Coastal Aquatic Ecosystems Under Stress: PICES experiences

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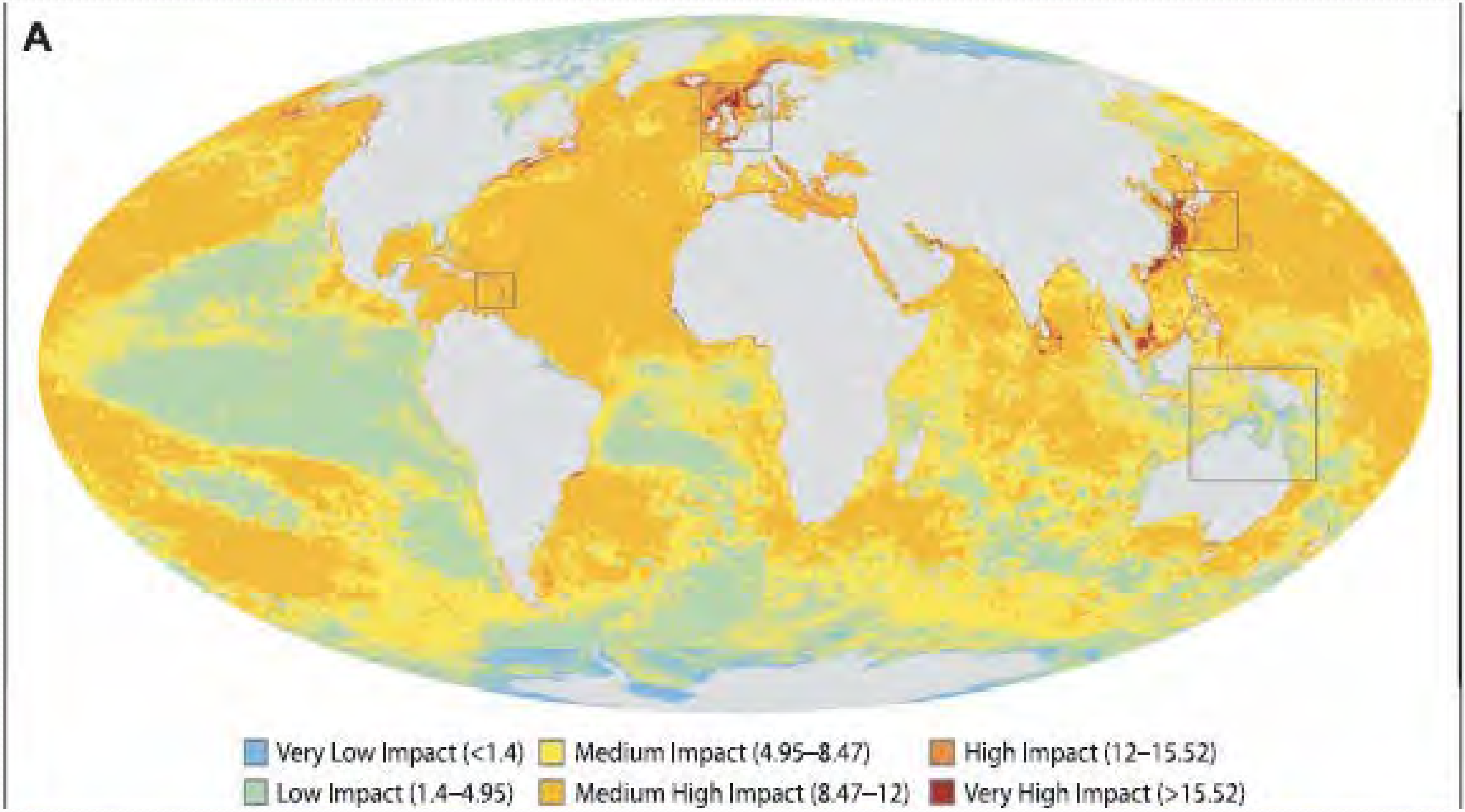
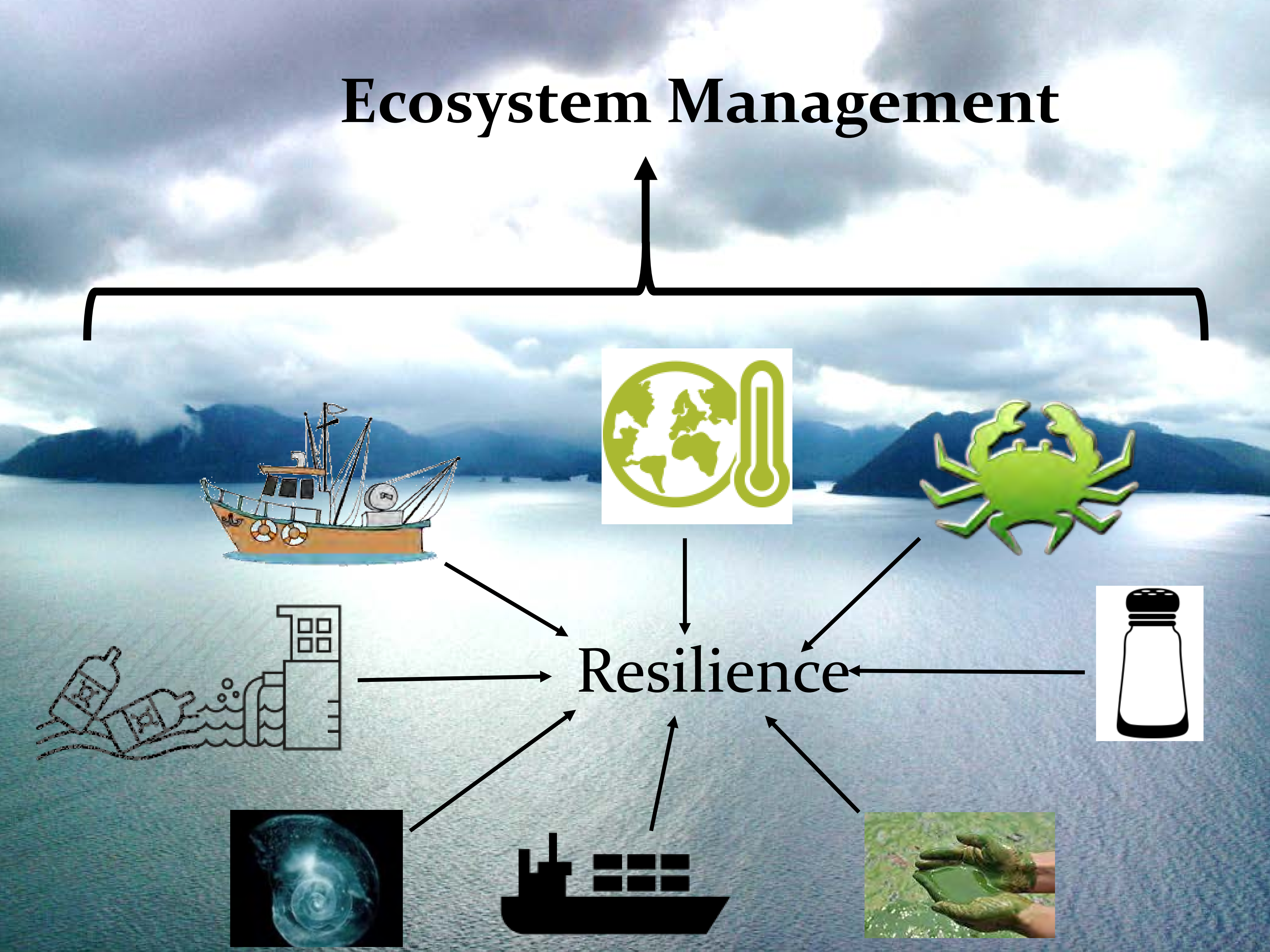
Ocean Health Index



Halpern et al. 2008 Science


Ecosystem Management
Resilience

Ecosystem Resilience

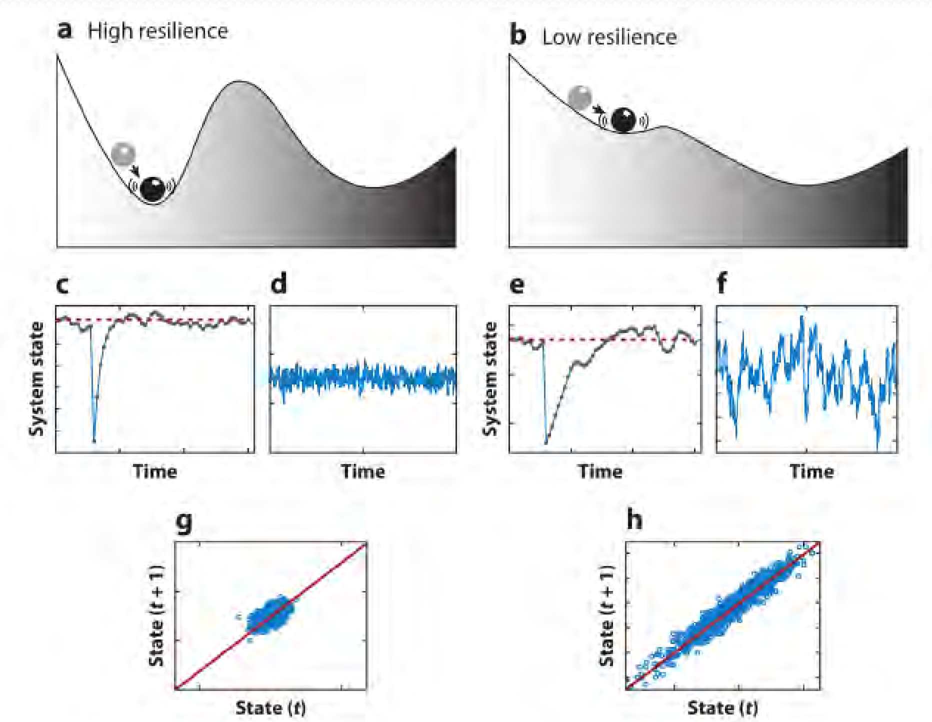
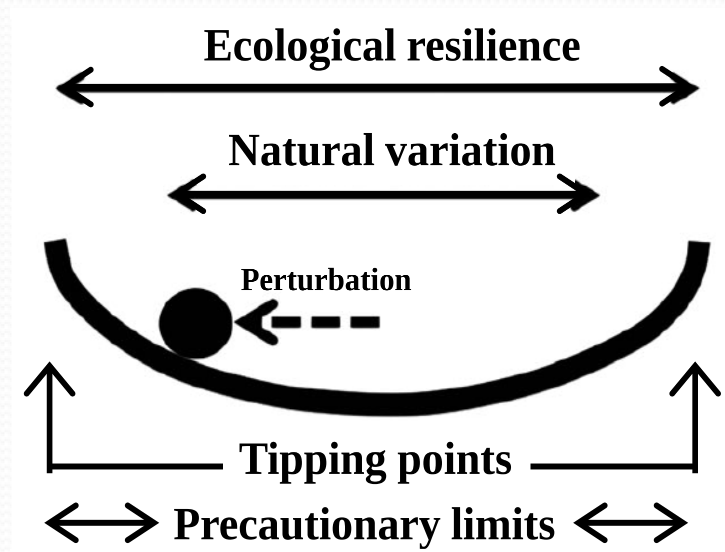


Figure 2

Critical slowing down as an indicator of low resilience. Recovery rates upon perturbations (*c* and *e*) are slower when the basin of attraction is shallow (panels *b*, *e*, *f*, *h*) than when the basin of attraction is deeper (panels *a*, *c*, *d*, *g*). The effect of this slowness is reflected in natural (externally driven) fluctuations in the state of the system (*d* and *f*) and can be detected as increased temporal autocorrelation and variance (*g* and *h*). Abbreviation: *t*, time. Figure adapted from Scheffer et al. (2012a) with permission.

