ARC Centre of Excellence
Coral Reef Studies

Combining stressor information:

Experiences from Canada's Pacific waters and Australia's Great Barrier Reef

By **Natalie Ban**, Stephen Ban, and Hussein Alidina

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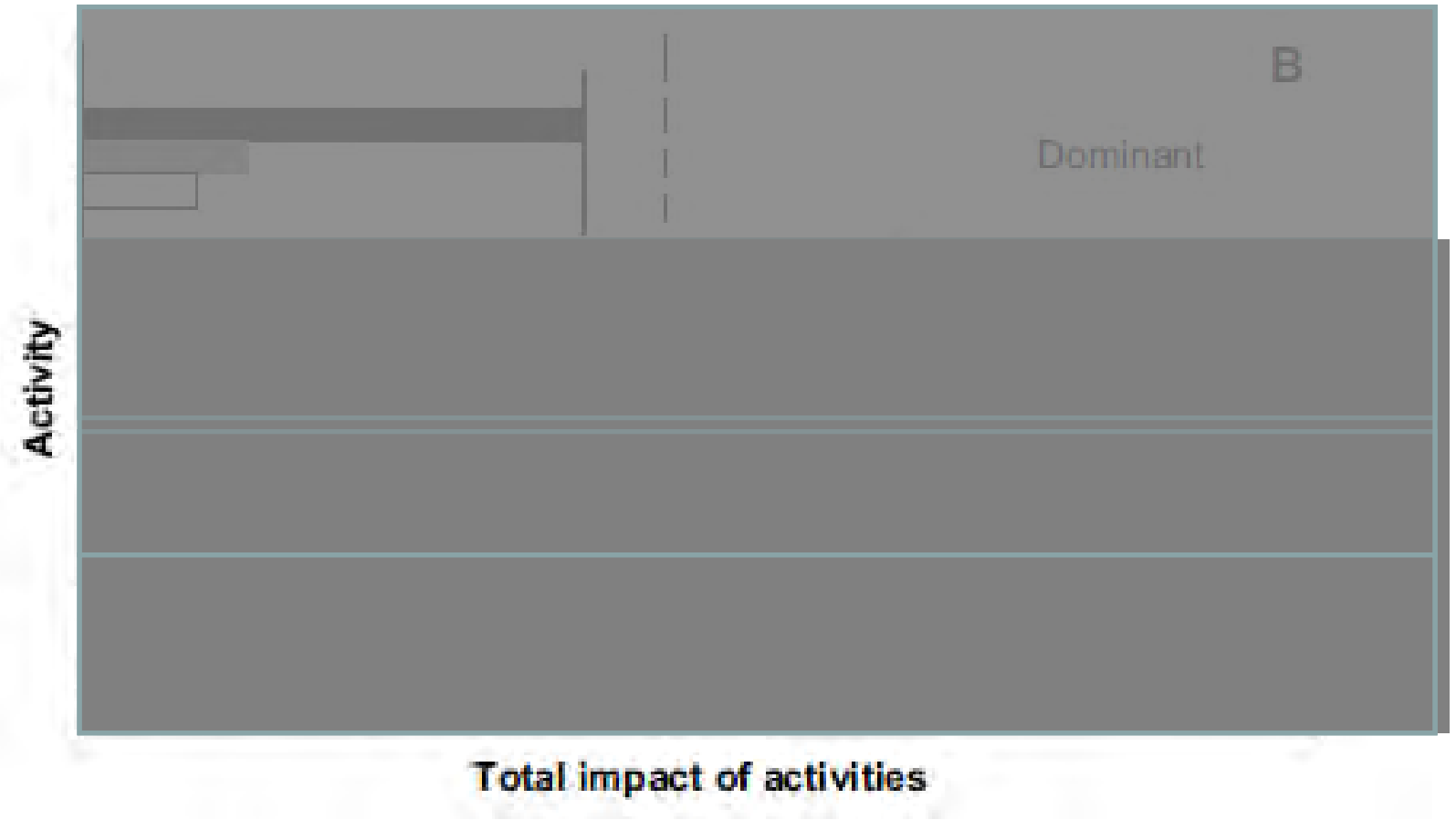
www.coralcoe.org.au

Multiple stressors

- Global concern about multiple stressors
- Little information about how multiple stressors interact
- Yet a lot of interest in characterizing and mapping multiple stressor interactions
- How do we make the best of existing knowledge to characterize and map multiple stressors?

Stressor Interactions



Halpern et al., 2008

What approaches can be used to analyze and combine multiple stressors?

1. Data-based: Meta-analysis
2. Expert-based
3. Combined 1&2, spatial: Regional mapping, GIS approaches
4. Experimental
5. Model-based

