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Comparison of environmental indicator sets using a unified indicator classification framework

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ABSTRACT

Environmental indicator sets (EIS) are tools to monitor and assess sustainability, and many environmental organizations have embraced their use. Due to the large number of EIS, it is a challenge to compare and reconcile their differences and gain a comprehensive view of their utility. To compare EIS, the first step is to classify their component indicators, for which several frameworks exist. Among the most widely used, is the causal-chain framework, also referred to as PSR after its categories of Pressure, State and Response. Other frameworks classify indicators by subject, yet none is widely applied. Aiming to compare EIS, we first proposed a unified classification criteria for indicators using PSR and five subject categories (*i.e.*, biodiversity and ecosystem health, E; natural resources, N; physical and chemical contamination, C; human environment, H; and general, G). Then, we used these classification criteria to describe and compare fourteen existing environmental indicator sets. Finally, we compared EIS based on their production characteristics and goals. Across the fourteen EIS, we analyzed 706 indicators (which represent ~1200 variables) and selected 16 and 79 keywords for classification in the PSR and ENCHG categories respectively. We found on average that the ratio of categories in the causal chain framework was 2.5S:1.5P:1R, while we observed a large variability across EIS. For the subject categories, C-E-N were nearly equally represented among EIS, and better represented than H-G. Also, the evaluated EIS showed a polarization between C-H and E categories that we interpreted as a human vs. natural-ecosystem welfare focus. Finally, we identified three broad categories of EIS based primarily on the organization that produced them, non-governmental organizations, governmental organizations, and international organizations. Our results can contribute to the design and implementation of scientifically robust and representative EIS, which are key to incorporate environmental data to policymaking in the search of sustainability.

1. Introduction

Human activities are responsible for changes in the environment, which may impair ecosystems for the sustainable provision of goods and services. The exploitation of natural resources such as land, water, and wild populations has often jeopardized the continuous utilization of these resources. Additionally, industrialization has led to global changes in natural cycles. An awareness of this environmental degradation has developed in the last half century, leading to the concept of environmental sustainability, one of three traditional "pillars" of sustainability (economic, social and environmental) that, despite much ongoing controversy, still makes up the predominantly used framework for this concept (Cinelli et al., 2014; Goodland, 1995).

In this context, environmental indicators have emerged as tools for monitoring environmental sustainability (OECD, 2001). Environmental indicators are used to simplify the monitoring of complex ecological systems and are made up of objective and quantifiable variables that report on specific aspects of the environment, such as the number of threatened species or the presence of air pollutants. (Heink and Kowarik, 2010). Several organizations, such as the European Environmental Agency and the World Wildlife Fund, have compiled environmental indicator sets (EIS) that seek to give a holistic view of environmental sustainability (Niemeijer and de Groot, 2008). EIS allow their users to "organize and synthesize" environmental data that are often complex and heterogeneous. (Ziegler et al., 2015). Some EIS can be reduced to a single index, often a number that further synthesizes a measure of environmental sustainability. Because the sustainability of the environment is an ongoing concern, the number and diversity of EIS are expected to increase, and the purpose of this research is to describe and quantify that diversity.

To compare EIS, it is necessary to classify their component indicators. Efforts have been made to organize and describe measures of

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Table 1
List of Environmental Indicator Systems selected in this study. Complete name, abbreviation code and reference.

