

Supplementary Material

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Ecosystem services provision today and in the past: A comparative study in two Baltic lagoons

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Table S1 Definition of Indicators used in the assessment

Ecosystem Service Section: Provisioning Services				
Division: Nutrition	Group: Biomass	Class: Wild plants, algae and their outputs	Indicator: Harvest – ton yr ⁻¹ km ⁻²	Biomass of all plants and algae used for human consumption. It can be directly consumed, or indirectly by extraction of elements or parts of the organism that is used for consumption
			Indicator: N ^o of species – n ^o km ⁻²	Number of all species used by humans for nutritional reasons
		Class: Wild animals and their outputs	Indicator: Landings – ton yr ⁻¹ km ⁻²	All reported biomass connected with commercial fisheries. It includes the biomass of all species (fish or shellfish) of the fisheries of the assessment area. It can include fisheries from elsewhere outside of the study area but that are unloaded and sold in the fish markets within the assessment area
			Indicator: Landing of key market species – ton yr ⁻¹ /km ⁻²	Biomass of key market species only.
		Class: Animals from in situ aquaculture	Indicator: Harvest – ton yr ⁻¹ km ⁻²	Harvested biomass of animals from in aquaculture facilities in the study area. It includes the biomass of all species and facilities per year
			Indicator: N ^o of species – n ^o km ⁻²	Number of species used in aquaculture.
		Class: Plants and algae from in situ aquaculture	Indicator: Harvest – ton yr ⁻¹ km ⁻²	Harvested biomass of all plants from aquaculture facilities in the study area, used for human consumption. It includes

				the biomass of all species and facilities per year.
			Indicator: N ^o of species – n ^o km ⁻²	Number of algal/plant species used in aquaculture.
	Group: Water	Class: Surface water for drinking purposes	Indicator: Use of water – m ⁻³ km ⁻²	Use of water taken from the ecosystem for drinking purposes.
Division: Material	Group: Biomass	Class: Fibres and other materials from plants, algae and animals for direct use or processing	Indicator: Harvest – ton yr ⁻¹ km ⁻²	Harvest of fibres and other material from organisms, for direct use as a material or processing for cosmetics or pharmaceutical industries as an example.
		Class: Materials from plants, algae and animals for agriculture	Indicator: Harvest – ton yr ⁻¹ km ⁻²	Harvest of materials from organisms, which are used for agriculture (for example as fertilizers).
	Group: Water	Class: Surface water for non-drinking purposes	Indicator: Use of water – m ⁻³ km ⁻²	Use of water for all purposes except for drinking, for example irrigation for agriculture.
Division: Energy	Group: Biomass-based energy	Class: Plant base resources	Indicator: Use – ton yr ⁻¹ km ⁻²	Use of plant-based material used to generate energy, for example by burning or for biofuel.
		Class: Animal base resources	Indicator: Use – ton yr ⁻¹ km ⁻²	Use of animal-based material used to generate energy, for example by burning carcasses of dead animals (e.g. wales).
Ecosystem Service Section: Regulating & Maintenance Services				
Division: Mediation of waste, toxics and other nuisances	Group: Mediation by ecosystems	Class: Filtration/sequestration/storage/accumulation by ecosystems	Indicator: N-fixation – kg yr ⁻¹ km ⁻²	Atmospheric Nitrogen fixation to the lagoon.
			Indicator: Burial of P – kg yr ⁻¹ km ⁻²	The burial of Phosphorous in the sediment.
			Indicator: Denitrification – kg yr ⁻¹ km ⁻²	The breakdown of nitrates by bacteria, resulting in the release of free nitrogen.
		Class: Dilution by atmosphere, freshwater and marine ecosystems	Indicator: Average of beach closures per year – n ^o km ⁻²	Number of beach closures per year, due to microbial contamination (according to the Bathing Water Directive).
Division: Mediation of Flows	Group: Mass Flows	Class: Mass stabilisation and control of erosion rates	Indicator: Extent of selected emerged, submerged and intertidal habitats – km ⁻² km ⁻²	Area covered by the most common habitats in the study area. These habitats should be representatives of the study area.
		Class: Buffering and attenuation of mass flows	Indicator: Sediment accumulation rate – cm yr ⁻¹	Accumulation of sediment in centimetres per year.
	Group: Liquid Flows	Class: Flood Protection	Indicator: Shoreline erosion rate – mm yr ⁻¹	Erosion of the shoreline in millimetres per year, due to removal of coastal sediments by wave action, currents, drainage or strong winds.

