

# Information content of global ecosystem service databases and their suitability for decision advice – data repository

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## ABSTRACT

The concept of ecosystem services (ES) is attracting increased attention as a way to communicate the value of nature for human well-being by using a language that reflects dominant political and economic views. Progress in ES research has been rapid (Guerry et al. 2015), and there is an increasing information demand for diverse groups of decision makers (Schaefer et al. 2015; Bouwma et al. 2017). Incorporating ES information into decision making, however, is a long-term project and requires successfully addressing a number of challenges. One challenge is to efficiently exploit available information sources for decision advice. In Schmidt and Seppelt (2018) we reviewed how information contained in ES databases can support policy instruments to better take nature's benefits into account. Here the data compiled within Schmidt and Seppelt (2018) was made available. In total 29 databases with global coverage were reviewed that contain information of 36,112 studies, projects and methods within more than 600,000 entries. Additionally, I identified 93 indicators of information demand for six major policy instruments which deal with or are directly related to the use of natural resources or land. Database entries were then matched with indicators of information demand. The resulting dataset encompasses the total number of data entries of ES databases that could be thematically linked to information requirements from indicators of information demand. Also, data was made available that provides broader insights into the content, design and impact of reviewed ES databases. Facilitating data discovery and linking ES databases with policy instruments are essential steps for the incorporation of ES information into decision making.

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## Overview of data

The data provided here represents the number of data entries available in 29 databases for a set of six policy instruments. Details and sources of the ES database were described in Schmidt and Seppelt (2018). The six policy instruments were specified by 93 indicator of information demand. Indicators of information demand were defined below (Table 1). The number of data entries represents the total number of data entries available for a specific indicator of information demand.

Databases are designed in a format that stores data entries in cells, with multiple cells represented in a system of rows and columns. For the counting of the total number of data entries all columns and rows for all databases were reviewed and relevant data entries selected. A data entry was relevant when the content could be linked to one of the indicator of information demand. For instance the database ESVD (Van der Ploeg et al. 2010) contains 1,310 data entries in one column that indicate the monetary value of ES and can be linked to the indicator of information demand 'monetary valued' (see Table 1) for the policy instrument 'extending accounting system through nature-based indicators'. For more details on the accounting see Schmidt and Seppelt (2018).

Additionally, data is made available that refers to others than data entries. This data provides broader insights into the content, design and impact of reviewed ES databases. General characteristics of ES database contents were documented for eight indicators (Table 2). Depending on the indicator documented values refer to ES studies considered, databases' column headers or ES types. For more details see Table 2. The design and impact of ES databases illustrates databases' functionalities, characteristics, and effects on situations or persons (Table 2). This data contains six indicators which

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represent the total number of databases. For instance, for the indicator ‘functional type’ each of the databases was assigned to either ‘research’, ‘resource’ or ‘reference collections’.

**Table 1. Overview of policy instruments and indicators of information demand.** In the table are six policy instruments listed (‘Name’) that contain descriptions and examples for 93 indicators of information demand. The column ‘Description’ defines specific topics of information needs required for a policy instrument. ‘Examples from databases’ relate to column headers or data entries of the databases considered for the analysis.

