Chapter 1
Working in Networks to Make Biodiversity Data More Available

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Abstract It became apparent a few decades ago that biodiversity is declining worldwide at nearly unprecedented rates. This poses ethical and self-interested challenges to people, and has triggered renewed efforts to understand the status and trends of what remains. Since biodiversity does not recognise human boundaries, this requires the sharing of information between countries, agencies within countries, non-governmental bodies, citizen groups and researchers. The effective monitoring of biodiversity and sharing of the data requires convergence on methods and definitions, best achieved within a relatively loose organisational structure, called a network. The Group on Earth Observations Biodiversity Observation Network (GEO BON) is one such structure. This chapter acts as an introduction to the GEO BON biodiversity observation handbook, which documents some of the

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co-learning achieved in its first years of operation. It also addresses the basic questions of how to set up a biodiversity observation network, usually consisting of a number of pre-existing elements.

Keywords Network · Management · Biodiversity · Observations · Indicators · EBV · Organisation

1.1 Observing Biodiversity

People have observed biodiversity—the variety of life on Earth, in all its forms and levels (Fig. 1.1; based on Noss 1990)—throughout history. Indeed, having a deep understanding of biodiversity was an essential element for survival for most of the human past. The description of new species and mapping of their distribution was an important activity in post-enlightenment science (Costello et al. 2013a). Today there are hundreds of millions of observations of biodiversity in museums, herbaria, databases, field notebooks and learned publications (Wheeler et al. 2012). Despite this abundance, the fraction of the information which is available and accessible

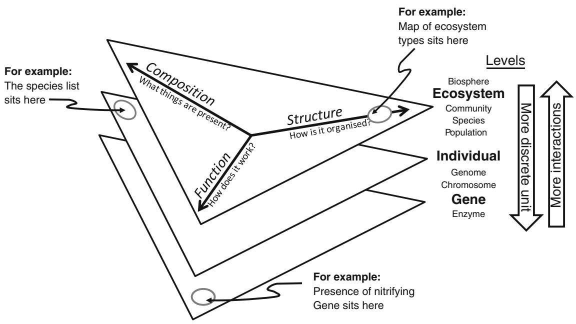

Fig. 1.1 The contemporary definition of biodiversity embraces three aspects of variation (differences in composition, structure and function) and several levels of biological organisation (from the enzyme, to the biosphere). There is not a 'right' level to observe biodiversity, nor a 'right' aspect to observe: ideally you should be capturing elements of all aspects and all levels, and be able to move seamlessly between them. In practice, in any particular situation there will inevitably be stronger emphases on some levels or aspects. Historically, many people considered 'biodiversity' to consist only of composition, at the species level. Be guided primarily by what the users of the information need, secondly by what is observable using the available technology, and only then by what happened to have been collected in the past. As you shift downward from the ecosystem towards the organism and ultimately the gene, the entities with which you are dealing become more focussed and precise, but the price you pay is a loss of information about interactions between them and the emergent properties which arise from those interactions (*Source* based on Noss 1990)

remains inadequate to address the emerging challenges to biodiversity, human development and planetary management (Costello et al. 2013d).

It is well known that biodiversity is in world-wide decline (Butchart et al. 2010 summarises recent evidence). This impoverishment takes the form of local and global extinctions, but also more pervasive and subtle simplification, hollowing-out and dominance by a few species of formerly complex, abundant and equitable ecosystems (e.g., see Pereira et al. 2012). The resources of the Earth—land, oceans, water, primary productivity and nutrients—are increasingly appropriated by humans and their client species (Haberl et al. 2007). The process of human domination has been underway for nearly ten thousand years, ever since the domestication of crops and livestock, but has accelerated over the past century or two. It has reached such proportions that we have entered the 'Anthropocene'—the era when human actions are the dominant Earth-shaping force (Crutzen 2002). There is little doubt that the current and projected rate of biodiversity loss exceeds its rate of generation. As a result, the world is getting poorer in terms of the biological variation it supports.

