Ecosystem Services - Concept and Methods

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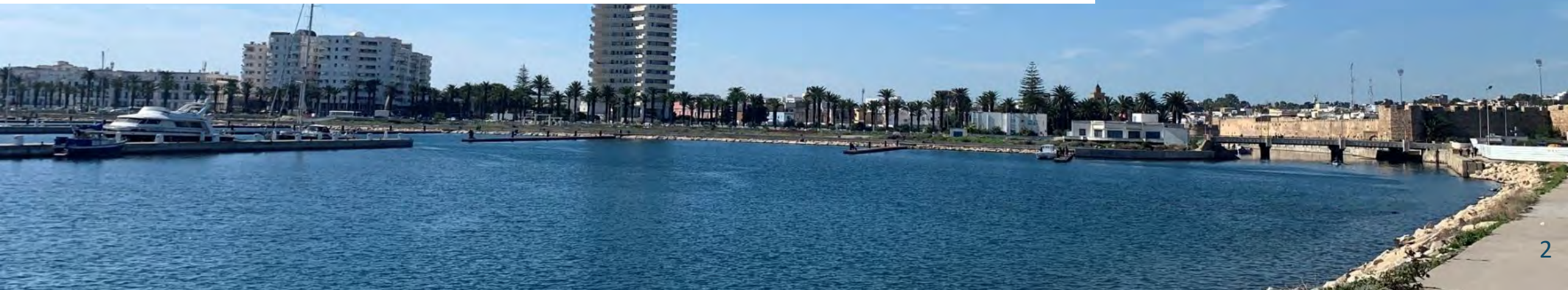
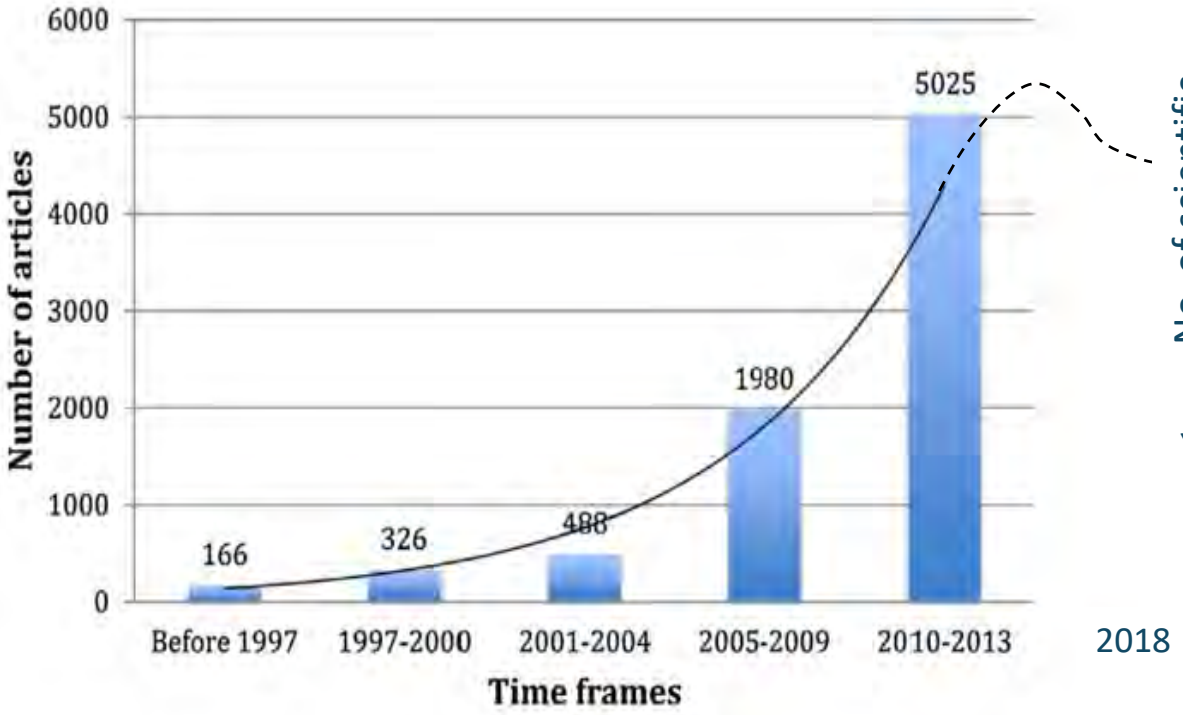
Overview

1. Introduction
2. Concept – Definition and classification
3. Methods for assessment and evaluation
4. Example: Integrative assessment of sandy beaches
   - Baltic Sea
   - Mediterranean Sea
5. Summary

