# MULTIPLE INTERACTING NATURAL PRESSURES AND HUMAN ACTIVITIES IN NORTH PACIFIC MARINE ECOSYSTEMS

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# PICES WORKING GROUP 28

**“Development of ecosystem indicators to characterize ecosystem responses to multiple stressors”**

Linkages to PICES FUTURE Program:

WG 28 will contribute directly to goals 1 and 3 of the FUTURE Science Plan and partially to goal 2:

1) What determines an ecosystem’s intrinsic resilience and vulnerability to natural and anthropogenic forcing?
2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
3) How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

# Presentation Objectives

Provide an overview of progress by WG28 on two of seven Terms of Reference:

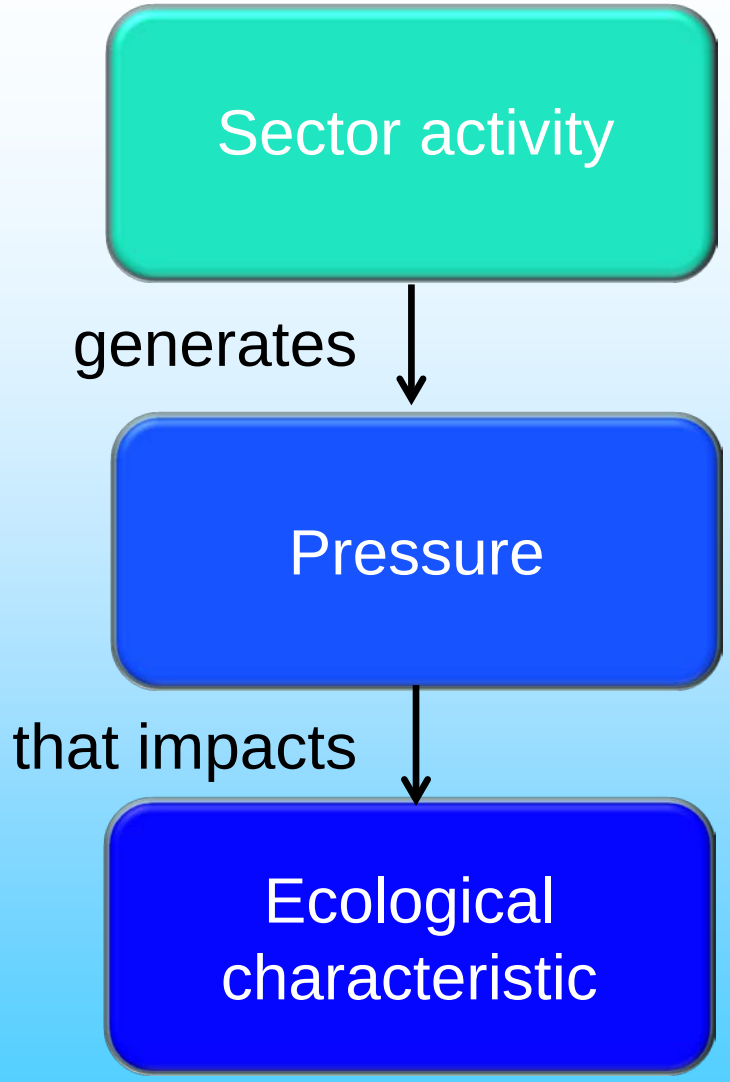
1) review frameworks proposed and in use in the North Pacific for linking natural pressures and human activities to ecosystem responses; and

2) characterise multiple pressures and activities on North Pacific marine ecosystems.

Presentation by Boldt et al. will provide an overview of progress on Terms of Reference regarding:

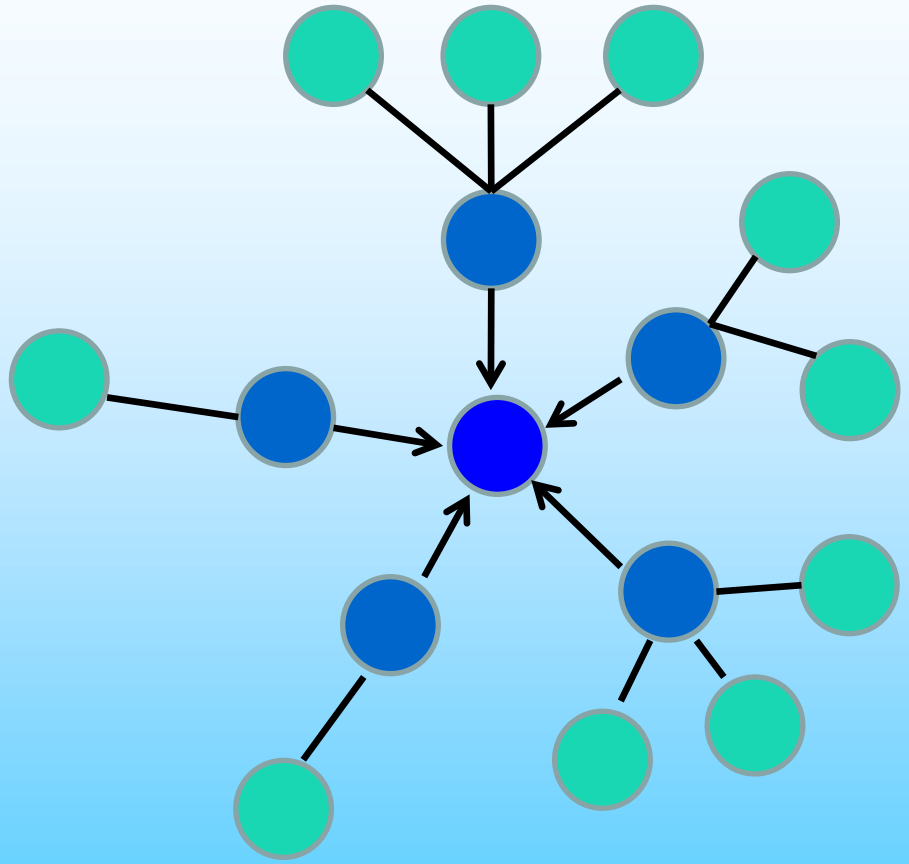
- categories of indicators to document status and trends of ecosystem change in response to multiple stressors

