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Ecosystems Services in the Marine Environment: Indicators and Monitoring

Mel Austen

Marine Ecosystems Research Programme

DEVOTES www.devotes-project.eu Development of innovative tools for understanding marine biodiversity and assessing good environmental status

VECTORS

NERC SCIENCE OF THE ENVIRONMENT

Coastal Futures 2015

What I aim to cover today….

- **Context of the research – VECTORS**
- **Ecosystem services and ecosystem benefits**
  - New marine typology
  - **Indicators – we now have some!**
- **But there are difficulties applying them**
  - **Application of indicators to ecosystem services in the Dogger Bank, North Sea**
- **Mi8salignm3nt with MSFD indicators and monitoring?**
- **Where to find out more…**

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VECTORS of Change in European Marine Ecosystems and their Socio-Economic Impacts

Mel Austen (Project Coordinator)
Plymouth Marine Laboratory

- Feb 1 2011 - Jan 31 2015
- Total cost €16.6 million
- €12.5 million funding from EC

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Project Summary – in a nutshell…

EU OCEANS OF TOMORROW

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Changes in marine life:

- **Invasive alien species**
- **Outbreak forming species**
- **Changes in fish distribution and productivity**

Ecosystem Approach:
Environmental, Economic and Social perspectives

Drivers and pressures
Mechanisms
Impacts
Future projections
Risk assessments
Policy and management implications

Baltic Sea

North Sea

West Mediterranean

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Ecosystem services

Biodiversity and natural resources

Ecosystem processes and functions

Ecosystem services

Multiple Ecosystem benefits and values

- Drivers
- Pressures
- Impacts (ecological, economic, welfare)
- Indicators
- Responses

Ecosystem services in practice: Development of indicators for application in management/policy/regulation

1. Define the services – new marine typology ☑
2. **Define indicators of services, functions, benefits**
   - **Measurable, sensitive, specific**
3. **Apply and test**

Hattam C, Atkins JP, Beaumont N, Börger T, Böhnke-Henrichs A, Burdon D, de Groot R, Hoefnagel E, Nunes PA, Piwowarczyk J, Sastre S, Austen MC (2014). Marine Ecosystem Services: linking indicators to their classification. Ecological Indicators, 49, 61-75. http://dx.doi.org/10.1016/j.ecolind.2014.09.026 [open access]

Ecosystem services	Generic marine ecosystem service indicators	Measurement (Units)
1a: Food provision - Wild capture sea food	Fish and shellfish populations, seaweed stock	Biomass (tonnes km^{-2}) or abundance (nos km^{-2}) of fish and shellfish; area (m^2) or biomass (tonnes km^{-2}) of seaweed
	Quality of the fish, shellfish, seaweed stock	Species composition, Age profile; length profile; % affected by disease; mortality rates
1b: Food provision - Farmed sea food	Fish and shellfish populations, seaweed stock	Biomass (tonnes km^{-2}) or abundance (nos.km^{-2}) of fish and shellfish; area (km^2) or biomass (tonnes km^{-2}) of seaweed;
	Quality of the fish, shellfish, seaweed stock	% affected by disease; mortality rates
2a: Biotic raw material - Genetic resources	Presence and diversity of species with potential/actual useful genetic material	Presence/absence of desirable species; diversity of desirable species
	Quality of species with potential/actual useful genetic material	Endemism and uniqueness of species
2b: Biotic raw material - Medicinal resources	Quantity of available raw material	Total quantity available in a fixed area (g raw material)
	Quality of raw materials	Concentration of raw material (g l^{-1} seawater, g m^{-3} sediment)
2c: Biotic raw material - Ornamental resources	Quantity of raw material	Mass available in a fixed area (tonnes)
	Quality of raw materials	Concentration (g l^{-1} seawater, tonnes km^{-2} sediment); purity

Example indicators of selected ecological functions contributing to service delivery

Service	Function	Example Unit
1a: **Food provision - Wild capture sea food**	Primary production	g C per unit area/volume
	Maintenance of food web dynamics	Changes in community composition (abundance, biomass, species diversity)
	Nutrient cycling to maintain food web dynamics for target species	Amount of nitrates, phosphates, silica (g per unit area/volume)
	Supply of larvae & gametes of target species	Number per m^3
	Support breeding population of suitable size and quantity	Male:female ratio; adult:juvenile ratio
	Provision of suitable habitats	Area of habitat (per m^2); quality of habitat; Number of juveniles