Coordinating Organization	Environmental Indicator Set	Abbreviation
Organization for Economic Cooperation and Development	Key and Core Environmental Indicators (OECD Environment Directorate, 2008)	OECD
United Nations Environmental Programme.	Convention on Biological Diversity Framework Indicators (UNEP/WCMC, 2010)	CBD
European Union European Environment Agency	Sustainable European Biodiversity Indicators (EEA, 2007)	SEBI
Yale and Columbia Universities	Environmental Performance Index (Yale Center for Environmental Law and Policy, 2012)	EPI
Secretariat of the Pacific Community	Environmental Vulnerability Index (SOPAC and UNEP, 2004)	EVI
World Wildlife Fund and Zoological Society of London	Living Planet Index (World Wildlife Foundation, 2012)	LPI
Global Footprint Network	Ecological Footprint (Lazarus et al., 2014)	EF
United Kingdom Department of Environment	United Kingdom Biodiversity Indicators (UK Biodiversity Partnership, 2010)	UKBI
United States Environmental Protection Agency	Report on the Environment (U.S. Environmental Protection and Agency, 2008)	EPA
Heinz Foundation	State of the Nation's Ecosystems (Heinz and Tufford, 2003)	Heinz
Mexico Secretary of Environment and Natural Resources	National System of Environmental Indicators (SEMARNAT, 2012)	SNIA
Argentina Secretary of Environment and Sustainable Development	System of Sustainable Development Indicators (Environmental Subset) (SAyDS, 2010)	SIDS
Environment Canada and Statistics Canada	Canadian Environmental Sustainability Indicators (Environment and Climate Change Canada, 2014)	CESI
Australia Department of the Environment	State of the Environment Environmental Indicator Report (Saunders et al., 1998)	EAus

environmental sustainability including indicators and EISs (Böhringer and Jochem, 2007; Goodland, 1995; Jorgensen et al., 2013; Moldan et al., 2012; Singh et al., 2012; Vačkář, 2012). These efforts have resulted in various classifications designed for a specific EIS within local specifications. The causal chain framework is a widely-used tool for describing and classifying indicators (OECD, 1998). Also referred to as PSR after its categories Pressure, State and Response, this framework places indicators within a chain of cause and effect that starts and ends with human society (Heink and Kowarik, 2010; Niemeijer and de Groot, 2008). According to this framework, an environmental indicator can either represent an anthropogenic pressure affecting the environment, the state of the environment itself, or a societal response to modify the pressures on the state of the environment.

Alternatively, some EIS also classified indicators by subject. For example, OECD uses thirteen "issues" from climate change to soil degradation (OECD, 1993); the Environmental Performance Index (EPI) uses ten "policy categories" split into two broad "policy objectives" of "environmental health" and "ecosystem vitality" (Yale Center for Environmental Law and Policy, 2012); and, the U.S. Environmental Protection Agency uses land, air, water, human exposure and health, and ecological condition for the "chapters" of its Report on the Environment (EPA) (U.S. Environmental Protection and Agency, 2008). Other classifications divide indicator subjects into two major categories: "ecosystem well-being' and 'human well-being' (Prescott-Allen, 1996). Within ecosystem well-being, this classification includes land, water, air, biodiversity, and resource use (Prescott-Allen, 1996). However, environmental sustainability has also been defined in the utilitarian terms of 'natural capital', or the ability of the environment to act as both a source and a sink for society, thus performing the "maintenance of human life-support systems" (Goodland, 1995). In contrast, Holdren et al., 1995 defines environmental sustainability in purely biogeophysical terms, declaring that human well-being should be excluded from environmental sustainability and remain entirely in the categories of social and economic sustainability. He classifies indicators conceptually by physical, geological, biological and chemical and also assigns them to lithosphere, hydrosphere, and atmosphere categories (Holdren et al., 1995). Given the considerable variability in classification criteria for indicators, a comparison across EIS can be quite intricate.

Organizations that want to develop new EIS or use the existing ones, are challenged by the diversity of indicators and how are they implemented. Implementation of EIS range from comparisons to describe holistic differences in sustainability across world countries (*e.g.* EPI) or focus on specific categories within national boundaries (*e.g.* EPA). To reduce and simplify the diversity of indicators and EIS, here we proposed a broad classification framework. We utilized both the causal-chain classification and an original subject-based classification of indicators. We included an approach to apply these classifications to already existing EIS using keywords. Our overarching goals were to provide a unified reference classification criteria for indicators and to understand the diversity of existing EISs. To achieve these goals, we first explored the composition of EIS, and then how these are produced and used. In order to accomplish this, we compiled a selection of fourteen major existing EIS and developed a comprehensive classification criteria for environmental indicators. With this classification criteria as a tool, we characterized the diversity of EIS, describing what types of indicators they use, and how their developers implement them. We hope that understanding the diversity of EIS will facilitate end users to select the appropriate indicators and EIS to apply environmental data to policymaking.