Name	Description	Example from databases
<b>1) Policy instrument: Extending accounting systems through nature-based indicators</b>		
Trait concept	The trait concept describes characteristics of species that affect ecosystem processes and population dynamics across space and time. They seem to play an important role for provisioning, regulating and cultural ES and are highly relevant for conservation planning (de Bello et al. 2010).	De Bello et al., 2010: ‘Relationships’ estimates relationships between trait components of plants, vertebrates, invertebrates, and ES.
Biophysical quantification	Numerical documentation of ecological values for ES indicating, for instance, their diversity (García and Martínez 2012), quantity (Reyers et al. 2009), quality (Russo et al. 2017) or alterations of ES (Richter and Thomas 2007).	ESML: ‘Variable Values’ quantify the numerical values for outputs of ecological models.
Monetary valued	Documentation of monetary values for ES quantitatively (de Groot et al. 2012) or qualitatively by string variables (e.g. yes/no entries). This includes indicators of costs that emerge due to transition to more ES-friendly activities or products, such as transition costs (van Zyl 2014).	EVRI: ‘Estimated (Service Flow) Values’ from economic valuation studies of ES. PESD: ‘Transaction Amount (USD\$)’ to enable PES projects in developing countries.
Metrics	Unit of measurement by which ES are assessed (Kontogianni et al. 2010).	ESVD: ‘Unit’ encompasses units and currencies of monetary values of ES, e.g. US-Dollar per hectare and year.
Identification of critical thresholds	Quantification of non-linear transitions in the functioning of coupled human-environmental systems affecting ecosystems accretion, productivity and resilience (Lenton et al. 2008; McClanahan et al. 2011).	No information provided, only indirectly indicated, e.g. in ReefLink Database: McClanahan et al. (2011).
Time frames	Temporal extent and resolution of state or flow of ES, payments for ES, or other types of analysis (Gibson et al. 2000).	ESML: ‘EM Temporal extent’ describes the temporal boundaries of the ecological system modeled, which are typically the earliest and latest dates represented by the data in the modeling application.
Static investigation	Analysis of ES for a specific point in time (Carr and Mendelsohn 2003).	BUVD: ‘Methodology Comments’ and ‘Data Comments’ explain assumptions, method type, and data used for monetary valuation of ES.
Dynamic investigation	Analysis of variations of ES as a function of time (Holland et al. 2011).	BUVD: ‘Methodology Comments’ and ‘Data Comments’ explain assumptions, method type and data used for monetary valuation of ES.
Prioritized ES	Evaluation and ranking of ES, methods, results, etc., in accordance to their importance or urgency for a particular purpose (Klein et al. 2010).	No column headers refer to the indicator, only in titles of references, e.g. in ReefLink Database: Klein et al. (2010).
Consumption quantified	Numerical valuation of the amount of ES actually used, enjoyed or consumed in a particular time (Stiglitz et al. 2009).	EVRI: Combination of ‘Economic Measure(s)’ and ‘Estimated (Service Flow) Values’ that explain the measure of the payment and provide monetary values of ES respectively.
Trade-offs quantified	Numerical valuation of interactions between ES that involve diminishing or losing quality or quantity of a set of ES in return for gains in other ES (Millennium Ecosystem Assessment 2005c; Haase et al. 2012).	EVRI: Combination of ‘Valuation Equation/Function Information’ and ‘Estimated (Service Flow) Values’ which explain the valuation approach used and provide monetary values of ES respectively.
Driver	Identification of ecological or socio-economic factors that exert pressure on the environment and lead to changes in ecosystem conditions such as population growth or climate change (Nelson et al. 2005).	ReefLink Database: ‘Socio-Economic Drivers’ include the sectors that fulfill human needs for ‘Food & Raw Materials’, ‘Water’, ‘Shelter’, ‘Health’, ‘Culture’, and ‘Security’.
Location of ES	Name of geographic location or description of spatial extent of investigation area of ES (Gibson et al. 2000;	ESML: ‘Spatial Extent Name’ or ‘Latitude/Longitude, Granularity (Grain Type and

	Hein et al. 2006).	Size)’ explain the application areas of ecological models.
Payer of costs	Identification of people that faces the costs of losing ES (not necessarily ES recipients) (TEEB 2011).	Goldman et al., 2008: ‘Who pays/who receives payment’ explain social groups that pay or receive payment for ES.
Location of costs	Spatial allocation of costs of maintaining or losing ES (TEEB 2011).	EVRI: Combination of ‘Location’ and ‘Estimated (Service Flow) Values’ which explain the study area and cost of ES respectively.
Time of costs	Temporal allocation of costs of maintaining or losing ES (TEEB 2011).	EVRI: Combination of ‘Year(s) of Data’ and ‘Estimated (Service Flow) Values’ which explain the study time and costs of ES respectively.
Long-term impact	Measurement over long time horizon that exceeds 10 years to estimate the consequences of, for instance, projects and interventions (Müller et al. 2010).	EVRI: ‘Year(s) of Data’ indicates the time span of input data that was used for the valuation of ES in monetary terms.
Transdisciplinary	A integrative, reflexive, scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by integrating knowledge from various scientific and societal bodies (Jahn et al. 2012).	IIED Watershed Markets: ‘Analysis of Costs and Benefits (Economic, Environmental, Social)’ explains analysis of costs and benefits of PES and actions aiming at PES from different disciplinary perspectives.
Stakeholder engagement	Indication whether stakeholder are involved within the study. Stakeholder are any group, directly or indirectly affected by a study, as well as those who may have interests in a study and/or the ability to influence its outcome (Durham et al. 2014).	IPBES Catalogue: ‘Key stakeholder groups engaged’ explains which stakeholder groups are involved in the ES assessment.
Level of decision makers	Documentation of level of decision makers committed to ES study. Levels are hierarchical structured based on institutional scale and reflect the different tiers at which decisions on the utilization of capital, labor and natural resources are taken (Hein et al. 2006). Institutional levels reach from individuals and households to international level.	IIED Watershed Markets: ‘Stakeholder (Supply, Demand, Intermediary, Facilitator)’ explains and differentiates stakeholder groups and their functions in PES.
Sector of decision makers	Description of socio-economic sector of decision makers committed to ES study. A sector is a distinct part of the society that reflects similar socio-economic situations (Martín-López et al. 2017), e.g. public and private sector or agriculture, marine fisheries, water supply (Durham et al. 2014).	IIED Watershed Markets: ‘Stakeholder (Supply, Demand, Intermediary, Facilitator)’ explains and differentiates stakeholder groups and their functions in PES.
Process of stakeholder involvement	Description of the process used in the study to involve relevant stakeholders (AccountAbility 2008). Stakeholder are any group, directly or indirectly affected by a study, as well as those who may have interests in a study and/or the ability to influence its outcome (Durham et al. 2014).	IIED Watershed Markets: ‘Stakeholder (Supply, Demand, Intermediary, Facilitator)’ and ‘Terms of payment’ explain and differentiate stakeholder groups and how they are involved in PES.
Uncertainty	Documentation of the quality of available evidence (Spiegelhalter and Riesch 2011).	ESML: ‘Model uncertainty analysis performed’ states whether propagation of uncertainties in model parameters and model structure of ecological models were examined.
Problem	Initial trigger for examination, e.g. how to measure ES, pollution increase, or land use conflicts (TEEB 2011; European Commission 2015).	TEEB Cases: ‘What is the problem?’ explains the socio-ecological circumstances, drivers, and pressures of a valuation study.
Objective	Aim, goal or target to achieve by conducting a study. Objectives can link the analysis of the problem with options for the policy response (TEEB 2011; European Commission 2015).	Keniger et al., 2013: ‘Purpose/Objectives’ of studies examining benefits of human-nature interactions.
Policy options	Description of alternative interventions that show how ES and biodiversity can be managed (TEEB 2011; European Commission 2015).	ESML: ‘EM scenario drivers’ describes the rationale behind different forcing conditions (such as alternative management strategies) that form the basis of modeled scenarios.
Impact real world	Documentation of economic, social, and/or environmental alterations due to realized ‘policy options’. Impact based on evidence from real world changes (TEEB 2011; European Commission 2015).	IIED Watershed Markets: ‘Analysis of Costs and Benefits (Economic, Environmental, Social)’ provides remarks on impacts on implemented PES mechanisms from different disciplinary perspectives.
Impact modeled	Documentation of economic, social, and/or environmental alterations due to ‘policy options’. Impacts are modeled by simple heuristic approaches or complex simulation tools (TEEB 2011; European Commission 2015).	ESML: Combination of ‘EM scenario drivers’ and ‘Variable values’ provide alternative management strategies used in ecological models and their results for a model run.