The loss of biodiversity has well-established immediate causes: the loss, degradation and fragmentation of habitat needed for the completion of life histories; over-harvesting of organisms which have commercial value (and the collateral damage to other organisms and ecosystems in the process); pollution of the environment by biocides and the waste products of human activity; and competition, predation or infection by invasive alien species deliberately or inadvertently introduced from other parts of the world are the leading causes (SCBD 2010). Climate change during the 21st century is projected to be high up on this list of the causes for biodiversity loss.

The contemporary decline in diversity is not entirely without precedent. On at least five previous occasions in the approximately five billion year history of this living planet, biodiversity has undergone relatively abrupt decreases (Leakey and Lewin 1995). In some cases, this has been the result of the rise to dominance of a new group of organisms, such as the evolution of oxygen-generating algae three billion years ago, which confined the previously dominant anaerobic bacteria to low-oxygen niches. In other cases, it is attributed to cataclysmic events such as the impact of an asteroid. Although previous episodes of biodiversity loss have left a lasting imprint on the biota of the world, biodiversity overall has always recovered, often in different forms. Disruption of the old order may even have been the stimulus for biological innovation. For instance, the end of domination by dinosaurs may have allowed a relatively obscure group of proto-mammals to evolve, ultimately, into our own species. Why then are we concerned about the current loss of diversity?

First, the current loss of biodiversity is just one element of an interconnected syndrome known as 'Global Change'. Another element is climate change, mostly driven by human activities, including the burning of fossil fuels and release of other waste gases. A key driver of both climate change and biodiversity loss is the ongoing transformation of the surface of the planet due to human activities, including agriculture, deforestation, settlements, transport infrastructure, fishing and mining. Underpinning these changes have been transformations in how people organise themselves economically, politically, socially and technologically—the accelerating processes of development, globalisation and modernisation. The fact that biodiversity loss is intimately connected to these other momentous reorganisations makes it both an indicator of change—a canary in the mine, warning of potentially life-threatening dangers—and a key part of that change itself. It also makes halting biodiversity loss difficult, because it requires addressing the development expectations of billions of people.

Second, although past extinctions appear sudden (and perhaps some of them were), the fossil record from which we derive much of our knowledge of them tends to distort our view of their actual rate. Previous episodes of species loss may have extended over many millions of years. The current loss of biodiversity is, by contrast, extremely rapid. Furthermore, although biodiversity in the abstract sense recovered from past crises, whole groups of affected species did not. From the particular perspective of our species, we run the risk of being in the latter group.

Third, despite amazing advances in biotechnology, the loss of biodiversity in its ultimate form (the global extinction of unique genetic lineages) remains effectively irreversible. It represents the loss of millions of years of evolutionary experimentation through mutation, adaptation and natural selection. With this loss, we lose options for the future, and knowledge of the past and present.

Finally, there is emerging evidence that diversity itself (variety, as opposed to the presence of one or more particular species) is important for maintaining the productivity and stability of ecosystems, from the local to global scale (Díaz et al. 2005; Hooper et al. 2005). As humanity enters what promises to be a critical phase of its development—the transition from a 'weedy species' to one in some form of equilibrium with its environment—ensuring the resilience of the biosphere is of crucial importance. Maintaining diversity is one element of a strategy for an adaptive Earth.

Three broad reasons have been invoked as to why humans have a responsibility to conserve biodiversity. The first is essentially aesthetic: the diversity of organisms is a thing of beauty and wonder, and that is a sufficient reason to preserve them. The second class of reasons are ethical: the desire to ensure that future generations of humans are able to enjoy and use their natural heritage; or increasingly, a view that organisms have unalienable rights to existence, just as humans have. The third category is utilitarian: humans depend for their present and future well-being on the presence and functional health of other organisms, and on the fact that those organisms are diverse in composition, structure and function.

Whatever the combination of motivations, the desire to know biodiversity and protect it from further loss is now widespread. It is expressed in many cultures, and at scales from the local to the global. It takes many forms: the biodiversity-aware actions of ordinary people, resource custodians, managers and consumers; the rise of biodiversity-oriented organisations, especially in urban societies; the promulgation of laws and regulations to protect biodiversity at all levels of government, including the proclamation of protected areas and the establishment of conservation agencies; and the emergence of international treaties and organisations dedicated to biodiversity conservation. All these initiatives share a need for information to assist them to fulfil their mandates effectively and efficiently: 'what gets measured, gets managed'.