Scheffer et al, 2015, Annu Rev Ecol Evol & Syst

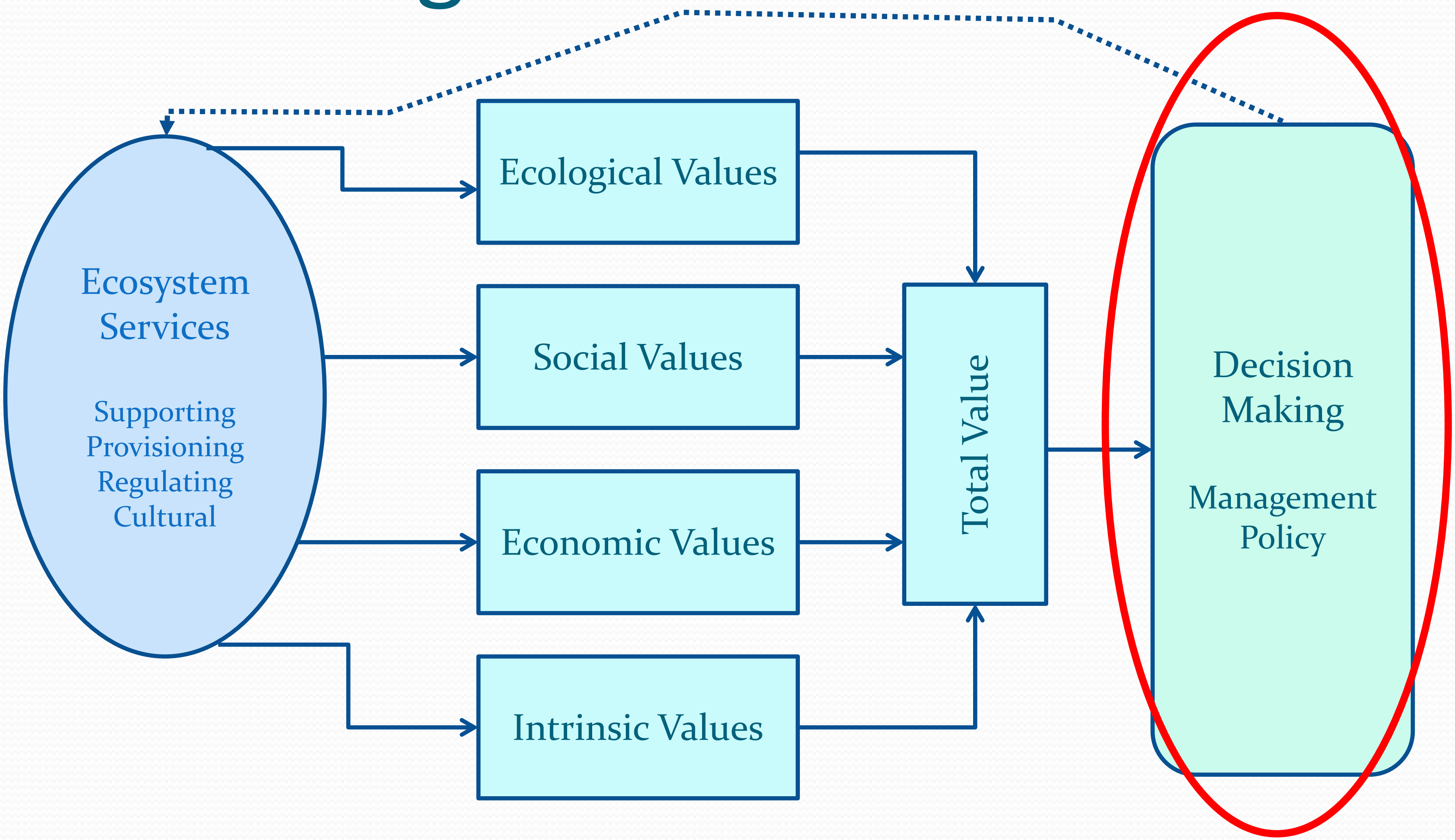
Identifying Tipping Points



Overall Goal (could be)

To identify the need to develop a **general framework** to inform sustainable ocean management and policy implementation by evaluating ecosystem resilience to multiple stressors that consider spatial and temporal scales.

Informing Sustainable Use



Modified from: DeGroot 2002

Multiple pressures in the North Pacific

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

Halpern et al. 2008 Science

PICES FUTURE AP-AICE Survey

Stressors	% Low	% Med	% High
Climate change	5	17	79
Sea level change	17	45	38
Loss of Sea Ice	20	17	63
Hypoxia	17	24	60
Ocean acidification	21	48	31
Nutrient Loading	14	31	55
Organic Pollutants	10	31	60
Inorganic Pollutants (heavy metals)	29	31	40
Human Alteration of Upland Systems	7	29	64
Capture Fisheries	7	26	67
Aquaculture	10	33	57
Non-indigenous Species (NIS)	7	44	49
Harmful Algal Blooms (HABs)	7	29	64
Habitat Loss	10	35	55
Oil and Gas Exploration and Mining	39	24	37
Alternate Energy Production	43	29	29
Dredging/Sand Extraction	36	29	36
Recreational Activities	31	33	36
Land reclamation (from sea)	31	17	52
Noise pollution	52	26	21
Illegal Fishing	33	24	43
Wind-induced Upwelling	24	26	50
Marine Debris/Litter	19	29	52

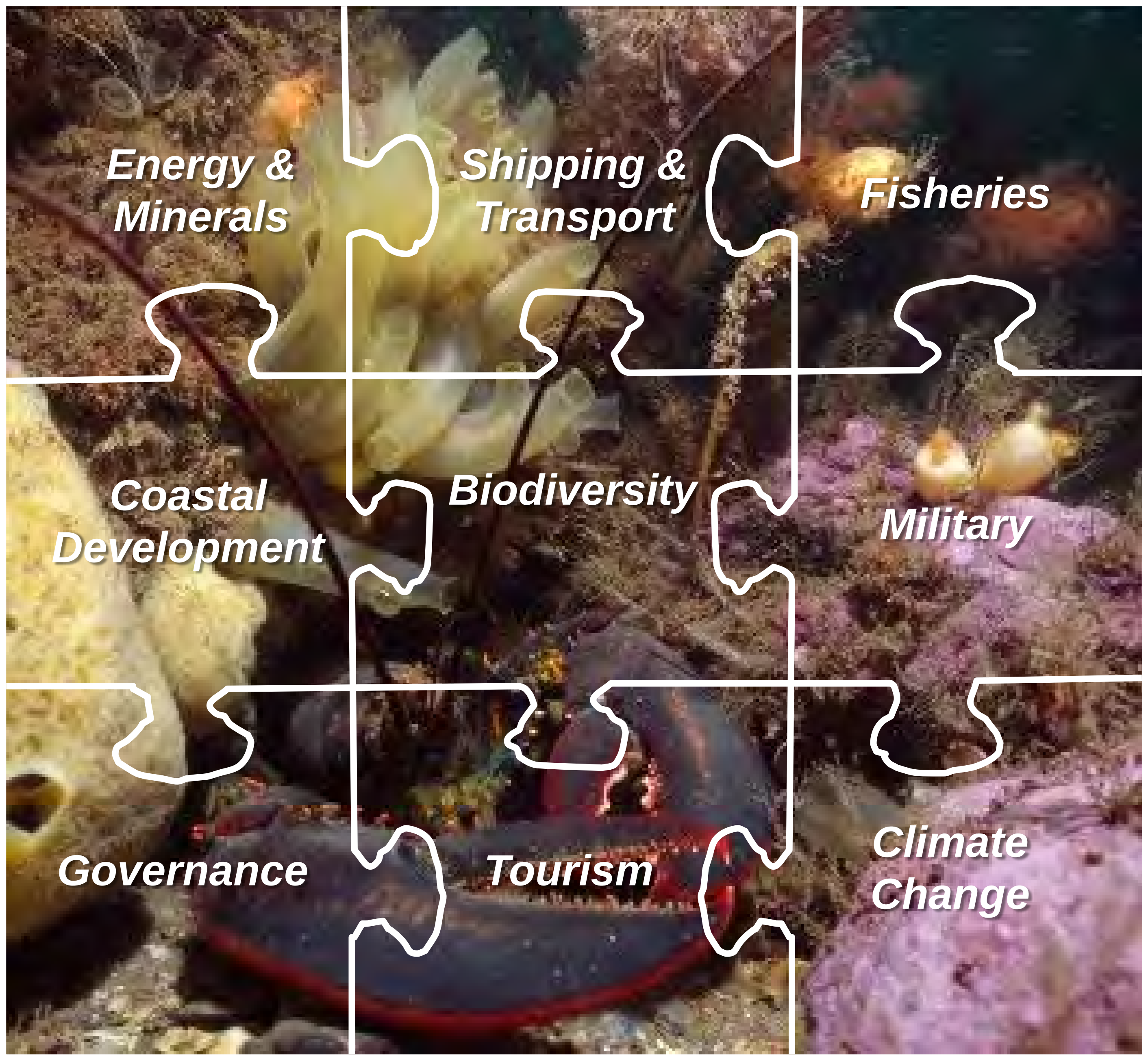
Survey was conducted at the start of the PICES FUTURE Program

Some stressors universally high like
Climate change

Importance of some stressors likely vary geographically

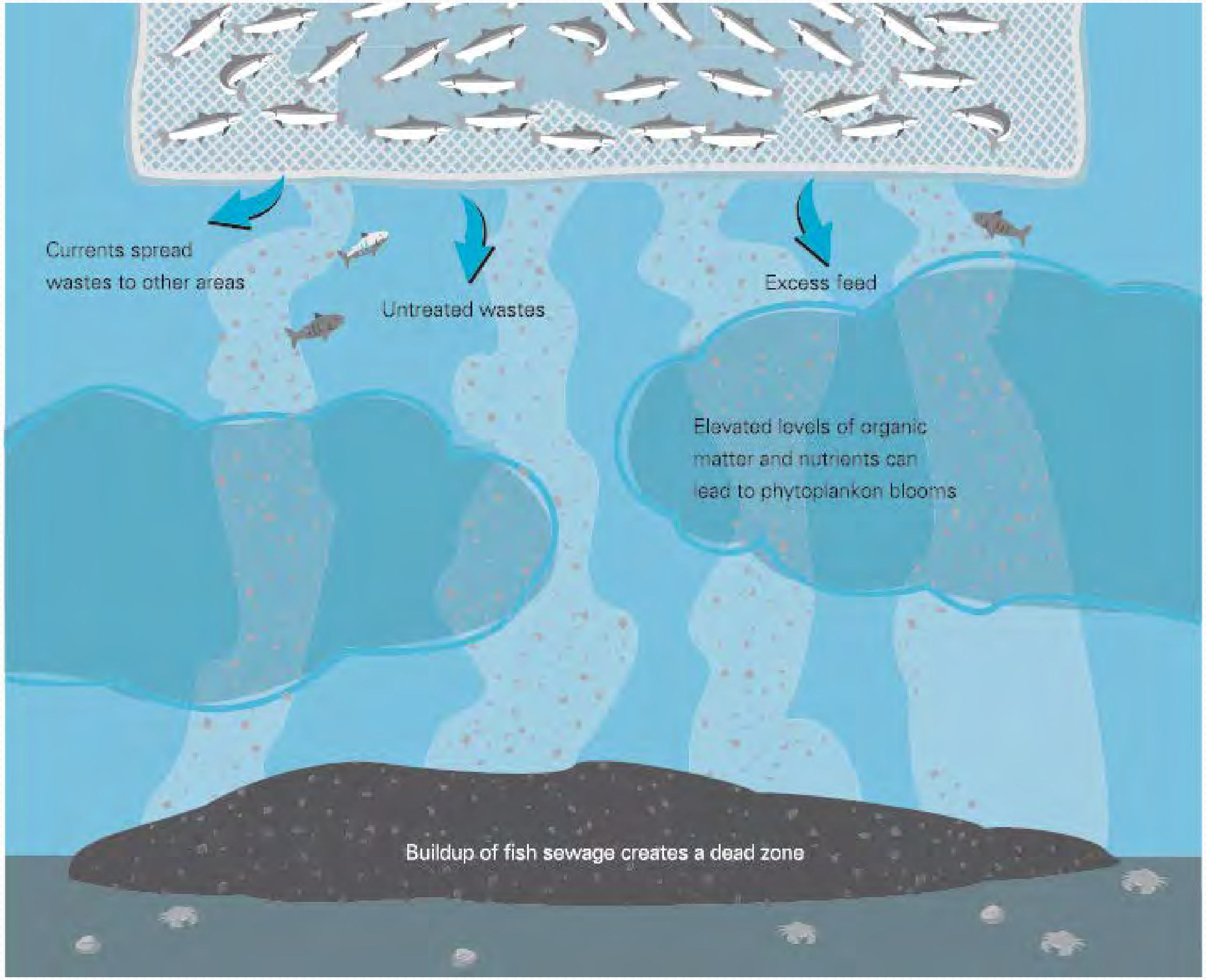
Some stressors likely have increased in importance since initial survey