Favorable option	Documentation of process for balancing and prioritization of 'policy options', including the final intervention agreed upon (TEEB 2011; European Commission 2015).	EVRI: 'Estimated (Service Flow) Values' encompasses distinct monetary values of ES for different policy options that are used in benefit-cost analysis for decision support.
Monitoring	Monitoring is a continuous and systematic process of data collection about an implemented policy intervention. It generates information for future evaluation and impact assessments. (TEEB 2011; European Commission 2015).	Goldman et al., 2008: 'Performance monitoring' explains monitoring approaches for ES, biodiversity and other socio-economic issues.
Evaluation of impact of project	Evaluation of economic, social, and/or environmental alterations due to interventions from ES project, and whether an intervention has achieved its objectives (TEEB 2011; European Commission 2015).	Goldman et al., 2008: 'Summary' of impacts from ES projects, e.g. number of acres restored, changes in flood risk, jobs created, or people educated.
Local scale	Number of studies conducted in an investigation area with a spatial extent of less than 10.000sqkm.	ESVD: 'Service area' is the quantified investigation area considered for monetary valuation of ES.
Environmental policies & regulations mentioned	Consideration of or commitments to laws, regulations and other policy mechanisms that manage effects of anthropogenic activities on nature and its natural resources (European Commission 2017b).	IIED Watershed Markets: 'Legislation Issues' explain legal provisions related to PES for watersheds.
Resource management policy (-ies) established	Establishment of study-initiated, new established principles, mechanisms, programs or organizations that manage effects of anthropogenic activities on nature and its natural resources based on ES information (European Commission 2017b).	IIED Watershed Markets: Combination of 'Market design' and 'Legislation Issues' explain different PES payment mechanisms established and how they are linked to legal conditions.
Global scale	Number of studies conducted in an investigation area with a spatial extent of greater than 20 million sqkm.	ESVD: 'Service area' is the quantified investigation area considered for monetary valuation of ES.
Poor regions	Number of studies conducted in areas of low human development. These areas are defined by a Human Development Index of less than 0.55 (UNDP 2014).	EVRI: 'Country (-ies)' encompasses the name of a country (-ies) in which a monetary valuation study took place.
Expenditure for environmental protection	Documentation of actual or potential expenditure for environmental protection or management and mitigation of degradation.	EVRI: Combination of 'Valuation Technique(s)' and 'Estimated (Service Flow) Values' provide monetary values for the costs of replacing or restoring the ES provided by the environmental resource (e.g. replacement costs).
Capacity building for trade-off assessment	Documentation of the development and strengthening of human and institutional resources for assessing and documenting ES state, value, and trade-offs (Bonner et al. 2012; IPBES 2016).	IPBES Catalogue: 'Capacity building needs identified during the assessment' and 'Actions taken by the assessment to build capacity' include educational measures for trade-off assessment.
Capacity building for policy assessment system	Documentation of the development and strengthening of human and institutional resources for advanced understanding of management options and how to establish and utilize an accepted policy assessment system in place (IPBES 2016).	IPBES Catalogue: 'Capacity building needs identified during the assessment' and 'Actions taken by the assessment to build capacity' include educational measures for policy assessment.
Primary studies	Investigation and collection of first-hand, empirical data (number of studies).	Seppelt et al. 2011: 'Data source' indicates primary analysis of ES.
Guidance benefit transfer	Documentation of tools or processes to develop and strengthen human and institutional resources for the application of benefit transfer techniques (TEEB 2011).	ValueES Methods: 'Monetary valuation methods' provides a factsheet on benefit transfer methods and introduces: 'How, when and where can the method be applied?'.
Outreach	Information on material in simplified form to explain analysis and results of research to different laypersons and stakeholders (LWEC 2012), e.g. leaflets, newsletters, videos or webinars.	IPBES Catalogue: 'Assessment outputs' summarizes and links different types of outreach material used to disseminate results of ES assessments.
Decision	Formal and informal rules by which human actions are framed and operationalized. This includes decision mechanisms in policies, strategies, responses, and interventions to change human behavior or ecosystem characteristics (Millennium Ecosystem Assessment 2003). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	IIED Watershed markets: 'Legislation issues' of different nations and how they are related to the establishment of PES, and 'Main policy lessons' learnt from PES projects.
Action & scenarios	Human actions or modelled scenarios to address specific issues, needs, opportunities, or problems in ecosystem governance and management. They include ecological, legal, economic, social and behavioral as well as technological responses; and may operate at local, regional, or international level and at various time scales	ReefLink Database: 'Responses' representing actions taken by groups or individuals in society and government to prevent, compensate, ameliorate or adapt to changes in ES or their perceived values.