			Indicator: Significant wave height – m	The significant wave height is defined traditionally as the mean wave height of the highest third of the waves. It depends on wind speed, fetch (the distance of the upwind coastline), duration of the wind and depth of a water body.		
			Indicator: Design-basis flood – m	The design flood water level is the fundamental high used for designing and planning of coastal defences. It is estimated based on the highest water level which has been reliably measured at a highest storm surge adding secular sea level rise (10-15 cm per century or 30 cm per 200 years).		
Division: Maintenance of physical, chemical, biological conditions	Group: Lifecycle maintenance, habitat and gene pool protection	Class: Maintaining nursery populations and habitats	Indicator: Submerged and intertidal habitats diversity – n° km ⁻²	Number of submerged and intertidal habitats within the study area.		
			Indicator: Occurrence of bottom oxygen concentration < 6 mg/L – days yr ⁻¹	Number of days per year when the bottom oxygen concentration is lower than 6 mg/L (which is considered the threshold for hypoxia).		
			Indicator: Secchi depth – m	Is a method used for estimating the transparency of water by submerging a white disc and recording the depth at which the disc is no longer visible.		
			Indicator: Species distribution - km ⁻² km ⁻²	Distribution area of species that use the water body to spawn or reproduce		
			Indicator: Nursery areas – km ⁻² km ⁻²	Area used as nursery grounds for marine species.		
			Indicator: Percentage of nursery areas which are under protection – km ⁻² km ⁻²	Area of nursery grounds, which is protected under any level of management or governance.		
			Group: Pest and disease control	Class: Pest and disease control	Indicator: Harmful Algal Bloom outbreaks – n° km ⁻²	Number of HAB outbreaks that led to a closure of a beach or lagoon in the study area.
					Indicator: Presence of alien species– n° km ⁻²	Presence of non-indigenous species (introduced outside of their natural range or dispersal potential) in the study area.
Class: Decomposition and fixing processes			Indicator: Nitrogen removal - %	Removal of Nitrogen through natural processes.		
Group: Soil formation and decomposition			Indicator: Water residence time – months	Time (in months) which a water mass spends in the study area. Related also to flushing time.		

Group: Water conditions	Class: Chemical conditions of salt waters	Indicator: Nutrient concentration – mg L	Total Nitrogen and Phosphorous concentration
		Indicator: Salinity – PSU	Salinity is the content of dissolved salt in the water.
		Indicator: Oxygen concentration – mg L	Concentration of dissolved oxygen in the water (bottom and surface).
Group: Atmospheric composition and climate regulation	Class: Global climate regulation by reduction of greenhouse gas concentration	Indicator: Carbon stock – tonC km ²	Carbon stored in the system (all components of the ecosystem), through fixation and burial processes.
		Indicator: Carbon sequestration – tonC yr ⁻¹ km ²	Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide.
		Indicator: pH	The numeric scale of pH is used for representation of acidity of alkalinity of the water.
		Indicator: Net primary production – tonC yr ⁻¹ km ²	Primary production (PP) is an intrinsic part of the carbon cycle. It stands for a synthesis of organic matter from carbon dioxide via photo- or chemosynthesis by primary producers. Net PP takes into account losses of carbon with respiration
	Class: Micro and regional climate regulation	Indicator: Evaporation rate – per km ⁻²	Evaporation of water from a water surface. Depends on the water temperatures, air temperature, humidity and wind speed.

