NEREUS PROGRAM
Predicting Future Oceans

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Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship

Stockholm University

Towards Common Ecosystem Reference Points for North Pacific Ecosystems

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Presentation Structure

1) Some terminology
2) Matching reference points to policy commitments
3) Recent work on ecosystem reference points
4) Incorporating human dimensions

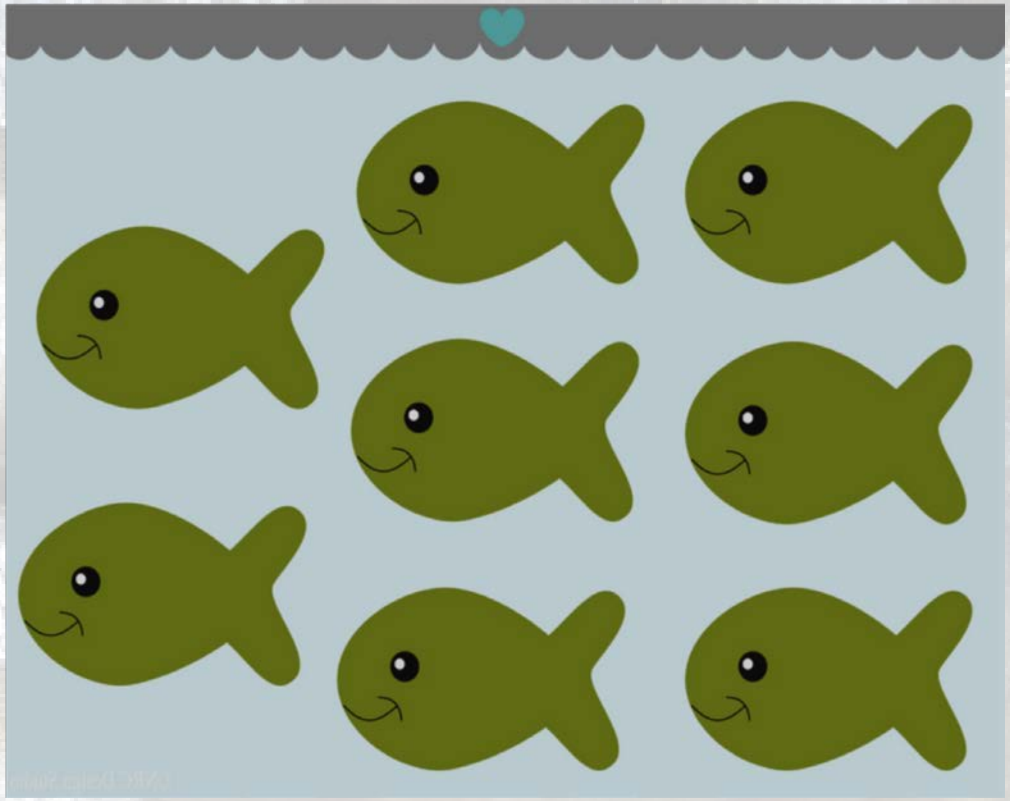
Presentation Structure

1) Some terminology

Scope of management

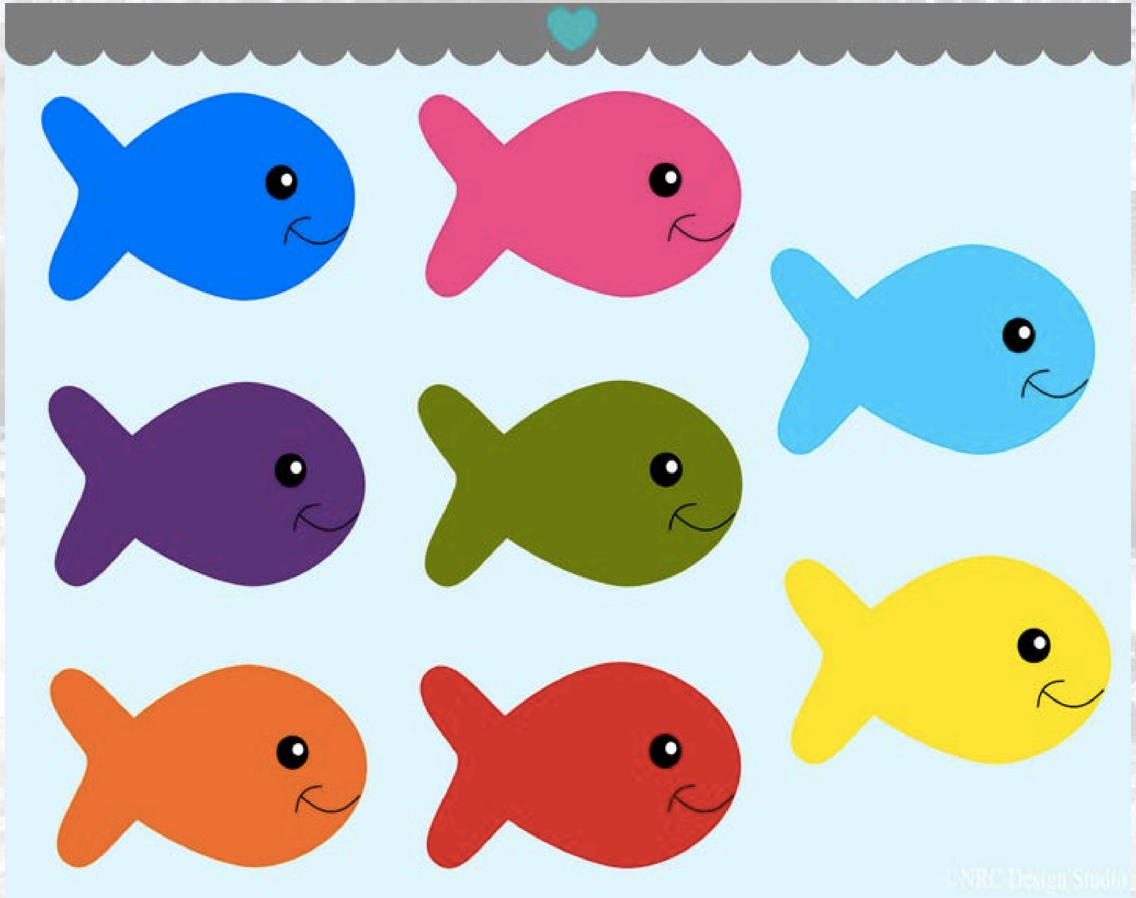
Single-species management (focused in particular on stock size and reproductive potential)