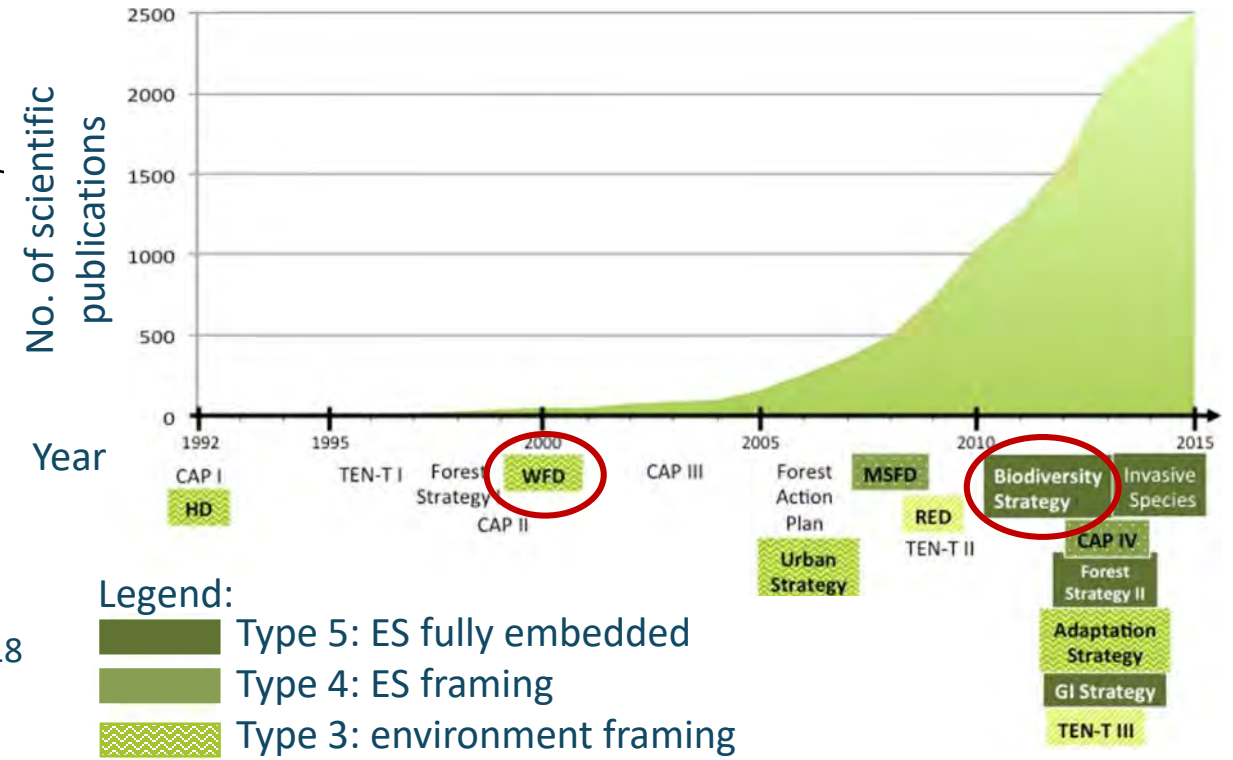


1. Introduction – Relevance in Science and Policy



2018

Adapted from Chaudhary et al. (2015)
(trend retrieved from Google Ngram Viewer)



Bouwna et al. (2018)

- **Fast growing and new** developing scientific field since 90s
- Arouse out of the **need for nature conservation** (from ecological economics)
- Similar development reflected by **high interest** on **policy level**