Ecosystem Service Section: Cultural Services				
Division: Physical and Intellectual interactions with biota, ecosystems, seascapes	Group: Physical and experiential interactions	Class: Experiential use of plants, animals and seascapes	Indicator: N° of visitors taking part in biota related activities – n° yr ⁻¹ km ⁻²	Number of people taking part in in-situ whale and bird watching, snorkelling, diving, and all other activities related to biota.
		Class: Physical use of land/seascapes	Indicator: N° of tourists (within 1 km of coastal zone) – n° km ⁻²	Number of tourists (or overnight stays) accommodated in an area of 1 km of the coastal zone (counting from the water line to land)
			Indicator: N° of ship berth in the marinas – n° km ⁻²	Number of ship berths in the marines within the study area.
			Indicator: N° of tourist boats – n°*capacity km ⁻²	Number of boats related to tourist tours, and the capacity of visitors per boat.
			Indicator: Scientific studies, Documentaries, educational publications – n° yr ⁻¹ km ⁻²	Number of educational and scientific material (in paper or online) related to the study area.
			Indicator: Visits to scientific and artistic exhibits – n° yr ⁻¹	Number of visitors attending scientific and artistic exhibitions (at least the most important ones occurring in the assessment period).
		Class: Heritage, cultural	Indicator: N° of cultural and heritage sites – n° km ⁻²	Number of cultural important and heritage sites. These are defined according to regional, national and international importance.
		Class: Entertainment	Indicator: N° of movies and broadcasts about the area – n° km ⁻²	Number of movies, clips, or media broadcasts having as a main focus the water body or coastal waters.

		Class: Aesthetic	Indicator: N° of pictures about the area – $\text{n}^{\circ} \text{yr}^{-1} \text{km}^{-2}$	Number of pictures, paintings and post-cards (paper or online) about the area.
Division: Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Group: Spiritual and/or emblematic	Class: Symbolic	Indicator: N° of Red List and iconic species – $\text{n}^{\circ} \text{km}^{-2}$	Number of Red List species within the area (international), and number of iconic species (local).
		Class: Sacred and/or religious	Indicator: N° of religious events (within 1 km of coastal zone) – $\text{n}^{\circ} \text{km}^{-2}$	Religious related events within 1 km of coastal zone. These include marriages, burials, Saint related events.
	Group: Other cultural outputs	Class: Existence	Indicator: N° of offers for health treatments (within 1 km of coastal zone) – $\text{n}^{\circ} \times \text{capacity km}^{-2}$	Number of places, within 1 km of coastal zone, related to health treatments. These include SPA's that use the environment (thermal waters, mud, etc.)
		Class: Bequest	Indicator: Extent of marine protected areas – $\text{km}^{-2} \text{km}^{-2}$	Extent of area within the study area, which is protected under local, regional, national and international management and policy.

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Table S2 Criteria for definition and attribution of a quality/reliability score

		Source of Data		
		Database / dataset	Reports / Literature	Expert valuation
Very High	1	Official data which is maintained on a regular basis with sound scientific accuracy (Example: EU Databases, Government or University/Institutes databases)	Published and Peer-Reviewed Scientific Papers in High ranking or high impact factor Journals. Official EU or Government Reports	Official EU, Government or EU funded Project websites or other sources of information.
High	2	Database maintained by Research Groups or individual researchers which can be access upon request	Public official reports by Government, Published Papers with a low impact factor and low-ranking Journals	Person with sound scientific or institutional knowledge about the selected service or indicator with proven knowledge regarding the topic addressed, more than 10 years of experience
Moderate	3	Public/private dataset that is not verified or validated	Public Reports, Scientific Papers not peer-reviewed	Unverified sources, public media and websites without a scientific background
Low	4	Unknown author or provider of data	Unknown author or Journal found on internet	Unknown source or provider

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Table S3 Original results of application for provisioning services for the initial status and present statuses. N/C – Not Considered. CC – Category of Change