2. Methods

2.1. Selection of environmental indicator sets

We selected fourteen EIS developed by international, governmental, and non-governmental organizations (NGOs) that operate on a national scale and that either (a) cover a broad range of environmental themes, or (b) cover one or two major environmental themes extensively (Table 1). We selected EIS that have reached the level of successful implementation, preferably over multiple years. Specifically, we chose all major international EIS associated with or branching from the Organization for Economic Cooperation and Development (OECD) and the United Nations (Table 1). We included some of the major non-governmental organizations' (NGO) EIS that are recognized globally (Table 1). Finally, we chose a selection of nation-based EIS from Europe, Latin America, USA, Canada and Australia (Table 1). For Argentina's *Sustainable Development Indicators,* we included only the indicators in the environmental and environmental interaction sections. Within our constraints we aimed to cover a diversity of EIS from different organizational contexts and with different potential goals and focuses. Our search was not intended to be exhaustive.

2.2. Indicator classification criteria

We created general classification criteria for two reference frameworks: "causal-chain" (i.e. PSR) and "subject-based". For each framework, we evaluated 14 EIS that contained a total of 706 indicators consisting of 1280 variables (many indicators represent more than one variable). The PSR framework is incorporated into two EIS (OECD, MEX) by their producers. In these cases, the pre-existing PSR classification of these indicators was not modified. These cases served as the

Table 2
Classification criteria for the Pressure-State-Response Framework. List of keywords to sort indicators into each category.

Pressure	State	Response
Emissions	Concentration	Recovery
Generation	Stock	Regulation
Deposition	Extent	Recycling
Withdrawals	Level	Treatment
Production		Reutilization
Yield		Efficiency

source material that was used to develop a set of keywords associated with the pressure, state, and response categories (Table 2), which was used as criteria to expand the PSR classification to the other twelve EIS.

To generate the conceptual subject classification, we synthesized ideas from the EIS selection and the literature. We proposed five subject groups: i) the physical and chemical contamination of the environment caused by human activities, ii) the quality and use of natural resources associated with direct economic value, iii) human environment, iv) the biotic environment and the health of wild ecosystems, and v) general unclassifiable or non-environmental socioeconomic indicators. We evaluated and synthesized 706 indicators from the 14 EISs (Table 1) into 73 generic concepts. which were nested within each of the five groups (Table 3). For example, we simplified "greenhouse gas emissions" from OECD, "carbon dioxide emissions per capita" from EPI and "pressure from air pollution" from UKBI to "emissions of pollutants" in the physical and chemical contamination category (Table 3).