Noise pollution
Marine debris/litter



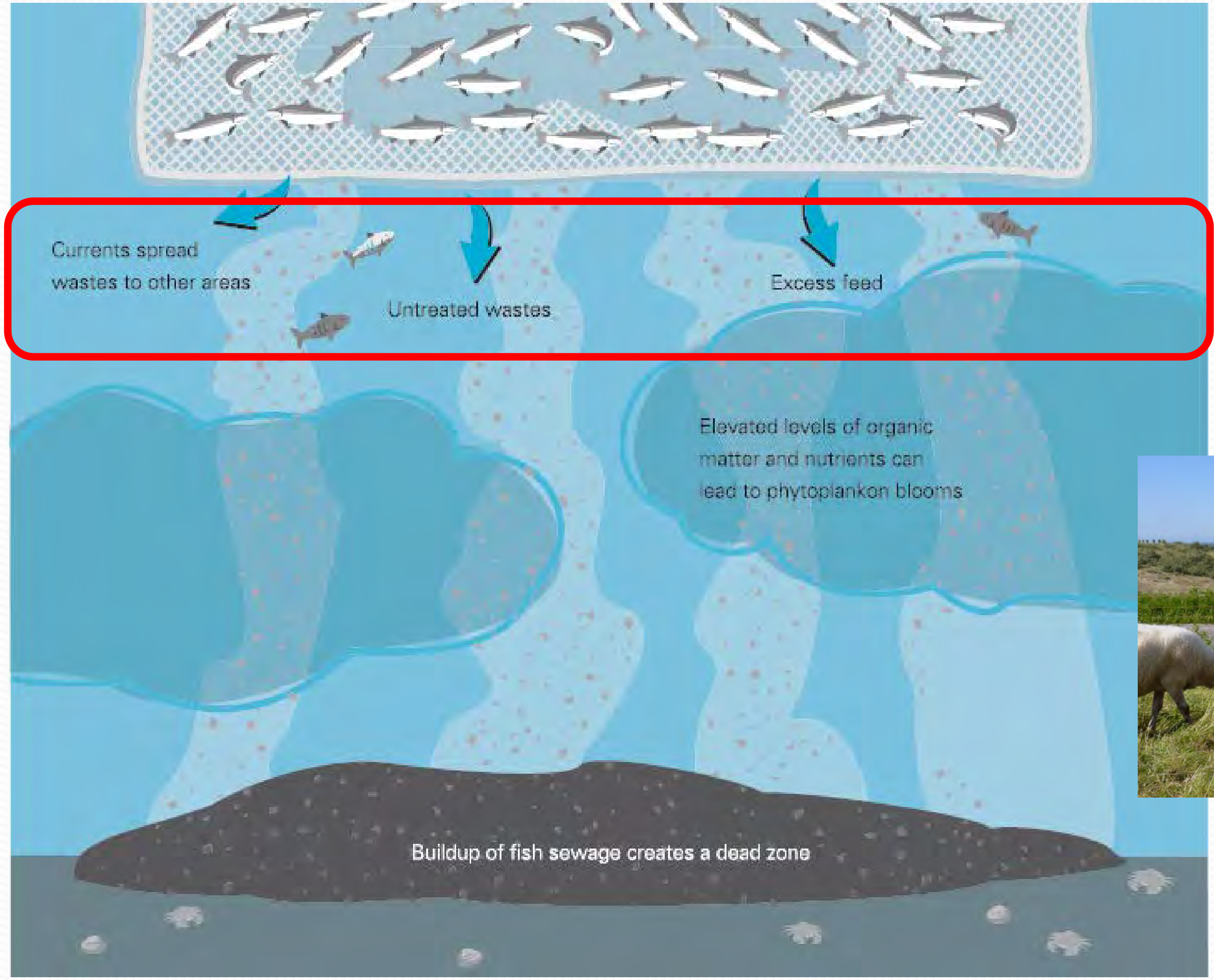
Energy & Minerals
Shipping & Transport
Fisheries
Coastal Development
Biodiversity
Military
Governance
Tourism
Climate Change