Example indicators of benefits generated by ecosystem services

Ecosystem services	Examples of ecosystem benefits	Indicators of benefits and their measurement (Units)
1a: Food provision - Wild capture sea food	Nutrition from wild catch seafood consumption	g protein/year/ head or per household
	Wild catch seafood landed for human consumption	Landings data at particular times and places (tonnes)
	Fisheries revenues and contribution to Gross Value Added (GVA)	Monetary value (e.g. in £, $ or €)
	Employment in fisheries	Number of jobs

Ecosystem services	Generic marine ecosystem service indicators	Measurement (Units)
3: Air purification	Air-sea flux of pollutants	Modelled or empirically determined pollutant air-sea flux rates and direction (µmol pollutant d^{-1} m^{-2}, µg pollutant l^{-1} seawater d^{-1} m^{-2})
	Distribution of air-sea fluxes of pollutants	Modelled or empirically determined maps of pollutant concentrations (µmol l^{-1} m^{-2}, µg air pollutant l^{-1} seawater m^{-2})
4: Climate regulation	Air-sea and sediment-water fluxes of carbon and CO_2	Modelled or empirically determined (mg C m^{-2} d^{-1}, mg CO_2 m^{-2} d^{-1})
	Air-sea fluxes of other greenhouse gases (e.g. dimethyl sulphide, methane, nitrous oxide)	Modelled or empirically determined (µg greenhouse gases m^{-2} d^{-1})
	Levels of carbon in different components of the marine ecosystem	Modelled or empirically determined carbon levels: biomass of carbon (g m^{-2}); dissolved organic or inorganic carbon (mg C m^{-3}); suspended organic or inorganic carbon (mg C m^{-3}); buried particulate organic or inorganic carbon (mg C m^{-2})
	Permanence of carbon sequestration	% of carbon turnover from sediments

Example indicators of selected ecological functions contributing to service delivery

Service	Function	Example Unit
4: Climate regulation	Pelagic and benthic fixation of carbon through photosynthesis	Concentration of chlorophyll; primary productivity
	Deposition and sequestration of carbon through hydrodynamic transport	Hydrodynamics determined through modelling
	Deposition and burial of carbon in seabed sediments through bioturbation	Carbon storage (g C m^{-2} $time^{-1}$) - carbon buried in sediments; depth of carbon in sediment; persistence of carbon in sediment
	C storage in living biomass (seagrasses, salt marshes, fish, benthic organisms etc.)	(g C m^{-2} $year^{-1}$)
	Calcification by marine organisms	(g Ca m^{-2} $year^{-1}$)
	Biogenic production/assimilation of greenhouse gases (e.g.dimethyl sulphide, methane, nitrous oxide) by phytoplankton, pelagic microbiota, benthic micro and macroalgae	Production of greenhouse gases (µg greenhouse gases m^{-2} d^{-1})

Example indicators of selected benefits generated by ecosystem services

Ecosystem services	Examples of ecosystem benefits	Indicators of benefits and their measurement (Units)
4: Climate regulation	Shadow price of Carbon (UK Treasury Green Book, CO_2 equivalent)	Monetary value (e.g. in £, $ or €)

Ecosystem services	Generic marine ecosystem service indicators	Measurement (Units)
12: Leisure, recreation and tourism	Seaspace available for recreation	Number of square miles of sea with safe water quality available for recreational use
	Number and quality of beaches	Number and size of accredited (blue flag) beaches
	Water quality	Chemical analysis (contaminant concentrations) and visual analysis; total coliforms or other pathogens (quantity per ml of water)
	Abundance and diversity of key species of recreational interest	Count data
	Area of biotopes of key interest to recreational users	For example, extent of seagrass, maerl or kelp beds (km^2)
13: Aesthetic experience	Uniqueness of a site	1/(Number of sights with similar features)
	Abundance of key species of individual interest	Count data
	Area of biotopes of key interest to individuals	For example, extent of seagrass, maerl or kelp beds (km^2)

