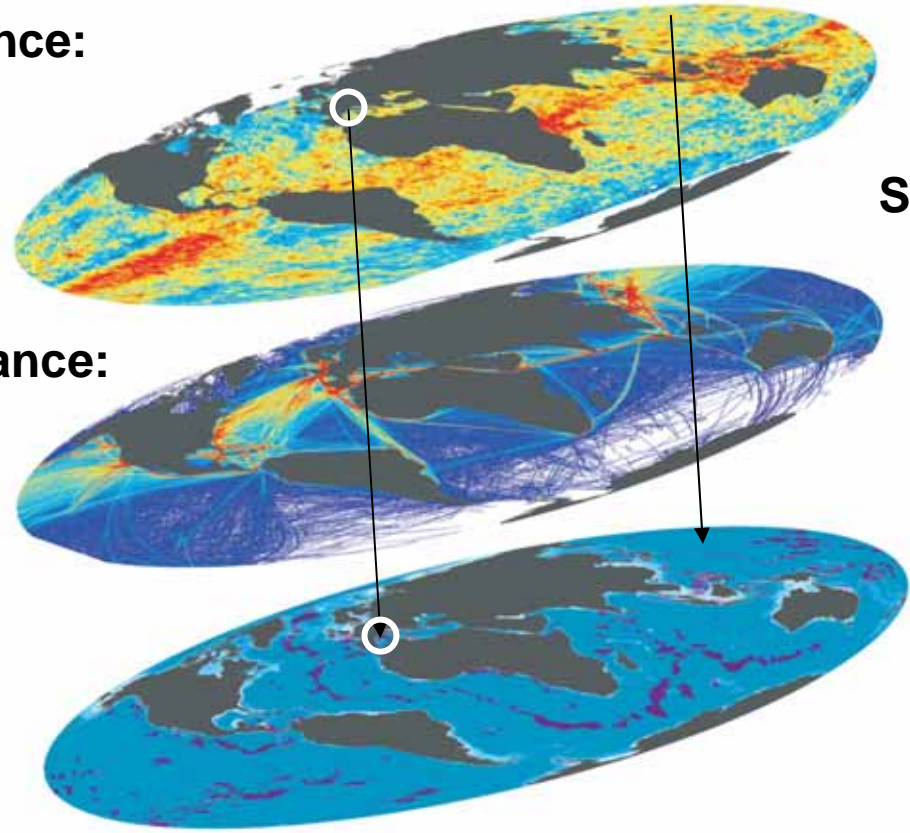
France:

Elevated UV: 33 x Vulnerability weight: 0.66 = 22
(UV in shelf waters)

Elevated UV, France:
22

Ship pollution, France:
24

Ship pollution, Pacific:
4



Pacific:

Elevated UV:

72

Vulnerability weight:

0.19

= 14

(UV in pelagic waters)

Elevated UV, Pacific:

14

Ship pollution, Pacific:

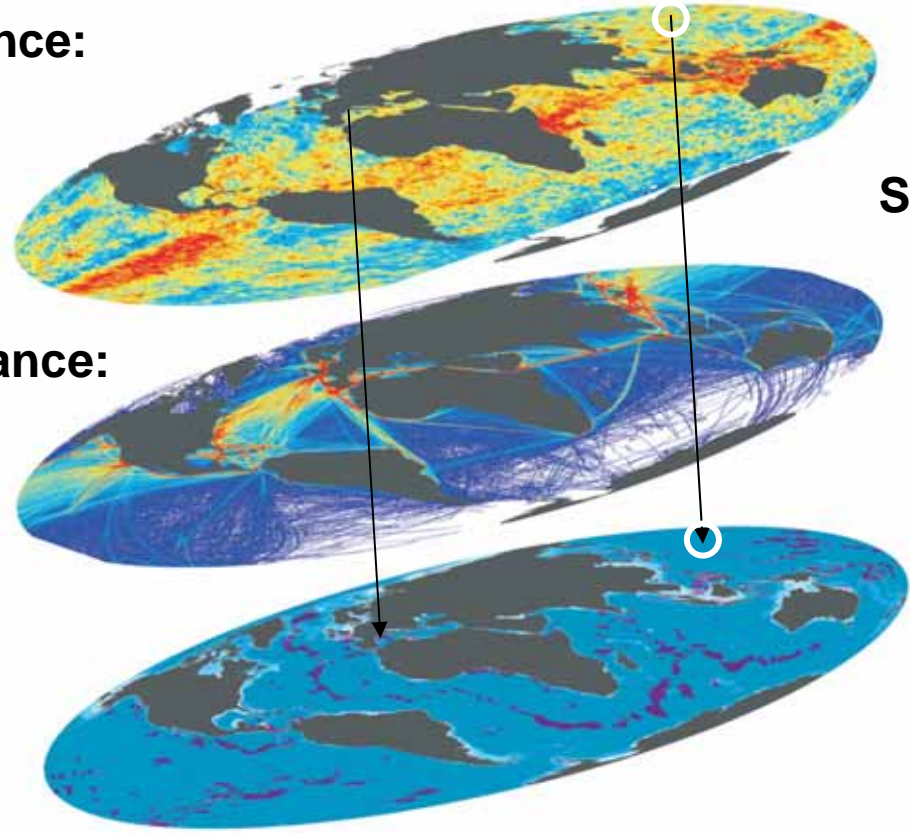
4

Elevated UV, France:

22

Ship pollution, France:

24



Summed Impact Scores

Pixel in France

$$22 + 24 = 46$$

Elevated UV, France:

22

Ship pollution, France:

24

Pixel in Pacific

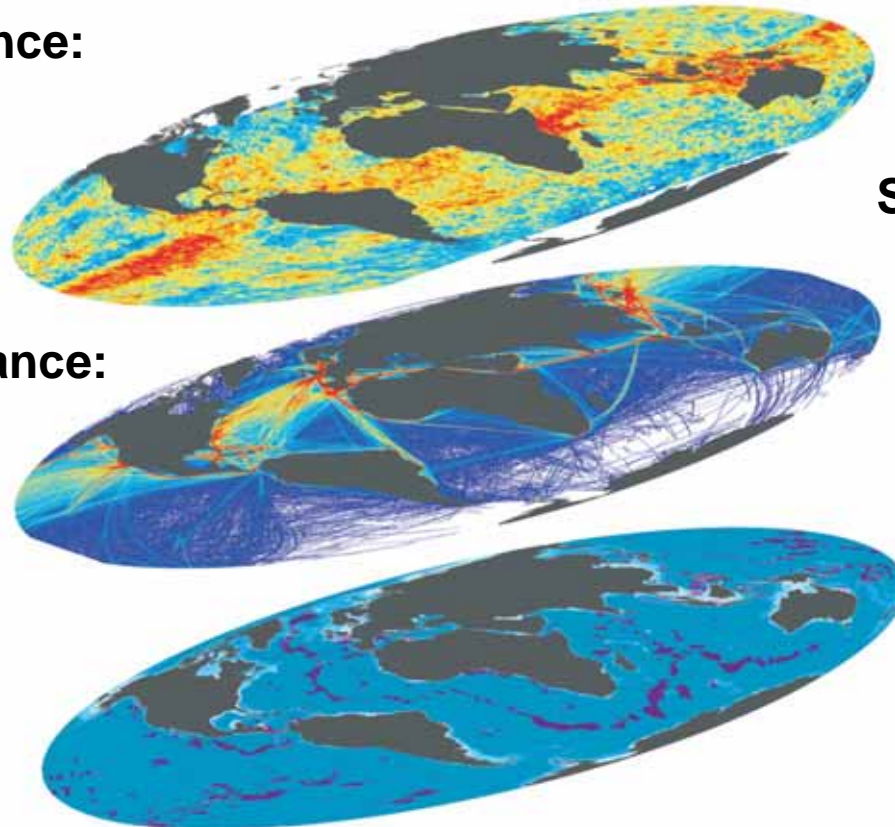
$$14 + 4 = 18$$

Elevated UV, Pacific:

14

Ship pollution, Pacific:

4



Cumulative Impact Scores