Nutrients – HABs – Hypoxia



NRC 2000

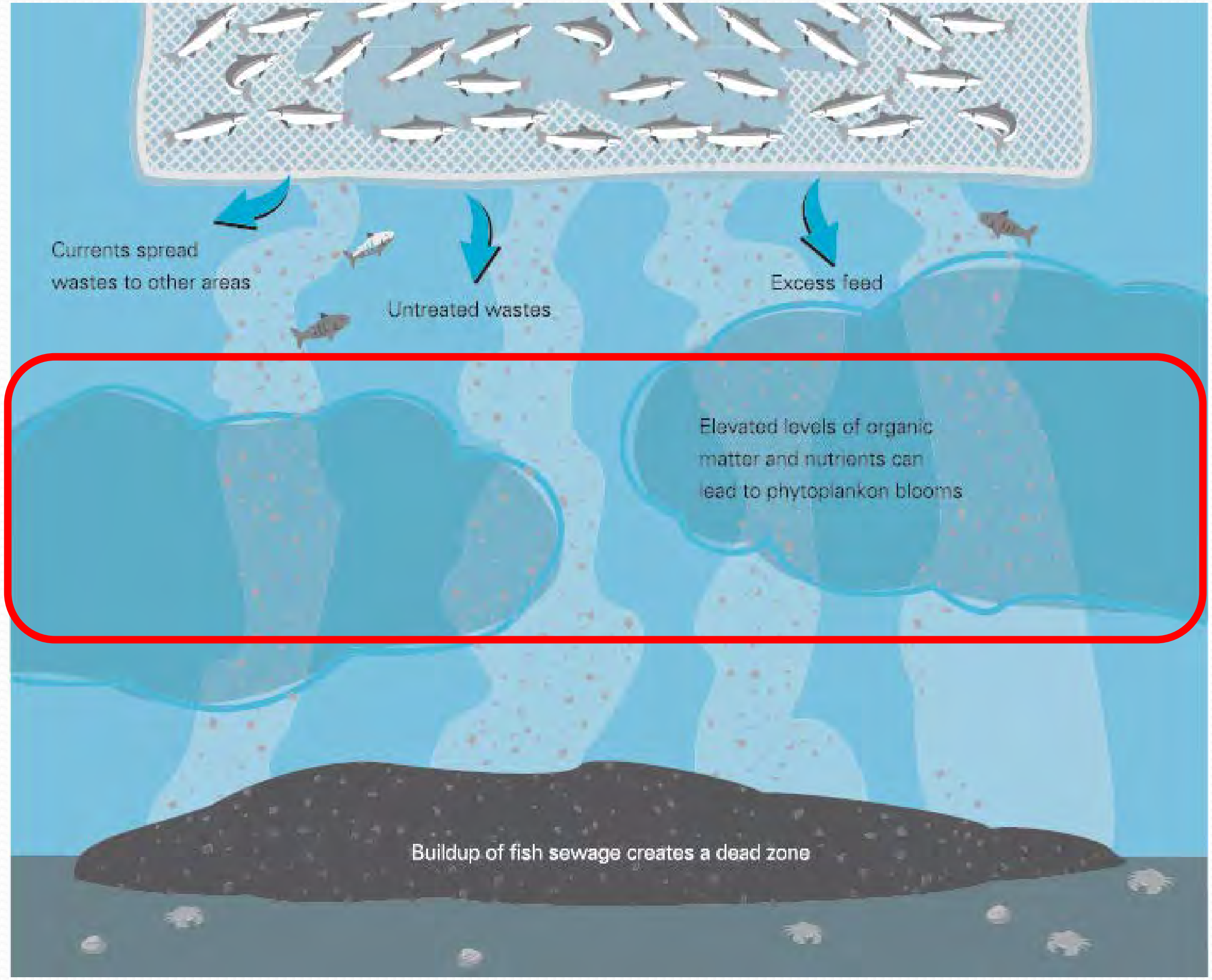
Nutrients – HABs – Hypoxia



Increased nutrient load due to land-based or sea-based farming

NRC 2000

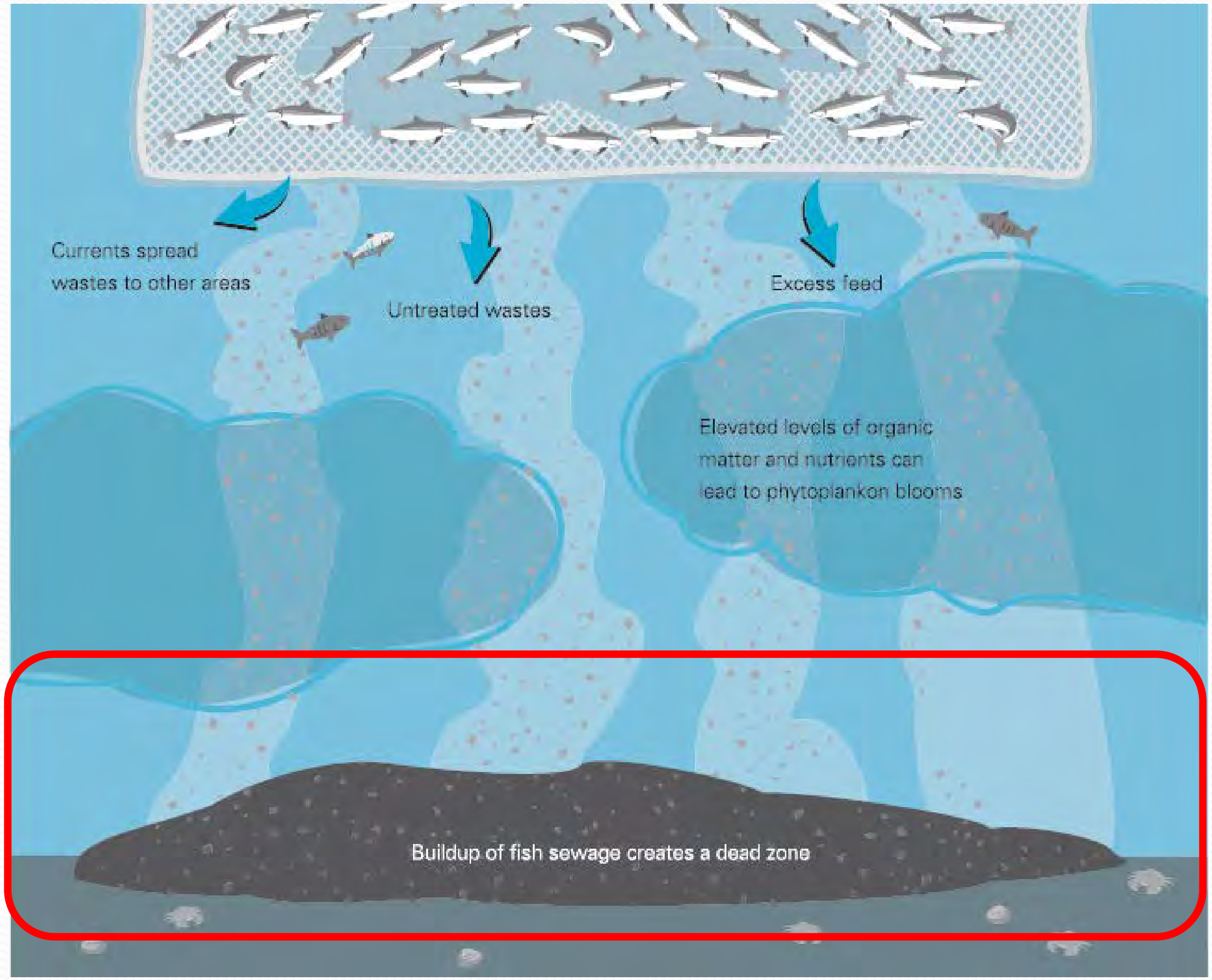
Nutrients – HABs – Hypoxia



Increased nutrient availability allows larger populations of plankton

NRC 2000

Nutrients – HABs – Hypoxia



As wastes and plankton break down, an oxygen-depleted area is created

NRC 2000

Nutrients – HABs – Hypoxia

- *Cochlodinium polykrikoides* blooms have been increasing in frequency and spatial area in the Northwest Pacific
- Possibly due to eutrophication and/or climate change
- Large economic impacts (in addition to ecological ones) of blooms:
  - 180 million yen damage in the Yatsushiro Sea in 1979
  - 8 billion yen in Imari Bay in 1999
  - 40 billion yen in Yatsushiro Sea in 2000
  - 76.5 billion Korean won in 1995
  - 2.1 billion won in 1996
  - 1.5 billion won in 1998

GEOHAB 2010

Fisheries

- Direct impacts of removals on stocks and bycatch
- Also can result in significant habitat damage/degradation issues

Fisheries

Glass sponge reefs

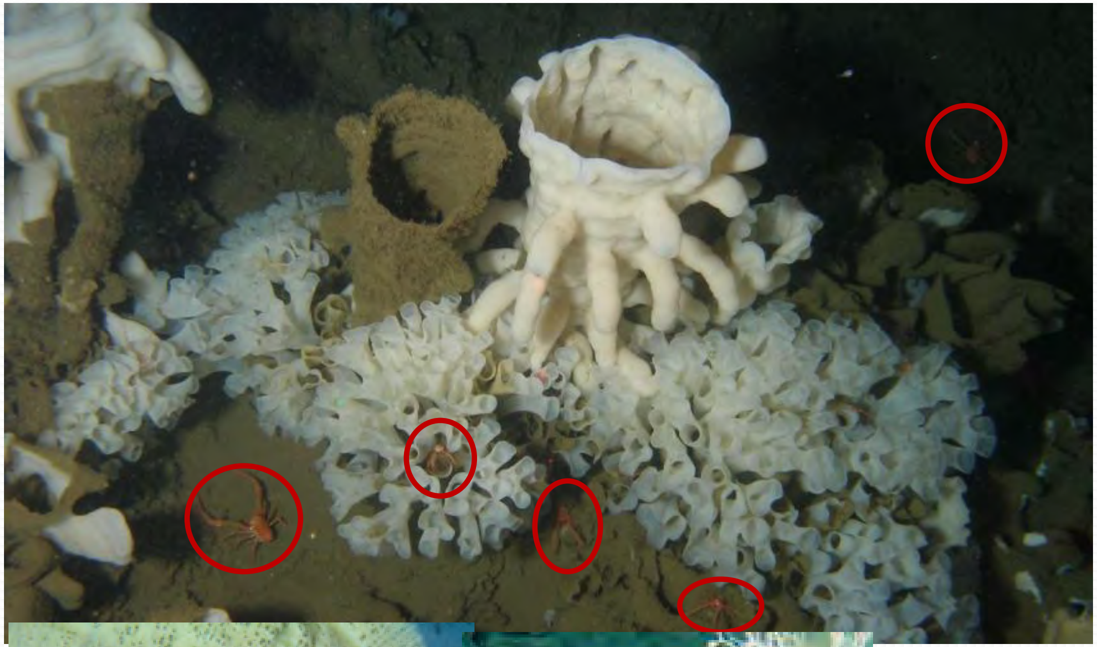
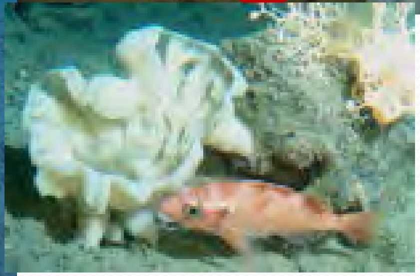


Photo: Sally Leys



Photos: NOAA

- Important benthic structural habitat
- Provide habitat and refuge for many aquatic species, including rockfish, flatfish, spider crab, box crab, king crab, shrimp, prawns, and euphausiids

Jamieson & Chew 2002. RD 2002/122. DFO/2010-1663

Fisheries

Glass sponge reefs


Photo: Jackson Chu and Sally Leys / ROPOS

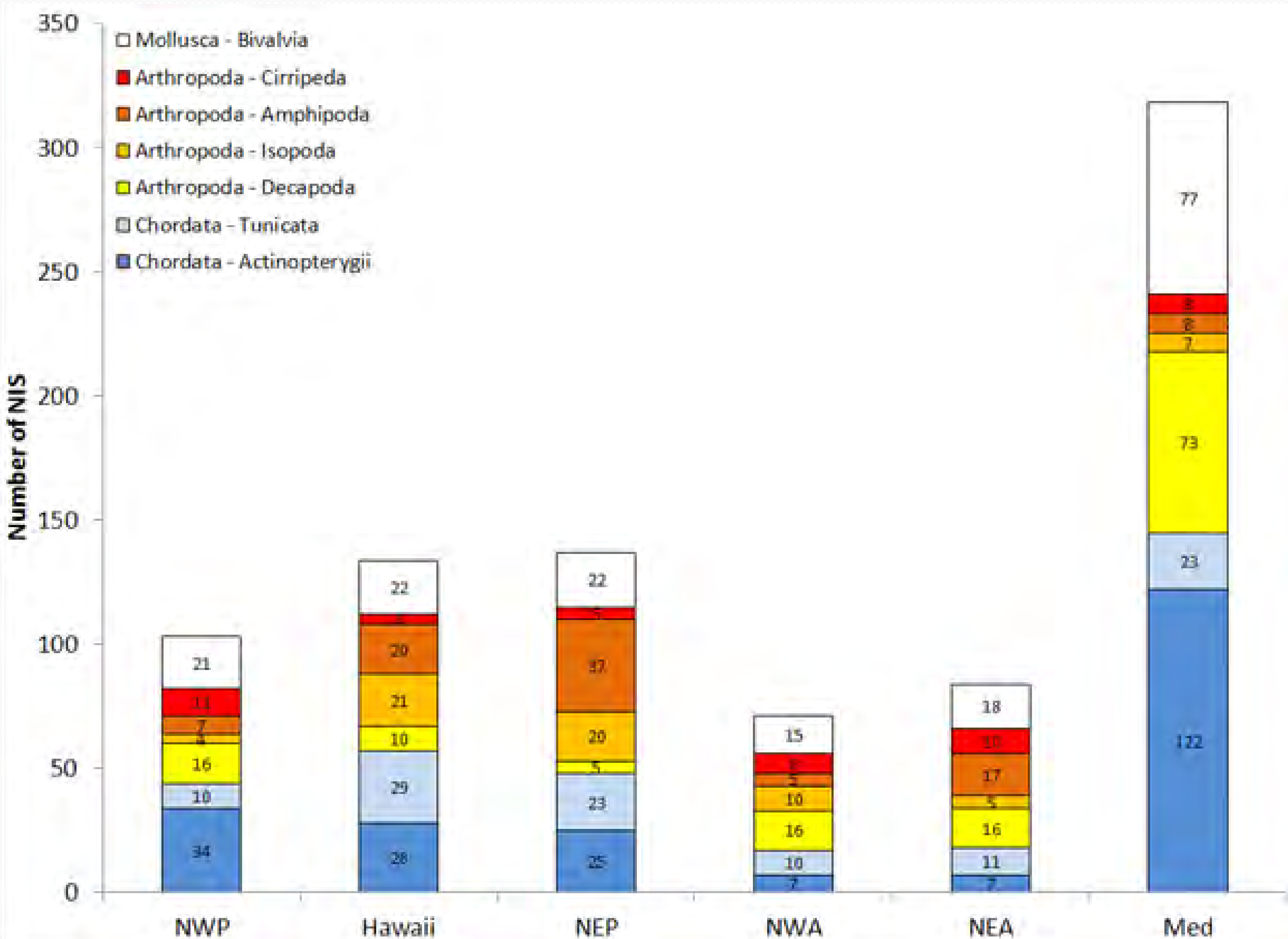
- Sensitive habitat is damaged by fishing gear, including trawls and dredges
- Slow to regrow (50-200 years), and some never return
- Habitat and associated species are lost

Jamieson & Chew 2002. RD 2002/122. DFO/2010-1663

Invasive Species

- NIS are second only to habitat loss when it comes to loss of native biodiversity
- NIS pose significant ecological/biological/genetic risks
- NIS pose significant risks to sustainable fisheries and aquaculture (i.e., tunicates and shellfish aquaculture)
- Global NIS introductions have increased substantially in recent years