To a large degree, single-species assessments are still the basis for much advice on fish stock management



(Mollmann et al. 2014)

Scope of management



Multi-species management (also considers predator/prey relationships and environmental conditions)

Scope of management

Ecosystem-based management
(more holistic approach – aimed at maintaining integrity of ecosystems as much as possible, while supporting sustainable levels of human use)

Goals and objectives

Regardless of scope, management should be guided by clearly stated goals and objectives

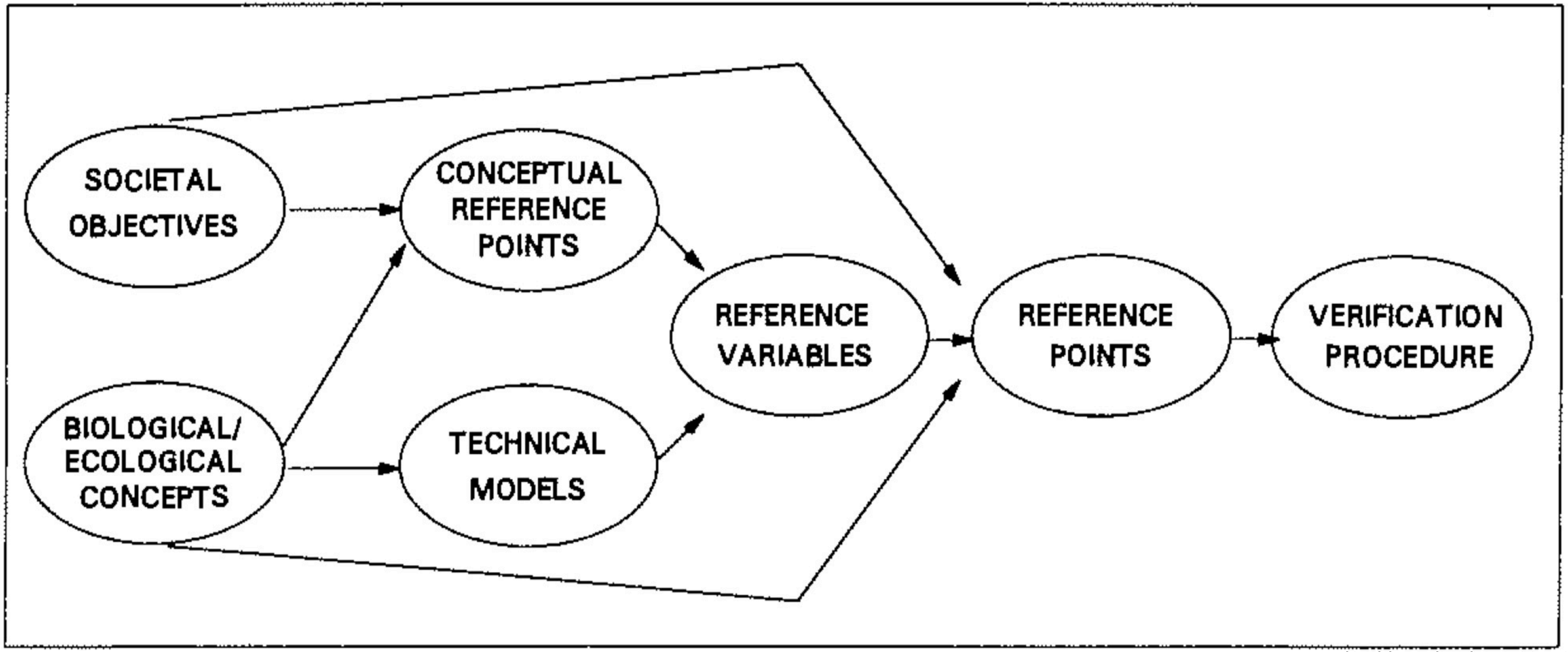
- Can be biological, ecological, economic, social
- Not always an obvious decision, as common goals are likely to be mutually exclusive to some degree

Goals and objectives (examples)

	Goals	Operational objectives
Biological	To maintain the target species at or above the levels necessary to ensure their continued productivity	To maintain the stock at all times above 50% of its mean unexploited level
Ecological	To minimize the impacts of fishing on the physical environment and on non-target (bycatch), associated and dependent species	To maintain all non-target, associated and dependent species above 50% of their mean biomass levels in the absence of fishing activities
Economic	To maximize the net incomes of the participating fishers	To stabilize net income per fisher at a level above the national minimum desired income
Social	To maximize employment opportunities for those dependent on the fishery for their livelihoods	To include as many of the existing participants in the fishery as is possible given the biological, ecological and economic objectives listed above

(Hoggarth et al. 2006: 25)

From objectives to reference points



(Caddy and Mahon 1995: 3)

Conceptual Reference Points

Target reference points (TRPs) → correspond to desirable conditions

Limit reference points (LRPs) → correspond to undesirable conditions to be avoided (thresholds)

Conceptual Reference Points

Reference points provide signposts for the manager: "here you are doing well" (target) and "if you go any further down this road, we are in trouble" (limit)

(Flickr CC Eddie C3)
Quotes: Cohrane 2002

Technical Reference Points

Conceptual reference points can subsequently be defined as specific “technical reference points”

(e.g. fishing mortality giving maximum total yield in a production model → F_{MSY})

Ecosystem Reference Points

More challenging in many ways, for example:

1) Management objectives for ecosystems are not always well-defined (e.g. in comparison with management objectives for single stocks)

2) More (diverse) stakeholders likely involved

3) Can encompass flora, fauna and abiotic conditions (and target/non-target species)

Ecosystem Reference Points

BUT… ecosystem-based regimes are diverse!
Can cover everything from a collection of single-species reference points (e.g. setting aside some percentage of forage fish as prey for target species or protected species (e.g. marine mammals)) to reference points that measure some level of ecosystem function (e.g. measures of biodiversity)

(Babcock and Pikitch 2004)

Presentation Structure

2) Matching reference points to policy commitments

2020 is coming soon…

Convention on Biological Diversity

Strategic Plan on Biodiversity 2011-2020 and Aichi Targets (#6)

"**By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches**, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits."

Presentation Structure

3) Recent work on ecosystem reference points

PICES Work (completed)

2003	**SG-EBM** Ecosystem-based management science and its application to the North Pacific
2004-2009	**WG19** Ecosystem-based management science and its application to the North Pacific
2011-2015	**WG 28** Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors
2015-2016	**SG CERP** Common Ecosystem Reference Points across PICES Countries

PICES Work (ongoing!)