2.3. Comparison of EIS

We compared the content of the 14 EIS (Table 1) using our classification criteria. All 746 indicators within the 14 EIS were classified using the causal chain and subject-based criteria described above (Tables 2 and 3). Next, we estimated the proportion of indicators in each category for each EIS. These proportions were used in correlations and principal component analysis (Di Rienzo et al., 2011). Further, we described EIS using technical dimensions of their production and use (Booysen, 2002; Vačkář et al., 2012). These dimensions consisted of: i) stated subject, ii) stated goal, iii) organizer, iv) sample scale, v) relativity, vi) level of synthesis, vii) variable to indicator ratio, and viii) total number of indicators. Stated subject and stated goal are both qualitative descriptors. Stated subject refers to what the EIS aims to describe, while stated goal refers to what the EIS claims to have as its primary impact or use case. Type of organizer classifies the institution that produced the EIS. This can be either a governmental agency or department; a non-governmental organization; or, an international organization, collaboration or convention such as the OECD. Sample scale refers to the maximum geographic range that the EIS covers, and given our EIS selection criteria this can be either national or global. A national sample scale applies and can be applied to only one nation and is not designed to be used elsewhere. A global sample scale also uses the nation as its unit of evaluation, but is not specific to one nation and often is comparable between nations. Relativity refers to whether an EIS requires comparisons or calculations with targets, standards or baselines. Absolute EIS are those sets that contain indicators which do not need comparison with the situation of other nations/regions or against a predetermined standard. Sets may contain a combination of absolute and relative indicators, but if the set contains any relative indicators the entire set was considered relative. Synthetic EIS present single numerical value derived from a mathematical calculation performed on values of its component indicators (i.e. an index). Non-synthetic EIS are simply a group of indicators. Variable to indicator ratio and number of indicators are calculated from the totals of the component indicators and variables of each EIS. Of these dimensions, all but stated goal and purpose can be put into a quantitative form. From these, type of organizer, sample scale, relativity, exhaustivity, and level of synthesis were converted into numeric form (0, 1, 2) and were analyzed for impact with PCA.

3. Results

3.1. EIS composition

EIS ranged in size from 1 to 128 environmental indicators and had a greater than one variable to indicator ratio in 10 out of 14 EIS (Table 4). Within the causal chain framework, an average EIS included half of its

Table 3
Classification criteria for the subject-based framework. List of keywords to sort indicators into each category.

Biotic Environment	Quality and Use of Natural Resources	Physical and Chemical Contamination	Human Environment	General/Socioeconomic
Biodiversity	Ecosystem services	Emissions of pollutants	Human diseases (morbidity)	Urban and rural population size
Invasive species	Use footprints	Atmospheric pollution concentrations	Life expectancy (mortality)	Urbanization and housing density
Threatened species	Use biocapacities	Carbon footprint	Access to sanitation	Tourism
Protected species	Land use change	Ground UV radiation	Contaminants in human bloodstream	Violent conflicts
Selected species of interest	Agricultural and pastoral land use	Acid rain and damage	Drinking water quality	Developed land
Habitat extent	Aquaculture	Ozone damage to forests	Pesticides and contaminants in food	Geological features
Habitat quality	Forest resources	Car traffic and densities	Contaminants in fish stocks	Natural disasters
Threatened area	Soil resources and quality	Waste and recycling systems	Urban micro-climate	Indigenous communities
Ecosystem disturbances	Dam capacity and water extraction	Sewage and sewage systems	Indoor air pollution	Climate status
Protected area	Water use and efficiency	Pesticides in the environment	Urban shallow water quality	Energy intensity and efficiency
Natural patches/corridors in utilized land	Coastal use	Freshwater quality	Other urban contaminants	Renewable energy
Population genetics	Fishing pressure	Macronutrient presence in watershed	Radon levels	Oil availability and reserves
Habitat restoration	Managed productive land	Macronutrient presence at sea	Urban green space	Industrial production
	Human recreation in nature	Algal blooms	Extreme weather warnings	Commerce, GDP, growth
		Wild fish contaminants		Expenditures on environment
				International agreements
				Road networks and transportation

Table 4
Characteristics for the environmental indicator sets not related to the content of the indicators. See Table 1 to reference EIS name from codes. Type of organizer includes international (INT), non-governmental and governmental organizations (NGO, GO).