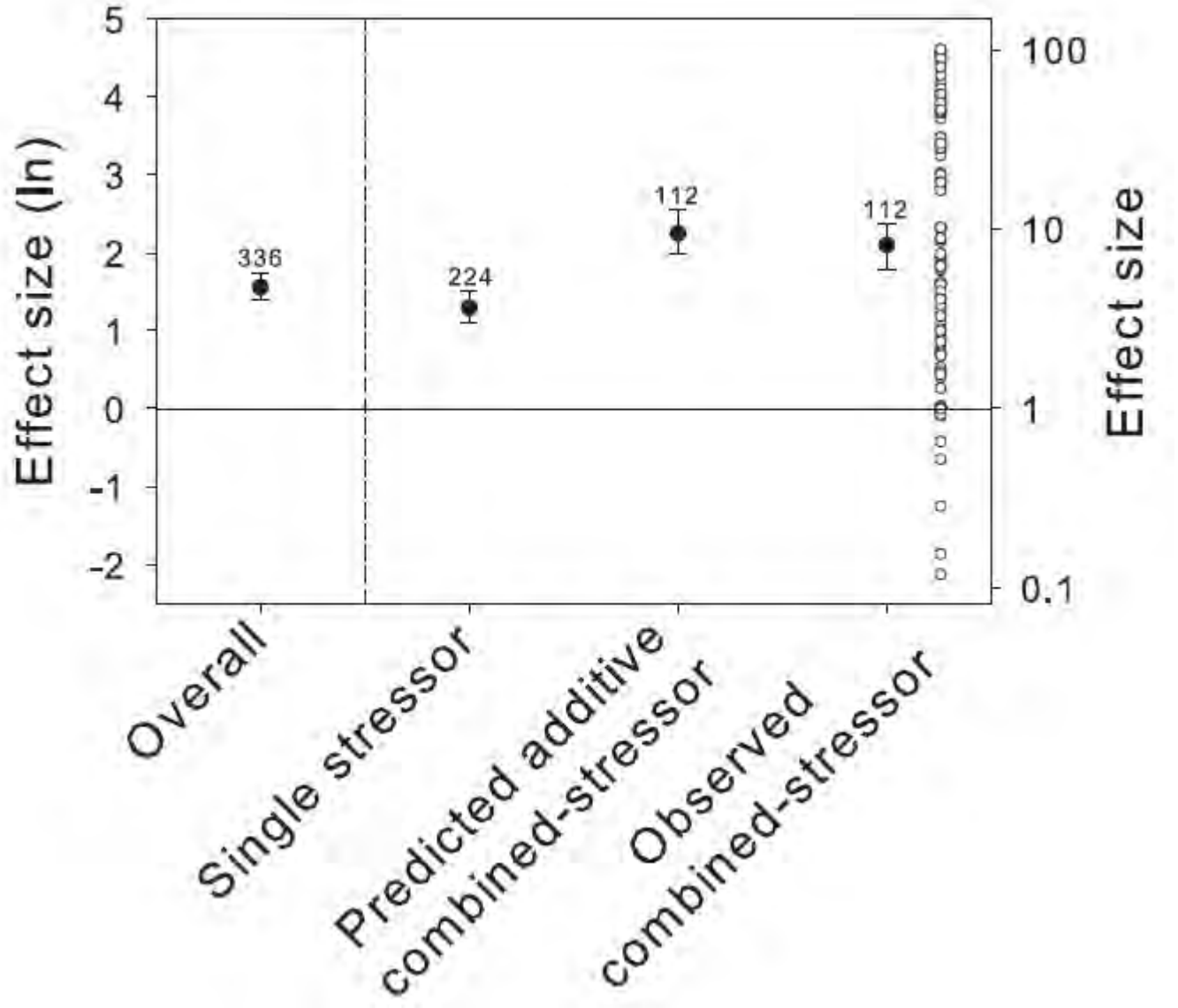
1. Meta-analysis approach

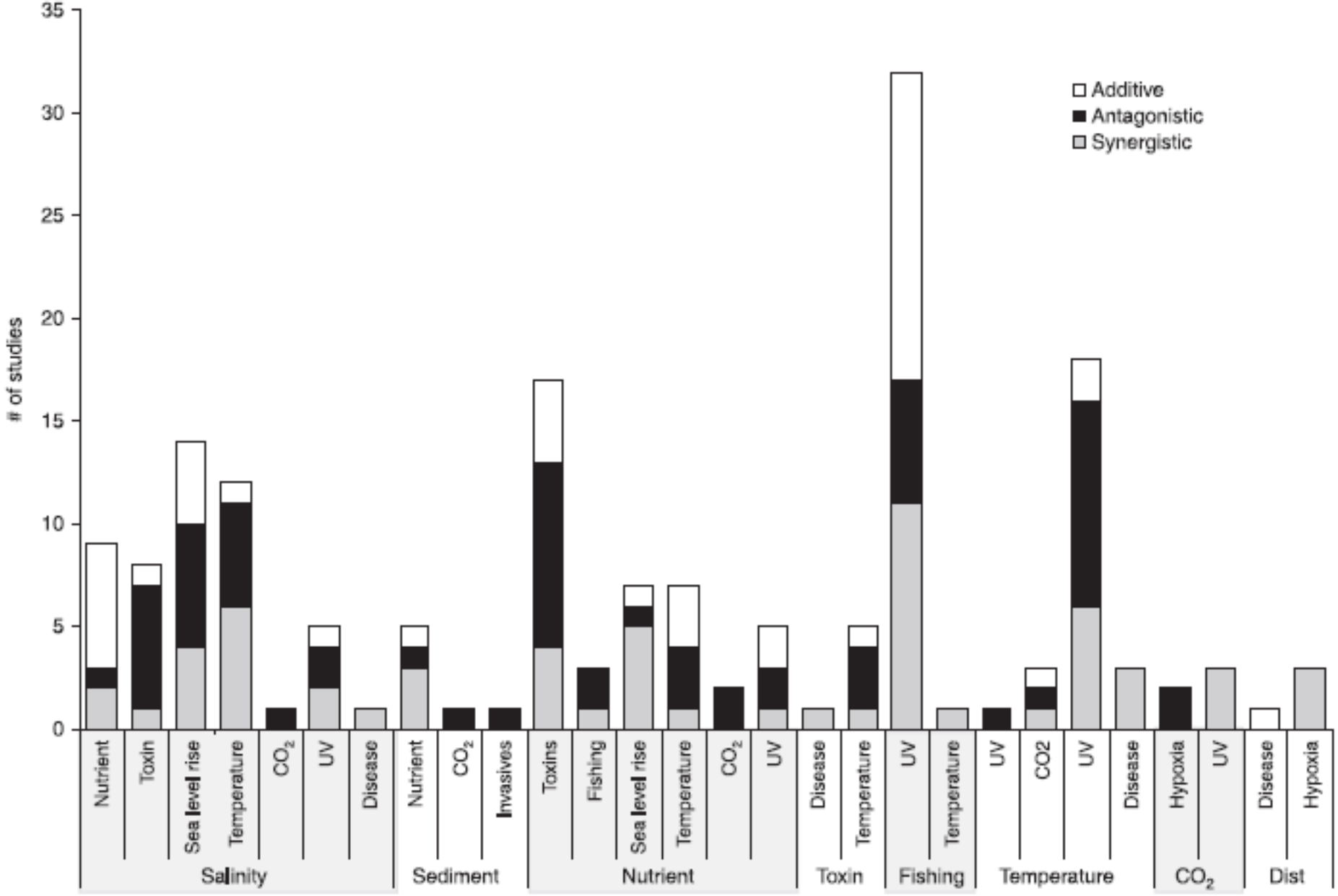
- Uses published studies
- Calculates effect sizes to combine and compare studies
  - Requires studies to have sufficient information
- Needs definition of what stressors are acting on (i.e., response variable, such as coral mortality)

Examples of meta-analyses

Darling & Cote 2

- Impacts of mu
  mortality in fre
  terrestrial com
- N=112 publish




35
30
25
20
15
10
5
0
# of studies
Additive
Antagonistic
Synergistic
Nutrient
Toxin
Sea level rise
Temperature
CO2
UV
Disease
Nutrient
CO2
Invasives
Toxins
Fishing
Sea level rise
Temperature
CO2
UV
Disease
Temperature
UV
Temperature
UV
CO2
UV
Disease
Hypoxia
UV
Disease
Hypoxia
Salinity
Sediment
Nutrient
Toxin
Fishing
Temperature
CO2
Dist

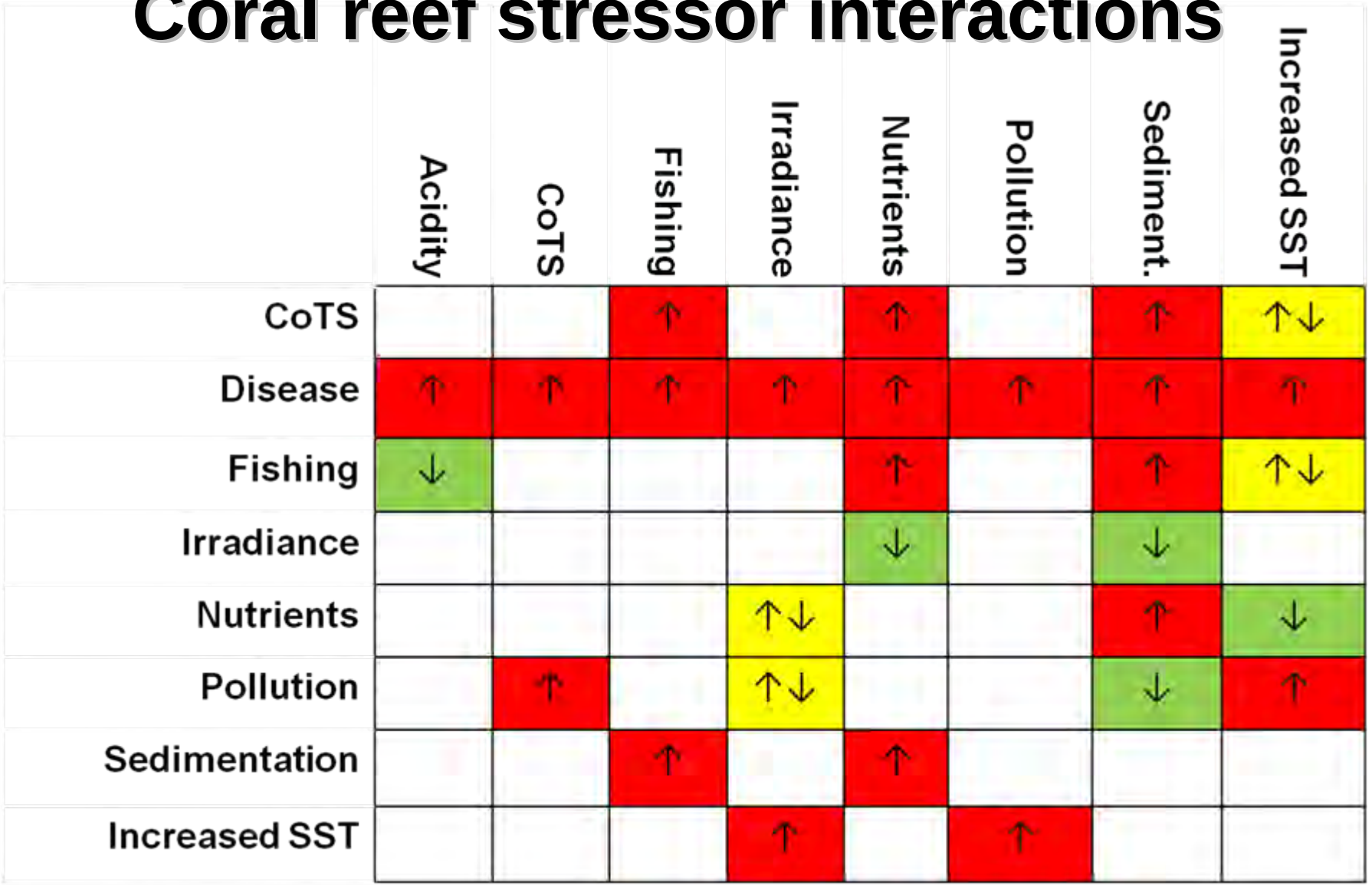
Examples of meta-analyses: Coral reefs (in prep)