Ecosystem services	Generic marine ecosystem service indicators	Measurement (Units)
14: Inspiration for culture, art and design	Species, habitat or ecosystems that have or can potentially inspire any piece of artwork	Insufficient information to define indicator
15: Cultural heritage	Species, habitats or ecosystems that can potentially form the core of, or contribute to a cultural custom, rite or way of life	Insufficient information to define indicator
16: Cultural diversity	Generic indicator can't be developed	Insufficient information to define indicator
17: Spiritual experience	Species, habitats or ecosystems that are being or can potentially be worshipped or be of significance to a religious belief	Insufficient information to define indicator
18: Information for cognitive development	Species, habitats or ecosystems that are being or can potentially be studied to increase scientific knowledge	Number of such species, habitats, ecosystems
	Species, habitats or ecosyster being or can potentially be st educational purposes	ts,

1. Define the services ✓
2. Define indicators of services, functions, benefits ✓
3. Apply and test

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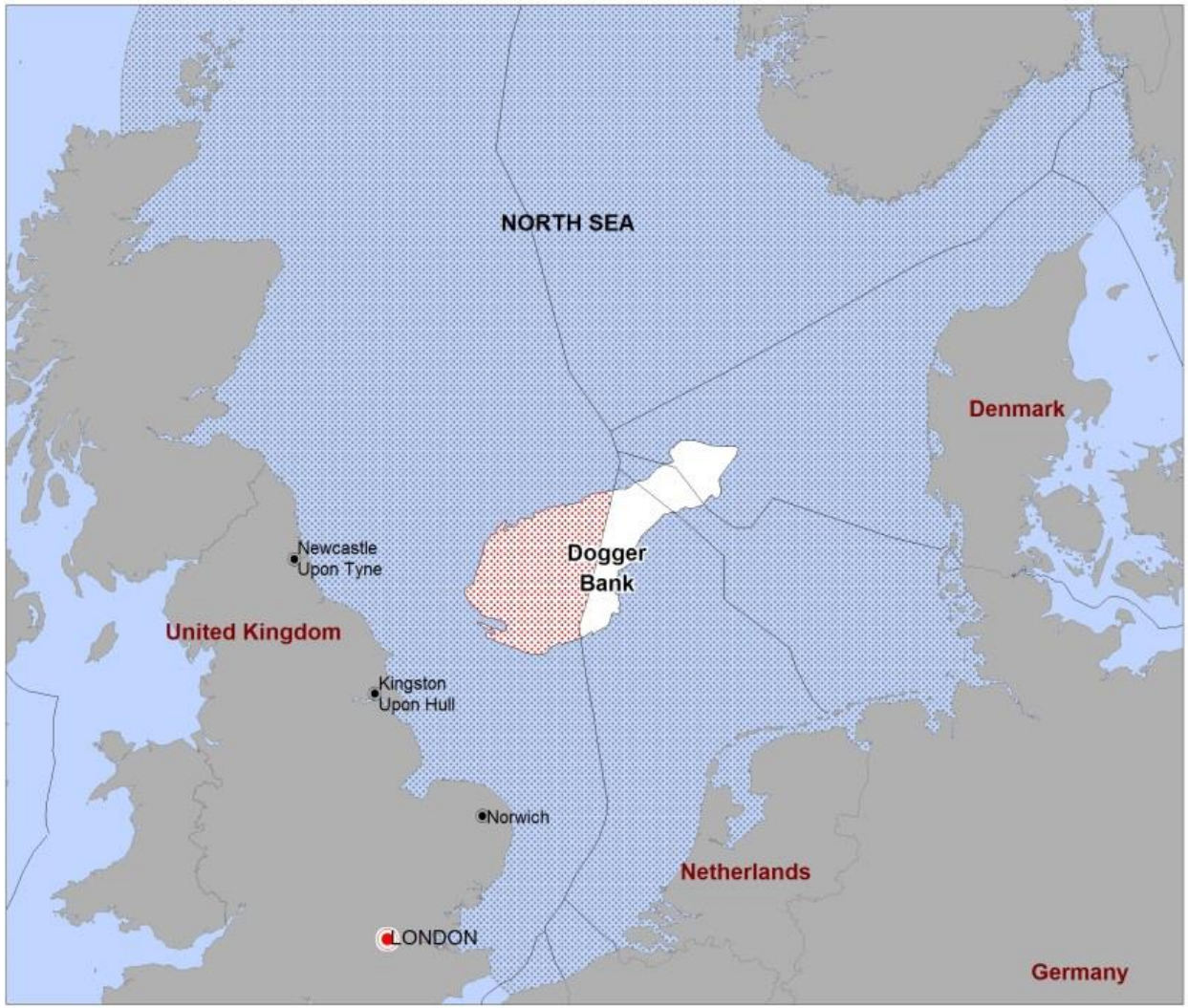
Case study site: UK Section of the Dogger Bank, North Sea