EIS	Stated Subject	Stated Goal	Type of Organizer	Sample Scale	Absolute or Relative	Level of Synthesis	Variable/ Indicator	Number of Indicators
OECD	Economic growth, pressures and environment	International coordination	INT	Global	Absolute	Indicators	2.23	64
CBD	Biodiversity	International coordination	INT	Global	Absolute	Indicators	2.62	24
SEBI	Biodiversity	Integration of monitoring and reporting	INT	Global	Absolute	Indicators	2.56	23
EVI	Environmental vulnerability	Evaluate simplify and report	INT	Global	Absolute	Index	1	50
EPI	Performance on environmental issues	Ranking for productive competition	NGO	Global	Relative	Index	1	22
LPI	Biodiversity population trends	Monitor and report	NGO	Global	Relative	Index	5	1
EF	Demand on nature and biocapacity	Monitor and report	NGO	Global	Relative	Index	4.28	7
UKBI	Biodiversity	Reduce biodiversity loss	GO	National	Relative	Indicators	1	36
EPA	EPA responsible aspects of environment	Assist in mission of legal and regulatory responsibility	GO	National	Absolute	Indicators	3.16	85
SNIA	Environmental performance	Report changes	GO	National	Absolute	Indicators	1.8	128
SIDS	Sustainable development	Evaluate and improve decision-making	GO	National	Absolute	Indicators	2.12	33
CESI	Environmental sustainability	Report state and progress of environment	GO	National	Absolute	Indicators	2.48	50
EAus	Environment	State of environment	GO	National	Absolute	Indicators	2.37	75
Heinz	National ecosystems	Report changes	NGO	National	Absolute	Indicators	N/A	108

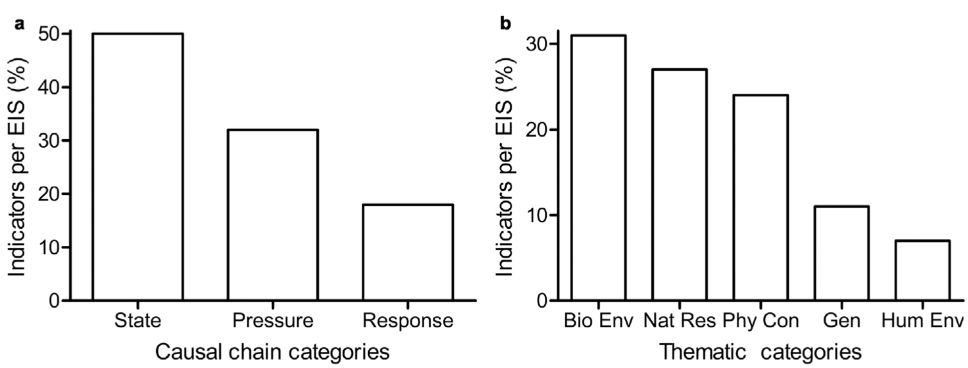

Fig. 1. Proportion of categories in environmental indicator set (EIS) for the a) causal chain and b) subject based framework categories; biotic environment (E), natural resources (N), physical and chemical contamination (C), human health and welfare (H), and general (G). Indicators contained within the 14 EIS included in this study were classified according to causal and thematic framework (Tables 2 and 3).

indicators in the state category, followed by pressure and response with 32% and 18% respectively (Fig. 1a). Within the subject-based framework, EIS focused on the biotic environment, natural resources, and physical contamination, accounting for 31, 27 and 24%, respectively. Less than 12% of indicators were related to the human welfare and general categories (Fig. 1B).

Across EIS, there was a large variability in the proportion of categories for the causal chain and subject frameworks (Fig. 3). PSR ranged from 100% state for the Living Planet Index (LPI) to 86% pressure for the Ecological Footprint (EF). Variability was also reflected in a negative correlation between state and pressure, no correlation between pressure and response, and a negative correlation between state and response (Fig. 2).

For the subject based framework, eight EIS contained indicators in all five categories, and only one (i.e. EF) had indicators in just one category. A PCA showed EIS along a primary axis explaining 42% of variance with many indicators in the ecosystem-based category on one end, and indicators in the contamination and human welfare categories on the other end (Fig. 3). EIS were ordered in a continuum between two ends where most indicators were either categorized in the biotic environment categories, or contamination and human welfare. In particular the Environmental Footprint (EF), UK Biodiversity Indicators (UKBI), EVI and LPI had 50% or more indicators on the biotic environment category; and on the opposite end, the Convention on Biological Diversity (CBD), the Sustainable European Biodiversity Indicators (SEBI), Environment Austraila (EAus) and OECD all presented more than 50% indicators summing categories of physical and chemical contamination and human health and welfare. The secondary axis of the PCA separated EIS with high percentage of indicators in the resource category (Fig. 3). The environmental subset of the System of Sustainable Development Indicators (SIDS) stands out, with 86% of its indicators identified in the natural resources category.