- Concern about impact of multiple stressors on coral reefs
- Key stressors:
  - Acidification
  - Coral bleaching
  - Crown-of-thorns seastar outbreaks
  - Cyclones
  - Disease
  - Irradiance
  - Nutrient loading
  - Increased water temperature

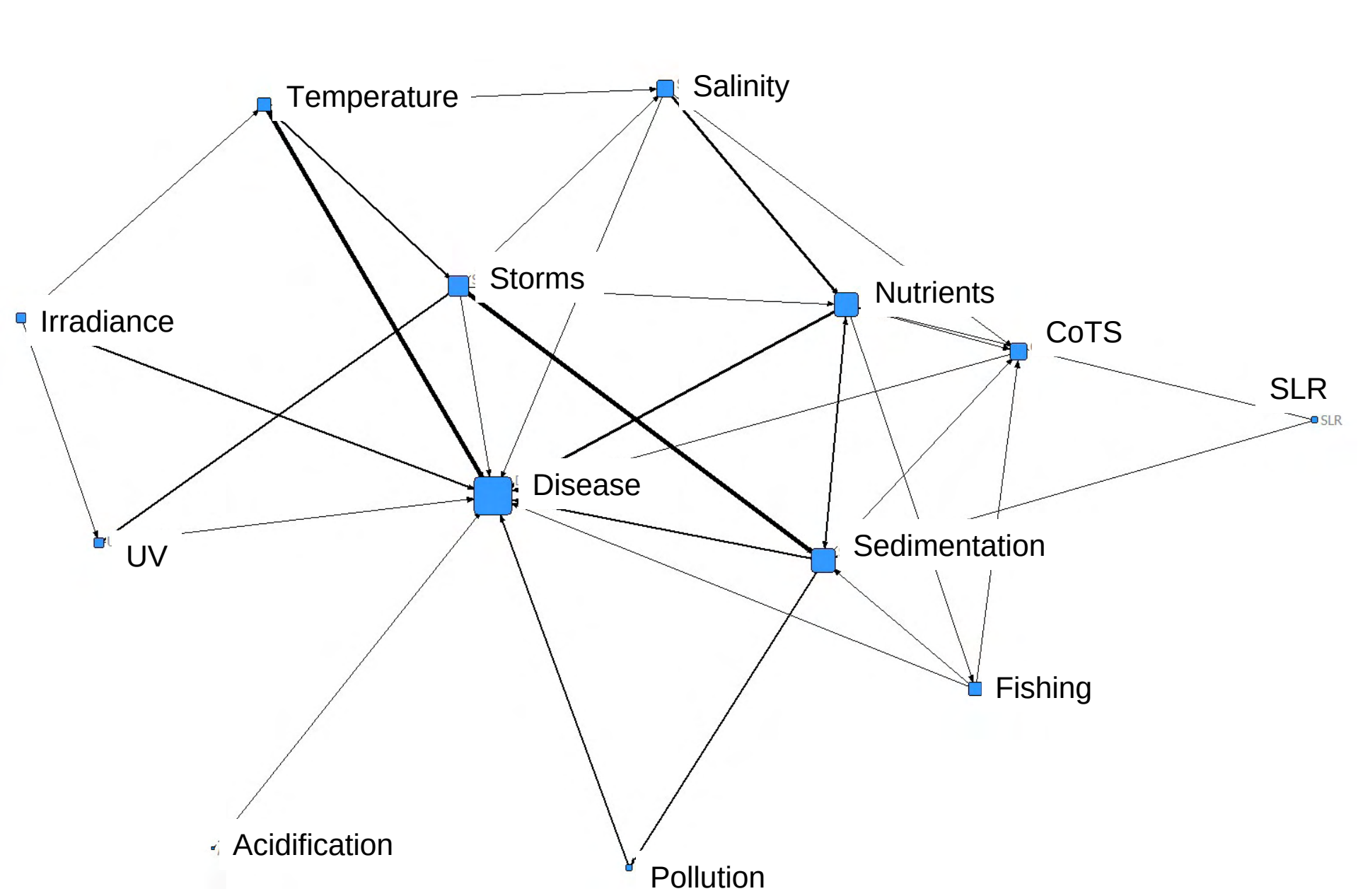
Examples of meta-analyses: Coral reefs (in prep)

- Literature review to identify studies to assess interactions
  - Studies with keywords: n=3500
  - Studies with qualitative data that examined at least two stressors: n=330