Invasive Species

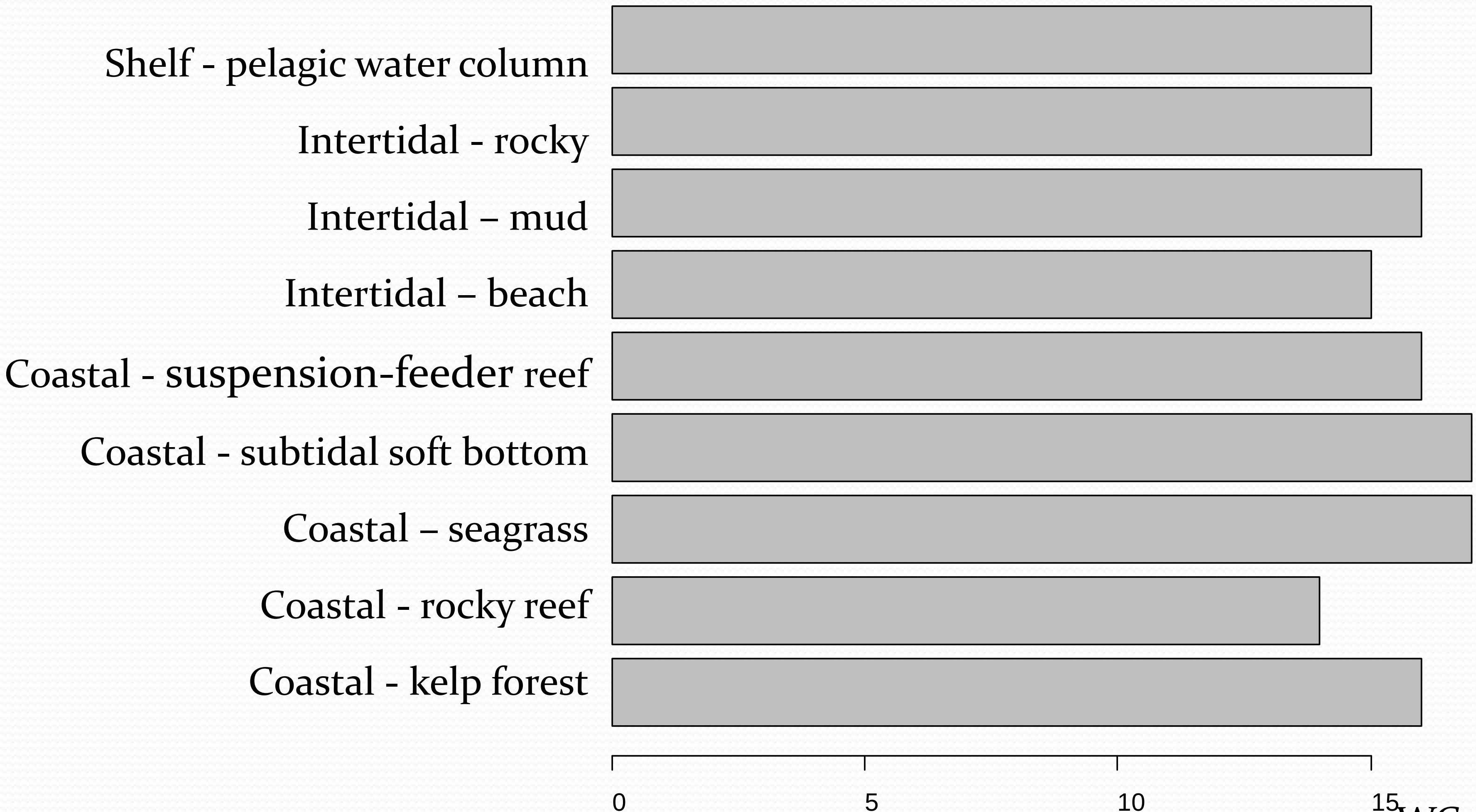


WG-21

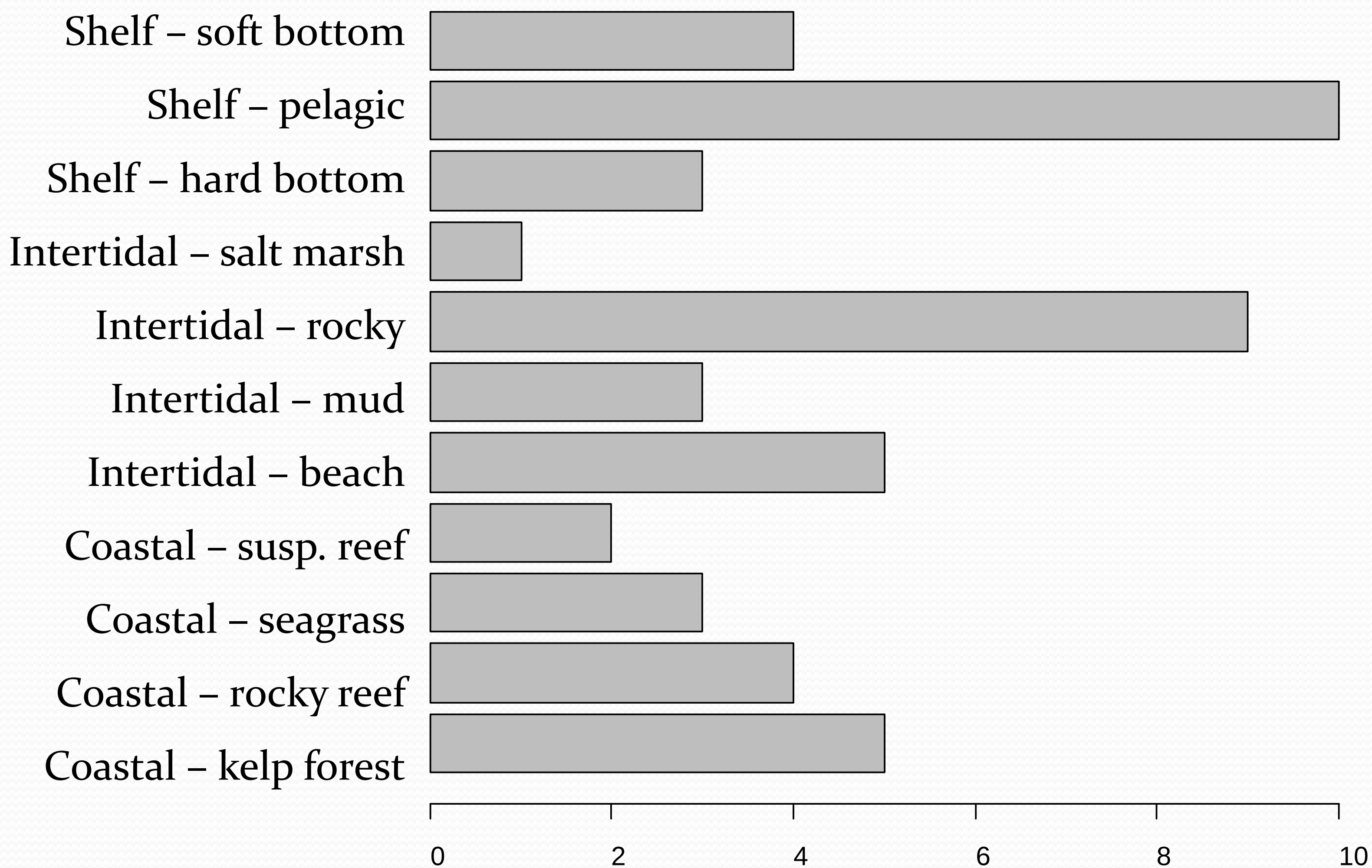
Invasive Species – Climate Change

- Some NIS are experiencing greater invasion success due to climate change
- Climate change also affecting NIS vectors (i.e., shipping via the Arctic)
- NIS are interacting with other coastal stressors resulting in greater ecological/economic impacts

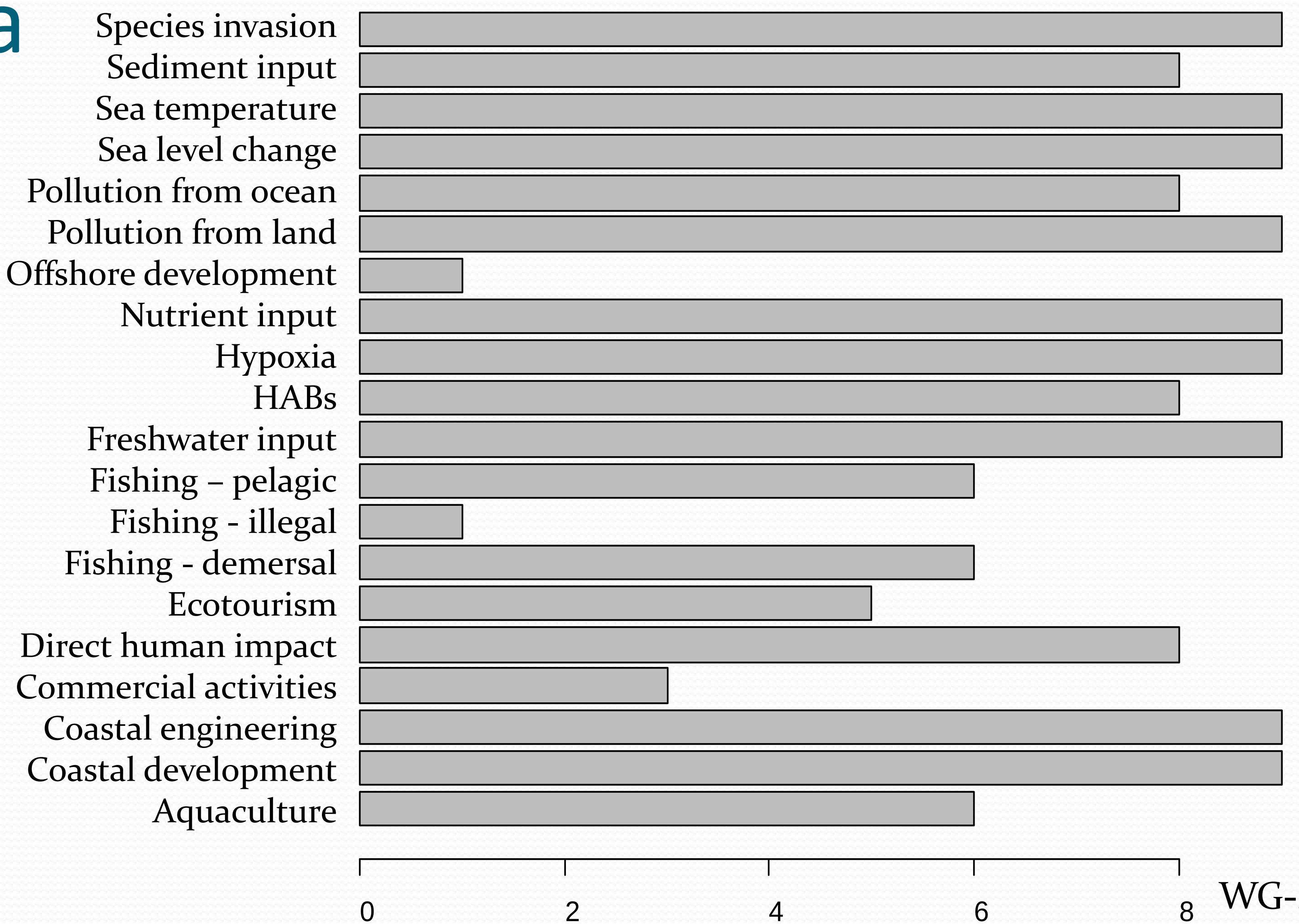
Stressors Per Habitat: Seto Inland Sea



Stressors Per Habitat: Strait of Georgia



Habitats per Stressor: Seto Inland Sea



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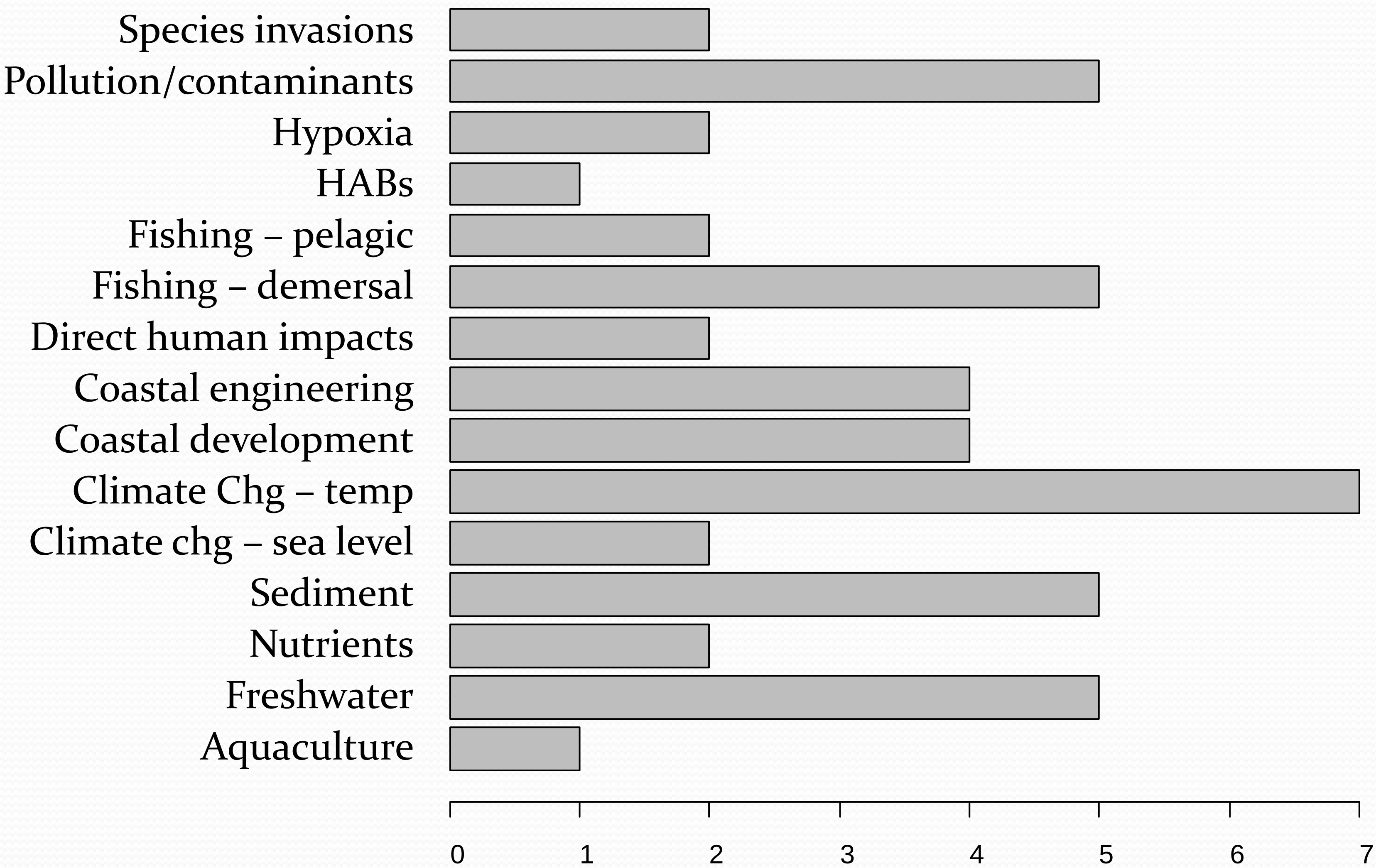
Habitats per Stressor: Strait of Georgia