	(Millennium Ecosystem Assessment 2005a, b). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	
Ecosystem	The state of the ecosystem is the condition, in terms of quantity and quality, of abiotic and biotic components including physical, chemical, and biological variables. Attributes of ecological structure or process that influence the quantity and/or quality of ES, but do not themselves qualify as final ES; because they are not directly enjoyed, consumed or used (Daily et al. 2009). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	ReefLink Database: 'Physical & Chemical Environment' and anthropogenic '(Contact) Uses' which directly affect the survival, growth, and reproduction of 'Reef Life'.
Biophysical models	Approaches and techniques to measure abiotic and biotic components of ecosystems, their interdependences, and dynamic changes, for instance, to develop ecological production functions that translate the structure and function of ecosystems into the provision of important services (Daily et al. 2009; Peh et al. 2013). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	ValuES Methods: Descriptions on functionality and requirements of methods for assessing ES.
Ecosystem services	Components of nature that can be enjoyed, consumed or used to yield human well-being. The following four common classes are distinguished: provisioning, regulating, cultural, and supporting services (TEEB 2010a). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	ESML: 'Ecosystem service' defined as outputs of ecological functions or processes that directly or indirectly contribute to social welfare, or have the potential to do so in the future. Ecological models can be selected according to two different classification systems (CICES, NESCS).
Economic & cultural models	Monetary and socio-cultural approaches to measure ES supply as an input for human health, satisfaction, security, and other socio-cultural benefits (Bagstad et al. 2013; IPBES 2016). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	Keniger et al., 2012: Overview of 'Research Design' for the analysis of benefits of interacting with nature. ESVD: 'Valuation Methods' indicating how the monetary values were estimated.
Valuation	Valuation of ES based on valuation indicators. Indicators of valuation reflect the magnitude of change in social and economic welfare by determining quantity of service use, human preferences for the service, etc. (IPBES 2016). Depending on the valuation purpose (e.g. ecological sustainability, equity and cultural perception or efficiency and cost-effectiveness) ES values may be conveyed in ecological (Odum and Odum 2000), socio-cultural (Kumar and Kumar 2008) or economic metrics (Liu et al. 2010). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	EVRI: Economic valuation of ES such as 'Estimated (Service Flow) Values' (EVRI). ESML: Ecological model variables, e.g. 'Social Benefit Indicator' and 'Monetary Value of Social Benefit'.
Information & influence	Approaches for outreach and capacity building that make use of results provided by ecological and socio-economic models to support decision-making and institutional change (LWEC 2012). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	IPBES Catalogue: 'Assessment outputs' summarizes and links different types of outreach activities used to disseminate results of ES assessments.
Institution	Context and conditions of institutions and their effects on human interaction shaping ecosystems change. Institutions operate at various levels and scales, such as global, regional, and local levels and on the basis of ethics, values, and attitudes usually ascribed to larger cultural contexts (Millennium Ecosystem Assessment 2005a; Young 2008). Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	Goldman et al., 2008: 'What institutional challenges were faced in setting up the project?' summarizes lessons learnt from ES projects.