1. Introduction - Societal Relevance

Drivers
e.g. tourism

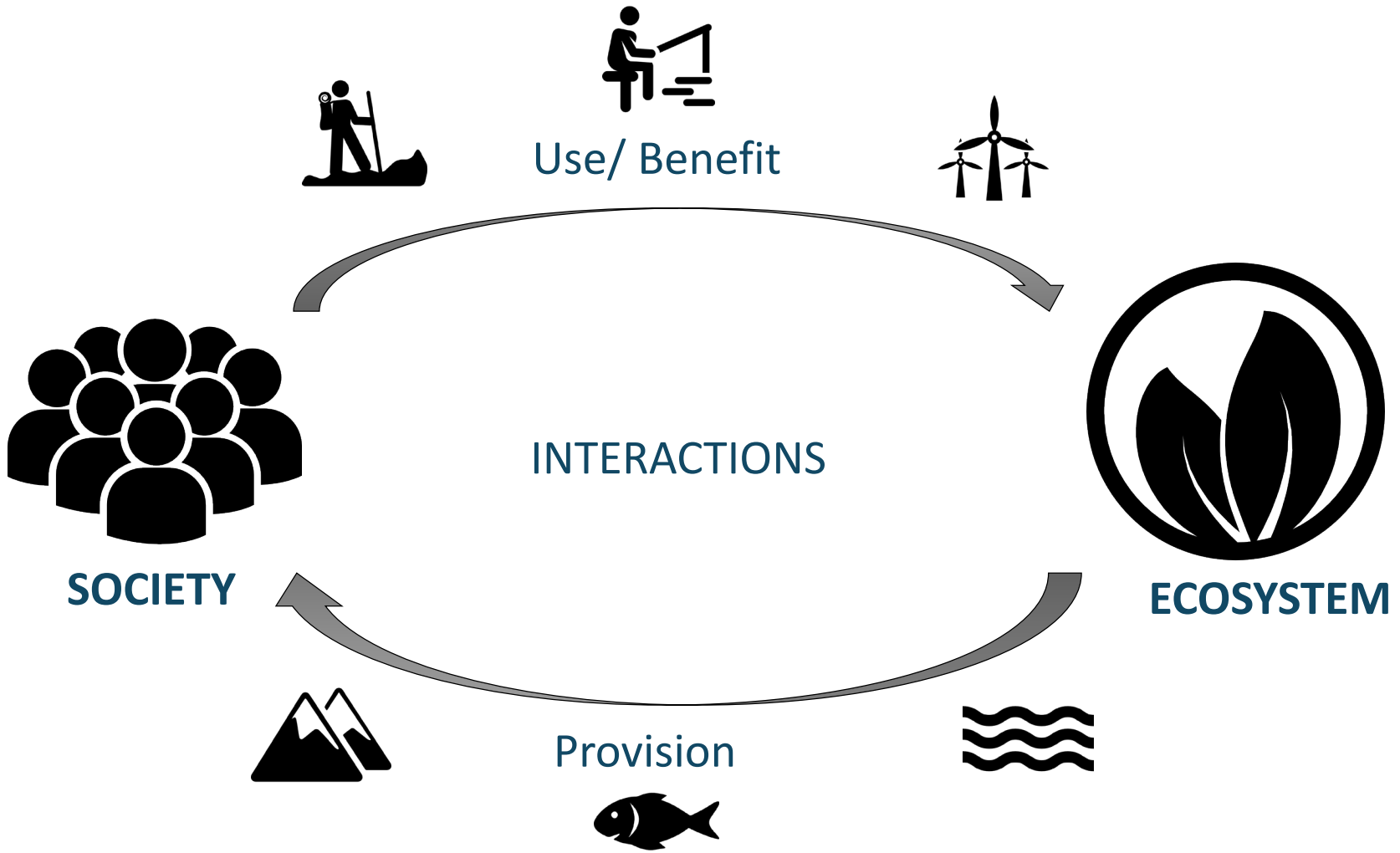
Pressures
e.g. pollution

State
e.g. marine litter

Impact
e.g. decrease in tourists

➔ To protect, conserve and preserve our ecosystems and their services, we need a **sustainable coastal management**!

2. Concept – Socio-ecological system



→ **Ecosystem Services – A concept to better understand human-nature interactions and support a sustainable coastal management?**

MEA, 2005

2. Concept – Definitions

Ecosystem services can be described

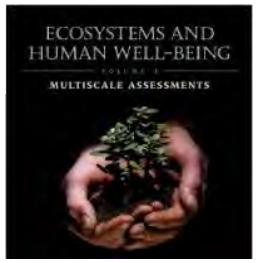
- as the **benefits** that people obtain from ecosystems (MEA, 2005)
- as the direct and indirect **contributions** of ecosystems to **human well-being** (TEEB, 2010).
- as contributions of **ecosystem structure and function** (in combination with other inputs) to human well-being (Burkhard et al., 2012; Burkhard & Maes, 2017).

→ As a quite new scientific and still developing concept, there is not one general definition nor classification.

2. Ecosystem Service Classifications

Common International Classification of Ecosystem Services (CICES):

- developed by the European Environment Agency (EEA) working on environmental accounting
- **systematic approach** for naming and describing ecosystem services
- most common and used within **Europe**

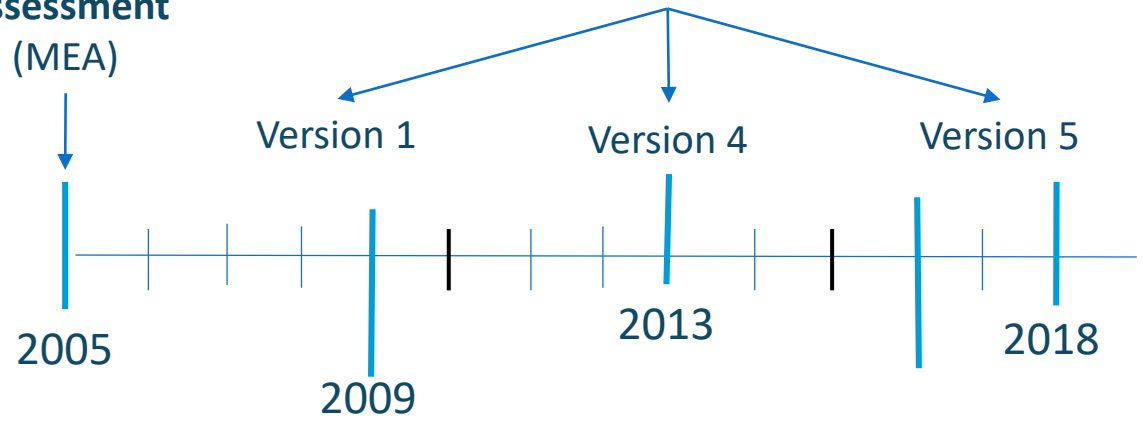


Millennium Ecosystem Assessment (MEA)

CICES

Towards a common classification of ecosystem services

Common International Classification of Ecosystem Services (CICES)



The Economics of Ecosystems and Biodiversity (TEEB)