2016- **WG 36** Common Ecosystem Reference Points across PICES Countries

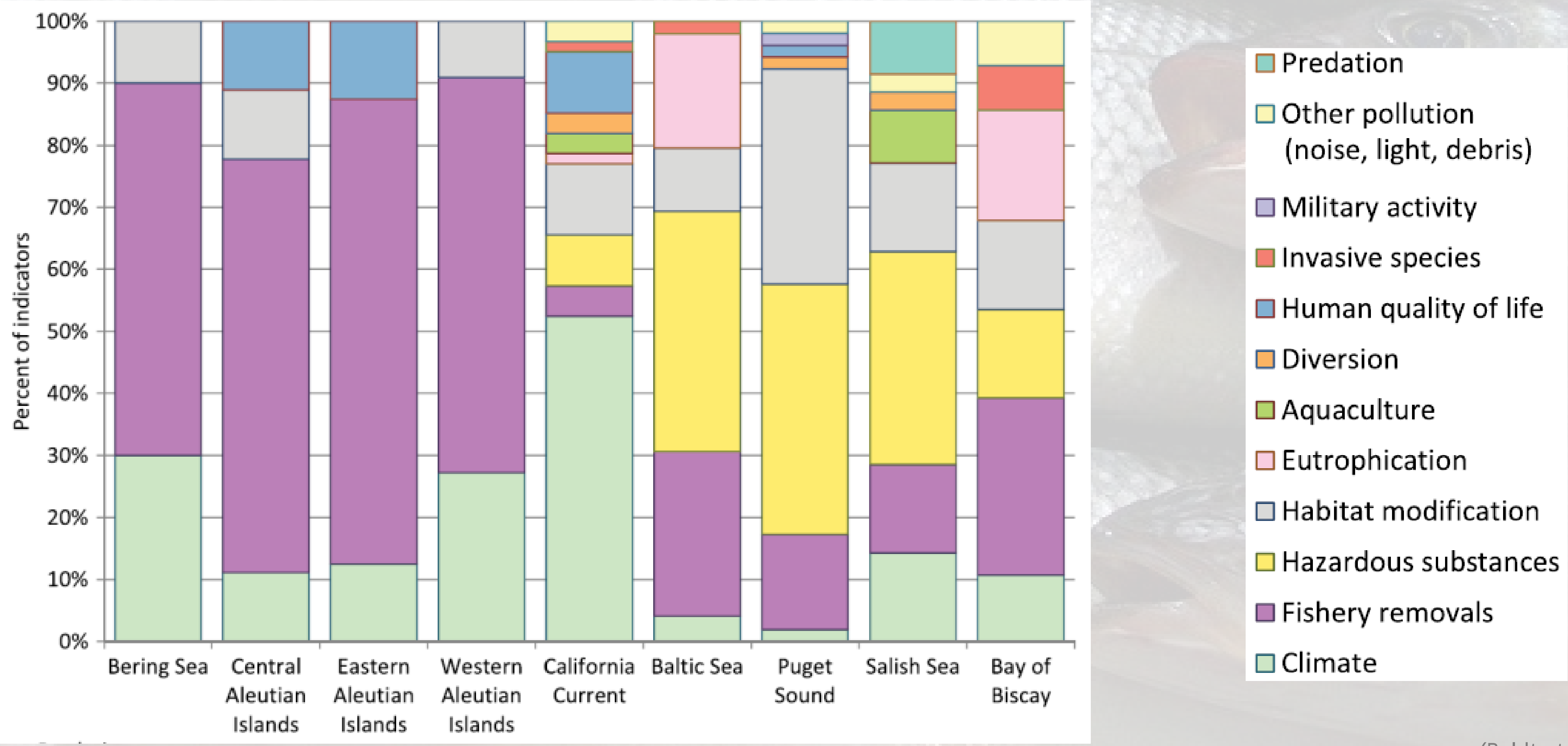
Co-chairs: Xiujuan Shan (China)
Mary Hunsicker (USA)

Join our session today!
S3 - Room D-504 (10:50 AM)

WG 28 - Identifying availability of biological indicators

		Canada	China	Japan	Korea	Russia	U.S.
Relative biomass							
	gelatinous zooplankton	N,N	Y,N	N,N	Y,Y	Y,Y	Y,Y
	cephalopods	N,N	Y,N	Y,Y	Y,Y	Y,Y	N,N
	small pelagic fishes	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y
	scavengers	N,S	N,N	N,N	S,S	Y,Y	N,Y
	demersals	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	N,Y
	piscivores	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	N,Y
	top predators	Y,Y	Y,Y	Y,Y	S,S	Y,Y	Y,Y
Biomass ratios	piscivore:planktivore	N,Y	Y,Y	Y,Y	Y,Y	S,Y	N,Y
	pelagic:demersal	N,Y	Y,Y	Y,Y	Y,Y	N,Y	N,Y
	infauna:epifauna	N,N	N,N	N,N	N,S	N,Y	N,N
Habitat-forming taxa	nearshore	Y,Y	S,N	S,S	S,S	Y,Y	N,N
	offshore	N,N	S,N	N,N	S,S	Y,Y	Y,Y
Size spectra		N,N	Y,Y	N,N	Y,Y	Y,Y	Y,Y
Taxonomic diversity		S,S	Y,Y	S,S	Y,Y	S,S	N,Y
Total fishery removals		Y,Y	S,Y	Y,Y	S,S	Y,Y	Y,Y
Max. (or mean) length		N,Y	Y,N	Y,Y	Y,Y	Y,Y	N,Y
Size-at-maturity	target species	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	Y,S
	bycatch	N,N	N,N	N,N	Y,Y	Y,Y	N,S
	top predators	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y	Y,Y
Trophic level or trophic spectrum of the catch		Y,Y	Y,Y	Y,Y	Y,Y	S,Y	Y,Y
Biophysical characteristics		S,S	Y,Y	Y,Y	Y,Y	S,S	S,S

WG 28 - Identifying variance in types of indicators being used in different ecosystems



(Boldt et al. 2014)

Samhouri et al. (2017)