3.2. How are EIS produced and used?

We found a wide range of subjects and goals across EIS. Issues they sought to focus on included biodiversity, pressures, policy performance, environmental status and sustainable development among others. Goals of the EIS were varied and included international coordination, monitoring and reporting, ranking, meeting policy goals, and improving decision-making. Indicators were evenly divided between international and national sample scales. Indicators were more often absolute, less often synthesized into a final index, and the average variable to indicator ratio was 2.43.

Analyzing the quantified versions of these categories, a PCA showed a wide spread of EIS across the two major axes. The primary axis was influenced by type of organizer and sample scale (both in the positive direction) and less so by level of synthesis (in the negative direction). The minor axis had effects from absolute vs. relative and level of synthesis (+) and a minor effect from sample scale (−). EIS were

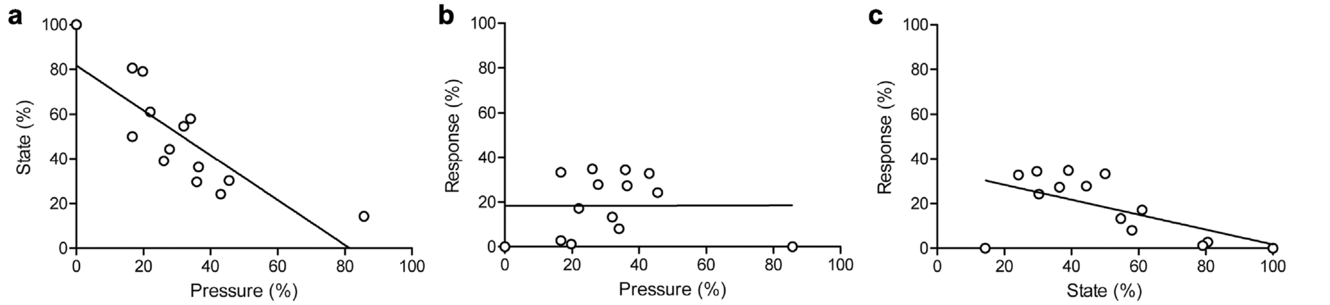

Fig. 2. Correlations between the causal chain categories for environmental indicators sets (EIS). Each symbol represents the percent of indicators within an EIS for the pair of categories a) pressure and state, b) pressure and response, and c) state and response. Lines represent correlation between categories which resulted significant for a) and c) ($p < 0.01$ and $p < 0.05$, respectively) and non-significant for b) ($p > 0.05$).

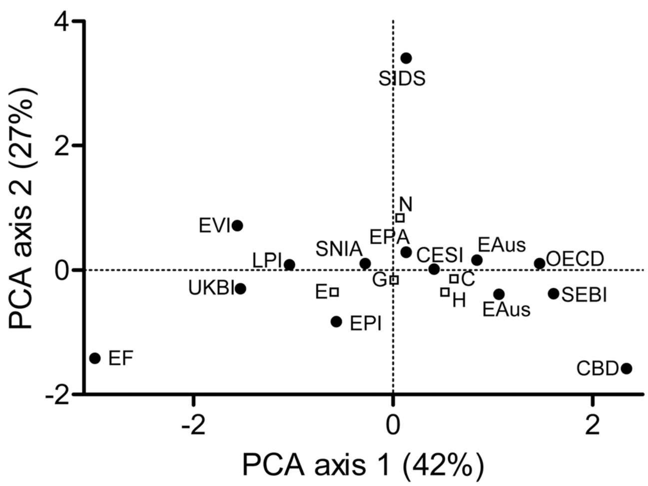

Fig. 3. Environmental indicator set (EIS) ordination based on the percentage of indicators within categories of the thematic framework. Circles represent EIS scores for the two first axes of a principal component analysis. Open squares represent loads of the thematic framework categories biotic environment (E), natural resources (N), physical and chemical contamination (C), human health and welfare (H), and general (G). Codes for EIS listed in Table 1.