Qualitative Data:
Coral reef stressor interactions



S. Ban et al. In Prep

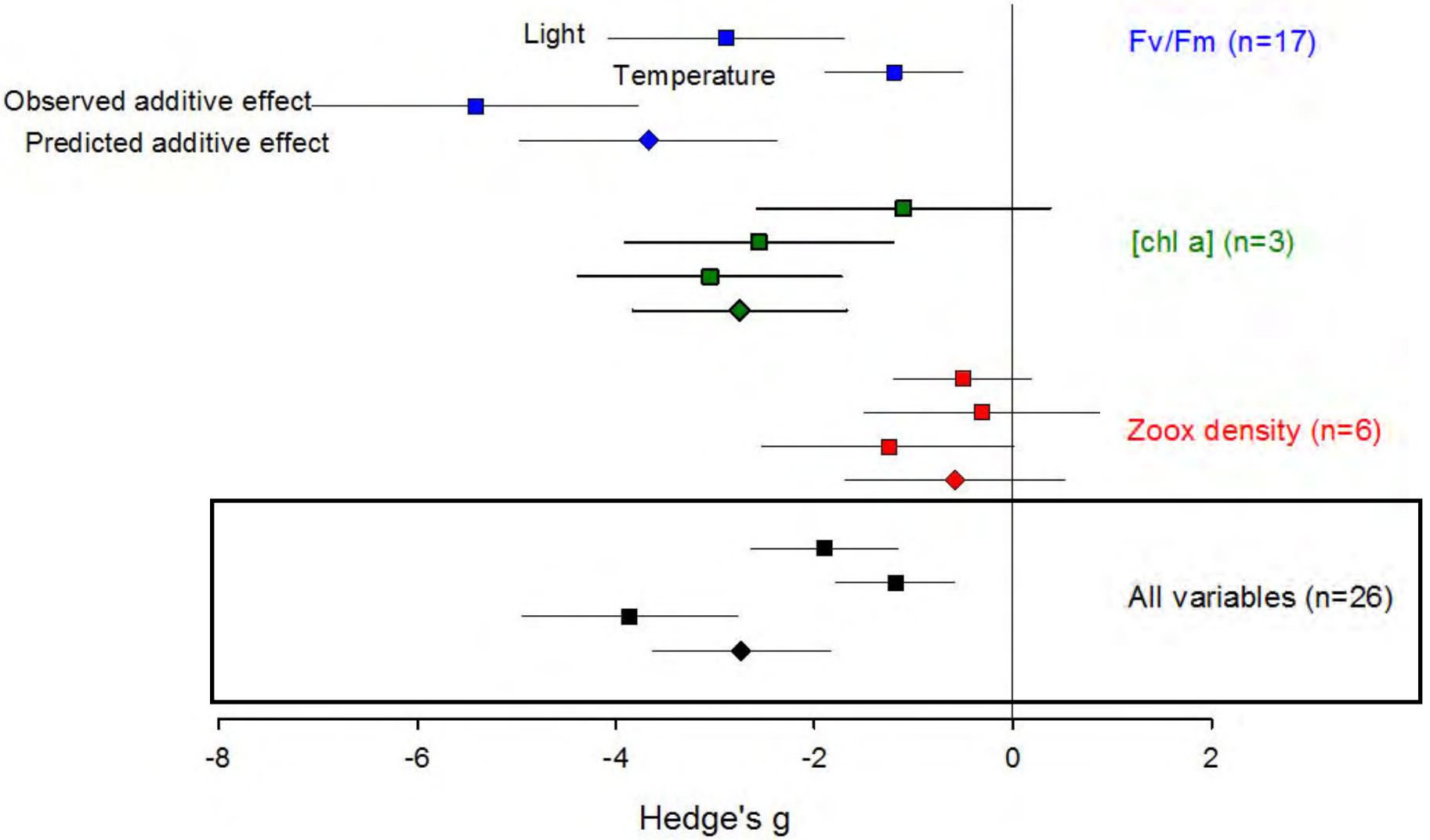


S. Ban et al. In Prep

Examples of meta-analyses: Coral reefs (in prep)

- Literature review to identify studies to assess interactions
  - Studies with keywords: n=3500
  - Studies with qualitative data that examined at least two stressors: n=330
  - Studies of sufficient detail and quality for meta-analysis: n=130
  - Two stressor interaction with common response variable, with enough studies to do meta-analysis: Light and temperature interaction on photosynthesis (n=26)

Light and temp. effect on photosynthesis



Meta-analysis summary

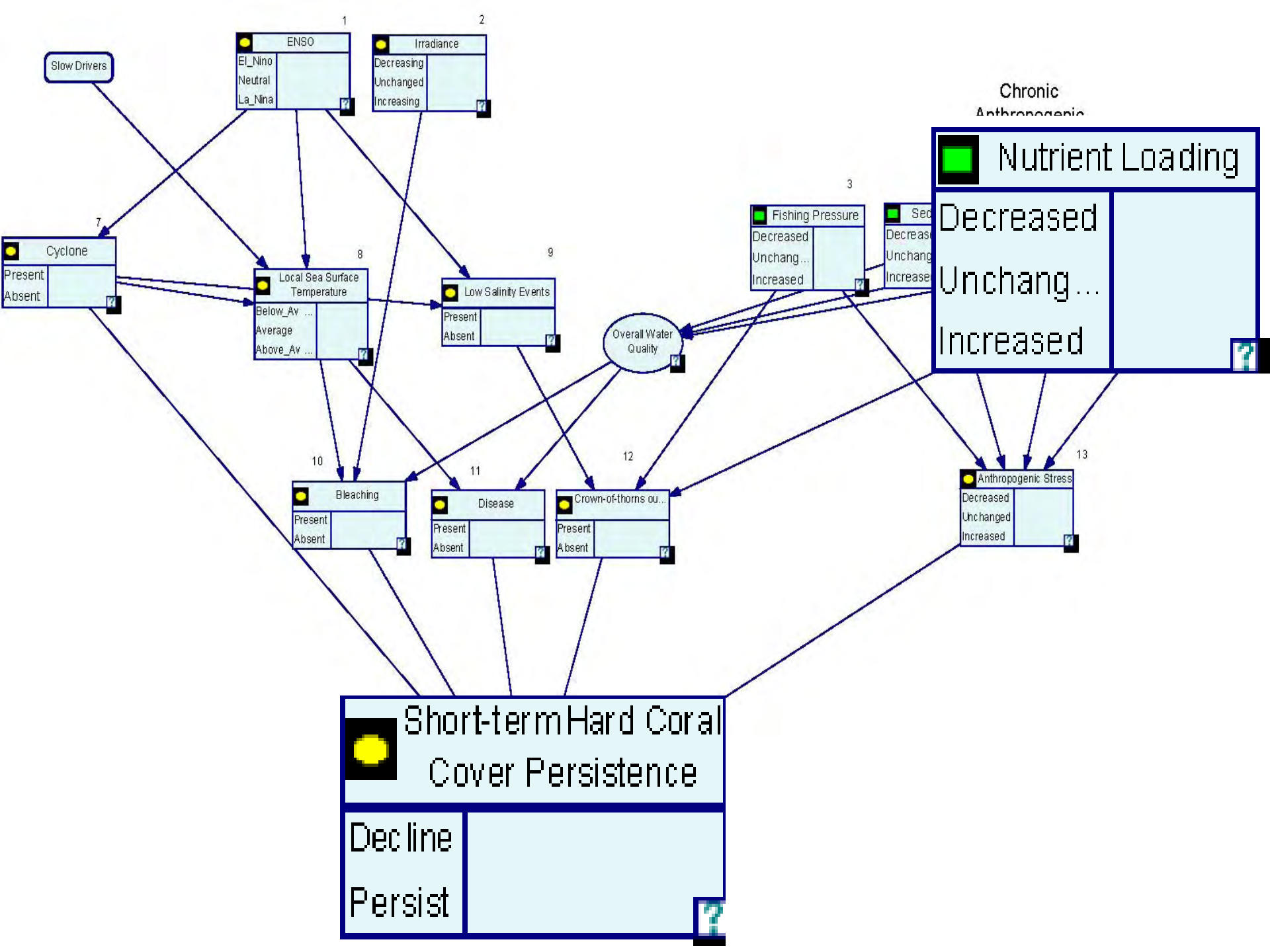
- Great way to summarize interactions if enough quantitative studies exist
- In reality, limited by paucity of studies

2. Expert-based elicitation

- A way forward when meta-analysis not possible
- Asks experts to give their best estimate of how stressors interact
- Different approaches of elicitation
- Bayesian approaches accounts for uncertainty
- Builds on research into how to best ask experts for information (e.g., Mark Burgman)

Bayesian Belief and Decision Networks

- Bayesian methods:
  - Incorporate prior beliefs/knowledge
  - Make probabilistic predictions about the state of the world
- BBNs are a decision-support tool
  - A BBN is a way of conceptualizing a system to be studied/managed
  - Does not require specialist skills; the users are the designers
  - Outputs are readily interpretable by laypeople
  - Designed to incorporate uncertainty


Slow Drivers
1
ENSO
El_Nino
Neutral
La_Nina
2
Irradiance
Decreasing
Unchanged
Increasing
Chronic
Nutrient Loading
Decreased
Unchang...
Increased
3
Fishing Pressure
Decreased
Unchang...
Increased
7
Cyclone
Present
Absent
8
Local Sea Surface Temperature
Below_Av ...
Average
Above_Av ...
9
Low Salinity Events
Present
Absent
Overall Water Quality
10
Bleaching
Present
Absent
11
Disease
Present
Absent
12
Crown-of-thorns ou...
Present
Absent
13
Anthropogenic Stress
Decreased
Unchanged
Increased
Short-term Hard Coral Cover Persistence
Decline
Persist

4-step question format

1. Realistically, what do you think the lowest plausible value is?

2. Realistically, what do you think the highest plausible value is?

3. Realistically, what is your best estimate?

4. How confident are you that the interval you created, from lowest to highest, could capture the true value? Enter a number between 50 and 100%