2. Common International Classification of Ecosystem Services (CICES)

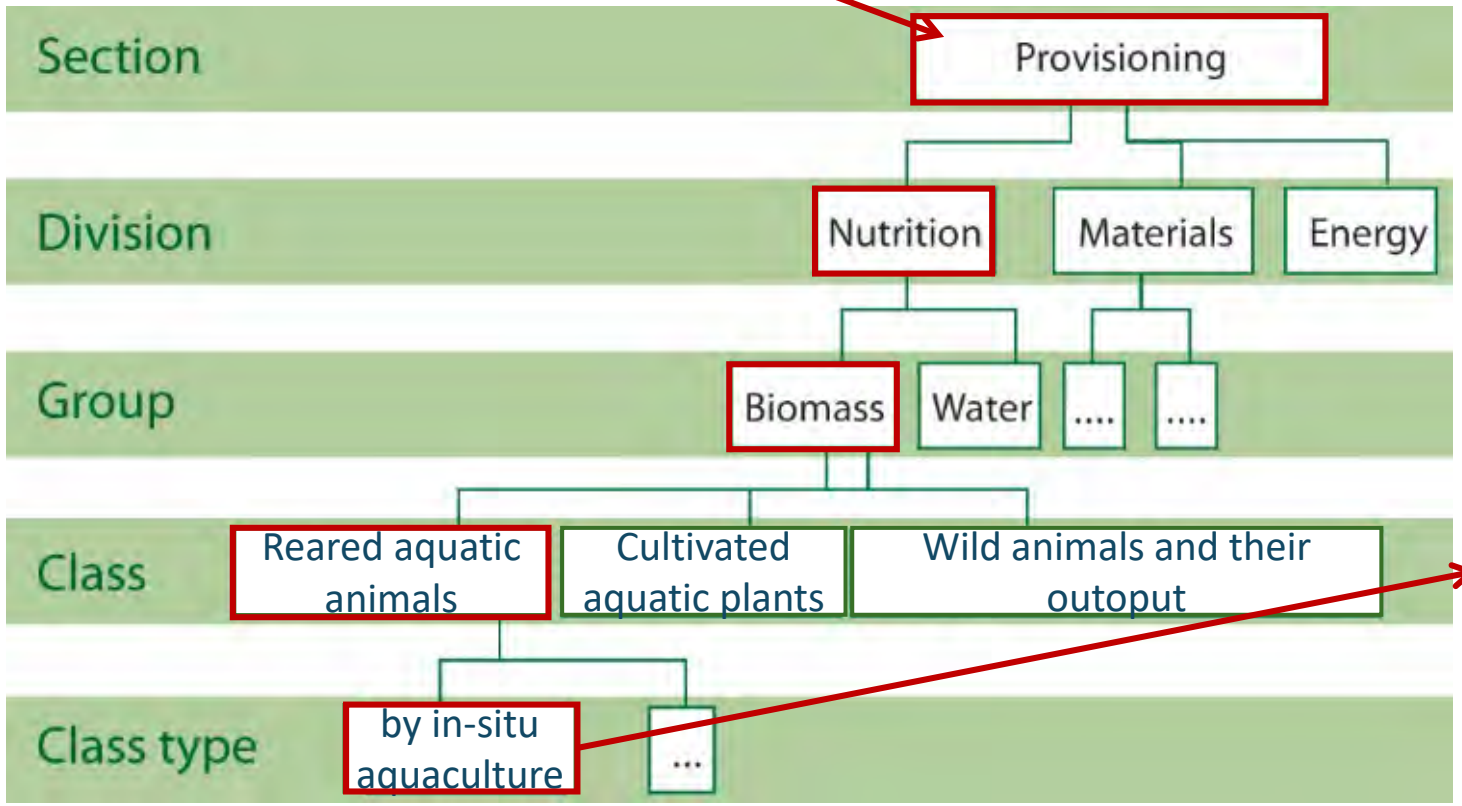
Main categories/ sections:

1. Provisioning services
e.g. mussels for nutrition

2. Regulating and Maintenance services
e.g. wave attenuation for coastal protection

3. Cultural services
e.g. aesthetic landscape for recreation

The hierarchical structure of CICES (MA, 2005)



Indicators:

- Harvested mussels/animals (in tonnes year^{-1})
- Value of total aquaculture sales (in € year^{-1})

von Thenen et al. (2020)

2. Provisioning services

They cover all **nutritional**, **non-nutritional material** and **energetic** outputs from living systems as well as abiotic outputs (including water).

Major divisions

Food/ Nutrition

- Cultivated or wild plants and animals and their outputs (e.g. fish, wheat, milk)
- Ground water as drinking water

Materials

- Biomass for direct use or processing (e.g. timber, hey, fibers)
- Genetic material for extraction

Energy & Others

- Biomass for energy
- Wind, wave and solar energy
- Water surface for shipping

2. Regulating and Maintenance services

All the ways in which living organisms can **mediate** or **moderate** the ambient environment that affects **human health, safety or comfort**, together with abiotic equivalents (not consumed directly).

Major divisions

Mediation of waste, toxics and other nuisances

- Bio-remediation
- Filtration/ sequestration/ storage/ accumulation
- Smell reduction, visual screening and noise attenuation

Regulation of physical, chemical and biological conditions

- Mediation of flows (e.g. control of erosion rates, hydrological cycle)
- Lifecycle maintenance, biodiversity and habitat protection (e.g. pollination and seed dispersal)

- Regulation of soil quality and water conditions
- Atmospheric composition and conditions (e.g. temperature)

2. Cultural Services

All the **non-material**, and normally **non-rival** and **non-consumptive**, outputs of ecosystems (biotic and abiotic) that affect **physical and mental states of peopl**e (symbolic, cultural or intellectual significance).

Major divisions

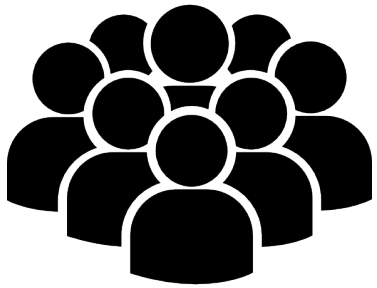
Direct, in-situ and outdoor interactions

- Physical and experiential (e.g. outdoor sports, bird watching)
- Intellectual and representative (e.g. research, education)

Indirect, remote, often indoor interactions

- Spiritual, symbolic and others (e.g. local heritage)
- Other biotic characteristics that have a non-use value (e.g. existence value, bequest value)

3. Methods
How can we assess ecosystem services?



Monetary **Biophysical** **Socio-cultural**

Criteria for choosing a suitable method:

- What is the **purpose**? (e.g. accounting/pricing, decision support, stakeholder involvement, monitoring..)
- What kind of **data** is available? (e.g. quantitative, qualitative, spatially-explicit..)
- What is the desired **output**? (e.g. ranking, maps, consensus-building, recommendations for management and policy..)