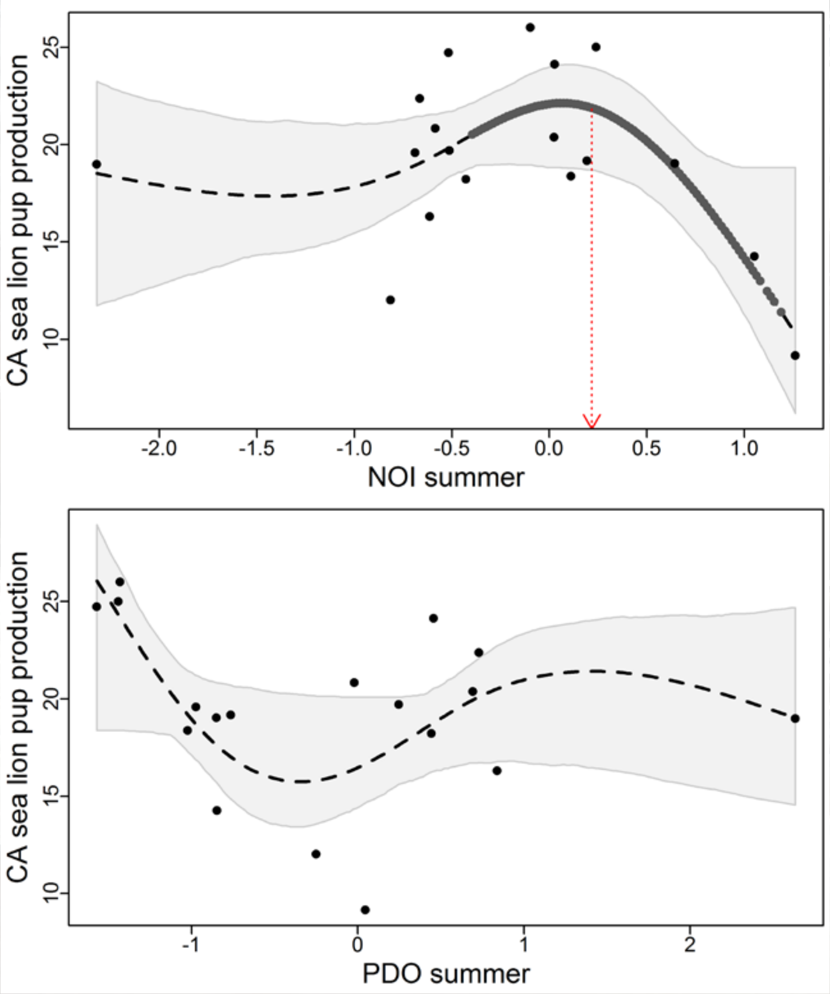
Presents quantitative framework based on multimodel inference (MMI) that allows for precautionary screening of threshold relationships between ecosystem states and environmental or human pressures.

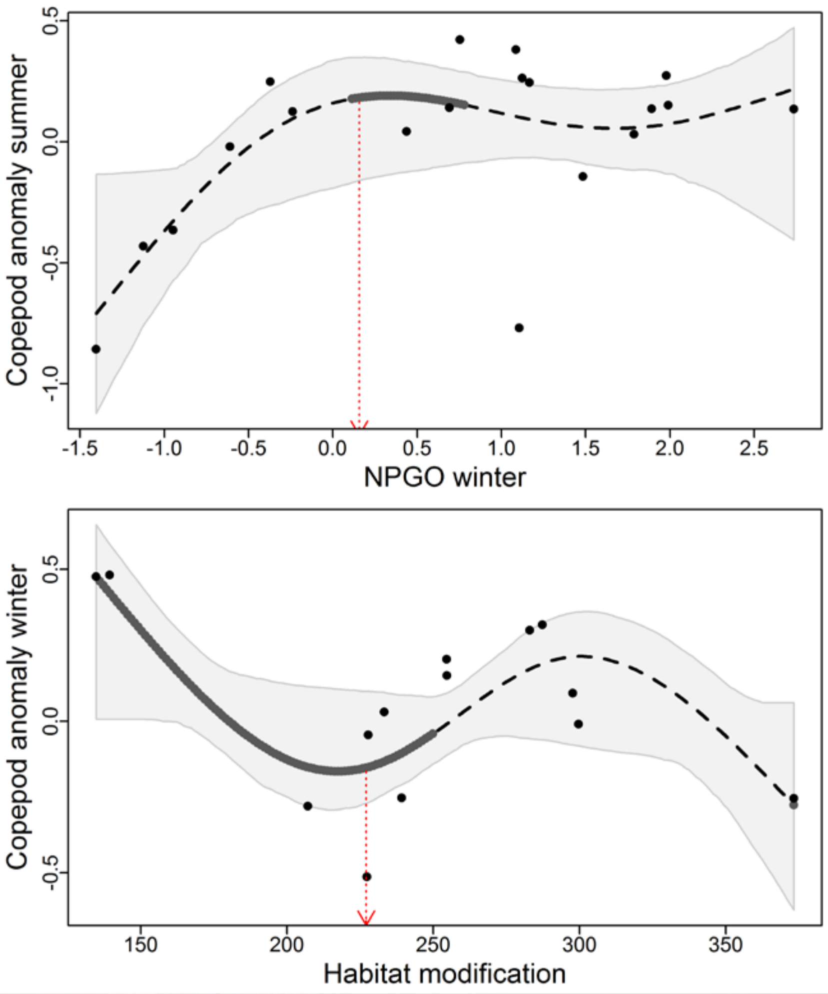
Methods: gradient forest and generalized additive model (GAM) analyses to look for nonlinearities and to identify potential ecosystem state thresholds

(Samhouri et al. 2017)

Samhouri et al. (2017)

Sea Lion Pup Production





Copepod anomalies

(Samhouri et al. 2017)