# Frameworks – Impact chains



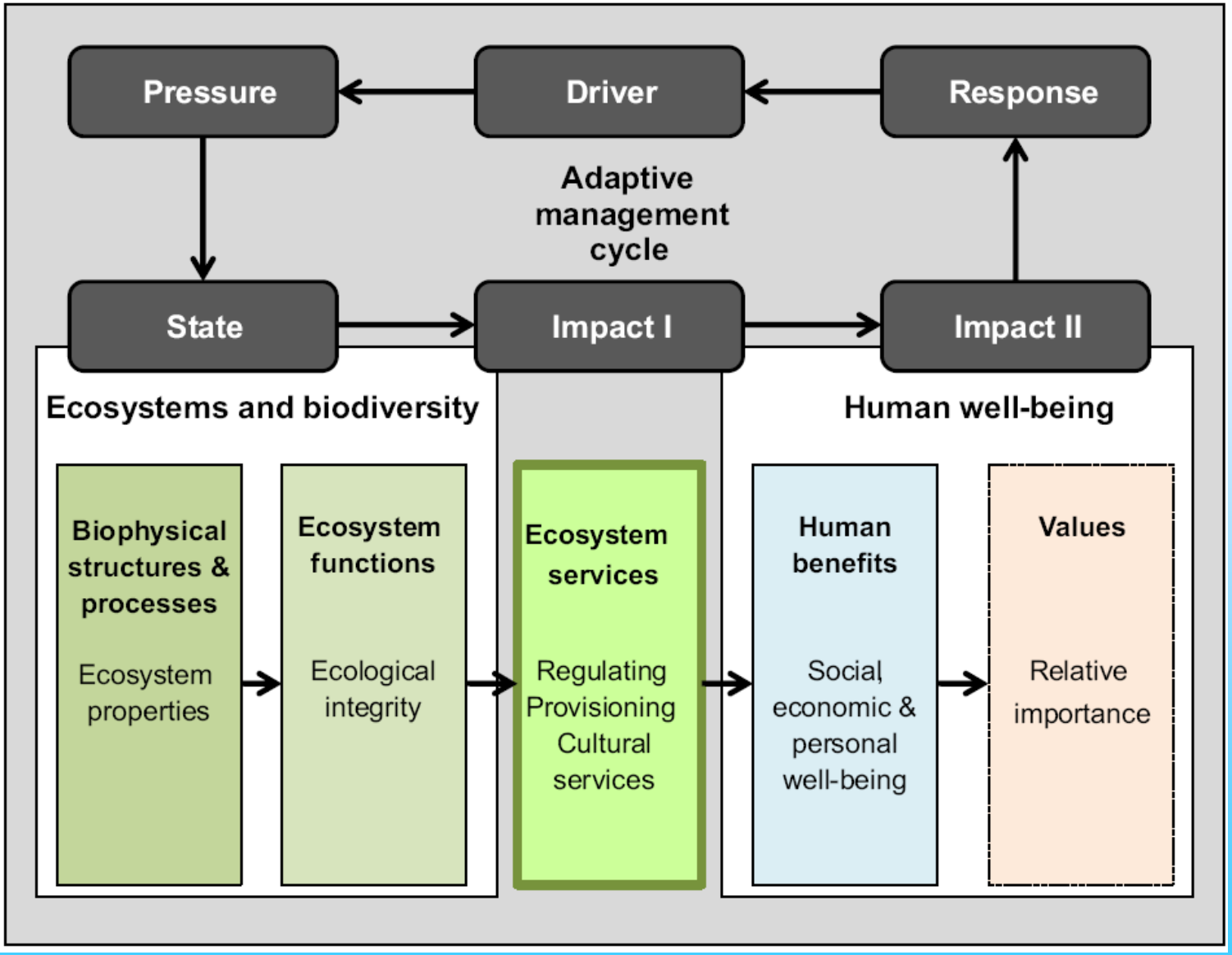

Knights et al. 2013.

Impact Chain



Multiple Sector Impacts

# Frameworks – Multiple sector impacts - DPSIR




Műller & Burkhard. 2012. Ecosystem Services

# Frameworks – Multiple sector impacts

Other approaches include:

- Multivariate statistical models
- Pathways of effects models
- Probabilistic (Bayesian) networks
- Ecosystem simulation models

All these frameworks require significant information

- can require tables with 100's or 1000's of cells to identify relationships between pressures and ecosystem components