3. Monetary valuation methods

- **Market-price/exchange-based:** directly observed or derived from market prices (cost-based); exchange-based costs of actual measures to maintain ecosystem service provision, i.e. restoration, replacement and clean-up costs (mitigation costs).
- **Revealed preference**: revealed indirectly through market prices (hedonic pricing, e.g. house prices) and behaviour (travel costs)
- **Stated preference**: via surveys on hypothetical choices, e.g. contingent valuation (willingness to pay or accept), choice experiments and contingent ranking
- **Benefit-Cost-Analysis** (BCA): decision support tools to screen alternatives
- **Cost-Effectiveness Analysis** (CEA): decision support tools to rank alternatives
- …

➔ **Monetary methods were the first developed, most tested and used over time; but nowadays highly controversial due to their pricing of nature; usually of single services.**

Costanza et al. (1997), Harrison et al. (2018)

3. Examples of monetary valuations

Mussels from aquaculture

Market price

Recreational activities

Revealed preferences
(hedonic pricing)

Exchange-based

Stated preferences
(contingent valuation)

➔ **Monetary methods and indicators are not generally suitable for all ecosystem services** (due to data availability or characteristics of the services/goods)

*in Warnemünde, Rostock (Germany), **Mossbauer et al. 2012)

3. Biophysical assessment methods

Modelling:

- **Biophysical**: assess biophysical processes and functions, i.e. ecological (e.g. species distribution), hydrological or soil erosion models
- **Ecosystem services**: assess the supply (or demand) by GIS-like software programs (e.g. InVEST, ESTIMAP) or conceptually (i.e. ES cascade model)
- **Agent-based**: simulate the human decision-making process within ES management or policy
- **Integrated Assessment**: coupling of multiple models to simulate land use change and /or delivery or ES

Mapping:

- **Simple GIS mapping** of spatially-explicit data of single services
- **Simple matrix mapping**: spreadsheet-based; links indicators and land-cover types to GIS maps
- **Advanced matrix mapping**: integrates multiple and extensive sets of spatial datasets
- …

Harrison et al. (2018)

3. Simple Matrix Mapping

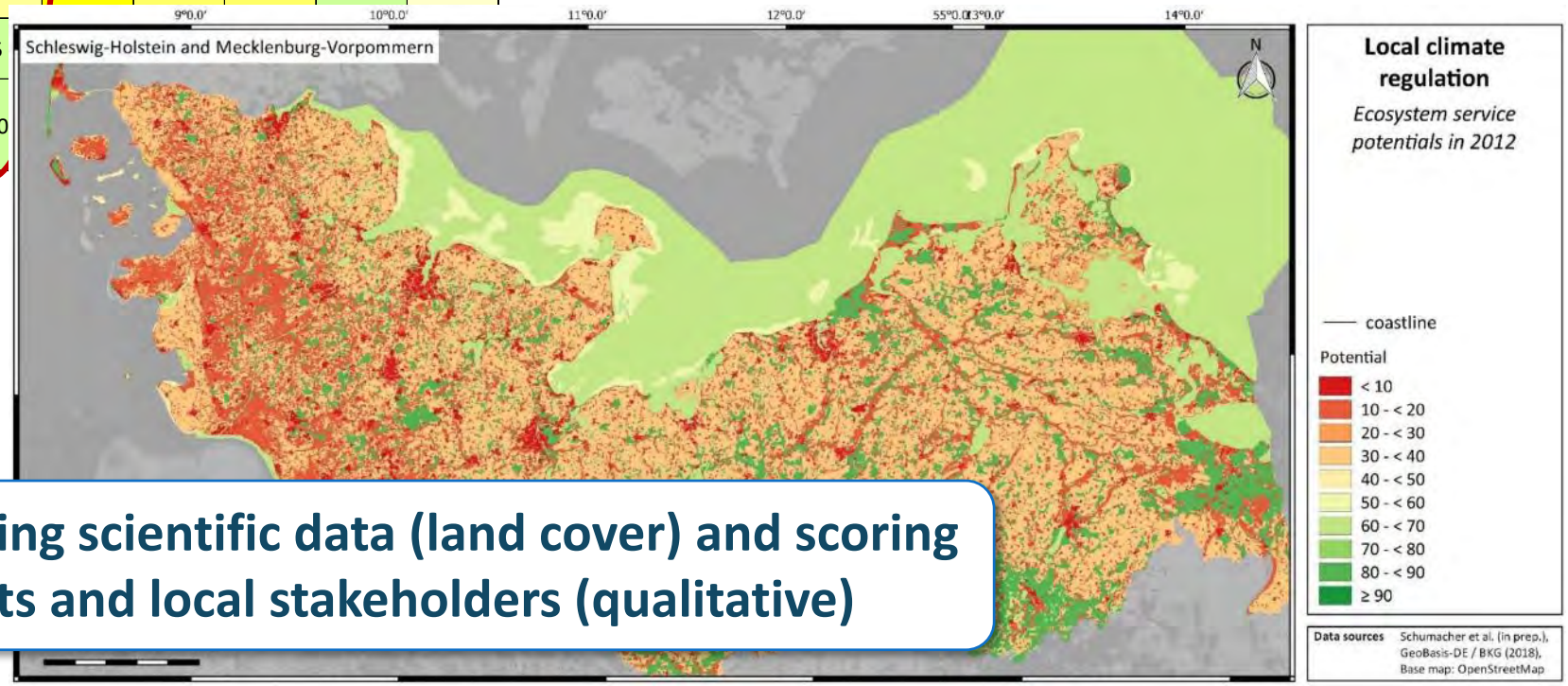
Example: Müller et al. (2020)

- Provides a tool for sustainability management (**purpose**)
- spreadsheet-based approach
- links land cover types to expert scores of each ecosystem service (**data**)