Incentives	Approaches that examine, reform and develop inducements that motivate changes in decisions and behavior (Tversky and Kahneman 1981), for instance monetary rewards, legal sanctions or approval by peers. Component of the integrative framework defined by (Daily et al. 2009) showing how ES can be integrated into decision-making.	ReefLink Database: 'Funding and incentives' summarizing budgetary decisions by public administration to improve the effectiveness of decisions through daily operations, research, monitoring, and outreach.
<b>2) Rewarding benefits through payments and markets</b>		
PES considered	Voluntary transaction for specific ES, or a form of land use likely to secure that ES, through a continual series of conditional payments for ES buyer and provider/seller (Jack et al. 2008; FAO 2011).	IIED Watershed Markets: Description of 'Market Design' of different PES schemes by providing information on 'Services' and 'Commodity', 'Payment Mechanism', 'Terms of Payment', and 'Funds Involved'.
Form of PES	Payment vehicle through which beneficiaries of the ES reward providers, e.g. financially or in-kind (Porrás et al. 2008).	IIED Watershed Markets: Description of 'Market Design' of different PES schemes by providing information on 'Services' and 'Commodity', 'Payment Mechanism', 'Terms of Payment', and 'Funds Involved'.
Condition of PES	Terms of payment under which beneficiaries of the ES reward providers (Porrás et al. 2008).	IIED Watershed Markets: Description of 'Market Design' of different PES schemes by providing information on 'Services' and 'Commodity', 'Payment Mechanism', 'Terms of Payment', and 'Funds Involved'.
Spatial analysis economic costs	Spatial-explicit appraisal of costs of maintaining or losing ES in monetary terms (Wunscher et al. 2008; Abson et al. 2014).	ESML: Combination of 'EM spatial distribution' and 'Variable values' describe the modeling area and whether or not ecological models allowing the value of one or more model parameters to be varied over the spatial domain; and provide results for a model run.
Spatial analysis economic benefits	Spatial-explicit appraisal of ES benefits for human well-being in monetary terms (Remme et al. 2015).	ESML: Combination of 'EM spatial distribution' and 'Variable values' describe the modeling area and whether or not ecological models allowing the value of one or more model parameters to be varied over the spatial domain; and provide results for a model run.
ES areas mapped	Documentation of graphical representations of areas most important for providing ES (Egoh et al. 2008; Burkhard et al. 2012).	No information provided, only indirectly indicated, e.g. in ValuES Cases: van Zyl (2014).
Provider distribution	Spatial-explicit mapping and quantification of provider of (multiple) ES (Schulp et al. 2014).	ESML: Combination of 'Abstract' and 'EM spatial distribution' explain whether or not providers and beneficiaries are spatially-explicit considered in ecological models.
Beneficiaries distribution	Spatial-explicit mapping and quantification of beneficiaries of (multiple) ES (Schirpke et al. 2014).	ESML: Combination of 'Abstract' and 'EM spatial distribution' explain whether or not providers and beneficiaries are spatially-explicit considered in ecological models.
Specific groups empowered	Documentation of distinct stakeholder groups – e.g. women, indigenous, young folks, etc. – and their authority or power to access, use, manage, or impair ES (Corbera and Brown 2008; Felipe-Lucia et al. 2015).	IIED Watershed Markets: Combination of 'Stakeholder (Supply, Demand, Intermediary, Facilitator)' and 'Market design (Terms of payment)' provide information on stakeholder and their role in PES schemes.
Locals in PES integrated	Engagement of local stakeholder in design and implementation of PES schemes (Porrás et al. 2008). Stakeholder are any group, directly or indirectly affected by a study, as well as those who may have interests in a study and/or the ability to influence its outcome (Durham et al. 2014).	IIED Watershed Markets: Combination of 'Stakeholder (Supply, Demand, Intermediary, Facilitator)' and 'Market design (Terms of payment)' provide information on stakeholder and their role in PES schemes.
Traditional local knowledge	Identification and/or utilization of indigenous and local knowledge on ES in valuations, assessments, and interventions (Kovács and Pataki 2016).	IPBES Catalogue: 'Incorporation of scientific and other types of knowledge' indicates whether or not traditional knowledge of local and indigenous communities is considered in an ES assessment.
Rights for access & benefit sharing for locals	Documentation of access rights to genetic resources and approaches for sharing of benefits arising from utilization of genetic resources for local communities (UNEP 2010).	ReefLink Database: 'Health policies', 'Biomedical Research Policies' and 'Pharmaceuticals & Cosmetics' explain activities in biomedical research and development as well as sale of