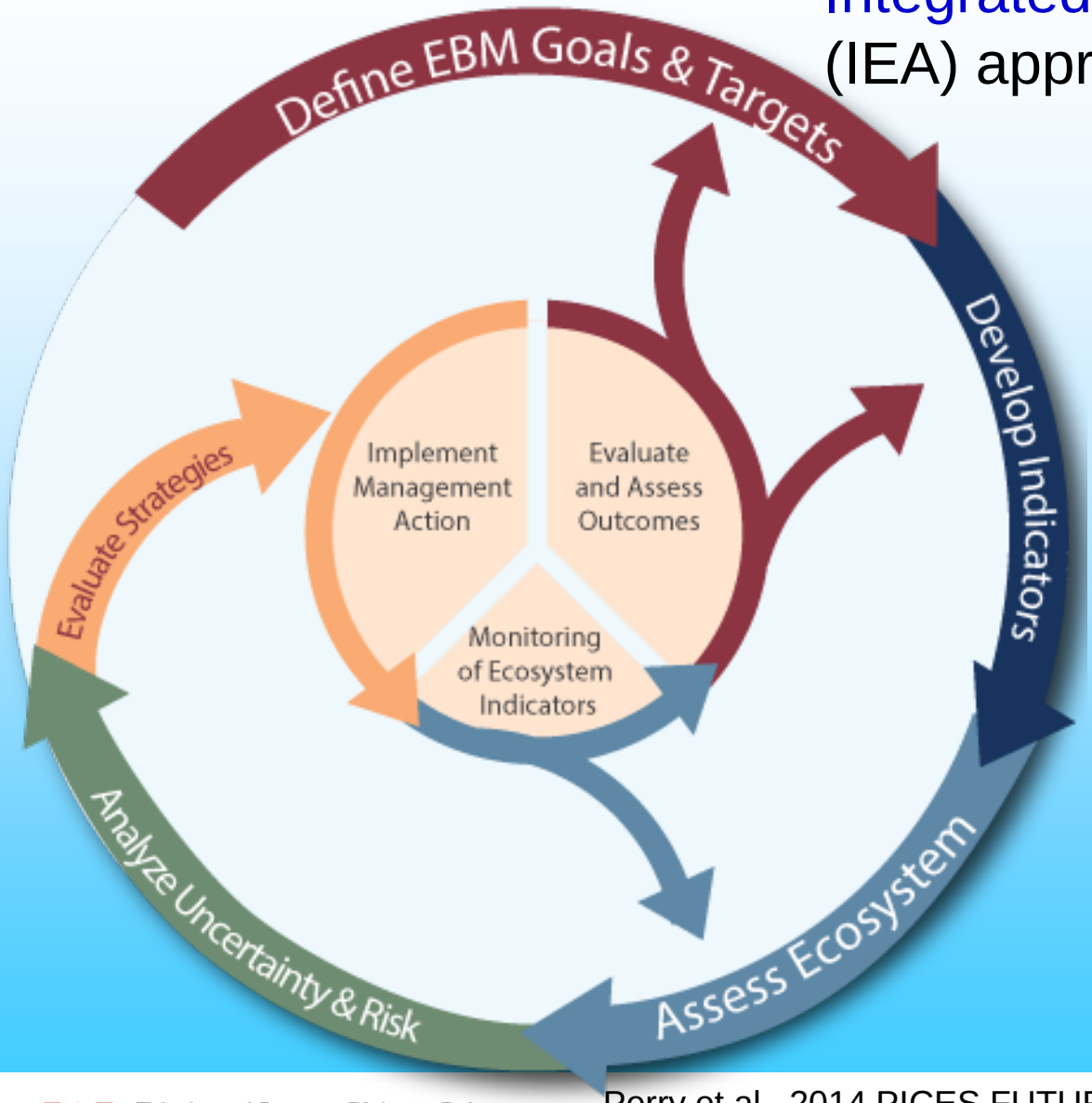
Expert Opinion is often only way to populate such tables

e.g. Questions such as:

1) How strong is the direct effect of X on Y?
2) What proportion of Y is directly affected by X?

A lot more information is needed for statistical and ecosystem model approaches

# “Management” Frameworks




Integrated Ecosystem Assessment (IEA) approach developed by U.S.

Other frameworks include:

Integrated Fisheries Risk Analysis Method for Ecosystems (IFRAME – Korea See Zhang S3 talk)

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST – US, Canada)