	Upgraded Ecosystem Service Matrix Table _ Version 6.1	Coastal ecosystem types					
	Integrity indicator (y) and ecosystem service vs. land and sea cover/use type (x)	Sandy beach bathing	Sandy beach natural	Stoney beach	Dunes	Active cliff	Passive cliff
Indicators of provisioning services	**Crops (human nutrition)** Cultivation of edible plants and harvest of these plants on agricultural fields and gardens which are used for human nutrition.	5	5	5	5	5	5
	Biomass for energy Plants used for energy conversion (e.g. sugar cane, maize)	5	5	5	5	5	5
	Crops (fodder) Cultivation and harvest of fodder for domestic animals.	5	5	5	5	5	5
	Livestock Production and utilization of domestic animals for nutrition and use of related products (e.g. dairy, wool).	5	5	5	5	5	5
	Timber Wood used for construction purposes.	5	5	5	5	5	5
	Fibers Cultivation and harvest of natural fibre (e.g. cotton, jute sisal silk, cellulose) for, e.g. cloths, fabric, paper.	5	5	5	5	5	5
	Wood fuel Wood used for energy conversion and/or heat production.	5	5	5	5	5	10
	Wild food Harvest of berries, mushrooms, (edible) plants, hunted wild animals, fish catch from recreational fishing	20	30	30	10	5	10
	Fish and Seafood Catch of fish, seafood/algae for food, fish meal and fish oil.	5					
	Beach wrack, Flotsam Organic Material from submerged macrophytes (e.g. seaweed and algae) which is accumulated regularly along the coast.	70					

Müller et al. 2020

Concept for ES mapping



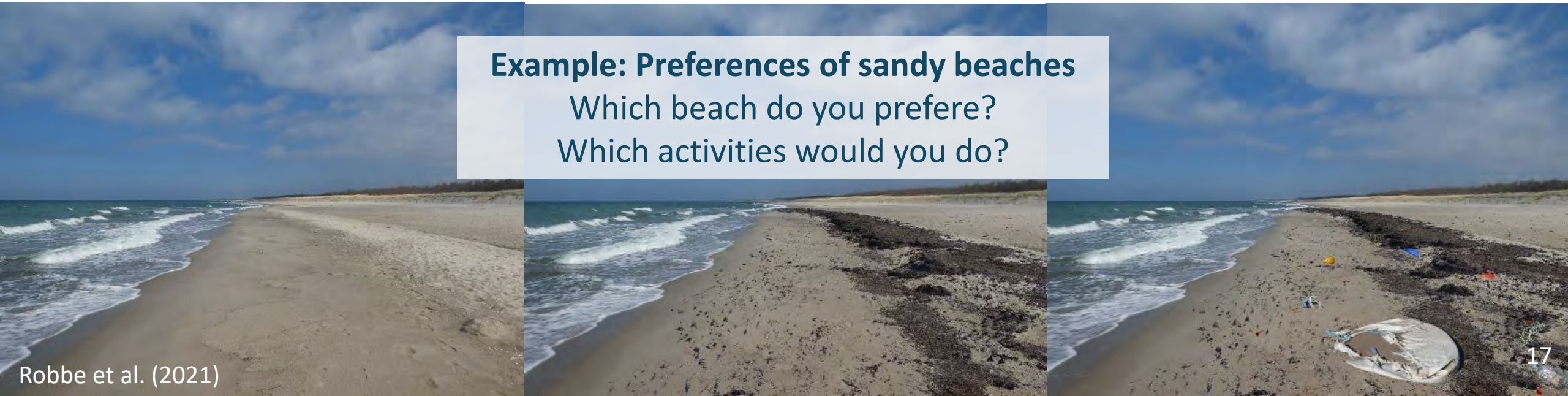
➔ **Integrative approach combing scientific data (land cover) and scoring data from scientific experts and local stakeholders (qualitative)**

3. Socio-cultural assessments methods

- **Narrative analysis:** captures importance of ES via stories and direct actions (verbally and visually)
- **Deliberative/Participatory mapping**: includes stakeholders, local knowledge, values and preferences; creates maps, e.g. Participatory GIS (PGIS), Smartphone Apps
- **Preference assessments:** direct and quantitative consultative method analysing **perceptions**, **knowledge** and **values**; data collection through **surveys**, e.g. free-listing exercises, ranking, rating or selection, also using visual stimuli (e.g. photos)
- **Photo-based:** photo-series analysis (via sharing websites), photo-elicitation
- ...

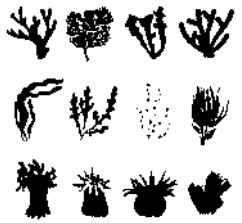
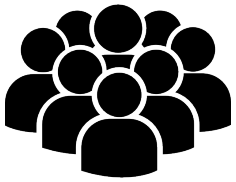
Harrison et al. (2018)

Example: Preferences of sandy beaches
Which beach do you prefere?
Which activities would you do?



Robbe et al. (2021)