		pharmaceuticals and cosmetics, including research funding and patent laws regarding natural biochemicals from coral reefs.
Other financial policies for biodiversity-friendly activities	Practice examples concerning the (successful) implementation of tax breaks or exemptions (Shine 2005), indemnification mechanism (Anon 2008) and other financial policies that reward nature-friendly stewardship and spur green markets (Bergsma 2000; Popp 2009).	ReefLink database: 'Funding & Incentives' includes budgetary decisions by public administration to affect activities related to coral reefs.
Number of studies genetic resources	Number of studies investigating genetic material of plants, animals, microbial or other origins containing functional units of heredity of value for human benefit (UNSD 1997).	ESVD: 'ESService' and 'ESSubservice' provide information on which studies examined genepool and genetic material.
Capacity building for genetic resources	Documentation of the development and strengthening of human and institutional resources for assessment, valuation, access, and benefit sharing of genetic material of plants, animals, microbial or other origins containing functional units of heredity of value for human benefit (UNEP 2010).	IPBES Catalogue: 'Capacity building needs identified during the assessment' and 'Actions taken by the assessment to build capacity' include educational measures for assessment, valuation, access, and benefit sharing of genetic resources.
<b>3) Reforming environmentally harmful subsidies</b>		
Subsidies considered	Practice examples on government actions that confer an advantage on consumers or producers in order to supplement their income or lower their cost (OECD 2005).	ReefLink Database: 'Agriculture & Aquaculture: Phase Out Unwanted Subsidies' describes potential actions managers could enact to preserve reef ecosystems.
Sectors of subsidies	Socio-economic sector in which subsidies are implemented (Ulibarri et al. 1998). A sector is a distinct part of the society that reflects similar socio-economic situations (Martín-López et al. 2017), e.g. public and private sector or agriculture, marine fisheries, water supply (Durham et al. 2014).	ReefLink Database: 'Agriculture & Aquaculture: Phase Out Unwanted Subsidies' describes potential actions managers could enact to preserve reef ecosystems.
Effectiveness against stated objectives	Accuracy and completeness with which implemented subsidies achieve an objective (OECD 1996; Ulibarri et al. 1998).	No column headers refer to the indicator, but databases such as BUVD provide remarks in 'General Comments', 'Methodology Comments', and partly in titles of references.
Cost-efficiency	Documentation of subsidies' ratio between results achieved (outputs) and resources used (inputs) (OECD 2005).	No column headers refer to the indicator, but databases such as BUVD provide remarks in 'General Comments', 'Methodology Comments', and partly in titles of references.
<b>4) Addressing environmental degradation through regulation and pricing</b>		
Driver with identifiable polluter	Attribution of a person (-s) or a thing (-s) that is directly or indirectly responsible for an ecologically harmful change in the environment (Pasha et al. 2012).	IIED Watershed Markets: 'Driver' and 'Stakeholders' describe local environmental problems and people involved in pollution and PES for watersheds.
Full cost recovery	Assigning full costs of ES recovery spatially explicit to recipients benefiting from the ES (TEEB 2011).	No column headers or reference found for the indicator.
(Non-) Financial incentives for ES regulation	Adjustments of incentives by introducing market-based instruments (price controlling through taxes, fines, fees (Bocker and Finger 2016) or quantity controlling through permits, quotas, licenses (Yandle and Dewees 2008)) or other compensation approaches (offsets, biodiversity banking (Carroll et al. 2012; Rosa et al. 2016)) that build upon ES-related standards.	Goldman et al., 2008 provides detailed information about 'Conservation Finance Tools' such as redistribution and creation of taxes, fees, right transfers, etc. implemented in ES projects.
Regulatory standard	Documentation of specific benchmarks that constitute commonly accepted practice upon which provisions of legislation can be enforced (BBOP 2012; Chaplin-Kramer et al. 2015).	Ecosystem Marketplace: 'Marketwatch Carbon Markets', 'Marketwatch Water Markets', and 'Marketwatch Biodiversity Markets' encompass carbon emission standards, standards under the EU Water Directive, and BBOP (Business and Biodiversity Offsets Programme) Standards for Biodiversity Offsets respectively.
Sustainable techniques	Documentation of technologies that refer to efficient and effective production or distribution activities that can lead to healthier, environmentally and economically improved practices, and can save energy, resources, and money over time (Millennium Ecosystem Assessment	Innovation Seeds: 'Sharing good practices', 'Technical waste treatment', 'Producing energy', etc. encompass factsheets of sustainable production or distribution activities.