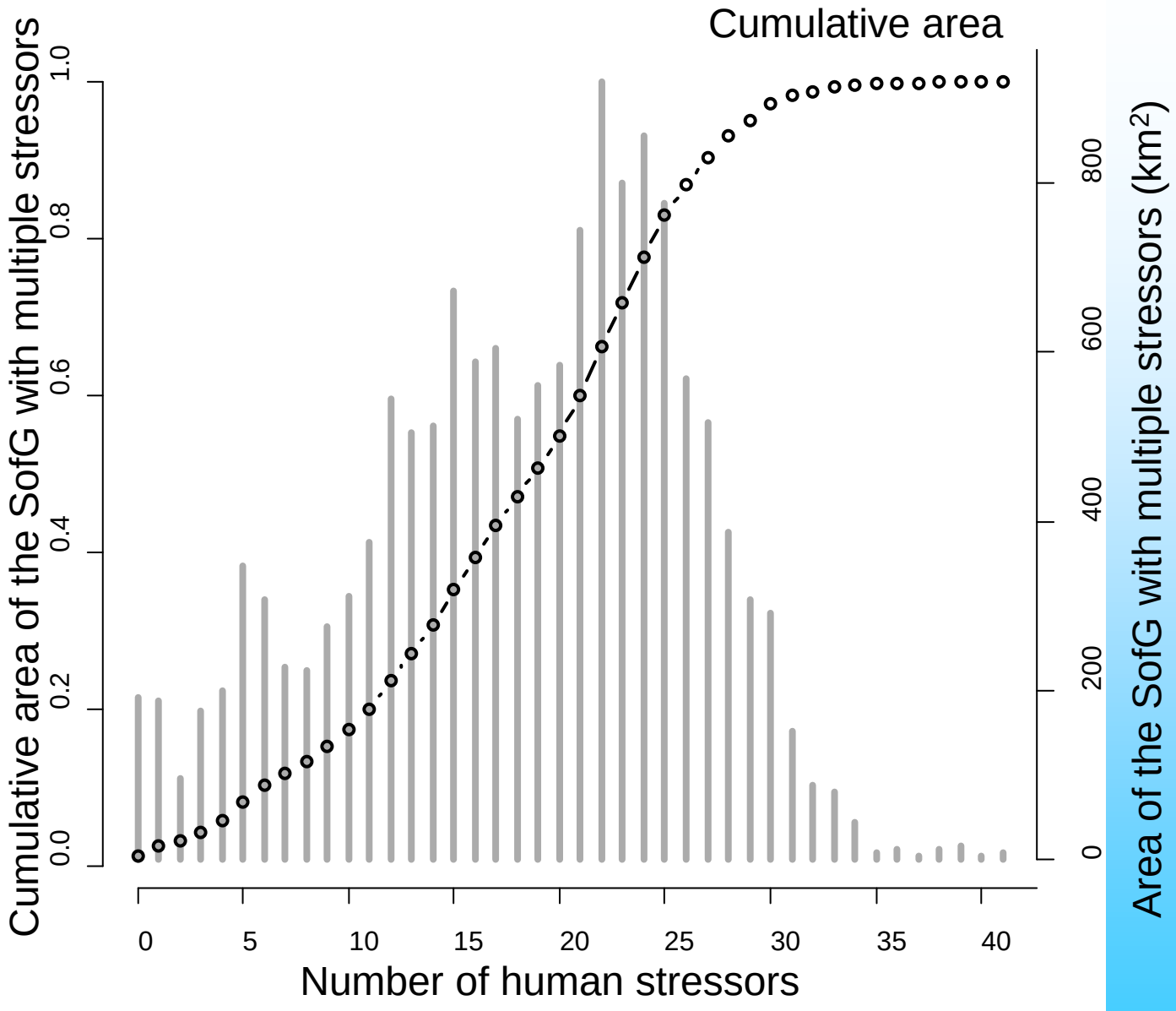
# Presentation Objectives

Provide an overview of progress by WG28 on two Terms of Reference:

1) review frameworks proposed and in use in the North Pacific for linking natural pressures and human activities to ecosystem responses; and

2) characterise multiple pressures and activities on North Pacific marine ecosystems
   - using literature, case studies approach (Bering Sea, Aleutian Islands, Strait of Georgia, Puget Sound, Monterey Bay, Seto Inland Sea, Kuroshio/Oyashio, East China Sea, Sea of Okhotsk)

# Multiple stressors in the North Pacific – Strait of Georgia, Canada

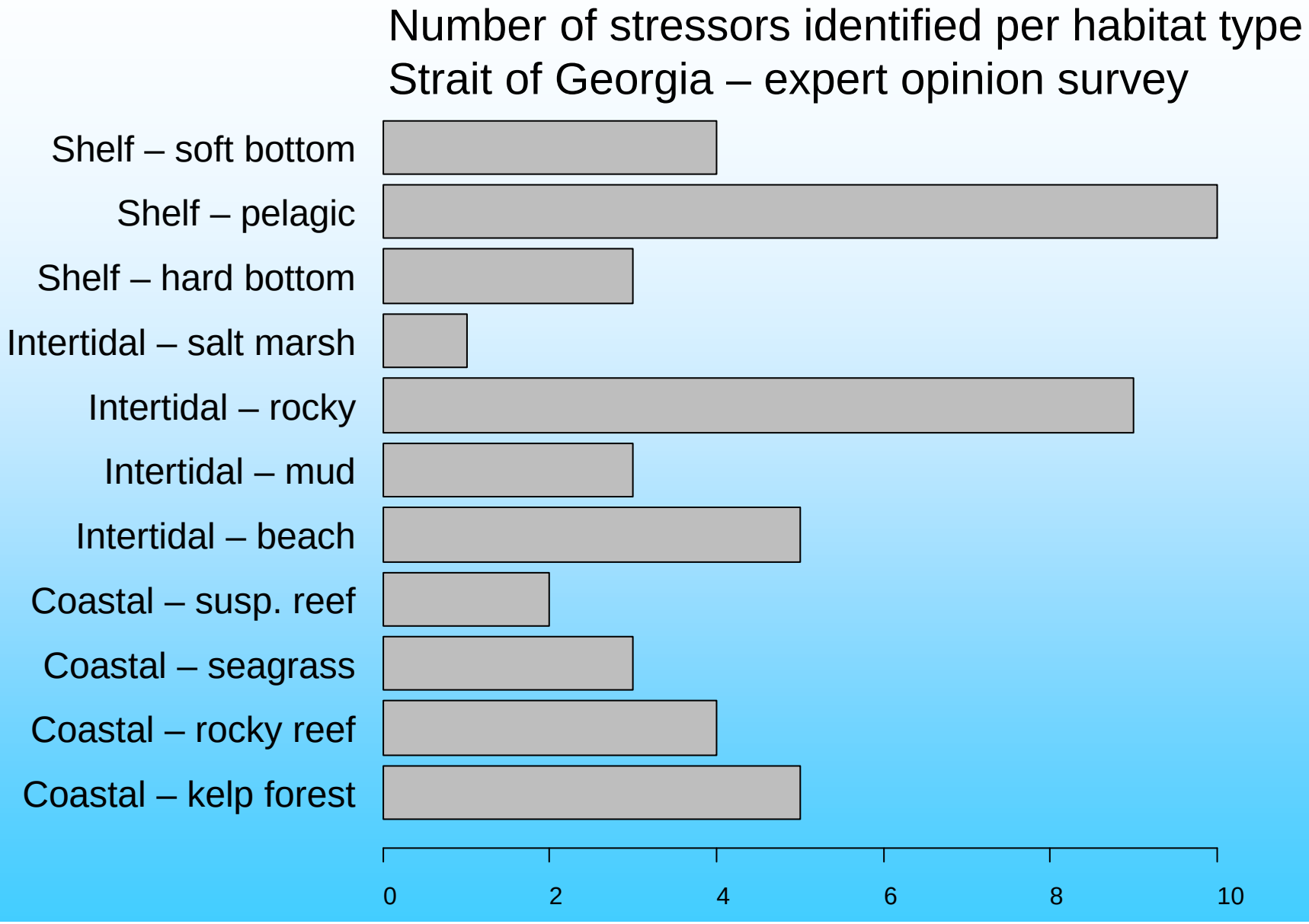



"Most common" number of stressors in any 4 $km^2$ spatial unit is 20-25;