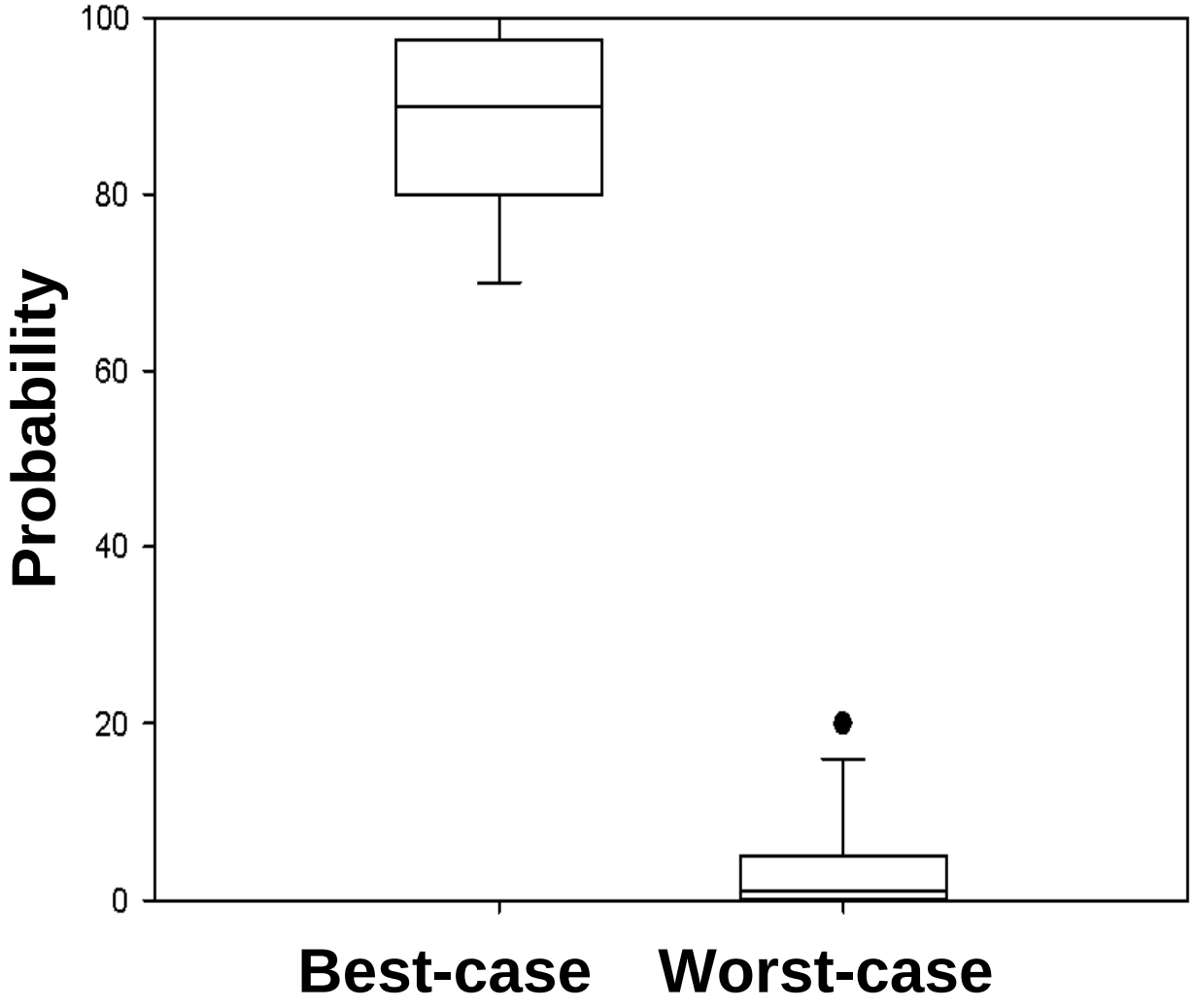
Speirs-Bridge et al., 2010

Scenarios, Great Barrier Reef

	Cyclones	CoTS	Bleaching	Disease	Anthrop. Stress
Best-Case					
Worst-Case					

S. Ban et al. In Prep

Results of best- and worst-case scenarios



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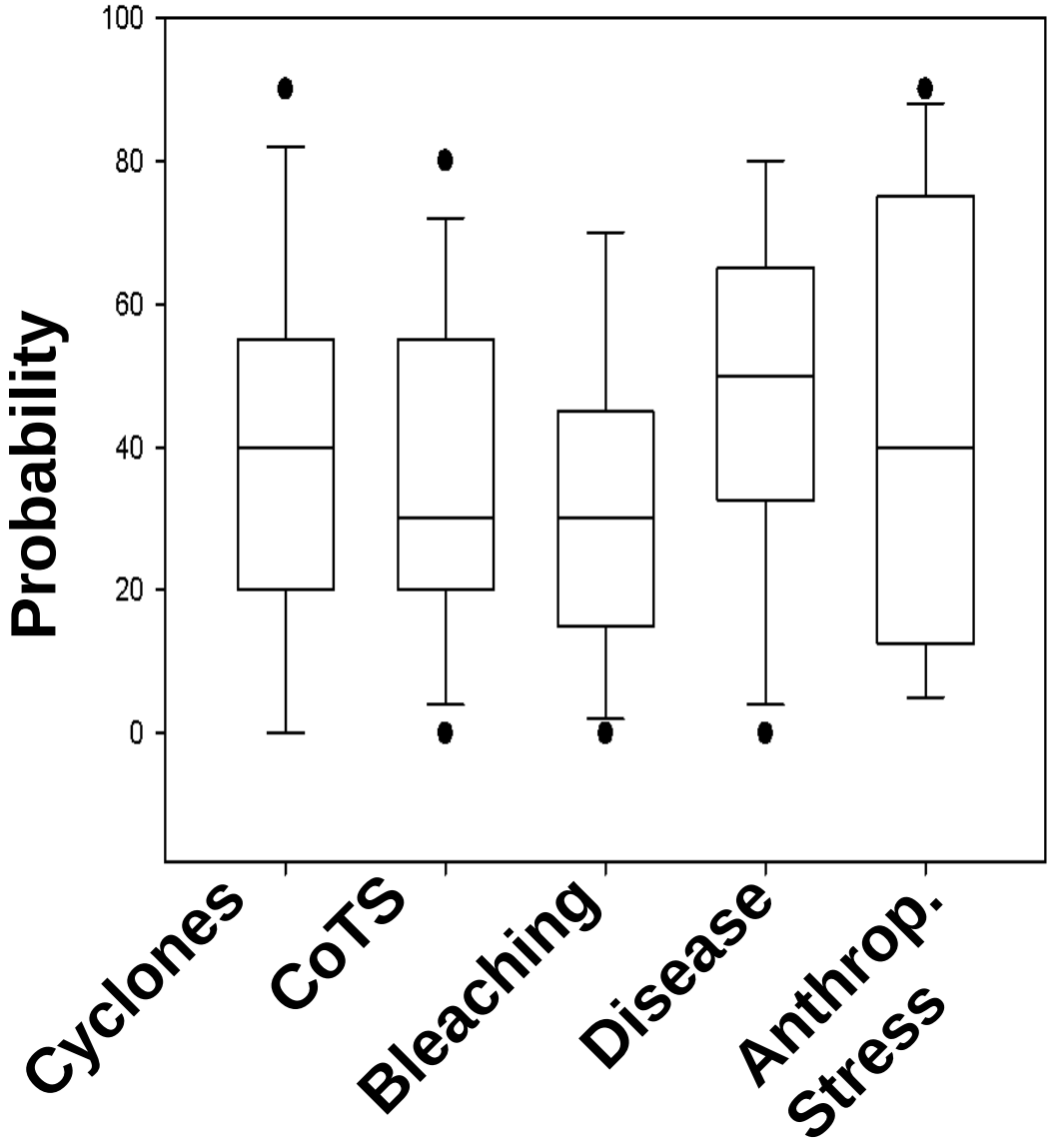
Results of other scenarios