Several assessments have concluded that the current state of knowledge about biodiversity is far from adequate for the purpose of conserving it and managing it sustainably (Walpole et al. 2009; GEO BON 2011). Many existing biodiversity monitoring programs lack the power needed to detect and attribute trends in biodiversity (Legg and Nagy 2006). Even the most fundamental step, knowing what species exist on Earth, may be at best two-thirds complete and will only be achieved before a significant fraction goes extinct with coordinated international efforts (Costello et al. 2013b, c, e). This book is a contribution to fixing that problem. Better biodiversity information is essential to slow biodiversity loss and achieve a sustainable planet. To this end, several hundred countries and organisations pooled their skills and knowledge to form the Group on Earth Observations (GEO). One of its areas of concern is biodiversity, and the 'community of practice' that arose to help implement global data sharing on this topic is called the Biodiversity Observation Network (BON), or GEO BON. This handbook represents the pooled wisdom of that network.

1.2 Working Together Makes Sense

It has never been possible for any individual to know more than a tiny fraction of the biological diversity on Earth. Therefore, the investigation of biodiversity has always been a collaborative effort. Even Linnaeus, originator of the scientific system for classifying biological diversity, personally knew only a few thousand varieties and relied on a network of colleagues' observations. We now estimate that the total number of species on Earth runs into millions and at least hundreds of thousands remain to be described (Costello et al. 2013b).

The species that exist within one defined area may be different from those in another area (Gaston 2000). Thus, local experts may misapply the name of a similar species from another region to a local endemic, or describe a local species as new to science without realising it has been described from another region. The biological world is spatially organised in a way that bears little relationship to how humans have chosen to divide up the world. Considerations of political jurisdiction, culture, language and human history are ignored by biodiversity, but often form an impediment to the sharing of information about it. Improved communication, online species checklists, and greater access to species descriptions should minimise such problems and increase taxonomic efficiency (Wheeler et al. 2012; Costello et al. 2013b).

Contemporary global environmental consciousness began to emerge in the late twentieth century. It led, in 1992, to the 'Rio Conventions' on climate change, biodiversity and desertification. Each of these international treaties contains language about the need to share information relating to the topic between countries.

For example, the Convention on Biological Diversity (UNCBD) states, in article 17.1 '*The Contracting Parties shall facilitate the exchange of information, from all publicly available sources, relevant to the conservation and sustainable use of biological diversity…*'. On the tenth anniversary of the Rio meeting, one of the outcomes of the World Summit on Sustainable Development was the realisation that the management of globally pervasive issues required the global sharing of pertinent data and information. This led to the formation of the voluntary association of countries and member organisations known as GEO, dedicated to data sharing on a range of topics deemed to be of 'societal benefit', including those of biodiversity and ecosystems (GEO 2005).

The principle benefits of cooperation in the collection, sharing and coordinated analysis of biodiversity information are self-evident, but bear repeating.

Whatever biodiversity level is under consideration—for instance gene, species or ecosystem—often either has an extent of occurrence which goes beyond the jurisdiction of a single organisation, or a set of influences (acting on it, or from it) which does. Furthermore, many biodiversity elements are highly variable in space and time, thus requiring significant effort to establish baselines and detect trends. Therefore, even the largest and best-resourced institutions depend on information collected and curated elsewhere.

A full accounting, which is seldom done, of the costs of biodiversity observation and data curation would show that it represents a large historical and ongoing expense. The benefits that flow from this outlay result from the use of the information, not its collection. The benefits to society multiply synergistically as the information is made available in such a way that it can be combined with other sources of information. Even the benefits to the host organisation usually outweigh the additional costs of making such information available: having many eyes scan it and many minds interrogate it is better than a few.

Efficiencies in observation, storage, analysis and application can be achieved by learning from others. The benefits of harmonisation of methods become progressively greater as the degree to which information needs to be 'interoperable'—i.e., visible and exchangeable between systems—increases.