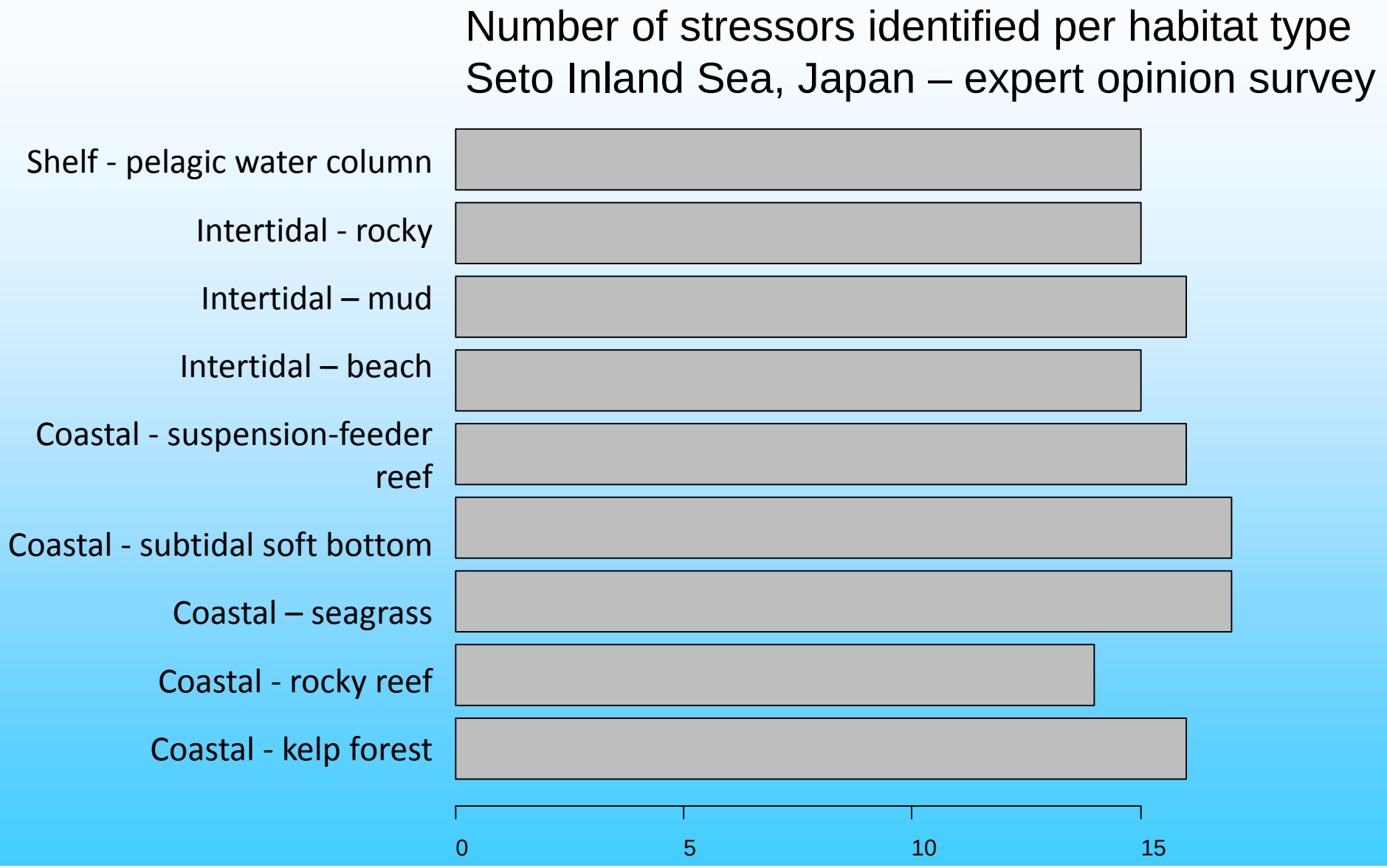
Relatively few spatial units have >30 stressors

Data courtesy of www.bcmca.org

# Multiple stressors in the North Pacific (20 stressors x 22 habitats)



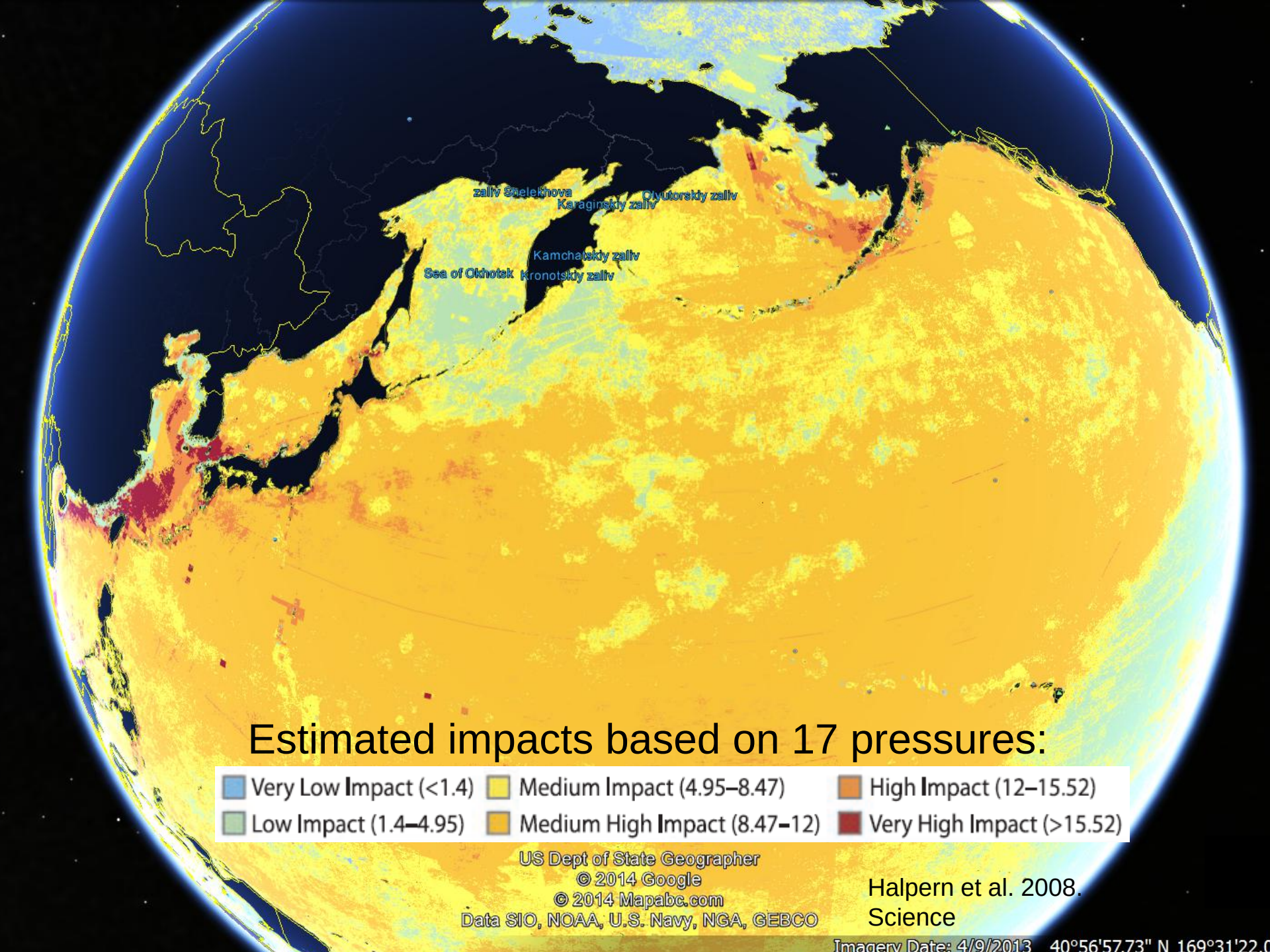
# Multiple stressors in the North Pacific (20 stressors x 22 habitats)