Total area: 18,700km^2

UK Sector: 12,300km^2

- High levels of biodiversity
- Important fishing grounds
- Proposed marine renewables development
- EU conservation status
- Economically and ecologically important area



Dogger Bank: changes in ecosystem services under differing VECTORS future scenarios

- The Dogger Bank contributes to wellbeing by providing ecosystem services (ES)
- ES assessment to inform ecosystem approach to management

Implications of VECTORS scenarios for Dogger Bank

- Abandonment of CFP: more destructive fishing practices
- 15% cover of windfarms
- Increased oil and gas exploration
- 0.8°C SST increase

- Precautionary approach to MSY
- 50% cover of windfarms = no take zone
- Reduced oil and gas exploration
- 0.3°C SST increase

ES assessment based on indicators

- Literature review
- Modelling approach
- Expert judgement

Trends in ES

		A2	B1
Food provision			
Fish/ shellfish populations:	Biomass	↓	↑
	Abundance	↓	↑
	Species composition	↓	↔
	Age profile	↓	↑
Quality of the fishery:	Length profile	↓	↑
	Fishing mortality	↑	↓
	% affected by disease	↔	↔

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University of Hull
Wageningen UR For quality of life
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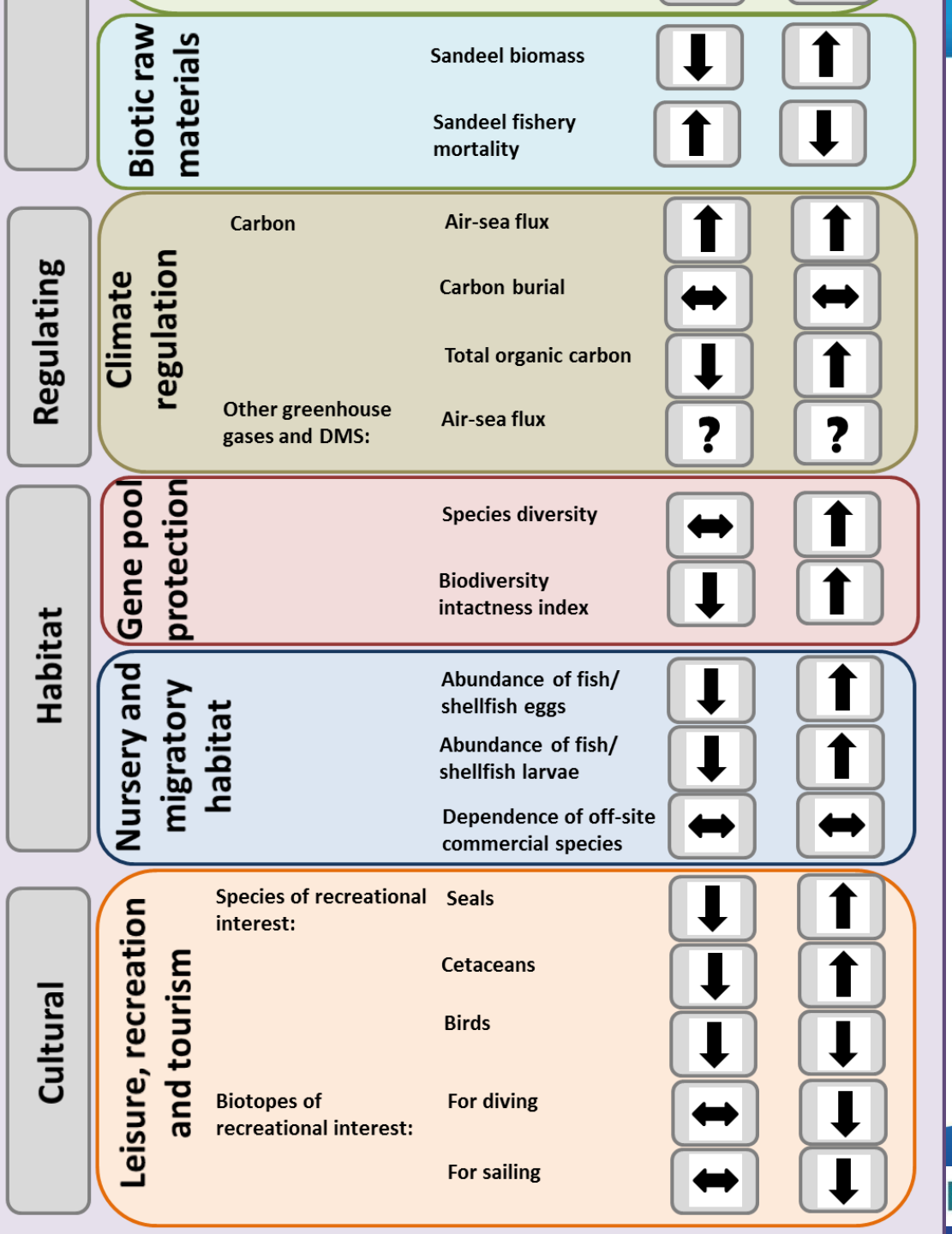
More projected changes Dogger Bank ecosystem services under differing VECTORS future scenarios