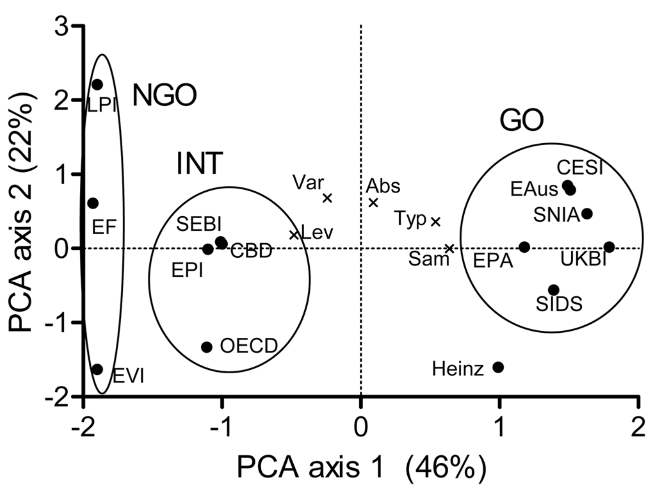

Fig. 4. Environmental indicator sets (EIS) ordination based on the characteristics of their production. Dots represent EIS scores for the two first axes of a principal component analysis. Crosses represent loads for level of synthesis (Lev), variable to indicator ratio (Var), sample scale (Sam), type of organizer (Typ), absolute vs. relative (Abs). Clusters identify international organizations (INT), non-governmental organizations (NGO), and governmental organizations (GO). Codes for EIS listed in Table 1.

spread out along gradients across both axes. We identified three clusters defined by their organizer: the international group (OECD, SEBI, CBD, EVI), the NGO group (LPI, EF, EPI) and the national group (all others including Heinz which is an NGO working closely with the US EPA) (Fig. 4).

4. Discussion

4.1. Indicator classification frameworks

In developing our classification, we chose to emphasize interactions between environment and society by including the PSR framework and in the development of our subject categories. The main value of classifying in this way is that EIS exist to inform policy and the public, and these uses have a society-based perspective (Perrings et al., 2011; Singh et al., 2012). Our classification was informed by the source and sink concept (Goodland, 1995) and the ecosystem service concept (De Groot et al., 2010), both of which attempt to describe interactions between society and environment. The former concept is that the environment can be thought of as both a source of inputs and value to human society (roughly this maps onto our natural resources and human welfare categories) and a sink for our outputs and waste products (physical and chemical contamination category) (Goodland, 1995). Similarly, the ecosystem service model looks at the environment as providing services, which again is reflected with our natural resources and human welfare categories (De Groot et al., 2010). Our biotic/ecosystem category is the only explicitly non-anthropogenic category.

However, our classifications are not the only way to categorize environmental variables, and there are challenges and false dichotomies implicit in separating concepts into subject categories that are deeply interwoven (De Groot et al., 2010; Gibson, 2006; Hattam et al., 2015). In fact, even the three pillars of sustainability are so fundamentally connected that their boundaries are not often clear. This challenge is also reflected in the causal chain, which is in fact a cycle without a beginning or an end (Gibson, 2006). The PSR classification has been reinterpreted in various ways to add definition and precision, the most common of which is the Driver-Pressure-Impact-State-Response (DPISR) framework (Kristensen, 2004).