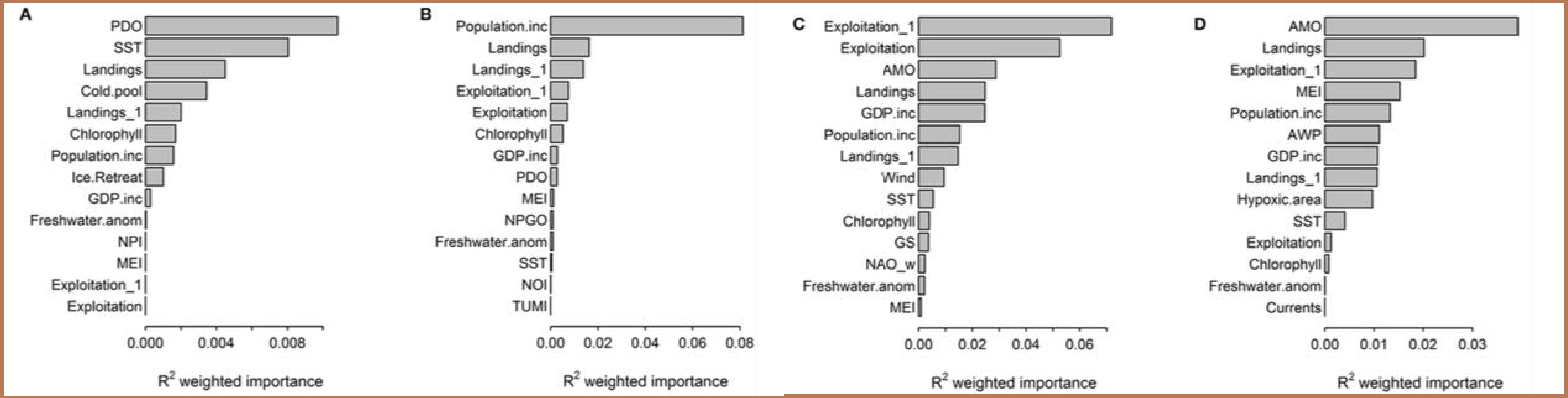
Tam et al. (2017)

Thresholds of ecological indicators represent points at which a small increase in one or many pressure variables results in an abrupt change of ecosystem responses.

Tam et al. (2017) develop thresholds using gradient forests for a suite of ecological indicators in response to multiple pressures that convey ecosystem status for large marine ecosystems from the US Pacific, Atlantic, sub-Arctic, and Gulf of Mexico.

(Tam et al. 2017)

Tam et al. (2017)



Alaska | California Current | Northeast US | Gulf of Mexico

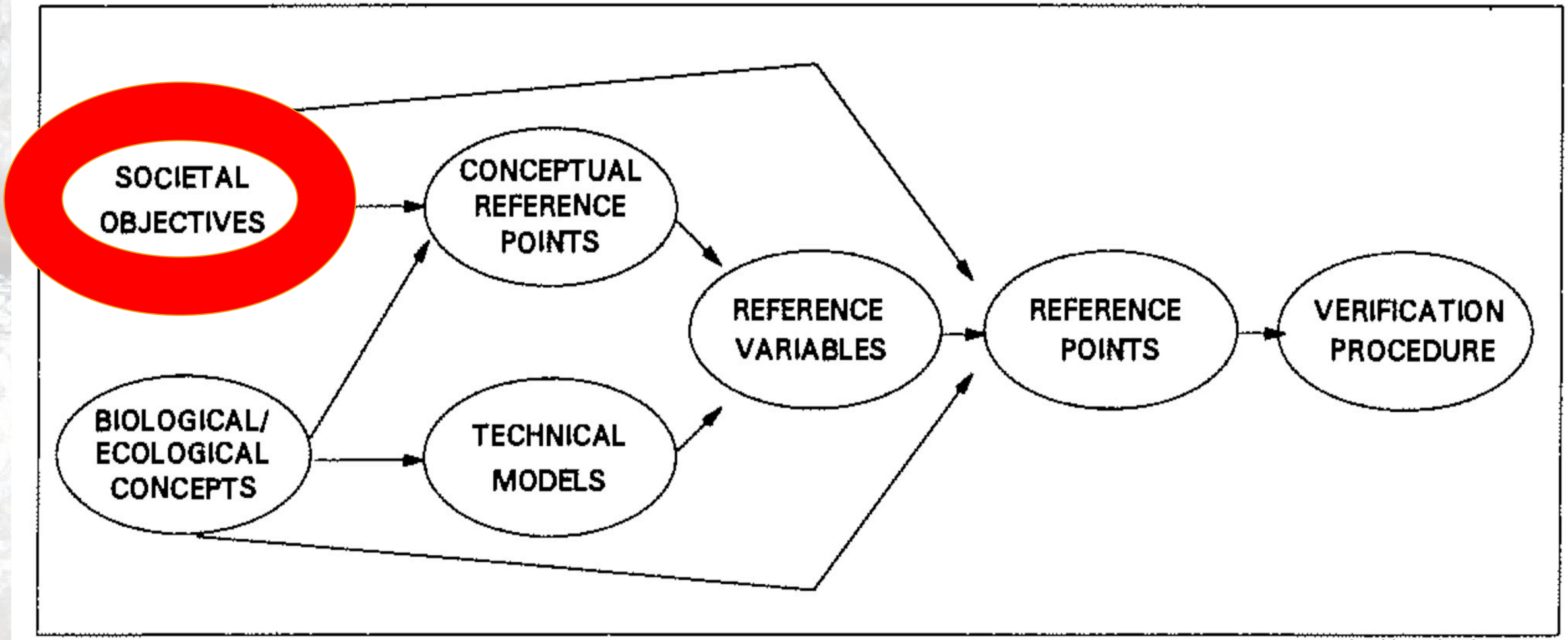
Importance of human and environmental pressure variables across ecological indicator outputs (gradient forest analyses)

(Tam et al. 2017)

Presentation Structure

4) Incorporating human dimensions

This slide again



(Caddy and Mahon 1995: 3)

Dealing with shifts in societal objectives

Interviews with fishers and fishery managers in Matsushima Bay (Japan) and Salish Sea (Canada / USA) about changes in livelihoods and management objectives

"Our social systems are in as much change – if not more – as our ecological systems. [...] Our knowledge and data on both are changing. We have much more data now on our ecosystems than we had 10 years ago"

"the ecosystem needs to be in balance [..] our ocean health has got to be our number one priority, it isn't an ocean we have total control over."

"There must be something which keeps you there, giving you a sense of satisfaction, while at the same time, it must also give you enough to support yourself".

(Minohara, Cooling and Blasiak. *in press*)

Dealing with shifts in societal objectives

Traditionally, seaweed farming in Matsushima Bay was operated in family units. Husband-and-wife teams frequently worked in tandem on a boat ("meoto-bune"), and received support from their children when they landed.