Ecosystem Services Assessment - Provisioning (Initial Status)										
Section	Class	Indicator	Units	Value	Type of Data	Reliability				
Provisioning Services	Wild plants, algae and their outputs	Harvest	ton yr ⁻¹ km ⁻²	N/C	N/C					
		Nº of Species	nº km ⁻²							
	Wild animals and their outputs	Landings	ton yr ⁻¹ km ⁻²	3.937	Reports/ Literature	2	High			
		Landing of key market species	ton yr ⁻¹ /km ⁻²	1.082	Other Sources	2	High			
	Animals from in situ aquaculture	Harvest	ton yr ⁻¹ km ⁻²	N/C	N/C					
		Nº of Species	nº km ⁻²							
	Plants and algae from in situ aquaculture	Harvest	ton yr ⁻¹ km ⁻²							
		Nº of Species	nº km ⁻²							
	Surface water for drinking purposes	Volume of water	m ⁻³ km ⁻²							
	Fibres and other materials from plants, algae and animals for direct use or processing	Harvest	ton yr ⁻¹ km ⁻²							
	Materials from plants, algae and animals for agriculture	Harvest	ton yr ⁻¹ km ⁻²							
Surface Water for non-drinking purposes	Volume of water	m ⁻³ km ⁻²								
Plant based resources	Amount	ton yr ⁻¹ km ⁻²								
Animal based resources	Amount	ton yr ⁻¹ km ⁻²								
Ecosystem Services Assessment - Provisioning (Present Status)										
Section	Class	Indicator	Units			Value	CC	Type of Data	Reliability	
Provisioning	Wild plants, algae and their outputs	Harvest	ton yr ⁻¹ km ⁻²			3.36	-1	Reports/ Literature	1	
		Nº of Species	nº km ⁻²	N/C						
	Wild animals and their outputs	Landings	ton yr ⁻¹ km ⁻²		-4					Reports/ Literature
		Landing of key market species	ton yr ⁻¹ /km ⁻²	Very High						
			0.331							

Animals from in situ aquaculture	Harvest	$\text{ton yr}^{-1} \text{km}^{-2}$	N/C
	Nº of Species	$\text{n}^{\circ} \text{km}^{-2}$	
Plants and algae from in situ aquaculture	Harvest	$\text{ton yr}^{-1} \text{km}^{-2}$	
	Nº of Species	$\text{n}^{\circ} \text{km}^{-2}$	
Surface water for drinking purposes	Volume of water	$\text{m}^{-3} \text{km}^{-2}$	
Fibres and other materials from plants, algae and animals for direct use or processing	Harvest	$\text{ton yr}^{-1} \text{km}^{-2}$	
Materials from plants, algae and animals for agriculture	Harvest	$\text{ton yr}^{-1} \text{km}^{-2}$	
Surface Water for non-drinking purposes	Volume of water	$\text{m}^{-3} \text{km}^{-2}$	
Plant based resources	Amount	$\text{ton yr}^{-1} \text{km}^{-2}$	
Animal based resources	Amount	$\text{ton yr}^{-1} \text{km}^{-2}$	

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Table S4 Original results of application for regulating & maintenance services for the initial and present statuses. N/C – Not Considered. CC – Category of Change

Ecosystem Services Assessment - Regulating & Maintenance (Initial Status)							
Section	Class	Indicator	Units	Value	Type of Data	Reliability	
Regulating & Maintenance Services	Filtration / sequestration / storage / accumulation by ecosystems	N-fixation	kg yr ⁻¹ km ⁻²	0.121	Other Sources	3	Moderate
		Burial of P	kg yr ⁻¹ km ⁻²	23.05	Other Sources	3	Moderate
		Denitrification	kg yr ⁻¹ km ⁻²	23634	Other Sources	3	Moderate
	Dilution by atmosphere, freshwater and marine ecosystems	Average of beach closures per year	n° km ⁻²	0	Database/ dataset	1	Very High
	Mass stabilisation and control of erosion rates	Extent of selected emerged, submerged and intertidal habitats	km ⁻² km ⁻²	0.10	Other Sources	3	Moderate
	Buffering and attenuation of mass flows	Sediment accumulation rate	cm yr ⁻¹				
	Flood Protection	Shoreline erosion rate	mm yr ⁻¹ km ⁻²				
		Significant wave high	m	0.185	Other Sources	4	Low
		Design-basis Flood	m	0.769	Local Expert	1	Very High
	Maintaining nursery populations and habitats	Submerged and intertidal habitats diversity	n° km ⁻²	0.006	Local Expert	3	Moderate
		Occurrence of Oxygen concentration < 6 mg/L	days yr ⁻¹	0.5	Other Sources	3	Moderate
		Secchi depth	m	1.1	Database/ dataset	1	Very High
		Species distribution	km ⁻² km ⁻²		N/C		
		Nursery areas	km ⁻² km ⁻²				
	Pest and Disease control	% of nursery areas which are protected	km ⁻² km ⁻²	0	Reports/ Literature	2	High
		Harmful Algal Bloom Outbreaks	n° km ⁻²				
		Presence of alien species	n° km ⁻²	0	Reports/ Literature	1	Very High
	Decomposition and fixing processes	Nitrogen removal	%	79	Other Sources	3	Moderate
		Water residence time	months	2	Reports/ Literature	2	High