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Expert elicitation summary

- Increasingly popular to fill gaps in knowledge about multiple stressors
- Relatively quick
- But results cannot be verified unless empirical data are gathered

3. Combined data- and expert-based approach

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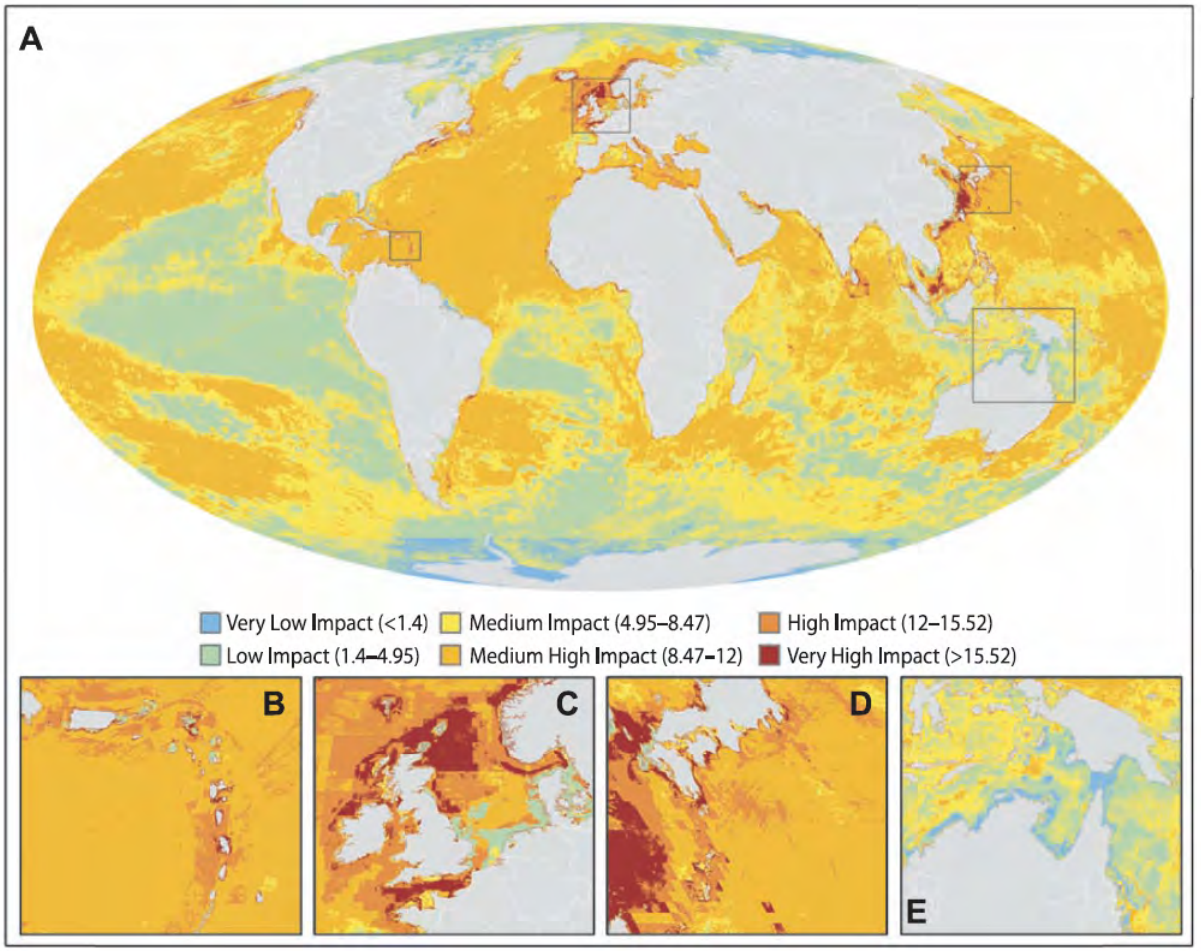
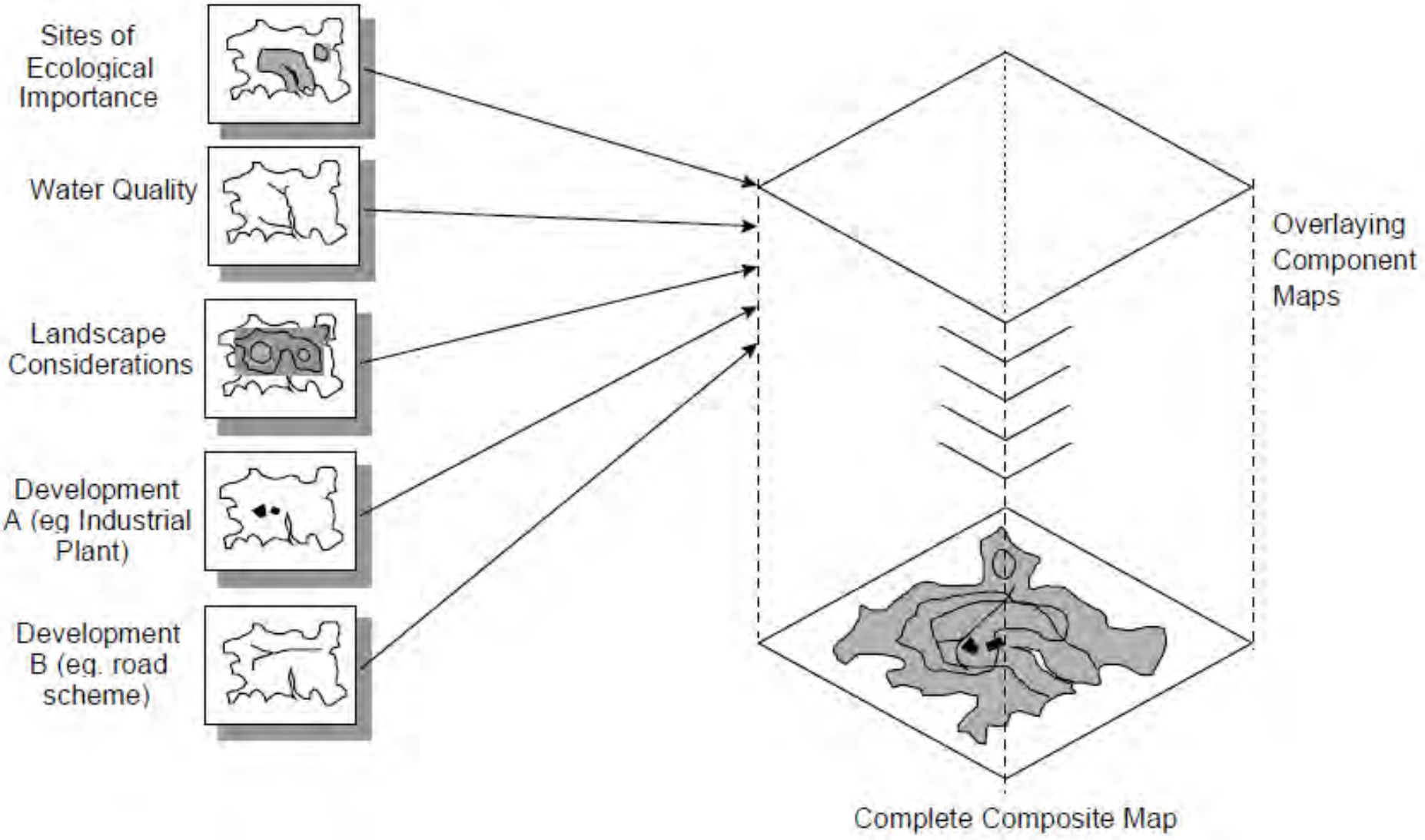