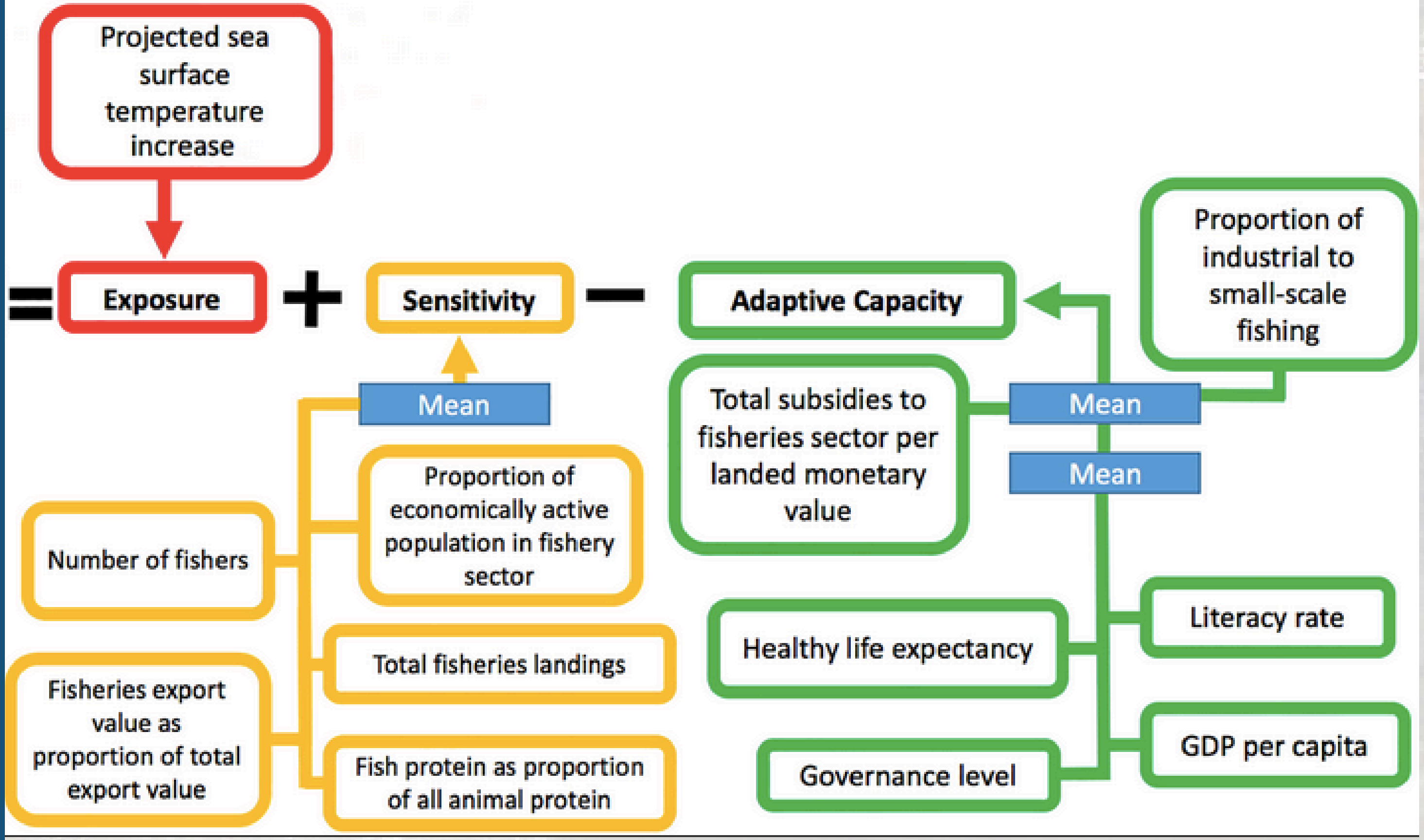
However, the seaweed farming and production facilities were **washed away by the tsunami in 2011**, and the only way to receive government support to rebuild the industry was to form a group and work collaboratively.

They **decided to establish a company** and restart their operations, but some struggled to change their traditional way of doing things, feeling uncomfortable with a situation that was **"like having a lot of CEOs in one company"**. Another respondent explained that working individually was much harder, and **he used to "wear out [his] body", while working in a group is "wearing out [his] mind".**

(Minohara, Cooling and Blasiak. *in press*)

Bringing together human dimensions and biological / ecological indicators

- Update of Allison et al. 2009
- Constructed vulnerability index for 147 coastal countries
- Methodology: Exposure + Sensitivity - Adaptive Capacity = Vulnerability
- Based on a set of 12 primary variables



(Blasiak et al. 2017)

So how did the updated vulnerability index look?

Allison et al. 2009	
1	Angola
2	DR Congo
3	Russian Federation
4	Mauritania
5	Senegal
6	Mali
7	Sierra Leone
8	Mozambique
9	Niger
10	Peru
11	Morocco
12	Bangladesh
13	Zambia
14	Ukraine
15	Malawi

Updated/revised index	
1	**Kiribati**
2	**Micronesia**
3	**Solomon Islands**
4	**Maldives**
5	**Tuvalu**
6	Haiti
7	Sierra Leone
8	China
9	Seychelles
10	Indonesia
11	Guinea-Bissau
12	Cote d'Ivoire
13	Sao Tome e Principe
14	Senegal
15	Ghana

(Blasiak et al. 2017)

List of most to least vulnerable countries

Near-future scenario (2016-2050)			
RCP 2.6	**RCP 4.5**	**RCP 8.5**	**(Rank)**
KIRIBATI*	KIRIBATI*	KIRIBATI*	1
MALDIVES*	MALDIVES*	MICRONESIA, FED. STATES*	2
SOLOMON ISLANDS*	SOLOMON ISLANDS*	SOLOMON ISLANDS*	3
MICRONESIA, FED. STATES*	SIERRA LEONE	MALDIVES*	4
MOZAMBIQUE	MICRONESIA, FED. STATES*	VANUATU*	5

(Blasiak et al. 2017)

List of most to least vulnerable countries

Near-future scenario (2016-2050)				Distant-future scenario (2066-2100)		
RCP 2.6	RCP 4.5	RCP 8.5	(Rank)	RCP 2.6	RCP 4.5	RCP 8.5
KIRIBATI*	KIRIBATI*	KIRIBATI*	1	KIRIBATI*	KIRIBATI*	KIRIBATI*
MALDIVES*	MALDIVES*	MICRONESIA, FED. STATES*	2	MALDIVES*	MOZAMBIQUE	SOLOMON ISLANDS*
SOLOMON ISLANDS*	SOLOMON ISLANDS*	SOLOMON ISLANDS*	3	SOLOMON ISLANDS*	SIERRA LEONE	TUVALU*
MICRONESIA, FED. STATES*	SIERRA LEONE	MALDIVES*	4	MICRONESIA, FED. STATES*	SAMOA*	VANUATU*
MOZAMBIQUE	MICRONESIA, FED. STATES*	VANUATU*	5	SIERRA LEONE	COMOROS*	MALDIVES*