Chemical condition of salt waters	Nutrients concentration	mg L	0.662	Other Sources	3	Moderate
	Salinity	PSU	0.9	Database/ dataset	1	Very High
	Oxygen Concentration	mg L	11.3	Other Sources	3	Moderate
Global climate regulation by reduction of greenhouse gas concentrations	C stock	tonC km ⁻²				
	C sequestration	tonC yr ⁻¹ km ⁻²				
	pH		8.550	Database/ dataset	1	Very High
	PP	tonC yr ⁻¹ km ⁻²	0.003	Other Sources	3	Moderate
Micro and regional climate regulation	Evaporation rate	per km ⁻²	513750	Other Sources	3	Moderate

Ecosystem Services Assessment - Regulating & Maintenance (Present Status)

Section	Class	Indicator	Units	Value	CC	Type of Data	Reliability
Regulating & Maintenance Services	Filtration / sequestration / storage / accumulation by ecosystems	N-fixation	kg yr ⁻¹ km ⁻²	0.063	-3	Other Sources	3 Moderate
		Burial of P	kg yr ⁻¹ km ⁻²	17.04	-2	Other Sources	3 Moderate
		Denitrification	kg yr ⁻¹ km ⁻²	22756	0	Other Sources	3 Moderate
	Dilution by atmosphere, freshwater and marine ecosystems	Average of beach closures per year	n° km ⁻²	0	0	Database/ dataset	1 Very High
	Mass stabilisation and control of erosion rates	Extent of selected emerged, submerged and intertidal habitats	km ⁻² km ⁻²	0.04	-4	Other Sources	2 High
	Buffering and attenuation of mass flows	Sediment accumulation rate	cm yr ⁻¹		0	Reports/ Literature	2 High
	Flood Protection	Shoreline erosion rate	mm yr ⁻¹ km ⁻²		0	Reports/ Literature	2 High
		Significant wave high	m	0.163	0	Reports/ Literature	2 High
		Design-basis Flood	m	0.476	-3	Reports/ Literature	2 High
	Maintaining nursery populations and habitats	Submerged and intertidal habitats diversity	n° km ⁻²	0.006	0	Other Sources	3 Moderate
		Occurrence of Oxygen concentration < 6 mg/L	days yr ⁻¹	1	0	Other Sources	3 Moderate
		Secchi depth	m	0.6	-3	Database/ dataset	1 Very High
		Species distribution	km ⁻² km ⁻²			N/C	
		Nursery areas	km ⁻² km ⁻²	0.136	-4	Other Sources	2 High
		% of nursery areas which are protected	km ⁻² km ⁻²	1	5	Reports/ Literature	1 Very High
	Pest and Disease control	Harmful Algal Bloom Outbreaks	n° km ⁻²		0	Local Expert	2 High
		Presence of alien species	n° km ⁻²	7E-05	-4	Reports/ Literature	2 High
	Decomposition and fixing processes	Nitrogen removal	%	79	0	Other Sources	3 Moderate
		Water residence time	months	2	0	Other Sources	3 Moderate
	Chemical condition of salt waters	Nutrients concentration	mg L	0.7604	-1	Other Sources	3 Moderate
		Salinity	PSU	0.72	-1	Database/ dataset	1 Very High
		Oxygen Concentration	mg L	11.1	0	Other Sources	3 Moderate
	Global climate regulation by reduction of greenhouse gas concentrations	C stock	tonC km ⁻²		0	Other Sources	3 Moderate
		C sequestration	tonC yr ⁻¹ km ⁻²				
		pH		8.660	0	Database/ dataset	1 Very High
		PP	tonC yr ⁻¹ km ⁻²	0.004	1	Other Sources	3 Moderate
	Micro and regional climate regulation	Evaporation rate	per km ⁻²	528077	0	Other Sources	3 Moderate