WG-28

Main pressures impacting western Pacific ecosystems

East China Sea, Seto Inland Sea, Kuroshio/Oyashio

Activities/Stressors	ECS/YS	SETO	K/O
1. Pollution from land	2.7	3.0	
2. Coastal engineering	3.4	3.2	
3. Coastal development	3.4	3.2	
4. Direct human impact		3.0	
5. Ecotourism		2.3	
6. Commercial activity		3.0	
7. Aquaculture		3.0	
8. Fishing - demersal	3.5	2.9	2.8
9. Fishing - pelagic	2.6	2.7	3.3
10. Fishing - illegal		2.6	
11. Offshore development	2.1	2.9	
12. Pollution from ocean	3.1	2.9	
13. Freshwater input	2.9	2.7	
14. Sediment input	2.5	2.8	
15. Nutrient input	2.9	3.1	3.0
16. HABs	2.8	2.7	
17. Hypoxia	3.2	2.8	3.0
18. Species invasion	2.5	2.9	
19. Sea level change		3.1	3.2
20. Sea temperature	3.2	3.5	3.2

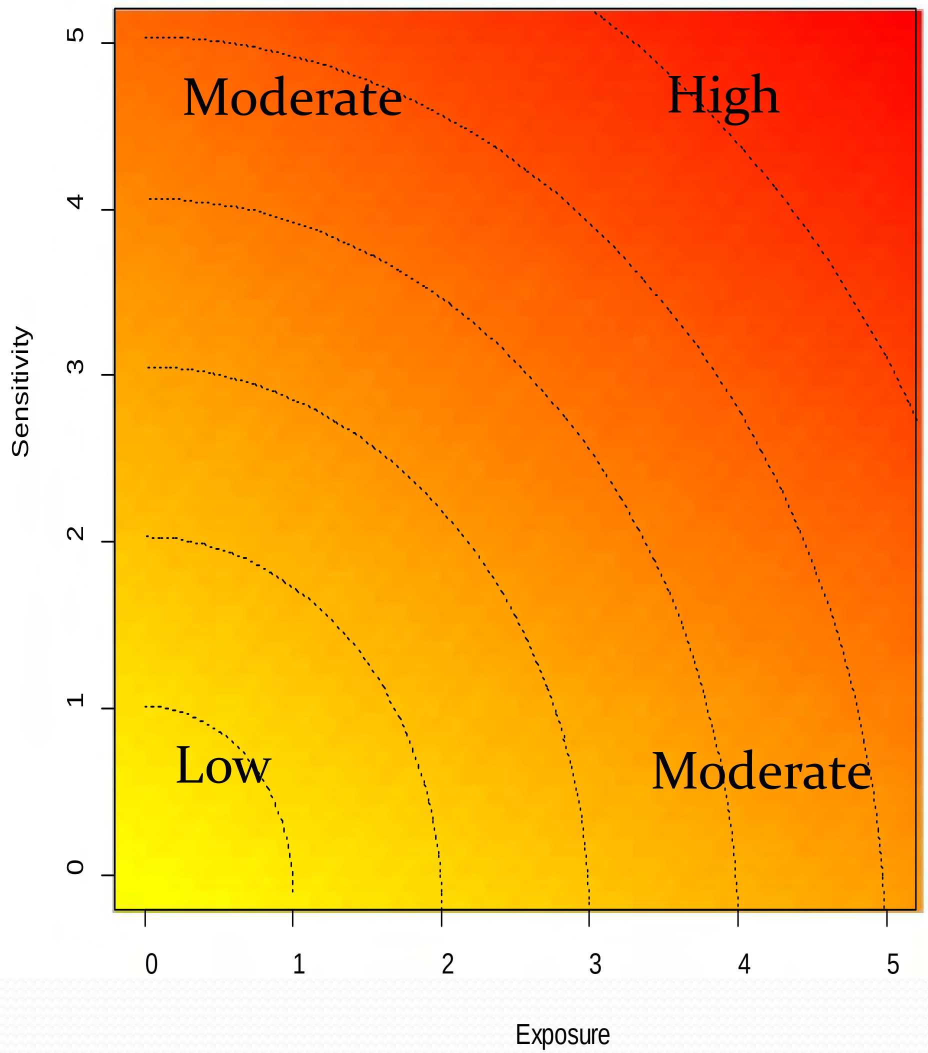
Coastal development and engineering have strong impacts to the ECS/YS and the Seto Inland Sea.

Demersal and pelagic fishing impact the ECS/YS and the K/O, respectively.

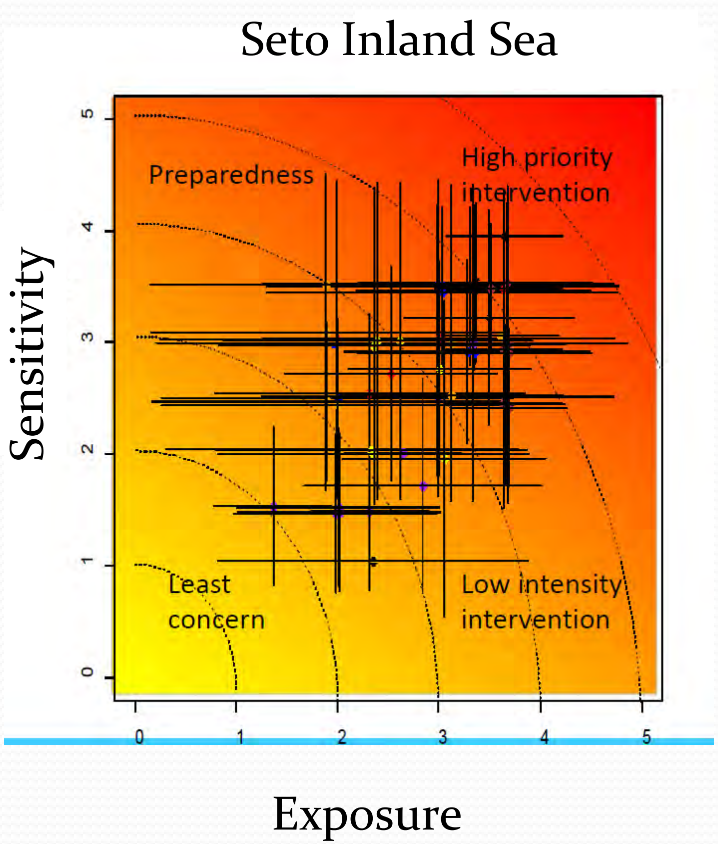
Nutrient input has resulted in HABs and Hypoxia in summer.

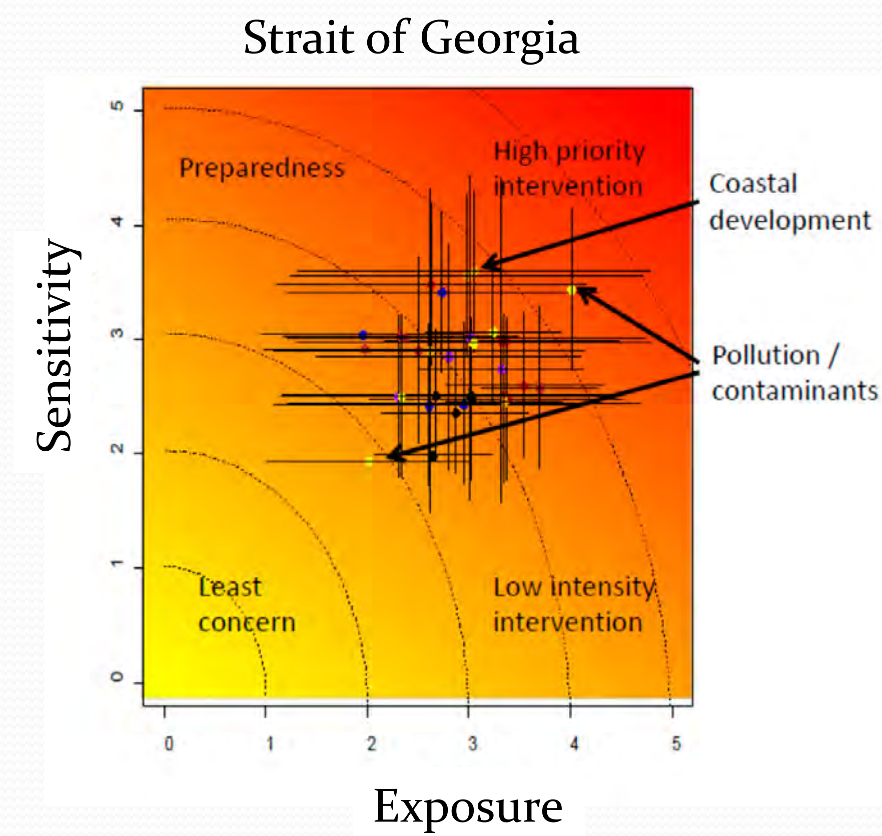
Increasing sea temperature strongly affects all 3 ecosystems.