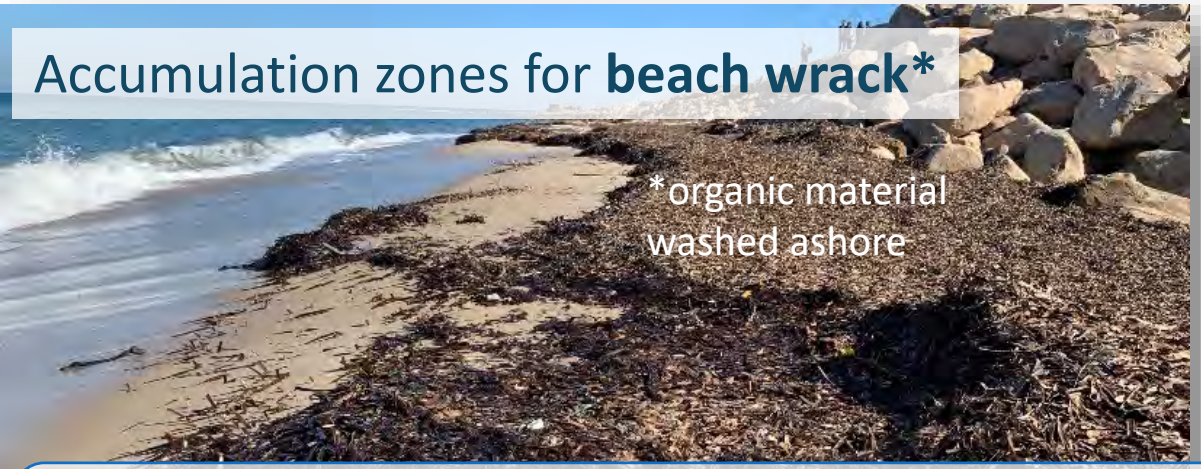
3. Methodological comparison

	Strengths & Opportunities	Weaknesses & Threats
	▪ Most used, tested and harmonized methods (high **comparability** and **transparency**) ▪ Can serve as indicator for **decision-making** and **awareness raising** (showing the "invisible" value for protecting nature)	▪ Assessment of **single** service ▪ High efforts in **time** and **expertise** (large surveys needed) ▪ Most **controversial** and criticized: pricing on nature ▪ Results depend on socio-cultural setting
	▪ Fast and easy **visualizations** for monitoring and **awareness raising** ▪ Data is **spatially-explicit** ▪ Can involve **stakeholders** ▪ Assessments of **multiple** services	▪ High **dependency** on expert knowledge regarding data availability and quality ▪ **Oversimplification**
	▪ **Fast** and **easy** to apply, also remotely ▪ Supports **stakeholder involvement**, decision-making, awareness raising and consensus-building ▪ Assessments of **multiple** services	▪ High **subjectivity** ▪ Focus on human view on nature ▪ Limited **reliability** ▪ Low **comparability** among other studies

4. Example: Integrative assessment of sandy beach ecosystem services in the Baltic and the Southern Mediterranean Sea

Often reduced to **cultural ecosystem services**

Beach management (cleaning costs)



Accumulation zones for **beach wrack***

*organic material washed ashore

Sink and source of **pollution/ marine litter**

➔ **An integrative approach of monetary** (clean up costs), **biophysical** ("invisible" value of beaches) **and socio-cultural** (acceptance among tourists) **methods is needed for a sustainable beach management.**

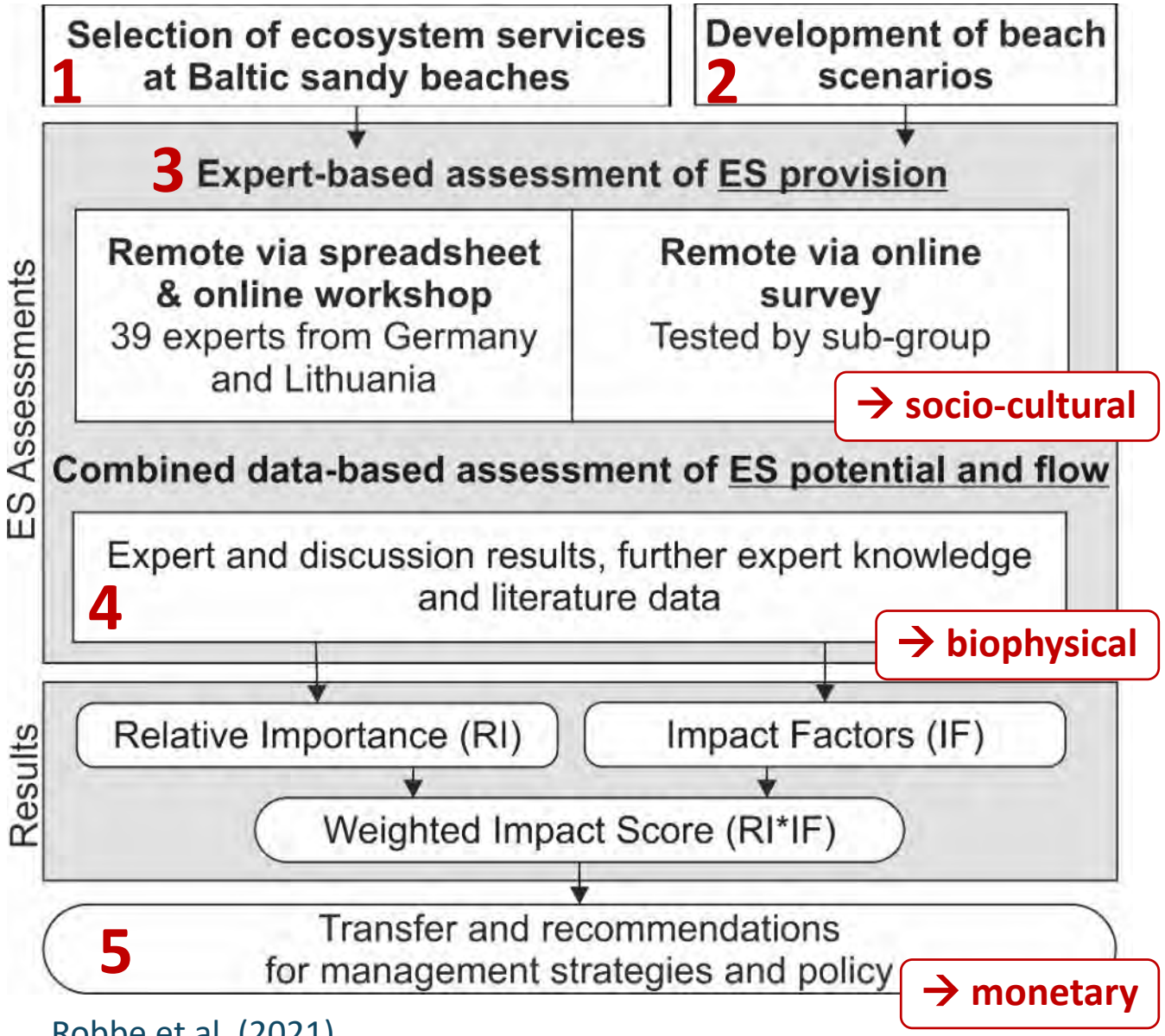
4. Integrative approach

Objective

- to apply a **holistic, integrated and multidisciplinary assessment** of beach ecosystem services
- to assess the **impact of beach wrack and litter** on their provision at sandy beaches