(Blasiak et al. 2017)

Data quality concerns
Ecological indicators (example)

Allison et al – exposure calculated from land surface temperature anomalies

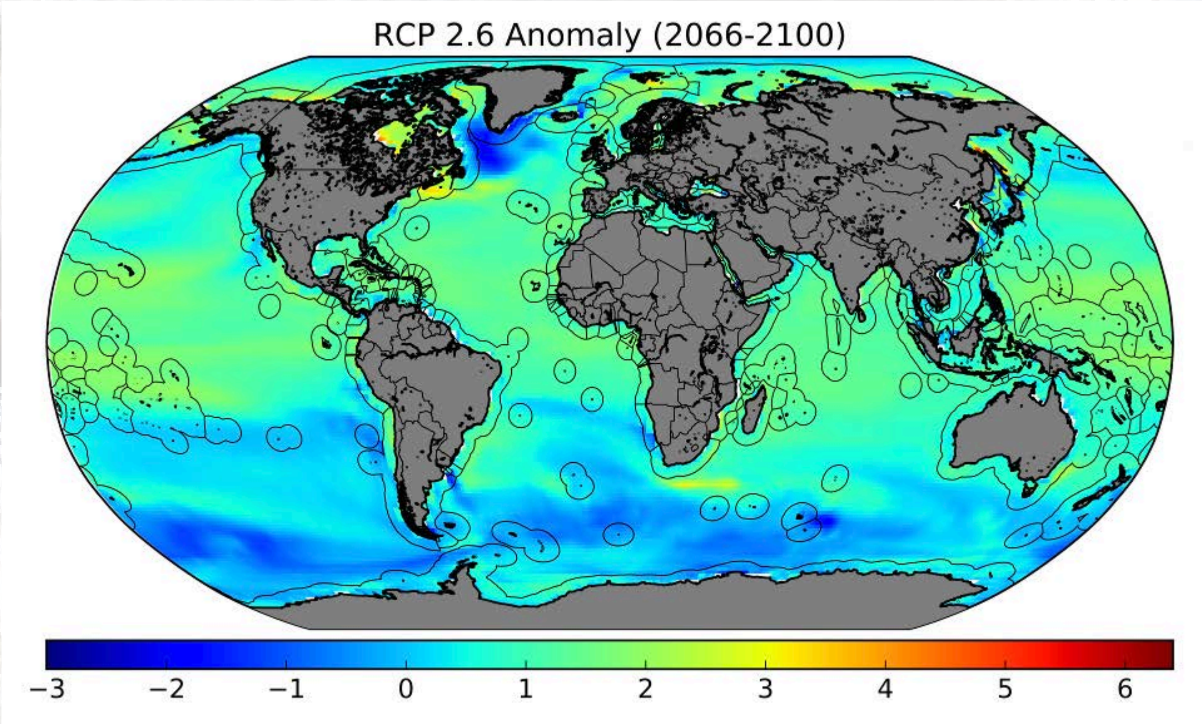
But now, much more ecological model output data available

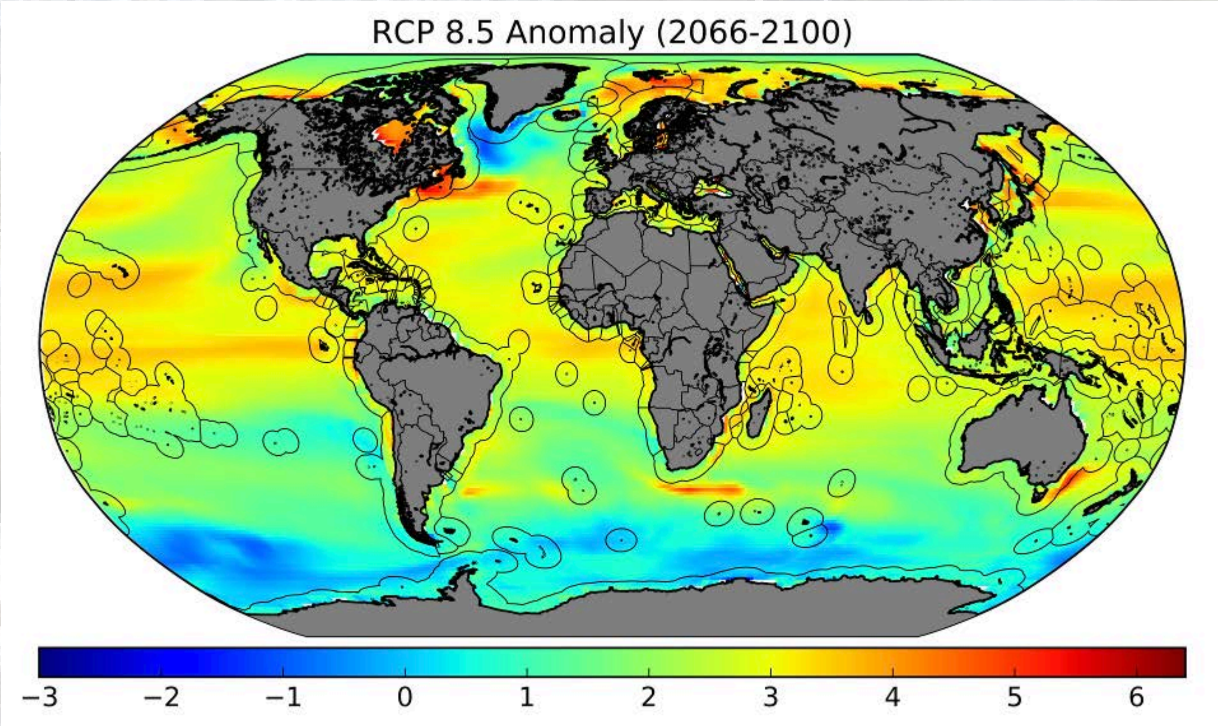
Calculated multi-model ensemble means using CMIP5 output data from 14 models (historical and near-future (2016-2050) and distant-future (2066-2100); averaged across exclusive economic zones (EEZs) of different countries

CMIP5 models used: CanESM2, CNRM-CM5, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, GISS-E2-H, GISS-E2-R, HadGEM2-AO, MIROC-ESM-CHEM, MIROC5, MPI-ESM-LR, MPI-ESM-MR, NorESM1-M, NorESM1-ME

(Blasiak et al. 2017)

Sea Surface Temperature Anomalies





Optimistic (CO2 reductions, mitigation, etc.)