1.3 Networks as an Organisational Structure

The network—defined as a relatively loose affiliation of organisations that agree to create value by collaborating towards a common purpose while retaining their individual mandates, resources and management—has risen to prominence as a way of organising many activities in the modern era. A cynic might say this is because the world has lost the appetite for creating and funding new institutions or that networking is a way to suggest that some action has been initiated without actually taking responsibility for ensuring that it gets done (Provan and Milward 2001). However, if a global-scale source of biodiversity data is the desired goal, it would be hard to achieve except via the mechanism of a network, simply because sampling and species identification is more cost-effective and situation-appropriate if conducted using local and regional expertise.

A more positive view is that networks are the appropriate structure for addressing certain categories of problems, which happen to be pervasive in the modern era. These include complex and interconnected issues (like biodiversity loss) in which there are many affected parties, none of whom can solve the issue by working alone (Kickert et al. 1997). Networks are intrinsically adaptive, arguably more so than top-down structures, despite the *apparent* power and responsiveness of traditional command-and-control approaches. This paradox is explained by the fact that centrally-directed action is only effective if the goal is clearly defined, relatively unchanging and shared by all parties. Polymorphous, emerging and shifting objectives are better served by a more devolved approach. Anyone who has been part of a large, hierarchical organisation will know they have inherent inertia.

Notable examples of biodiversity networks are the Global Biodiversity Information Facility (GBIF), Species 2000 (Roskov et al. 2013), and World Register of Marine Species (WoRMS; Boxshall et al. 2014; Costello et al. 2014). GBIF is a network of countries and affiliated NGOs. Species 2000's members publish species databases through its website, and WoRMS is a network of over 200 individual taxonomists who edit parts of a common online database. Other forms of partnerships also exist, such as consortium agreements (e.g., FishBase) (reviewed by Costello et al. 2014), but the most enduring initiatives are international.

GEO BON is a 'network of networks'. Its parent body (GEO) was formed to catalyse a 'coordinated, comprehensive and sustained Earth Observation' system in support of informed decision-making worldwide'. Like its parent body, GEO BON is a voluntary 'community of practice' that serves to translate user needs in the broad arena of biodiversity (but especially at national to global scales, where the needs are often related to international treaties), into observational products and services, through collaboration between the many existing biodiversity information sources and other Earth observation systems.

Biodiversity observation, while intrinsically a collaborative activity, has not always been achieved through networks. Even in the present time, much of the primary work is done within centrally-managed organisations. As the scope of the activity increases and as larger scale drivers of biodiversity change increase in prominence, those organisations are increasingly dependent on the activities of other organisations to effectively detect and attribute biodiversity change. It is possible to imagine a global unitary organisation focussed on biodiversity observations, but it would almost certainly be unachievable in the foreseeable future given issues of national sovereignty and the sheer scale of the task. To address the urgent current needs for increased and shared biodiversity observations, some form of collaborative network seems inevitable.

While networks are often presented as a 'low-cost' option involving little more than existing efforts, they come with additional transactional costs which can be large enough to overwhelm the benefits flowing from collaboration (Costello et al. 2014). Apparently-simple guidelines can avoid this outcome: don't work through a network unless it is the most effective and achievable option for reaching the objective; include key partners; keep the network structure simple and efficient; ensure continuity through high-level commitment; be mindful of ensuring value-addition exceeds incremental costs for both network members and network funders; have well-defined roles and responsibilities; and pay close attention to minimising the transactional costs and budgeting for them—especially the hidden ones. The key transactional costs include the high level of communication required in networks and the additional costs of data management across multiple platforms. The product of the network must also be sufficiently unique, of appropriate size, quality assured, and thus prestigious, that host institutions, individual scientists and funding agencies will commit to its long-term support (Costello et al. 2014).