Despite these challenges and ambiguities, there is value to defining categories and criteria. The criteria and associated frameworks that we developed in Tables 2 and 3 can be applied to any indicator. Both the PSR and the subject frameworks allow users and producers of environmental indicators and EIS to focus on the appropriate subject. For some organizations, a specific aspect of the environment or of the cause and effect cycle may be most relevant, as in the case of the Living Planet Index or the Environmental Vulnerability Index. These EIS are organized by nonprofit organizations to quantify the specific issues of biodiversity and environmental risks. In other cases, such as most national EIS, our frameworks allow groups to assure that they are taking a broad and holistic approach to evaluating environmental sustainability. More specific EIS suited to a particular aspect of ecological sustainability may be ideal for short term responses, if the EIS is sensitive enough. On the other hand, holistic EIS, with a wide range of indicators, may be less responsive to temporary changes in one aspect and be more useful for long term policies. These complementary approaches are both useful and are facilitated by our classification frameworks.

4.2. EIS diversity and composition

Ranked by prevalence according to the PSR framework there were mostly state, then pressure, then response indicators. The greater abundance of state and pressure indicators, compared to response indicators, is likely a result of their relative ease to measure. Response indicators are conceptually more complex and difficult to assess, objectively weakening the EIS, and inclusion of response indicators in particular may require a greater level of policy awareness and specific goals (Dale and Beyeler, 2001). EIS varied in the proportion of indicators within each category, some with large proportions of either state or pressure indicators. We observed that those EIS that self-classified by PSR (OECD, MEX) have all three categories well represented, although equality of the three categories was not exclusive to these two EIS. EIS with unequal proportions of categories tended to include either more state or pressure indicators.

EIS also showed patterns within the subject framework. Dominant categories were contamination, biotic environment and natural resources, with a lower representation of human welfare and general. We found EIS spread across a gradient from a high proportion of biotic indicators focused on plant and animal communities to a high proportion of physical and chemical indicators focused on contamination. This can also be thought of as an ecosystem-welfare to human-welfare axis since physical and chemical contamination and human health are likely tied together (Prescott-Allen, 1996). Finally, the lower representation of the human welfare and general categories may reflect their more direct connection to concepts of social and economic sustainability and may be more appropriate in other non-environmental indicator sets. These categories may exist in EIS to provide context and to create a more direct connection to issues that are of interest to end users.

4.3. EIS production

Here we provided further characteristics to inform selection of EIS that relate to aspects such as ease of use (number of indicators, variable to indicator ratio), generality (absolute/relative, sample scale) and structure (level of synthesis, producer). EIS grouped in clusters related mostly to the type or organizer (Fig. 4). In general, the national-governmental produced extensive sets of indicators, were broadly distributed in thematic scope, and were exhaustive in the amount of data considered (Table 4). These sets were also designed to be used in a specific context to deal with specific national environmental concerns. In contrast, the EIS in NGO and international clusters were developed to be applied broadly. Both of these clusters were generally more indicative than descriptive in terms of the total number of variables concerned, and some focused on specific issues. For example, the Living Planet Index focused specifically on the biotic aspects of the environment (i.e. status of wildlife populations). These two clusters were much more similar to each other than they were to national EIS, but they were primarily distinguished by their level of synthesis (international EIS are all synthesized into indices) and their relativity (international indices measure indicators with reference to baselines, targets or conditions outside the system being measured). This relativity allows for the index to be comparable across different nations, while NGO EIS are often adapted to meet specific conditions before they are implemented and are therefore less explicitly comparable.

5. Conclusion

With this study, we have provided a novel classification framework of indicators that can be useful to organizations that want to create their own EIS. Our classification of indicators can be used to simplify, explain and develop EIS according to an organization's stated goals and available environmental data. At the same time, we provided a comparison of existing EIS that includes the composition of their indicators and how they are produced. Through this comparison, we have identified trends and patterns in some major existing EIS including trends towards state and pressure indicators, as well as towards biotic environment, natural resources, physical-chemical indicators. Predictable tradeoffs exist between certain categories of indicator across EIS, and EIS shared various characteristics depending on the type of organization overseeing them. An effective EIS will translate relevant environmental data into policymaking and thus its design is key for the coordination sustainable strategies.

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