# Multiple stressors in the North Pacific

| | |
|---|---|
| **Land-based** | Nutrients (fertilizer)<br>Organic pollutants (pesticides)<br>Inorganic pollutants (impervious surfaces)<br>Direct human (population density) |
| **Ocean-based** | Oil rigs<br>Invasive species<br>Ocean pollution<br>Shipping |
| **Fishing** | Artisanal fishing<br>Pelagic, low-bycatch fishing<br>Pelagic, high-bycatch fishing<br>Demersal, destructive fishing<br>Demersal, non-destructive, low-bycatch fishing<br>Demersal, non-destructive, high-bycatch fishing |
| **Climate** | SST<br>UV<br>Ocean acidification |

Halpern et al. 2008 Science


zaliv Shelekhova
Karaginskiy zaliv
Olyutorskiy zaliv
Kamchatskiy zaliv
Sea of Okhotsk
Kronotskiy zaliv
Estimated impacts based on 17 pressures:
Very Low Impact (<1.4)
Low Impact (1.4–4.95)
Medium Impact (4.95–8.47)
Medium High Impact (8.47–12)
High Impact (12–15.52)
Very High Impact (>15.52)
US Dept of State Geographer
© 2014 Google
© 2014 Mapabc.com
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Halpern et al. 2008. Science
Imagery Date: 4/9/2013 40°56'57.73" N 169°31'22.0

# Multiple stressors in the North Pacific

California Current region (Teck et al. 2010)

Relative vulnerability of 19 marine ecosystems to 53 stressors associated with human activities, based on surveys of 107 experts.

**Highest stressor rankings**

Coastal ecosystems:

- invasive species,
- ocean acidification,
- sea temperature change,
- sea level rise,
- habitat alteration

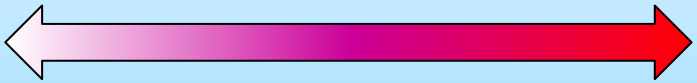
Offshore ecosystems:

- ocean acidification,
- demersal destructive fishing,
- shipwrecks

# Multiple stressors in the North Pacific

Working Group 28:
20 stressor x 22 habitat combinations rated on estimates of:

- **spatial scale of interaction**,
- **frequency of disturbance**,
- **trophic levels impacted**,
- **resistance to change**,
- **recovery time**

Weak  Strong

| Feature | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| Spatial scale | < 10 $km^2$ | 10-100 $km^2$ | 100-1000 $km^2$ | > 1000 $km^2$ |
| Frequency | > 5 yrs | 1-5 yrs | Seasonal | Continuous |
| Trophic level | Species | Single trophic | Multitrophic | Community |
| Resistance | Positive impact | High | Moderate | Low |
| Recovery time | < 1 yr | 1-10 yrs | 10-100 yrs | > 100 yrs |

# Multiple stressors in the North Pacific

Following Samhouri and Levin (2012) [and others], define “Risk” as a function of ‘Sensitivity’ and ‘Exposure’:

Vulnerability or Exposure (E) = average scores of

**Spatial scale**,
**Frequency of occurrence**,
**Trophic level**

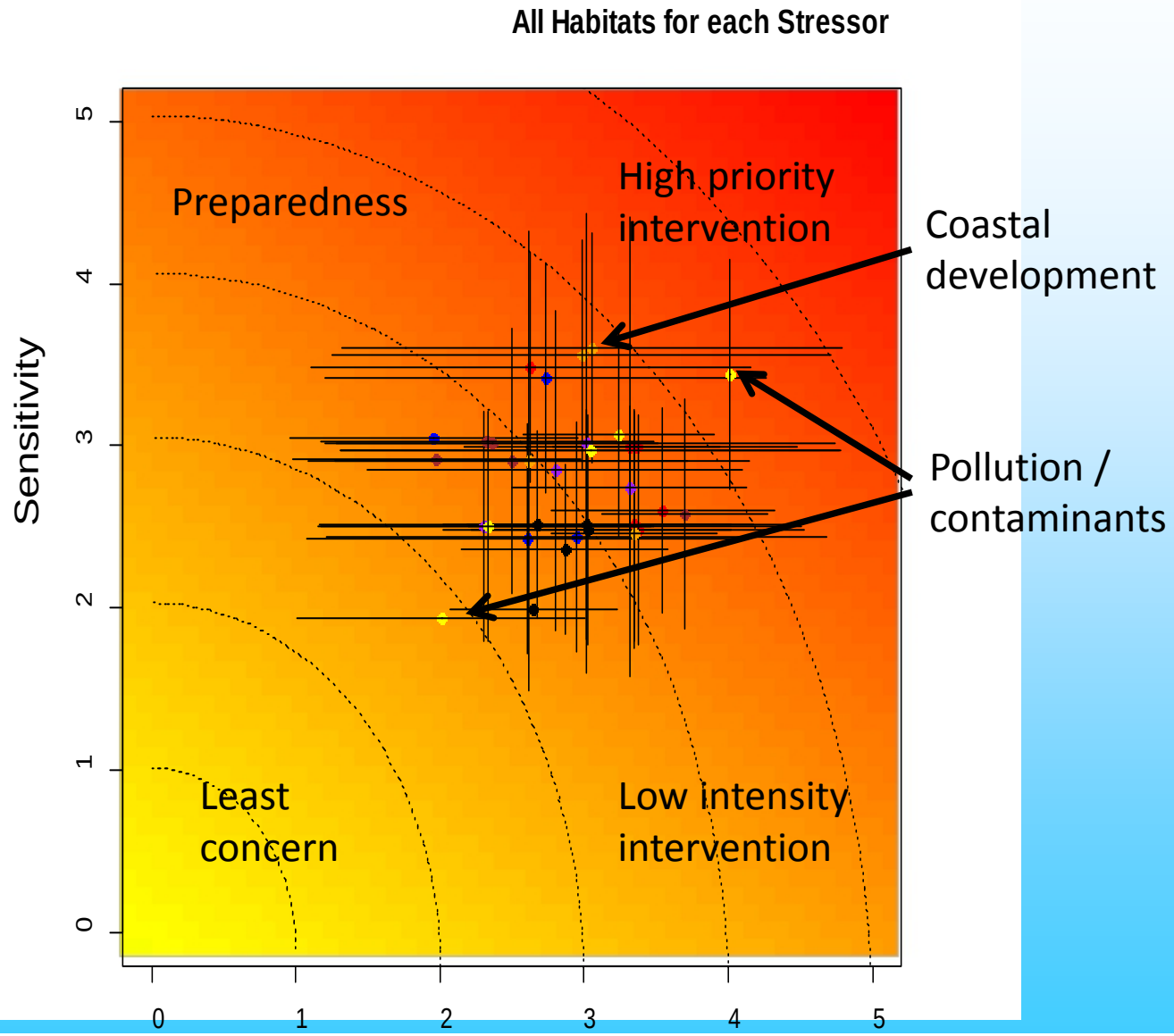
Resilience or Sensitivity (S) = average scores of

**Resistance to change**
**Recovery time**

Risk score (for Stressor *i* on Habitat *j*) $= \sqrt{(E-1)^2 + (S-1)^2}$

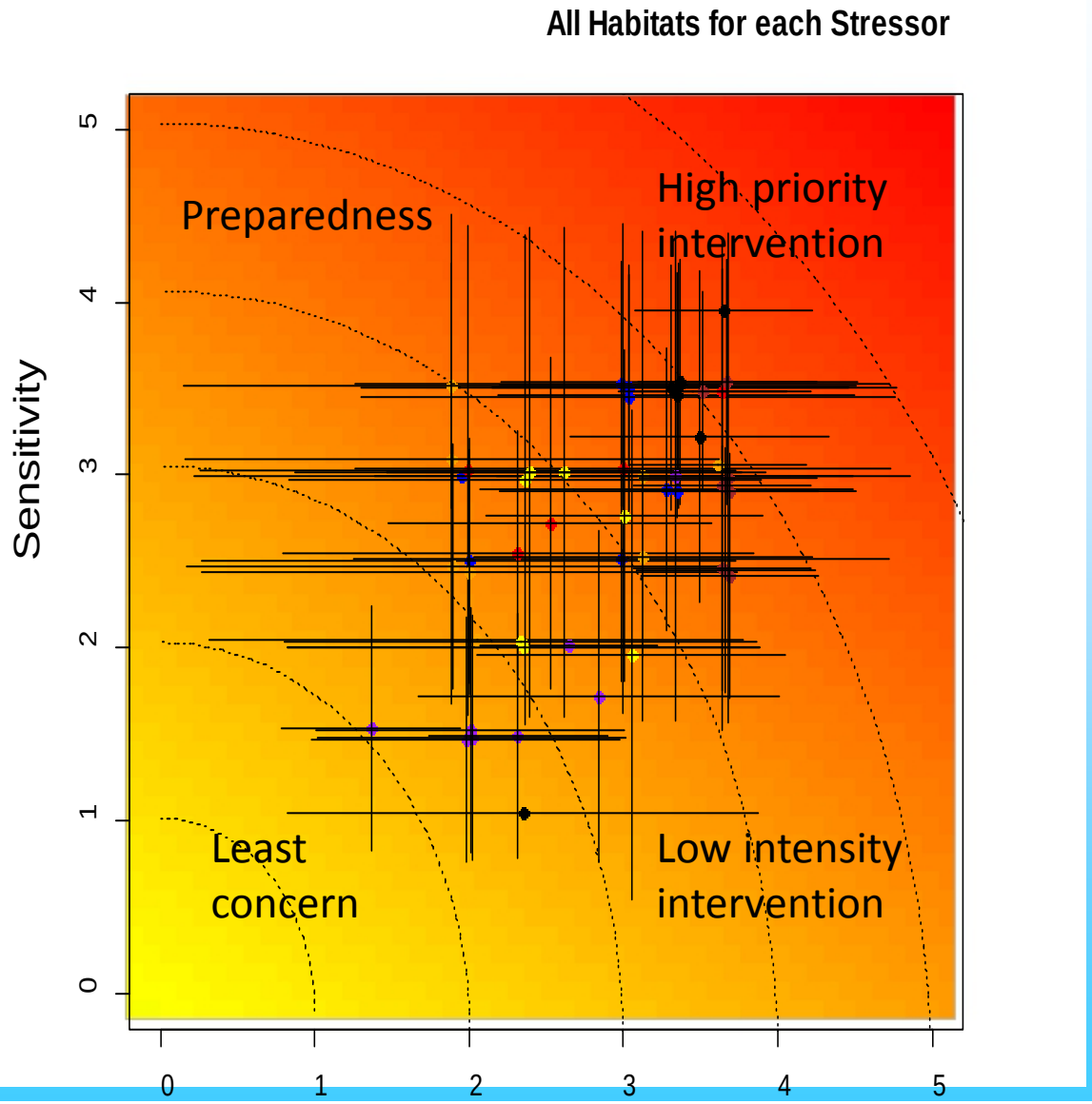
# Multiple stressors in the North Pacific – Strait of Georgia, Canada