1.4 Managing Networks

Every bookstore has shelves overflowing with management texts, but few offer useful advice on the management of networks, which is surprising given how pervasive networks are. There are some exceptions, such as Ford et al. (2011) and, in the context of biodiversity databases, Costello et al. (2014). The principal difference between networks and more conventional, centrally-controlled organisational forms (often referred to as 'hierarchical' or 'top-down') is the degree of direct control which the manager has over human and financial resources. A useful way for network managers to think of their environment is as consisting of three concentric spheres; a visualisation attributed to Covey (1989). The central sphere contains the things over which they have direct, almost assured control. The next larger one contains those things over which they can exert some influence—by persuasion, relationship management and co-allocation of resources. The outside sphere contains those things that are out of their control, but nevertheless have an impact on the attainment of their objectives. The manager must be aware of trends and events in this outer sphere, and adapt to them, without being able to change them. Traditional management takes place almost entirely in the central sphere. Network management occurs mostly in the middle sphere. The currency of network management is influence and information rather than authority or power. No single person or organisation really fully 'owns' or 'controls' a network, even if it is centrally managed. The network looks subtly different when viewed from the differing perspective of its various partners (Ford et al. 2011). Similarly, the outcomes of a network cannot be legitimately claimed by any single participant. There is usually a trade-off in organisational structures between efficiency—which comes with centralisation—and innovation, which benefits from more distributed approaches such as networking.

The distinction between 'standardisation' and 'harmonisation' of data collection, storage and exchange follows from this understanding of what is under direct control, and what can be influenced (and can influence you), but not controlled. Within networks, 'harmonisation' is often achievable where rigid 'standardisation' is not. Fortunately, for most purposes harmonisation is sufficient. Within a unitary organisation, it is usually possible and preferable to insist on a single method ('standard'), but precisely because of this legacy, it is generally unreasonable to expect other organisations to abandon their standards in favour of yours. The solution is to permit network partners to continue, as far as possible, to apply their own approaches, but to (1) ensure those methods are explicit and visible; (2) work out how the various combinations of standards within the network relate to one another, in order to allow inter-calibrations, conversions and sorting of data; and (3) sometimes to run several approaches in parallel. This is called 'harmonisation'. It may not seem efficient (though in the long run it is more efficient than being locked into a single, increasingly inappropriate standard), but it is achievable.

Two broad aspects of network management are equally important. The first relates to the content of the network—what information is passed between partners, in what form and through what channels, and who is responsible for its collection, quality control, storage and analysis. The second relates to 'soft systems', the management of the behaviours and social relationships that hold networks together. Both aspects need active management. GEO, and GEO BON, manage the former through collectively developing, documenting and disseminating protocols for data exchange. GEO BON manages the latter by a mixture of periodic 'face-to-face' meetings, interspersed with electronic exchanges.

While an argument can be made that the societal value addition achieved by networks is large, the incremental costs of networking are usually borne by individual organisations. This is a fatal problem for networks if institutional budget decisions are based on narrowly defined, short-term cost-benefit analysis. This highlights the need for networks to show, rapidly and convincingly, the value-addition of integrating efforts to these individual organisations. Fortunately, 'social capital' often provides the bridge that permits the realisation of larger, longer-term outcomes despite near-term deficits in 'financial capital'. Successful networks are inevitably driven by people who enjoy working together and have a strong sense of the collective and individual benefits of doing so. This element of human behaviour should not be left to chance in networks. It has to be nurtured through providing opportunities and incentives for people to get to know one another, to have fun, and to develop a shared vision and purpose.

1.5 Guiding the Enterprise

'Governance' is a topic that typically bores the action-oriented denizens of the biodiversity observation world. Nonetheless, an effective but minimal set of rules and structures is essential to guide collaborative activities, especially if they are built up of many organisations with independent and possibly divergent mandates and potential conflicts of interest. Informal arrangements are effective when the number of participants is small and the level of social trust is high. The need for formal organisational design and rules of procedure rapidly emerges as the scale increases and stakes are higher. In the field of scientific assessments, also often conducted in network-like structures, three key factors for success have been identified: legitimacy (which relates especially to having transparent governance, including traceability to an 'authorising environment' that establishes the mandate); salience, which means a focus on addressing the needs of the user group; and credibility, which in this context means due attention to scientific quality (Cash et al. 2002).

The simplest governance approach, which can work if the number of stakeholders (including users) is small, is to include representatives of all of the stakeholder groups in a single steering committee, which meets on a regular basis. Once procedures and trust have been established, many of the meetings can be 'virtual', making use of telecommunication technology to minimise time and travel costs; but there is currently no satisfactory substitute for physical meetings, at least initially, that allow the development of the interpersonal relationships ('social capital') alluded to above. It is these interpersonal relationships that lead to a sense of commitment and obligation from each member to advance the work of the network.