Risk Perceptions



Risk related to Stressors



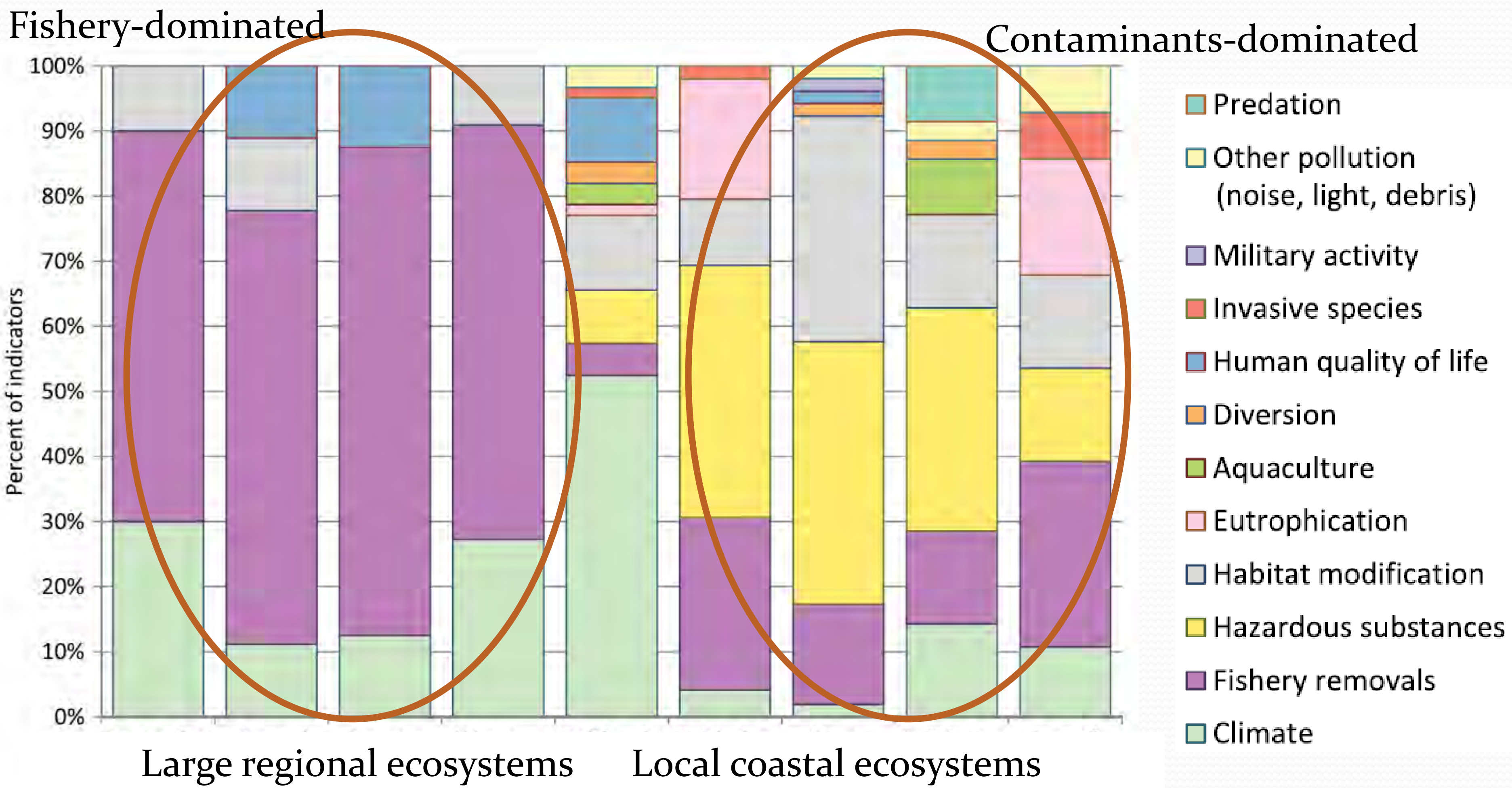


Drivers and Metrics

Driver / Stressor	Examples of metrics
Climate	- Temperature - Large-scale climate pattern - Salinity
Exploitation	- Fishing effort - Catch/landings - Fishing mortality
Pollution	- Nutrient loading - Oxygen - Water clarity
Food web	- Predator/prey biomass, abundance - Primary production, nutrients - Density dependence