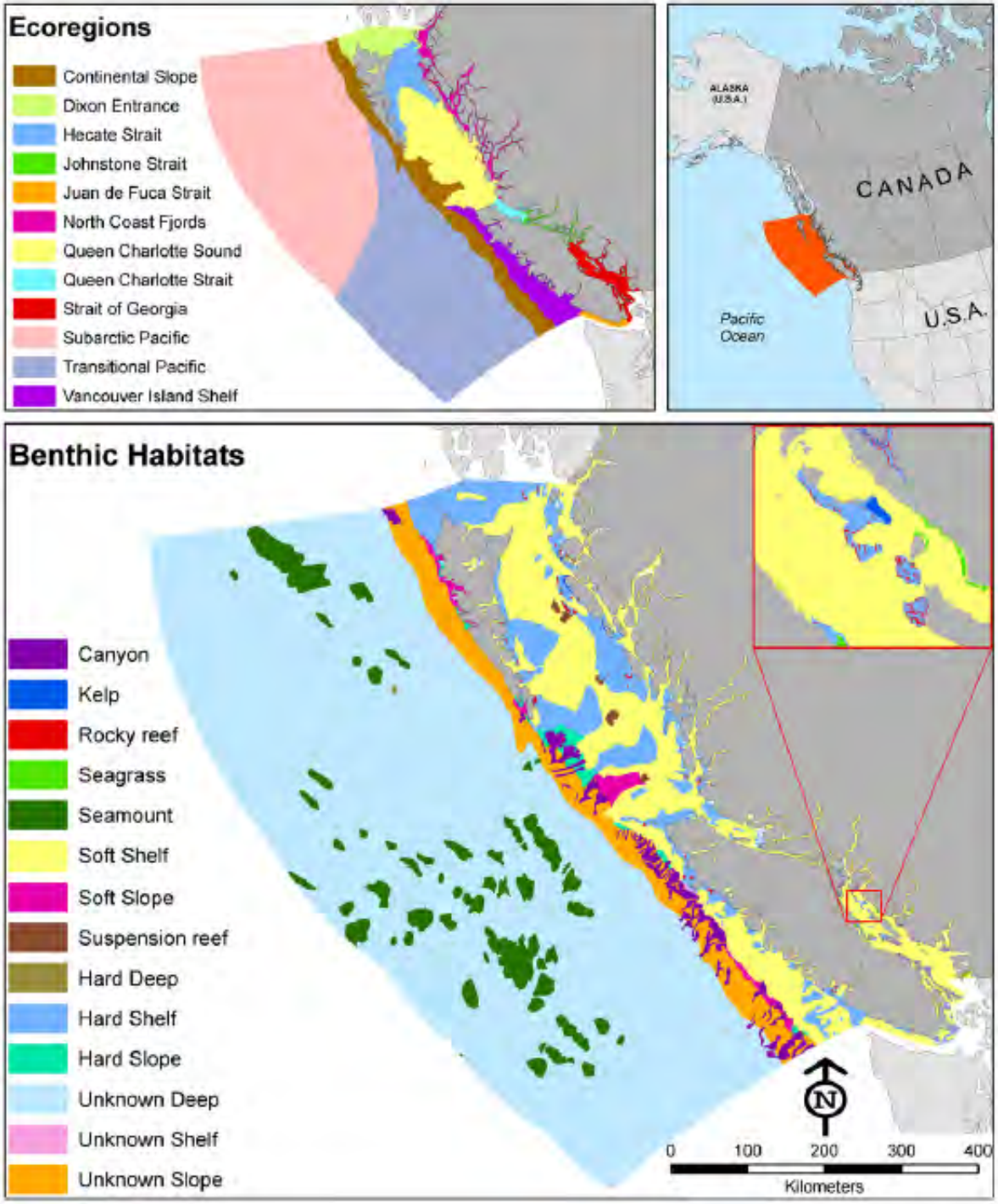
Halpern et al 2008

Using GIS to map cumulative impacts



Canada Pacific example: Methods

- Methods and data from other studies (Halpern et al 2008, Ban and Alder 2008)
- Four types of information needed:
  1. Locations of activities, and intensities if known (spatial data)
  2. Stressors resulting from these activities (literature)
  3. How vulnerable habitats are to those impacts (expert)
  4. How far the impacts are felt (literature)


Ecoregions
Continental Slope
Dixon Entrance
Hecate Strait
Johnstone Strait
Juan de Fuca Strait
North Coast Fjords
Queen Charlotte Sound
Queen Charlotte Strait
Strait of Georgia
Subarctic Pacific
Transitional Pacific
Vancouver Island Shelf
ALASKA (U.S.A.)
CANADA
U.S.A.
Pacific Ocean
Benthic Habitats
Canyon
Kelp
Rocky reef
Seagrass
Seamount
Soft Shelf
Soft Slope
Suspension reef
Hard Deep
Hard Shelf
Hard Slope
Unknown Deep
Unknown Shelf
Unknown Slope
N
0
100
200
300
400
Kilometers

Methods: mapping steps

(a) Assemble Spatial Information on use and Intensities

(b) Identify key stressors resulting from these activities

(c) Determine the distance to which individual activities have an impact from their point of its occurrence.

(d) Apply a sensitivity score that translates the relative impact of different activities on benthic (12 broad types), shallow pelagic (surface), and deep pelagic habitats.

(e) Model a spatially explicit impact score for each activity-habitat combination based on (a), (b), (c), and (d) above.

(f) Calculate the cumulative impact of activities – the cumulative impacts is the additive (summed) impacts of all activities over the different habitat types in which they occur.

Commercial Fishing	Recreational Fishing	Land-based
1. Groundfish Bottom Trawling 2. Groundfish ZN 3. Schedule II 4. Sablefish Trap 5. Sablefish Longline 6. Prawn Trap 7. Shrimp Trawl 8. Crab Trap 9. Red urchin Dive 10. Green urchin Dive 11. Commercial sea cucumber Dive 12. Commercial krill Net 13. Commercial geoduck Dive 14. Commercial scallop Dive/Net 15. Commercial salmon Troll 16. Commercial salmon Net 17. Commercial squid Net 18. Commercial octopus Dive 19. Commercial herring Net 20. Commercial herring roe Net 21. Commercial gooseneck barnacle Intertidal 22. Commercial dogfish Hook and Line	23. Recreational trap fishing (crab and prawn) 24. Recreational diving (dive, diving, scallops) 25. Recreational fishing – unspecified (probably mostly hook and line fishing) **Marine Tourism** 26. Dive sites 27. Kayak routes 28. Motorized boating 29. Fishing and other floating lodges **Aquaculture** 30. Finfish aquaculture 31. Shellfish aquaculture Anchorages **Marine Transportation** 32. Ports, moorage, ferry docks, marinas 33. Large vessel activity/traffic **Other** 34. Marine disposal sites 35. Logging-related Docks	36. Towns/Human Settlements 37. Pulp and paper 38. Other Industrial 39. Agriculture 40. Mining 41. Logging Related/sediment