For larger and more complex problems, such as biodiversity monitoring, a single, all-encompassing governing body may not work. A minimally more complex model that has been effective in similar contexts is to create two bodies, with clearly differentiated roles and responsibilities. One consists of representatives of intended beneficiaries, users and funders. It acts as the proxy for the authorising and receiving environment. This 'direction-setting body' addresses the questions of what to observe, and whether the result is fit for its intended purpose, as defined by this representative body. The second body consists of technical experts from all the essential implementation elements of the network, and addresses the question of 'how' to make and share the observations. Another way to think of the distinction between the two is that the first asks 'is this network observing the right things?' while the second asks 'is the network observing things the right way?' The direction-setting body defines the scope of the observation system, establishes an authorising environment, nominates the technical experts, and facilitates access to the resources needed to implement the network. The technical body then responds by developing a detailed implementation plan and a periodically updated description of activities, timelines, budget, and progress in terms of the plan. The direction-setting body approves these (or asks for revision if they are deemed inadequate to meet the goals) and resolves any conflicts that may arise between the implementation partners, for instance over roles or resources. Finally, the direction-setting body monitors and evaluates progress and acts as the final quality-control step: are the objectives being achieved? Each body may, if necessary, create sub-committees in order to address particular topics more efficiently. Financial and content-related accountability resides with both bodies, but sequentially. The direction-setting body has the final responsibility.

GEO BON, as a network of networks, is governed by an implementation committee, composed of working group leaders, regional and thematic Biodiversity Observation Network coordinators, and representatives of key projects and activities. GEO BON also has an advisory board, which provides guidance to the implementation committee, and is composed of representatives of organisations, governments, and experts, in a geographically balanced manner. Members of the advisory board serve 3 years, renewable once, and often combine, in one person, expertise in many parts of the observation-analysis-use chain—for instance, data collection in a particular biodiversity domain, scientific research, and use of data for policy purposes. The Chair and Vice-Chair of GEO BON are elected unpaid positions. The GEO BON committees reconstitute themselves in a staggered fashion, striving to keep a disciplinary, regional and other balance while adapting to emerging challenges. GEO BON working groups are established around specific tasks or themes and are open to membership by any expert or practitioner. Working groups are not permanent features, but last as long as they need to achieve a given objective, or for as long as that objective is a priority, and for as long as they are deemed effective.

Biodiversity Observation Networks (BONs) contribute to the collection and analysis of harmonised biodiversity observations, develop interoperable biodiversity monitoring programs, and help make biodiversity data and data products available. BONs can cover a political unit such as a country (National BON), a region (Regional BON), or a specific theme (Thematic BON) such as a taxonomic group, ecosystem type, or even monitoring approach. Working groups and BONs report to the implementation committee, but are given a great deal of individual freedom—and minimal resourcing—with respect to how they constitute themselves and achieve their objectives. GEO BON is supported by a small secretariat of employed officers, typically funded by a host organisation. GEO BON reports to GEO on its activities and responds to GEO initiatives as appropriate. Its activities are funded primarily by participating organisations through proposals, often endorsed or coordinated by GEO BON, to donor agencies.

1.6 Working Backwards to Move Forwards

The majority of current observing and data systems, such as GBIF and the Ocean Biogeographic Information System (OBIS), originated with the data collectors rather than the data users. This is fine where collectors and users are within the same or closely connected organisations—but increasingly they are not. As a result, what is provided by the observation system may deviate from what is needed (Sheil 2001), thus diminishing the viability of the observation system. An alternate approach is to start with the demands and work backwards to define what observations must be collected to satisfy them, including how often and where the observations must be made (Durant 2013). In defining needs, it is critical that they be clearly described, measurable and achievable in order to ensure successful outcomes. There may be several steps between primary observations and final products; each of these steps needs equal attention.

In practice, defining what to observe and how to process it so that it is of maximum utility is a two-way process: a negotiation (or conversation, if you prefer less adversarial metaphors) which in the best cases converges on a solution that is both useful and feasible. The design is said to be co-determined or co-produced, and is neither ‘user-driven’ nor ‘supply-driven’, but both. This approach helps to remove a sense that one group is in charge, and the others are subservient. That situation is detrimental to accountability, creativity and the sense of partnership that makes networks work. While it is customary to talk of ‘data providers’ and ‘data users’ as non-overlapping sets (with ‘data brokers’ sometimes interposed between them), in reality individual partners often play multiple roles simultaneously—they are providers of some observations, but users of others.