Study areas

1. **Baltic Sea** (Germany, Lithuania)
   - low state of pollution
   - beach wrack main nuisance to tourists
2. **Southern Mediterranean Sea** (Egypt, Morocco, Tunisia)
   - highly polluted beached
   - decrease in tourism income



Robbe et al. (2021)

4. Scenarios development

Realistic beach scenarios representative for common management measures

Baseline scenario: managed or cleaned beach - state of art and most common practice (tourism-driven); or near-natural

- **Scenario 1:** commonly polluted beach in the vicinity of cities and human settlements; ~ 300 macro litter items per 100m beach
- **Scenario 2:** near-natural beach usually in remote areas without direct access or parking lots; 35% coverage of beach wrack within 10 meters above coastline
- **Scenario 3:** not regularly managed nor cleaned beach

4. Comparative assessment of ecosystem service provision

Personal Information:

Expert´s name	
Institution	
Background/ Field of Expertise	

Expert´s self-assessment:	*1 = low, 2 = medium, 3 = high*
Knowledge in ecosystem services	
Knowledge in beach ecology	
Knowledge in beach management	
Knowledge in marine litter	

Scoring for Relative Importance (RI)

0	1	2	4	8
Not relevant	Low	Moderate	High	Very high

Impact Scoring (IS)

-3	-2	-1	0	1	2	3
High decrease	Medium decrease	Low decrease	No impact	Low increase	Medium increase	High increase

Scenarios or Management options:

Baseline Scenario: A Baltic sandy beach

Scenario 1: Marine and beach litter

Compared to Baseline Scenario

	Ecosystem Services (ES)	Description/ Examples	Relative Importance (RI) of each ES of a Baltic sandy beach (in general -	Weighting	Impact Score (IS) (-3 to +3)	Weighted Score (RI)	Impact Score (IS)	Weighted Score (RI)	Impact Score (IS)
Provisioning	1 **Wild plants for materials (further processing)**	Beach wrack for further processing, e.g. eelgrass for insulating material (construction) or stuffing material (pillows, mattress), or dune restoration		*0.00*		*0.0*			
	2 **Biomass as energy source**	Beach wrack or other organic material for energy conversion		*0.00*		*0.0*			
	3 **Extraction of minerals (sand, nutrients)**	Sand extraction or nutrients, e.g. fron… agriculture							
	4 **Timber/ Driftwood**	Driftwood used for further processing							
	5 **Natural Ornaments**	Collection of natural ornaments (e.g.							
Regulating and Maintenance	1 **Sediment storage and transport**	Beaches as sand storage and transpo…							
	2 **Coastal Protection/ Flood control**	Attenuation of wave energy and floo… beach, beach width, beach wrack..							
	3 **Biodiversity and habitats**	Sand and beach wrack providing suit… grounds							
	4 **Pest and disease control**	Sand and beach wrack as provider of … control agents							
	5 **Water purification**	Regulation of the chemical condition … (algae, seagrass,..), e.g. to combat eut…							
	6 **Groundwater regulation**	Groundwater regulation - Maintainin… and buffer)							
	7 **Carbon sequestration**	Regulation of chemical composition …							

Relative Importance

Impact Factor

Robbe et al. (2020)

3.1 **Remote expert assessments** individually via spreadsheet (and guideline)

3.2 Online **workshops** and **discussion**

4. Comparison to **combined literature-based assessment** (quantitative)

4. Recommendations for a sustainable beach management

We recommend:

- to **leave** beach wrack landed naturally wherever possible.
- to **remove** litter with lowest pressure possible (e.g. collecting items manually).
- to **use synergies,** when beaches are cleaned, i.e. further use of organic material as valuable resource.
- to develop **new and innovative beach cleaning techniques and procedures**, i.e. different spatio-temporal patterns.
- to implement management strategies targeting **awareness raising and environmental education** to **increase acceptance** and understanding of beach management measures.
- to consider **future indirect costs** of beach wrack removal, i.e. costs of future generations **to protect and conserve their coasts** (e.g. costal protection).

4. Conclusions of beach assessment

Our integrative assessment approach

- is **easy-to-apply** and **highly adaptive** in its study design
- is **fast, online** and **remote** method for expert and stakeholder involvement
- shows and compares the **impacts of management measures**
- is a suitable tool for **participatory stakeholder involvement, awareness raising** and **consensus building**
- and thus, is useful for **sustainable coastal management** and within **policy implementation** (i.e. support in decision-making, assessment and monitoring of measures)

5. Summary – Concept and methods

The ecosystem services approach is

- an **holistic** and **interdisciplinary concept** that supports the understanding of human-nature conflicts and possible solutions
- useful concept and tool within **sustainability management** and **policy**
- highly **adaptive**, but also highly **complex** in its approach and methods

Challenges are

- **comparability** and **transparency** of results of the various ES studies
- the choice of an **appropriate assessment methods** (depends on purpose, data availability and desired output)
- an **anthropogenic concept** often neglecting the intrinsic value of nature

We recommend

- depending on your assessment **purpose**, to follow an **integrative** approach combining monetary, biophysical and socio-cultural methods to support a **sustainable coastal management**

Thank you for your attention!

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