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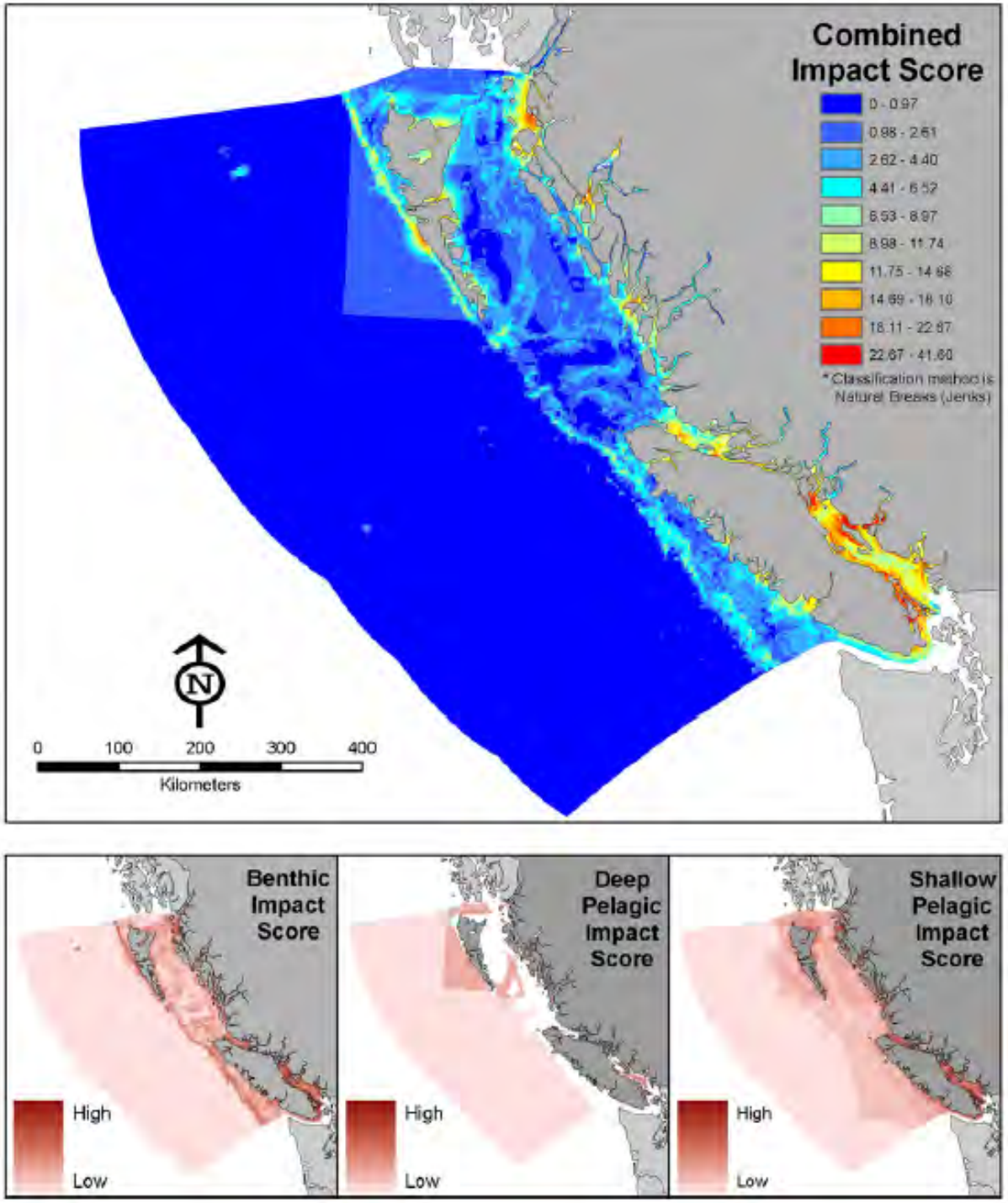
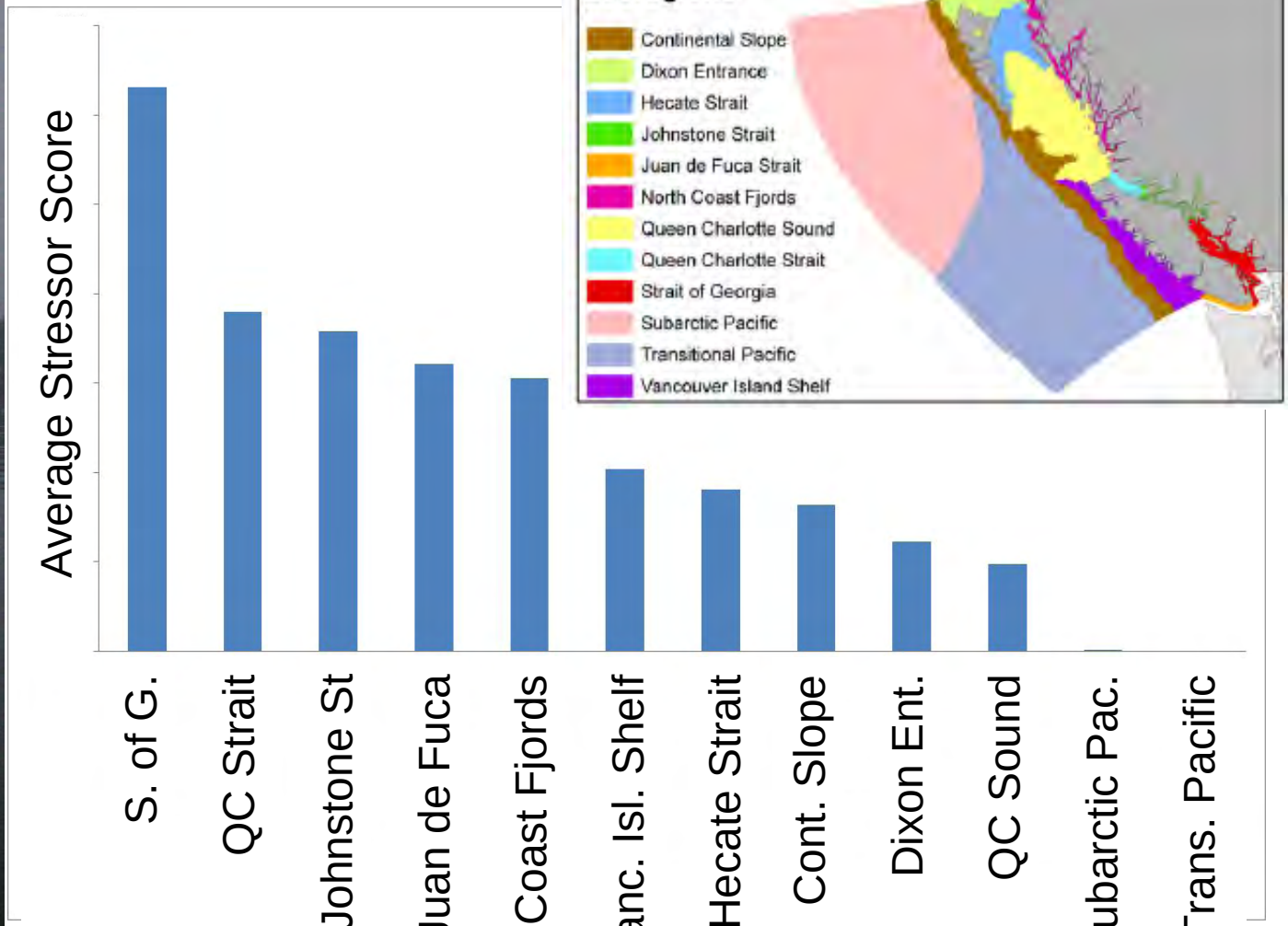

Combined Impact Score
0 - 0.97
0.98 - 2.61
2.62 - 4.40
4.41 - 6.52
6.53 - 8.97
8.98 - 11.74
11.75 - 14.68
14.69 - 18.10
18.11 - 22.67
22.67 - 41.60
*Classification method is Natural Breaks (Jenks)
N
0
100
200
300
400
Kilometers
Benthic Impact Score
High
Low
Deep Pelagic Impact Score
High
Low
Shallow Pelagic Impact Score
High
Low

Cumulative stressors by ecoregion, benthic habitats



Combined approach: summary

Summary

- Appropriate for global or regional visualizations
- Not enough information for specific response variables

Limitations

- Data availability and quality
- A snapshot in time
- A lot of assumptions, especially about how stressors interact

Overall discussion

- Need to better integrate results of meta-analyses and expert judgment with spatial data
- Expect surprises and non-linearities
- Additional studies needed (natural and lab experiments)
- But can do much with data we do have, and the knowledge of experts

Ban, N. C., H. M. Alidina, and J. A. Ardron. 2010. Cumulative impact mapping: Advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study. **Marine Policy** 34:876-886.

Stephen Ban: stephen.ban@my.jcu.edu.au

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