GEO BON is a meeting place for both ‘providers’ and ‘users’, and does not make a mutually exclusive distinction between them. They are all part of a continuum of stakeholders. It helps to refine user needs by organising periodic topically-focussed user workshops, where both users and potential suppliers are present. The outcome is thus ‘co-generated’, and takes the form of a discussion rather than a unilateral instruction in one direction or the other. If the needs cannot be currently met, the outcome is a set of specifications for future Earth observation activities.

A second key way of identifying needs is to be closely engaged with bodies that have a mandate to define such needs collectively. In the case of GEO BON, this includes for instance the Convention on Biological Diversity (CBD), whose agreed ‘Aichi Targets’ for national reporting towards global objectives include many explicit observational needs.

1.7 The Purpose, Structure and Content of This Volume

This handbook captures the collective learning, at the time of writing, of the organisations involved in the GEO Biodiversity Observation Network. We do not believe that it is the last word on the topic of biodiversity observations, since this is a rapidly evolving field. It is already clear, however, that a degree of convergence in biodiversity observation and information storage methods is highly beneficial to all parties, and easier to achieve if implemented early rather than late. There is a surge of biodiversity observation network activity at present, driven by the urgent need to address biodiversity loss effectively and efficiently and specific actions such as the CBD Aichi targets for the year 2020. As new networks start up and existing networks expand and reconfigure, some guidance can help them to avoid problems that have been encountered and solved elsewhere, and get going more quickly along a path that allows for better networks in the future.

A number of chapters in this handbook is structured around the Essential Biodiversity Variable (EBV) framework, which GEO BON started developing in 2012 with the purpose of representing a minimal set of fundamental observations needed to support multi-purpose, long-term biodiversity information needs at various scales (see Pereira et al. 2013).

By combining EBV observations with other information, such as on the attributes of biodiversity, or drivers and pressures of biodiversity change, indicators can be developed which are directly useful for policy support. EBVs can thus have multiple uses. For instance, an observation system that collects data on species abundance for several taxa at multiple locations on our planet, can support the derivation of the Living Planet Index (Collen et al. 2009), the Wild Bird Index (Butchart et al. 2010), the Community Temperature Index (Devictor et al. 2012), measures of species range shifts (Parmesan 2006), and a number of other high-level indicators on the CBD's indicative list of indicators for the strategic plan for biodiversity 2011–2020 (CBD 2015; Fig. 1.2).