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Ecosystem Services Assessment – Cultural (Initial Status)							
Section	Class	Indicator	Units	Value	Type of Data	Reliability	
Cultural Services	Experiential use of plants, animals and land-/seascapes in different environmental settings	nº of visitors taking part in activities related to biota	nº yr ⁻¹ km ⁻²				
	Physical use of land-/seascapes in different environmental settings	Nº of tourists (within 1 km of coastal zone)	nº km ⁻²	614.11	Reports/Literature	1	Very High
		Nº of ship berths in the marinas	nº km ⁻²	0	Local Expert	2	High
		Nº of Tourist Boat	nº*capacity km ⁻²	0	Local Expert	2	High
	Scientific and Educational	Scientific studies, Documentaries, educational publications	nº yr ⁻¹ km ⁻²	0.003	Other Sources	3	Moderate
		Visits to scientific and artistic exhibits	nº yr ⁻¹				
	Heritage, cultural	nº of cultural and heritage sites	nº km ⁻²	0.022	Reports/Literature	2	High
	Entertainment	Nº of movies and broadcasts in the area	nº km ⁻²	0	Other Sources	3	Moderate
	Aesthetic	Nº of pictures	nº yr ⁻¹ km ⁻²	0.007	Other Sources	3	Moderate
	Symbolic	Nº of Red List and iconic species	nº km ⁻²	0.001	Reports/Literature	2	High
	Sacred and/or religious	Nº of Religious events (within 1 km of coastal zone)	nº km ⁻²		Local Expert	2	High
	Existence	Nº of offers for health treatments (within 1 km of coastal zone)	nº*capacity km ⁻²				
Bequest	Extent of marine protected areas	km ⁻² km ⁻²	0	Reports/Literature	1	Very High	
Ecosystem Services Assessment – Cultural (Present Status)							

Section	Class	Indicator	Units	Value	CC	Type of Data	Reliability	
Cultural Services	Experiential use of plants, animals and land-/seascapes in different environmental settings	Nº of visitors taking part in activities related to biota	nº yr ⁻¹ km ⁻²		0	Local Expert	3	Moderate
	Physical use of land-/seascapes in different environmental settings	Nº of tourists (within 1 km of coastal zone)	nº km ⁻²	21229.86	5	Reports/Literature	2	High
		Nº of ship berths in the marinas	nº km ⁻²	2.712	4	Other Sources	2	High
		Nº of Tourist Boat	nº*capacity km ⁻²	0.123	3	Other Sources	3	Moderate
	Scientific and Educational	Scientific studies, Documentaries, educational publications	nº yr ⁻¹ km ⁻²	0.114	5	Other Sources	2	High
		Visits to scientific and artistic exhibits	nº yr ⁻¹					
	Heritage, cultural	Nº of cultural and heritage sites	nº km ⁻²	0.063	4	Reports/Literature	1	Very High
	Entertainment	Nº of movies and broadcasts in the area	nº km ⁻²	0.008	2	Other Sources	2	High
	Aesthetic	Nº of pictures	nº yr ⁻¹ km ⁻²	0.057	5	Other Sources	3	Moderate
	Symbolic	Nº of Red List and iconic species	nº km ⁻²	0.047	4	Reports/Literature	1	Very High
	Sacred and/or religious	Nº of Religious events (within 1 km of coastal zone)	nº/km ²	0.032	3	Local Expert	2	High
	Existence	Nº of offers for health treatments (within 1 km of coastal zone)	nº*capacity/km ²		0	Local Expert	2	High
	Bequest	Extent of marine protected areas	km ² / km ²	1	5	Reports/Literature	1	Very High

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The circular sunburst chart displays the distribution of indicators across three main service sectors: Cultural Services, Provisioning Services, and Regulating & Maintenance Services. The chart is divided into concentric rings representing different levels of hierarchy: Indicators, Classes, Group, Division, and Section. A legend at the bottom indicates the color coding for the indicators, ranging from -5 (dark red) to 5 (dark green), with 0 being blue. A detailed view of the outer rings on the right shows the nested structure of the data.

Indicators
Classes
Group
Division
Section

no data -5 -4 -3 -2 -1 0 1 2 3 4 5

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Fig. S2 Example about the possibility to compare two different indicators (Secchi depth and tourism) using category of change.