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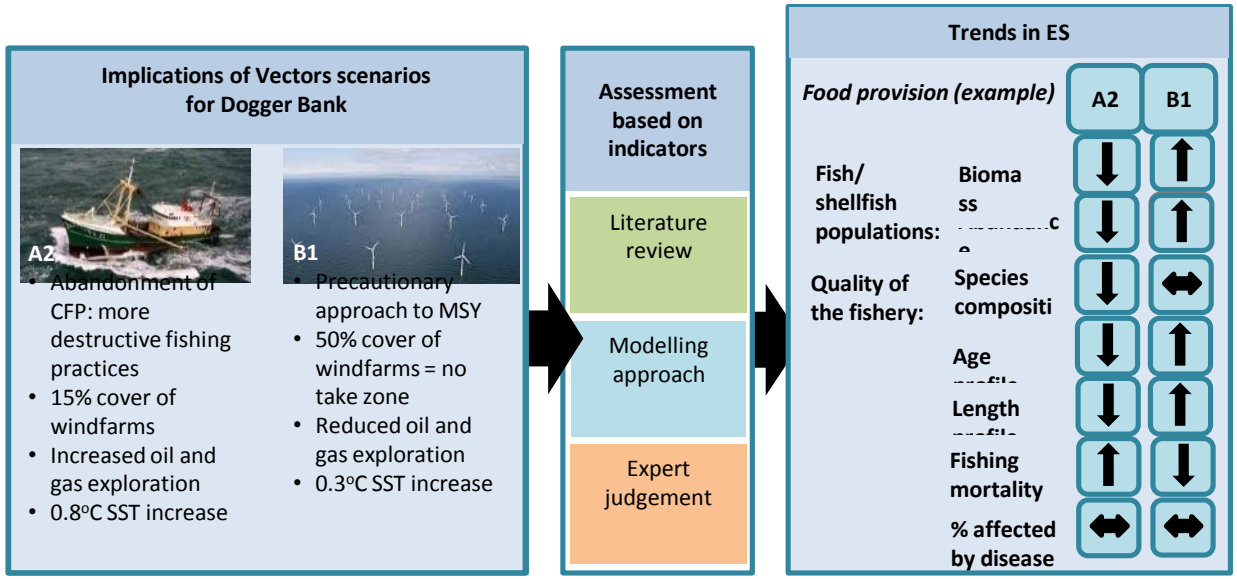
Dogger Bank: changes in ecosystem services under differing VECTORS future scenarios



Lessons learnt:

- Data limitation restrict ES assessment; more indicator specific data needed
- Results help prioritize research and monitoring
- Interdisciplinary teams are essential for ES assessment

Valuing the Benefits

- **Secondary data valuation**
  - Data available only for fisheries and carbon regulation
  - Not sufficiently spatially resolved at the level of Dogger Bank
  - No suitable benefit transfer data
  - No available model data for future scenarios at this spatial resolution
- **Primary valuation with choice experiment undertaken**
- **Deliberative valuation also undertaken**