20 stressors x
22 habitats



# Multiple stressors in the North Pacific – Seto Inland Sea, Japan

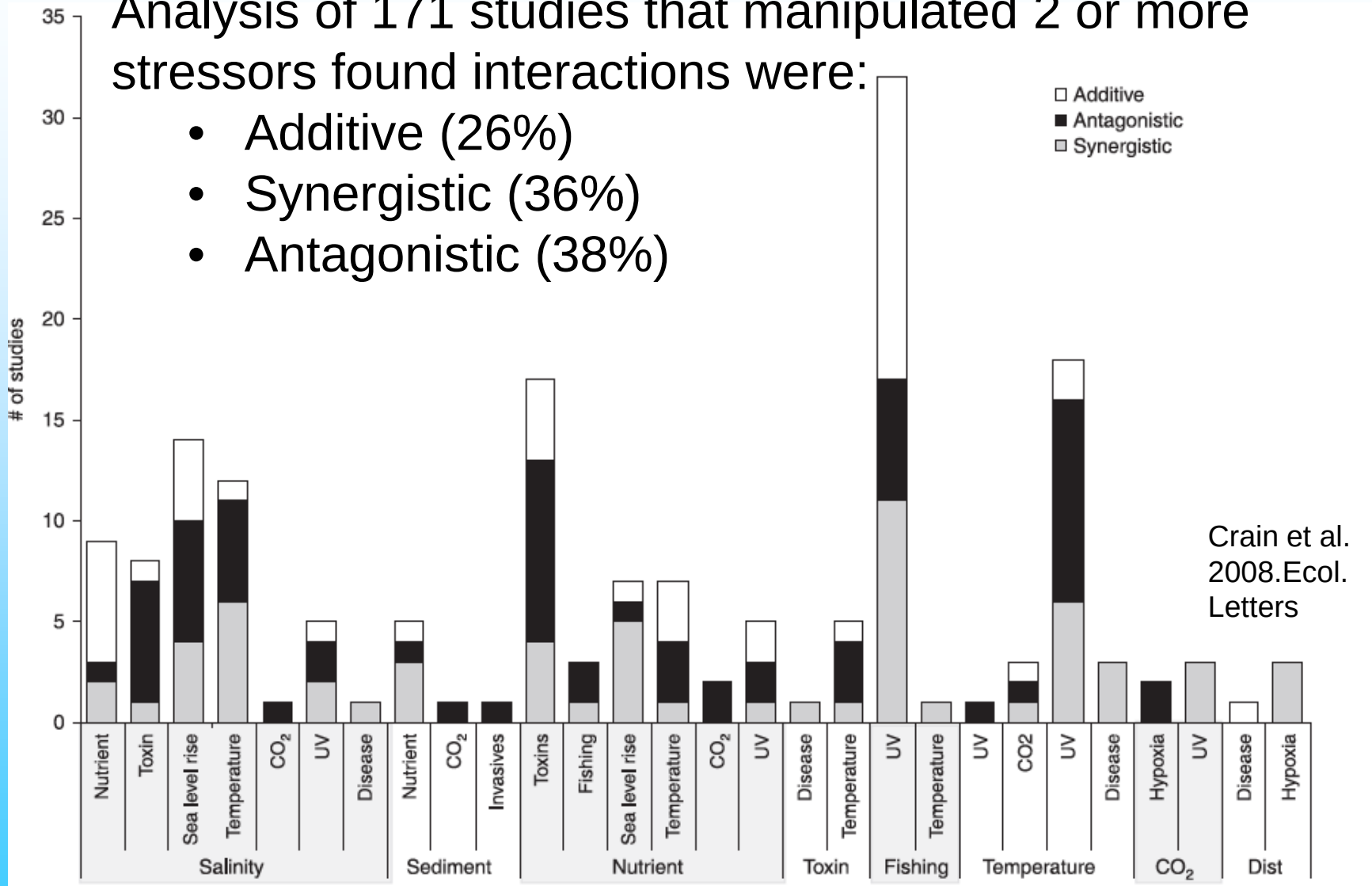
20 stressors x
22 habitats



# Multiple stressors in the North Pacific – “Reality Check”

Analysis of 171 studies that manipulated 2 or more stressors found interactions were:

- Additive (26%)
- Synergistic (36%)
- Antagonistic (38%)




Crain et al. 2008.Ecol. Letters

# Multiple stressors in the North Pacific - Conclusions

## Frameworks

- Several frameworks address cumulative impact issues on different scales
- in different stages of development

## Multiple stressors

- Multiple stressors are common; single stressors are rare
- To date considered potential impacts of ~20-50 stressors on ~20 ecosystem types (shoreline to deep ocean)
- More stressors, and greater impacts, in coastal than offshore areas
- Beginning to understand issues of sensitivity and exposure – more to do
- Important stressors at smaller scales also important at larger scales; reverse not necessarily true.
- Interactions of multiple stressors may be additive, synergistic, antagonistic
- Goal: To identify cumulative impact thresholds and relevant indicators to assist marine management with regulation of human activities

  (Halpern and Fujita. 2013. Ecosphere)