	2005a).	
Compliance monitoring	Surveillance and control of illegal conduct by continuously proving and detecting standards, commitments, agreements and/or violations and infractions, respectively (TEEB 2011; Van den Bosch and Matthews 2017).	Goldman et al., 2008: 'Compliance monitoring' explains monitoring approaches for ES, biodiversity, and other socio-economic issues.
Illegal conduct	Information on environmental crime and what constitutes illegal conduct such as trade prohibitions (Barnes 1996) or legal regimes for environmental issues (European Commission 2004).	ReefLink Databases: 'Accidental & Illegal Harvest' or 'Designated Uses' contain collections of species that are protected from harvest or concise statements of a state's management objectives and expectations for each of the individual surface waters under its jurisdiction, respectively.
Prosecution & penalties	Documentation of consequences of illegal conduct and approaches for the design of prosecution, arrest, conviction, and penalties (TEEB 2011).	No column headers refer to the indicator, but databases such as BUVD provide remarks in 'Laws', and partly in titles of references.
International law enforcements	International cooperation on law enforcements addressing illegal cross-border activities (Bruckner 2000).	ReefLink Database: 'Collaboration & Partnering' encompasses studies of international commitments on collaboration and partnering referring to management of coral reefs.
Offsets	Documentation of specific compensating equivalences for environmental damages arising from anthropogenic actions and interventions, and/or approaches to calculate offset requirements (Pilgrim et al. 2013). Examples for equivalence include protection and conservation offsets (Rosa et al. 2016), such as the same kind of habitat or species (like-for-like), different kinds of habitats and species of equal or higher importance, financial compensations through conditional payments for conservation (Zabel and Holm-Müller 2008) or traded offset credits (Sedjo and Marland 2003).	Ecosystem Marketplace: 'Marketwatch Carbon Markets', 'Marketwatch Water Markets' and 'Marketwatch Biodiversity Markets' explain offsets used in carbon, water and biodiversity markets.
<b>5) Regulating use through protected areas and recognition of their values</b>		
Protected areas considered	Consideration of any area of the terrestrial or aquatic environment that has been reserved by federal, state, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein (NOAA 2000; Gray and Campbell 2009; Laurans et al. 2013).	ESVD: 'Protected Status' contains information on the level of protection of the study area.
Establishment of new protected areas	Documentation of approaches to design and establish a geographically defined area that is designated or regulated and managed to achieve the long term conservation of nature with associated ES (Sanchirico and Wilen 2001).	No column headers refer to the indicator, only in titles of references, e.g. in ReefLink Database: Hall-Spencer et al. (2009).
Regulatory mechanism for costs & benefits	Documentation of policies or mechanisms for equitable sharing of benefits and costs arising from protected areas (Dixon and Sherman 1990; TEEB 2011). Costs of protection and earning potentials from non-protection choices are often short-term and spatial concentrated while benefits are often long-term, broadly disbursed and non-market.	No column headers refer to the indicator, only in titles of references, e.g. in NOEP Non-Market: Dharmaratne et al. (2000).
Funding instruments	Details on financial resources for the design, examination, implementation, maintenance, and management of protected areas (TEEB 2011).	IIED Watershed Markets: 'Market Design (Funds Involved)' explains details on funds applied for payment for watershed projects.
Win-win situations identified	Identification of synergies in national and international policy commitments to create win-win solutions for environmental conservation and socio-economic co-benefits, e.g. role of habitat protection for recovery of species and their effect on food security (Roberts et al. 2001).	No column headers refer to the indicator, only in titles of references, e.g. in ReefLink Database: Gjertsen (2005).
Engagement of locals in protected areas	Consideration and involvement of local stakeholder in the design, implementation, and/or management of protected areas (Camargo et al. 2009). Stakeholder are any group, directly or indirectly affected by a study, as well as those who may have interests in a study and/or the ability to influence its outcome (Durham et al. 2014).	IIED Watershed Markets: 'Stakeholder (Supply, Demand, Intermediary, Facilitator)' explains and differentiates stakeholder groups and their functions in PES in protected areas.



6) Direct public investment in ecological infrastructure and restoration		
Direct public investment	Financial resources that a government spends directly for creating, restoring, or conserving a network of interconnected structural elements and functions in the landscape, e.g. investing public funds in natural capital for reduction of environmental risks (UNFCCC 2016) or restoration of public ES with returns realized over the long term (Liu et al. 2008).	PESD: 'Transaction Amount (USD\$)' encompasses different financial resources, such as public payment schemes, to enable PES projects in developing countries.
Restoration	Provision of information on restoration. Restoration in accordance to Aronson et al. (2007) includes the replenishment of natural capital stocks, recovering of resilient and self-sustaining ecosystems as well as the improvement of human welfare on different scales.	ReefLink Database: 'Wetland And Reef Restoration', 'Ecosystem Monitoring And Restoration', etc. describe responses to directly restore the conditions of reef ecosystems.
Needs for adaption	Expected needs for investment in adaption to natural or social crises and catastrophes (Landry et al. 2011; Hochrainer-Stigler et al. 2014). Also methods to identify investment opportunities are considered, e.g. the Resource Investment Optimization System (RIOS) that supports cost-effective investments in watershed services (Vogl et al. 2016).	TEEB Cases: 'What was needed to solve the problem in terms of data, resources and capacity?' contain remarks for investment needs in adaption to natural or social crises and catastrophes.
Proactive strategies used	Application of proactive strategies, i.e. anticipatory, self-initiated behavior, acting, or investigation intervening in advance of a situation that is most likely to happen in future, for instance, prevention of natural hazards due to climate change (Innocenti and Albrito 2011) or the prevention of a hydropower-dam project to preserve natural assets (Reid 1999; Wittich et al. 2014).	BUVD: 'Method Description' of economic valuation studies includes approaches of averting behavior.
Recycling	Documentation of loop processes in which waste is seen as input and the notion of undesirable by-products is eliminated for a more efficient use of limited resources, e.g. straw waste recycling in a rice-wheat rotation farmland (Xuesong et al. 2011) or the European action plan for implementation of a circular economy (European Commission 2017a).	EVCBN: 'Waste and Recycling' contains summaries of economic studies on waste and recycling issues.
Number of studies dealing with extreme events	Number of studies investigating prevention and moderation of natural hazards, disturbances or extreme weather events such as salinization, droughts, fire, avalanches, landslides, tsunamis, floods and storms (Feagin et al. 2010).	ReefLink Database: 'Storms & Hurricanes' provide studies of periodic events of high precipitation, winds, wave action, and flooding that can potentially cause damage to reef habitat, property, or human lives.