Pessimistic (Business-as-usual)

(Blasiak et al. 2017)

Data quality concerns
Socio-economic indicators (example)

For number of fishers

FAO is only source of comparable country data, but large gaps exist:

-- data for many countries over 20 years old
-- some countries disaggregate inland / marine fisheries
-- some disaggregate aquaculture from capture fisheries
-- some disaggregate part-time and full-time fishers

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T-2 **Numbers of fishers by countries or areas (1984 - 1996)**
Nombre de pêcheurs par pays ou zones (1984 - 1996)
Número de pescadores por países o áreas (1984 - 1996)

Country or area / Pays ou zone / País o área		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Côte dIvoire														
Inland														
Full time	M	...	...	...	...	...	...	3 000f	...	...	...	...	...	3 805
Total	M	...	...	...	...	...	...	3 000f	...	...	...	...	...	3 805
Marine, nei														
Full time	M	...	...	...	...	...	...	11 000f	...	...	...	...	...	15 902
Part time	M	...	...	...	...	...	...	...	...	...	...	...	...	...
Occasional	M	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	M	...	...	...	...	...	...	11 000f	...	...	...	...	...	15 902
Total														
Full time	M	...	...	...	...	...	...	14 000f	...	...	...	...	...	19 707
Part time	M	...	...	...	...	...	...	...	...	...	...	...	...	...
Occasional	M	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	T	...	...	...	...	...	...	14 000f	...	...	...	...	...	19 707
Croatia[21]														
Inland														
Full time	M	...	...	...	...	...	...	...	606	633	1 127	536	446	366
Occasional	M	...	...	...	...	...	...	...	44 297	31 482	33 293	34 905	37 789	38 684
Total	M	...	...	...	...	...	...	...	44 903	32 115	34 420	35 441	38 235	39 050
Marine Coastal														
Full time	M	...	...	...	...	...	...	...	2 122	2 279	2 547	2 184	2 511	2 452
Occasional	M	...	...	...	...	...	...	...	9 001	10 181	9 753	9 772	9 245	8 725
Total	M	...	...	...	...	...	...	...	11 123	12 460	12 300	11 956	11 756	11 177
Total														
Full time	M	...	...	...	...	...	...	...	2 728	2 912	3 674	2 720	2 957	2 818
Occasional	M	...	...	...	...	...	...	...	53 298	41 663	43 046	44 677	47 034	47 409
Total	T	...	...	...	...	...	...	...	56 026	44 575	46 720	47 397	49 991	50 227
Cuba														
Inland														
Total	M	...	...	...	...	...	...	...	...	...	...	...	...	...
Marine, nei														
Full time	M	13 747	13 554	13 154	13 549	12 659	12 202	12 130	11 865	...	...	...	...	...
Part time	M	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	M	13 747	13 554	13 154	13 549	12 659	12 202	12 130	11 865	...	...	...	...	...
Total														
Full time	M	13 747	13 554	13 154	13 549	12 659	12 202	12 130	11 865	...	...	...	...	...
Part time	M	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	T	13 747	13 554	13 154	13 549	12 659	12 202	12 130	11 865	...	...	...	...	...
Cyprus														
Aquatic-life cultivation														
Full time	F	...	...	...	...	...	...	...	...	10	10	16	14	16
	M	...	...	...	...	...	...	...	...	56	70	85	91	104
Part time	F	...	...	...	...	...	...	...	...	0	8	3	11	2
	M	...	...	...	...	...	...	...	...	5	10	8	19	18
Total	F	...	...	...	...	...	...	...	...	10	18	19	25	18
	M	...	...	...	...	...	...	...	...	61	80	93	110	122
Inland														
Full time	F	...	...	...	...	...	...	...	...	2	5	4	3	4
	M	...	...	...	...	...	...	...	...	12	16	19	16	18
Part time	F	...	...	...	...	...	...	...	...	36	30	23	18	20
	M	...	...	...	...	...	...	...	...	39	27	27	10	12
Total	F	...	...	...	...	...	...	...	...	38	35	27	21	24
	M	...	...	...	...	...	...	...	...	51	43	46	26	30
Marine, nei														
Full time	M	210	530	503	469	477	444	230	565	1 019	1 035	974	1 097	1 182
Part time	M	115	229	264	317	306	314	171	370	...	...	...	...	...
Occasional	M	223	475	518	577	559	548	360	757	...	...	...	...	...
Total	M	548	1 234	1 285	1 363	1 342	1 306	761	1 692	1 019	1 035	974	1 097	1 182
Total														
Full time	F	...	...	...	...	...	...	...	...	12	15	20	17	20
	M	210	530	503	469	477	444	230	565	1 087	1 121	1 078	1 204	1 304
Part time	F	...	...	...	...	...	...	...	...	36	38	26	29	22
	M	115	229	264	317	306	314	171	370	44	37	35	29	30
Occasional	M	223	475	518	577	559	548	360	757	...	...	...	...	...
Total	F	...	...	...	...	...	...	...	...	48	53	46	46	42

(21) "Inland/occasional", includes also sport, seasonal and contract fishing.
"Eaux intérieures/occasionnels", comprend aussi pêcheurs sportifs, saisonniers ou travaillant sous contrat.
"Aguas continentales/ocasionales" incluye también pescadores deportivos, estacionales o que pescan bajo contrato.

(Blasiak et al. 2017)

Dealing with data issues

- Monnereau et al. (2017) → Looks at the methodological decisions behind vulnerability work (e.g. redundancy of variables, scaling of socio-economic variables to population size)

- Cheung et al. (2005) and Cheung and Jones (*in press*) – using fuzzy logic to deal with data gaps and differences in data quality

Identifying Common Ecosystem Reference Points

- Lots of exciting work going on, and lots of progress has been made with determining data availability across member countries

- Methodological toolkit rapidly evolving

- Societal objectives (and human dimensions!) are a key element towards setting goals/objectives and identifying appropriate ecosystem reference points (ecosystems AND social systems will remain dynamic and variable across PICES member states!)

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2017)

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Thank you!

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship

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