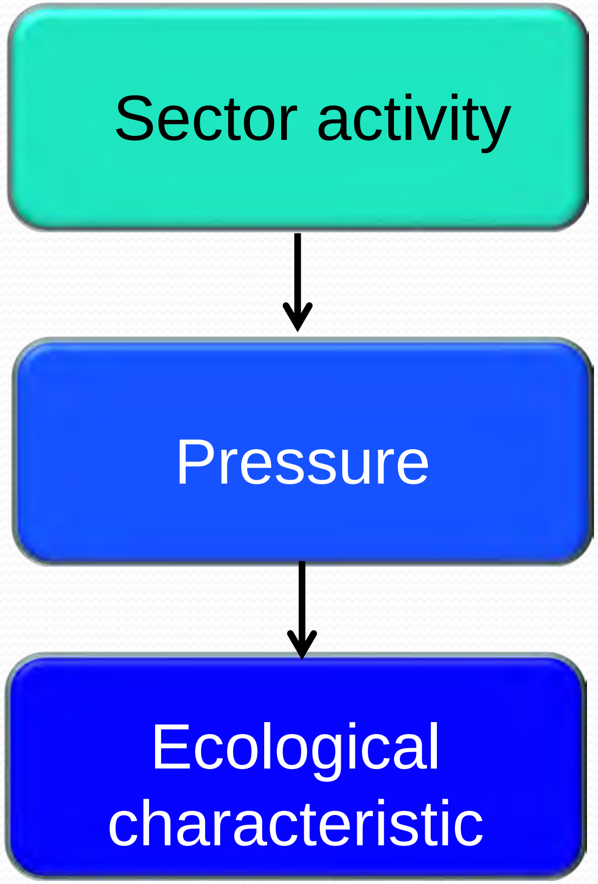
Hunsicker et al. 2016

Indicators among Ecosystems

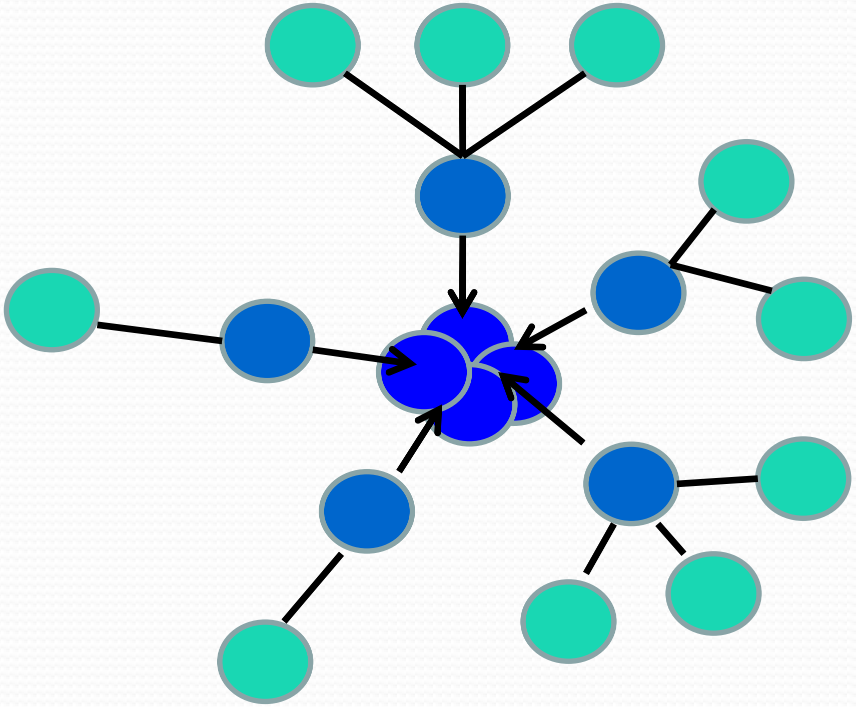


Boldt et al. 2014

Single vs. Multiple Stressors

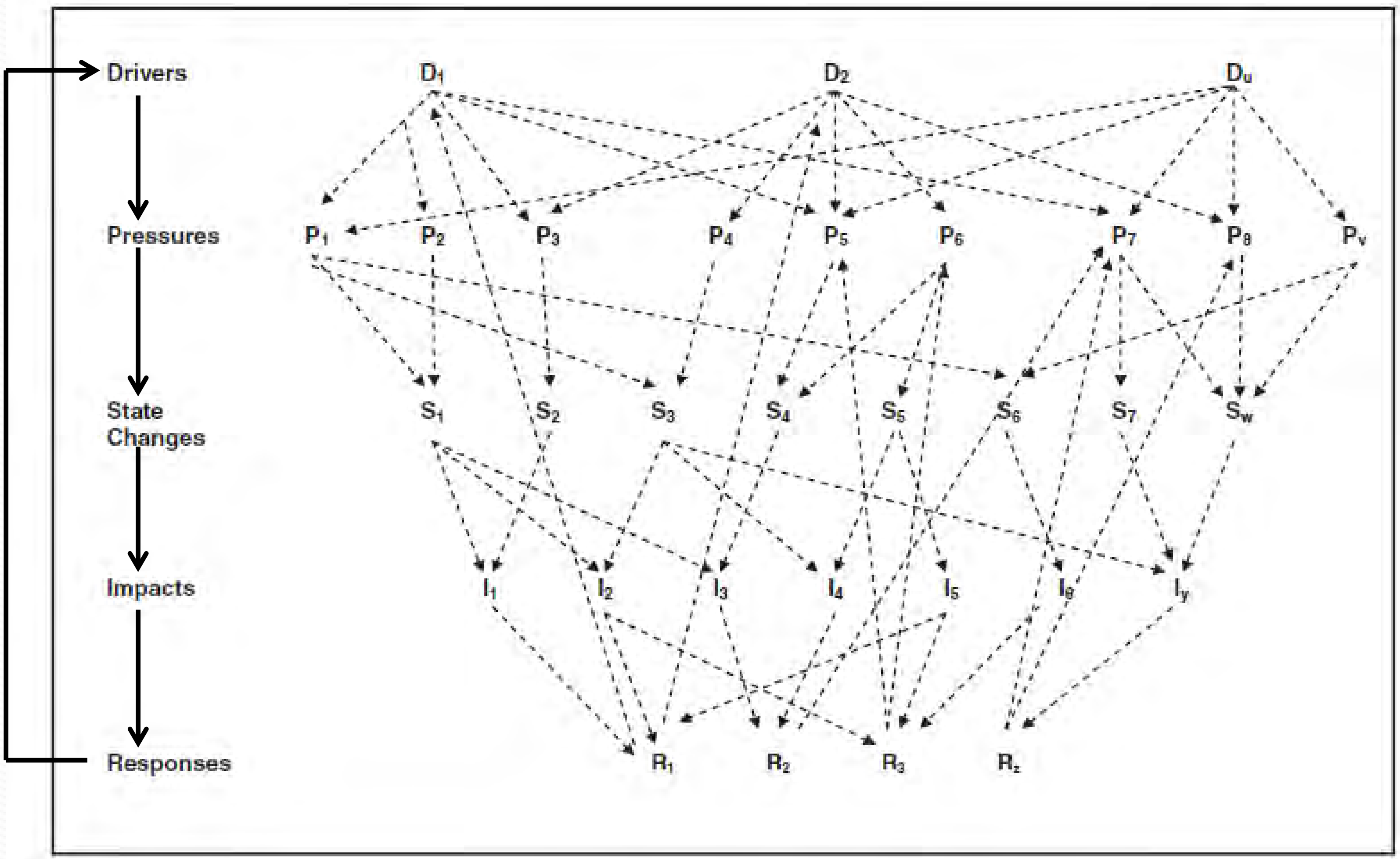


Impact Chain

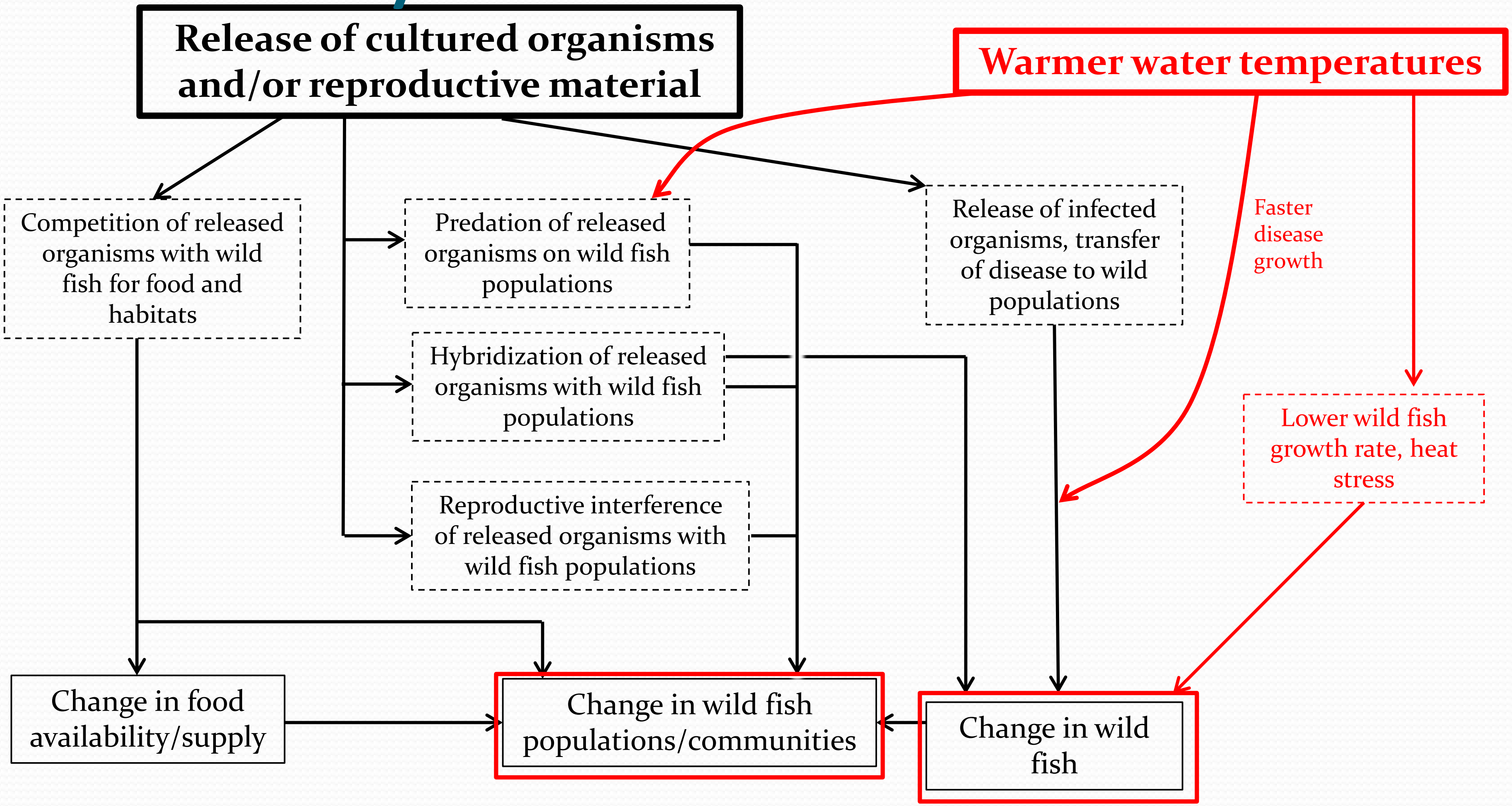


Multiple Sector Impacts

Driver-Pressure-State-Impact-Response (DPSIR)

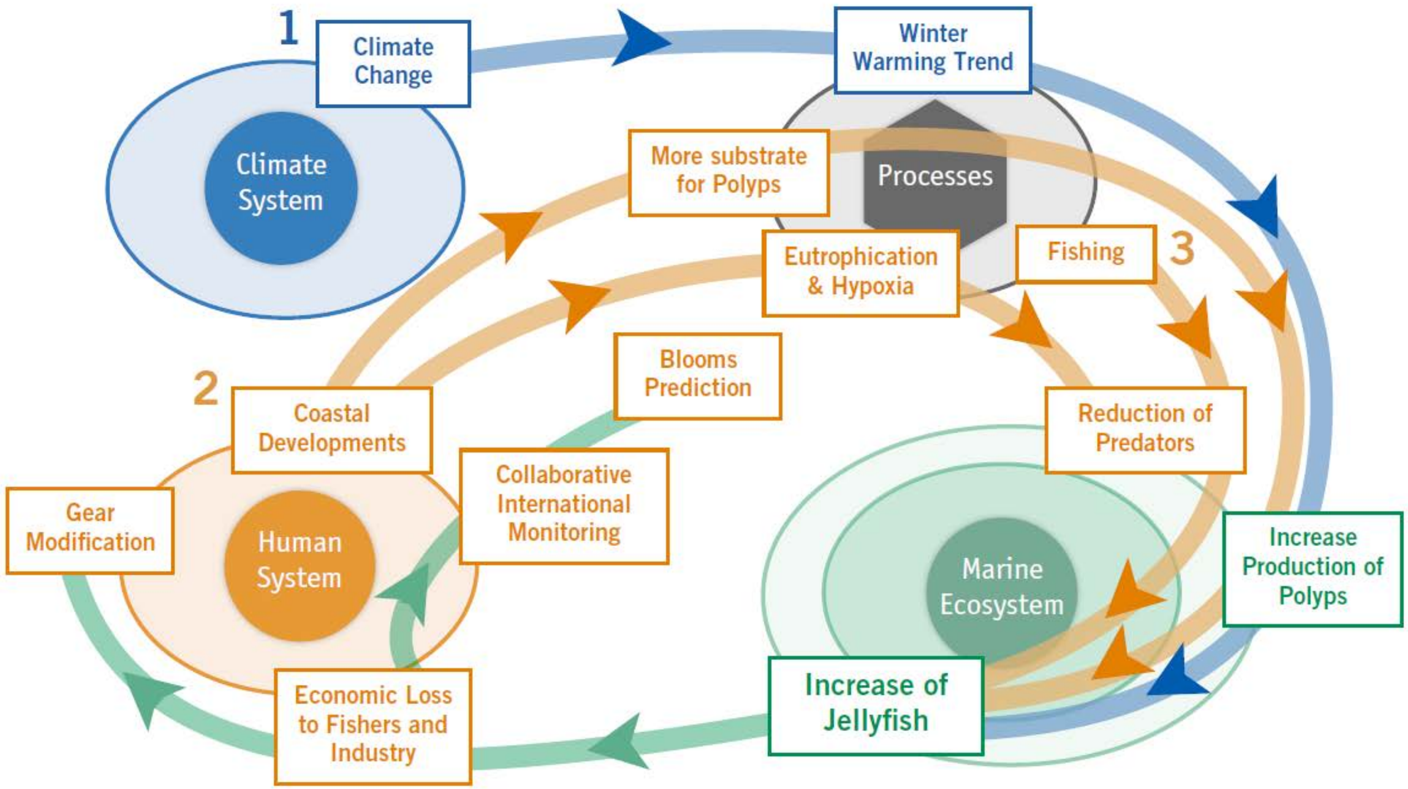


Pathway of Effects Models



Adapted from Leggatt et al. 2010. Pathway of effects of escaped aquaculture organisms or their reproductive material on natural ecosystems in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/019. vi + 70 p.

PICES FUTURE SEES Approach

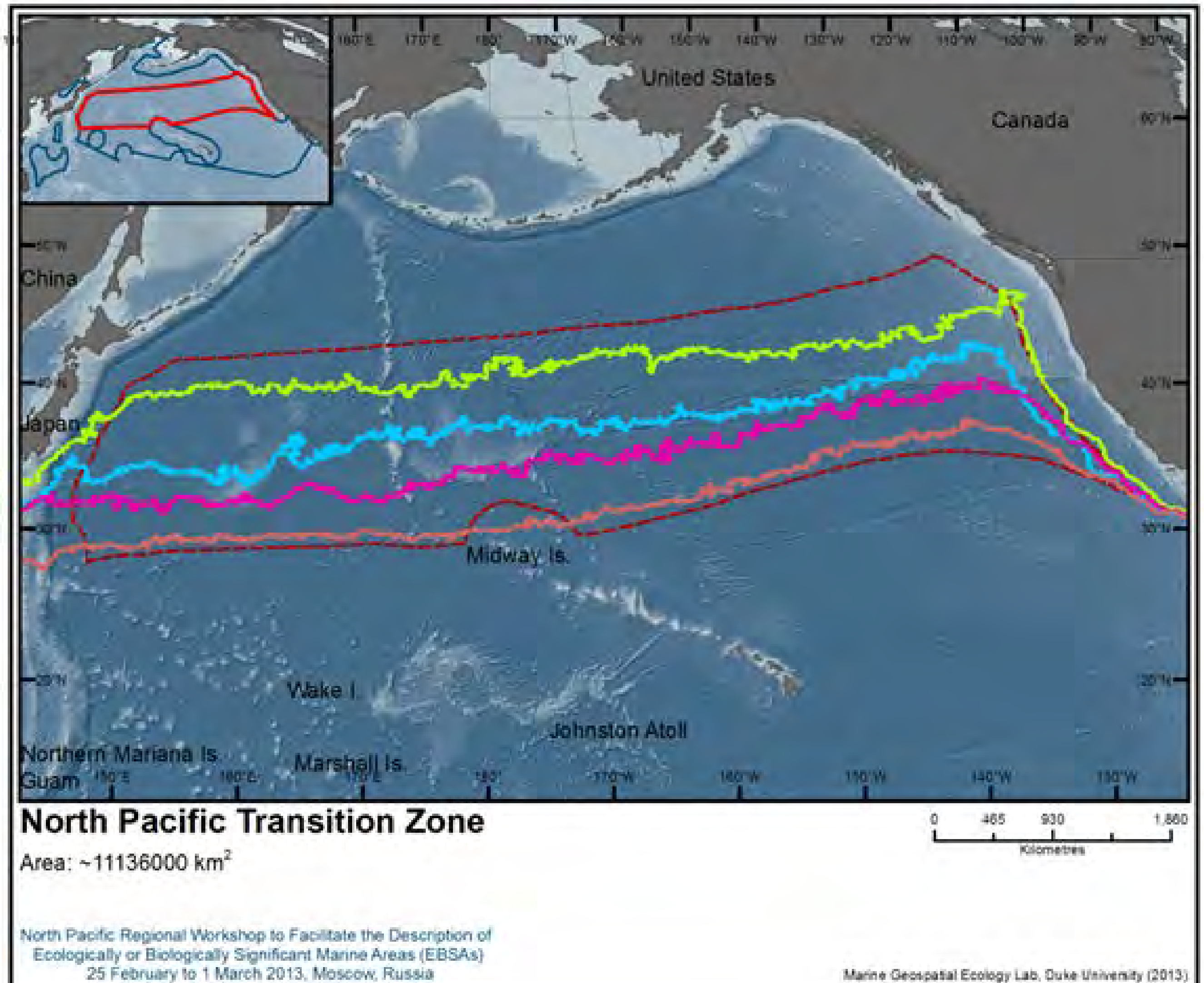


Case 1: Jelly Fish Blooms

Informing Management/Policy

- Using Ecologically and Biologically Significant Areas (EBSAs) as a Case Study
- PICES participated in a Workshop to Identify EBSAs in the North Pacific hosted by the Secretariat of the Convention on Biological Diversity (CBD)
- This workshop produced 20 EBSAs but will focus on the North Pacific Transition Zone

The NPTZ EBSA



EBSA Criteria for NPTZ

CBD EBSA Criteria	Description	Ranking of Criterion Relevance			
		No Data	Low	Medium	High
Uniqueness or Rarity			X		
Special importance for life-history stages of species					X
Importance for threatened, endangered or declining species and/or habitats					X
Vulnerability, fragility, sensitivity, or slow recovery			X		
Biological productivity					X
Biological diversity				X	
Naturalness				X	

EBSA Criteria Gaps

- But the template doesn’t explicitly collect information on the key <u>activities/stressors</u> within the potential EBSA that could inform management or policy development

- Even if some activity/stressor information is included by assessors:
  - multiple stressor/cumulative effects often are ignored
  - spatial/temporal scales are not specified

Summary: Informing Management/Policy

- PICES, like other international/national programs, has contributed to better understanding stressor-impact relationships in the North Pacific

- There is substantial interest from member nations to better understand **multiple stressors/cumulative effects** and PICES is well positioned to work on this

Looking Forward: Informing Management/Policy

- Within PICES this could include new elements in the North Pacific Ecosystem Status Report
- Beyond PICES this could include reports like World Ocean Assessment II
- However, to truly move to a fully-integrated ecosystem-based approach (beyond fisheries) will require the development of a framework to inform sustainable ocean use

Acknowledgements

- PICES for partial travel support

- The many members of various PICES expert groups who provided information/data presented here and J Nelson for collating background information

Questions?