Application issues

Insufficient data :

- Of 15 ecosystem services of relevance to the Dogger Bank, indicators for only six are measurable for present day
- Only one indicator can be projected forward (with some degree of confidence).
- In some cases data are not available for any indicators of processes and functions, services or benefits.
- In other cases, data only exist for services but not benefits or processes
- Highlighted data gaps and areas for future study.
- **Spatio-temporal data collected does not match needs**

Indicator specificity

- Many indicators selected respond to multiple drivers and pressures (e.g. climate change as well as changing fishing pressure).
- Indicators can show an ecosystem service is changing.
- Causes and possible management actions can then be explored

MSFD and Ecosystem Services

The EC Marine Strategy Framework Directive (MSFD) calls for an ecosystem approach to marine management

- MSFD doesn't mention ecosystem services
- The Biodiversity Strategy does ☺
- Indicators for MSFD monitoring and descriptors of Good Environmental Status were not developed to consider ecosystem services ☹

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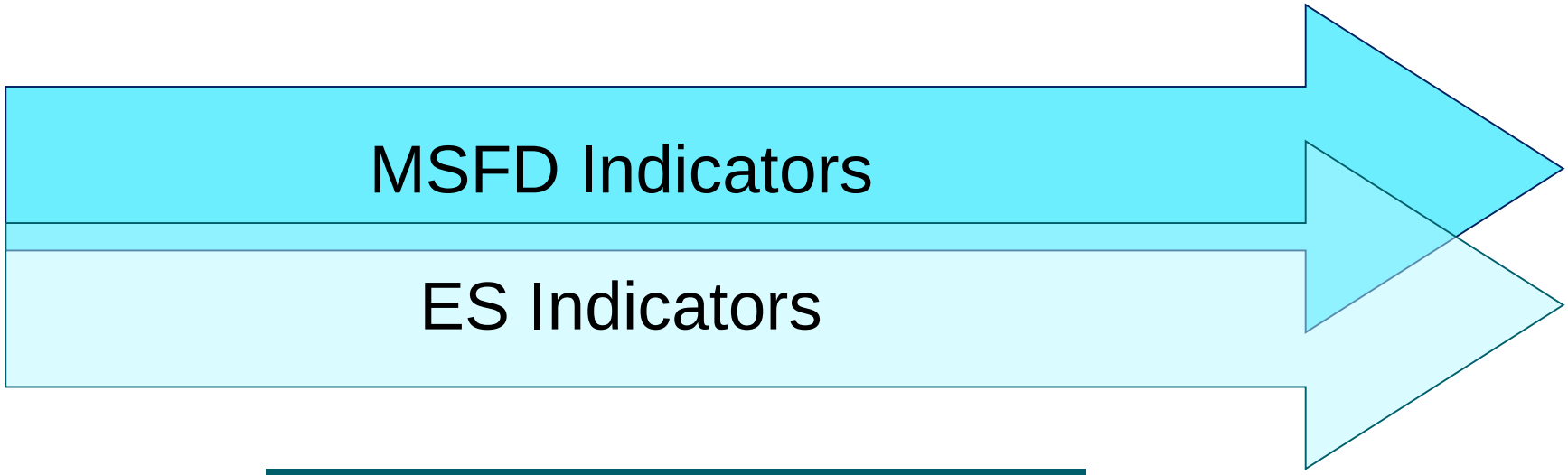
MSFD Descriptors for good environmental status

1. **Biological diversity** is maintained**.**
2. **Non-indigenous species** do not adversely alter the ecosystems
3. **Commercially exploited fish and shellfish** within safe biological limits
4. **Marine food webs** [sustainable]
5. **Eutrophication** minimised
6. **Sea-floor integrity** [sustainable]
7. **Hydrographical conditions** – no alteration that has adverse effects on ecosystems
8. **Contaminant concentrations** - no pollution effects
9. **Contaminants in fish and other seafood for human consumption** [safe]
10. **Marine litter** does not cause harm to environment
11. **Energy, including underwater noise,** do not adversely affect environment

Parallel, but independent development….



Overlap ☑
Complementary ☑

But not a complete match!

MSFD: Marine Strategy Framework Directive
ES: Ecosystem services

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More VECTORS information….

New design VECTORS website: Live by January 31st!

Thank you