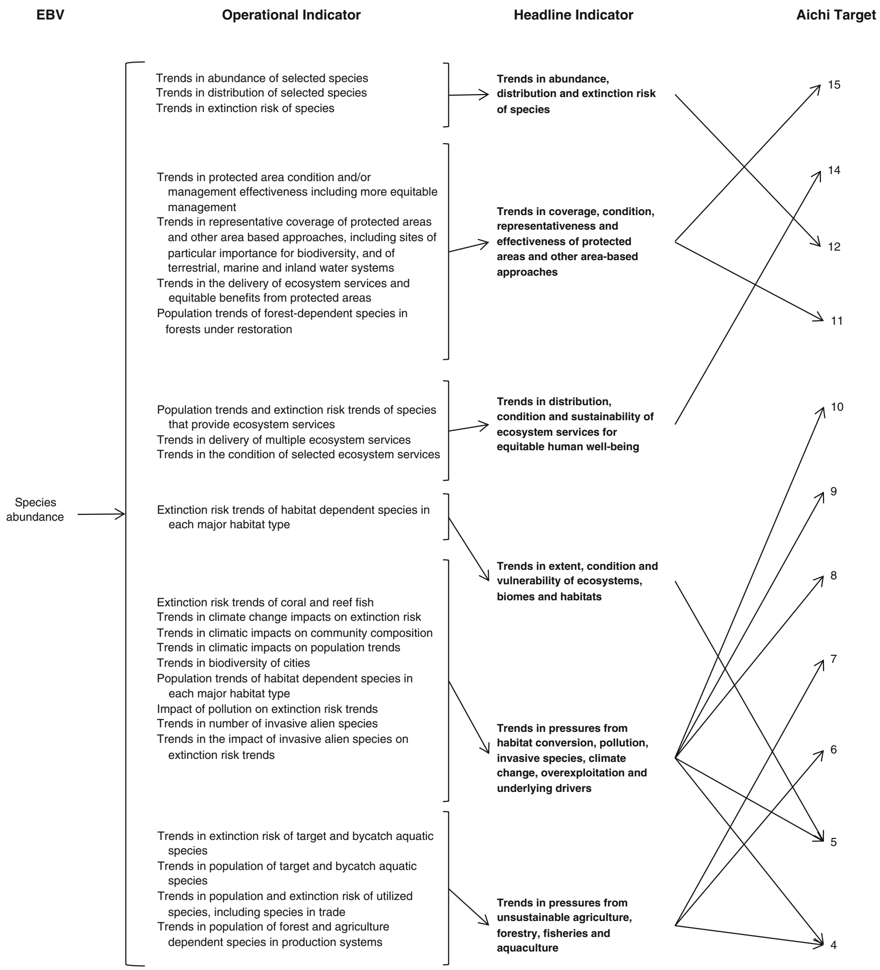

Fig. 1.2 Essential biodiversity variables (EBVs) may be combined with other variables to derive multiple high-level indicators used to measure progress against multiple targets. In this example the EBV 'species abundance' feeds into 24 possible indicators that may be used to derive the headline indicators for monitoring progress towards 11 of the Aichi biodiversity targets

Essential Biodiversity Variables may fall within six classes: genetic composition; species populations and ranges; species traits; community composition; ecosystem structure; and ecosystem function. Whilst the EBVs are currently still under development, a number of candidates have been suggested by the broader GEO BON community. The subsequent chapters of this handbook touch on some of these and provide details of how to measure EBVs in many different environments—on land, in freshwater ecosystems such as lakes and rivers, on the coast and in oceans; and for different types of organisms and at various scales.

Chapter 2 of this handbook addresses biodiversity observations at the ecosystem scale—the scale at which many policy, management and societal needs are focussed. It covers terrestrial ecosystems and leaves the practical special considerations for biodiversity observations in marine and freshwater environments to Chaps. 6 and 7, respectively.

An increasing number of countries are including ecosystem services and natural capital accounting in their national accounts, to better inform decision-making. Chapter 3 addresses the data requirements and the toolkits and models available for assessing and monitoring ecosystem services.

The observations needed for detecting changes in the abundance of individuals in populations of particular species are addressed in Chap. 4, which includes identification of the question to be addressed, the choice of variables, taxa and spatial sampling scheme.

Chapter 5 introduces the fast-growing field of gene-level observations, including the current state-of-the-art in genetic monitoring, with an emphasis on new molecular tools and the richness of data they provide to supplement existing approaches.

Chapter 6 expands on marine and coastal systems and the special approaches that are required when observing biodiversity in a three-dimensional, fluid environment that is often remote, unexplored and not owned by any particular country.

Chapter 7 deals with observing biodiversity in freshwater systems, and highlights special considerations for freshwater biodiversity and methods and tools available for monitoring these systems.

Chapter 8 discusses the use of remote sensing for observing biodiversity and provides a baseline set of information about using remote sensing for conservation applications in three realms: terrestrial, marine, and freshwater.

Biodiversity has long had a tradition of citizen observers, which is the topic of Chap. 9. How can ordinary people be organised and incentivised using modern technology, and how can the quality of the observations be assured?

The old distinction between observations and models is rapidly breaking down. Chapter 10 addresses the question of how models can help to fill gaps in space and time, and how one can use in situ and remotely sensed observations to detect changes in biodiversity.

Modern observation networks cannot function without paying attention to cyber-infrastructure (Chap. 11). How is data captured, stored, made discoverable and interoperable?

Chapter 12 explores the use of biodiversity data in decision-making processes, as well as the realities of indicator development and use. It reflects on what data might be used for, how it is packaged, and what the challenges are.

Finally, Chap. 13 reflects, through the presentation of several case studies, on various approaches for capacity building in the field of biodiversity monitoring.

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