**Table 2. General characteristics of ES database contents.** The table contains eight indicators that represent information on the number of ES investigations, the type of information and ES provided.

Indicator name	Description
Number of studies, projects or methods	The total number of studies, projects or methods contained in a database. In the reviewed databases information were compiled based upon ES studies, ES projects or for specific ES methods.
Quantitative information	The total number of databases' column headers that contain numerical information. This indicator represents information about quantities that were measured or referred to in ES investigations and written down with numbers.
Qualitative information	The total number of databases' column headers that contain descriptive, non-numerical information.
Provisioning	The total number of ES that indicate the material or energy outputs from ecosystems. They include food, water, organic raw material, inorganic material (energy), medical resources, genetic material, and ornamental species. See TEEB (2010b) for a comprehensive list of provisioning ES.
Regulating	The total number of ES that encompass services which ecosystems provide by acting as regulators, for instance, regulating air quality, climate, water quantity, water quality, soil retention, soil fertility, pollination, biological control, and moderation of extreme events. See TEEB (2010b) for a comprehensive list of provisioning ES.

Cultural	The total number of ES that include non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g. knowledge systems, social relations, and aesthetic values. See TEEB (2010b) for a comprehensive list of provisioning ES.
Supporting	The total number of ES that are necessary for the maintenance of all other ES. They include nursery and habitat function, maintenance of genetic diversity, and nutrient cycling. See TEEB (2010b) for a comprehensive list of provisioning ES.
Ambiguous	The total number of ES that could not clearly assigned to provisioning, regulating, cultural or supporting services. Ambiguous ES resulted from, for instance, missing information or generic categories such as ‘multiple ES’.

**Table 3. Design and impact of databases.** In the table are six indicators described that provide insights into databases’ functionalities, characteristics and effects on situations or persons.

Indicator name	Description
Functional type	This indicator distinguishes between three functional types of databases defined by the National Science Board of the National Science Foundation of United States (NSB 2005). According to purpose, design, funding, and maintenance databases can be divided into ‘research’ (1), ‘resource’ (2) and ‘reference collections’ (3).
Data organization	The type of data organization and storage. The following factor levels were differentiated: ‘tabular’ (1) or ‘relational’ (2). In a tabular design data entries are stored in cells, with multiple cells represented in a system of rows and columns. A relational data organization uses multiple tables which are interlinked via logical connection to allow interactions between these tables.
Search options	This indicator distinguishes between different abilities provided in databases to narrow queries by different filters. The following factor levels were used: 1) ‘categorical’: queries by selecting predefined options of different categories representing database entries; 2) categorical and ‘free text’: free text search that allows users to input keywords or numbers; 3) categorical and ‘geographical’: geographic queries by interactive maps; and 4) categorical, free text and geographical.
Data updates	This indicator measures if new or more accurate information is incorporated in the databases. We classified ‘ongoing data collection’ (1) and ‘finalized’ (2).
Add-ons	The type of software used to increase the capability of a database. The following factor levels were differentiated: 1) ‘none’; 2) ‘access to methods and studies only’; and 3) ‘analytical and visual software’. ‘Access to methods and studies only’ is less an add-on per se rather indicates hyperlinks to other software that stores and manages the original methods and studies analyzed in databases. ‘Analytical and visual software’ refer to programs that enable users to customize applications, for instance statistical and spatial analysis via geographic information system application programming interface (GIS API).
Policy uptake	The indicator measures if databases were applied within a decision-making context such as political agendas. For this indicator we directly contacted the developers of the databases. Answer categories differentiate between ‘no’ (1) and ‘yes’ (2).

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