Biological Conservation 252 (2020) 108843

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Perspective

The map of biodiversity mapping

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ARTICLE INFO

Keywords:
Alternative mapping
Critical cartography
Epistemic approach
Cartographic diversity
Viability
Systemic approach

ABSTRACT

In the face of rapid biodiversity loss, attention has been increasingly focused on the application of maps towards the challenges of protecting biodiversity. However, biodiversity maps can lead, or have led us into, errors since they are too often not questioned by ecologists, who perceive them as an objective and legitimate representation of the natural world. The aim of this paper is to acknowledge and question our assumptions of (biodiversity) mapping for conservation through an epistemic approach. Discussing two dominant metaphors explaining those cognitive processes involved in mapping and the conventional nature of maps supported by the wide cartographic diversity adopted by human societies, I will stress the need to leave behind the belief of an objective approach for biodiversity mapping and conservation goals as opposed to an alternative mapping approach – providing viable alternatives to mitigate or face rapid biodiversity loss in a more "systemic" way. This paper illustrates how biodiversity maps (even though based on up-to-date scientific assumptions), far from being objective and a neutral transcription of nature, are inevitably affected by personal constructions, dominant culture, and sometimes ignorance, or scientific blindness. As a result, it is important to strive and rate maps — not only in terms of scientific accuracy, but also on their "viability" — which is their range of application and how successful they are in achieving the aims for which they are drawn.

1. Current scenario in biodiversity mapping

Mapping the distribution of biodiversity has a long history and still represents one of the main advisable targets for ecologists. Alexander von Humboldt (1769–1859) was one of the first "spatial thinkers" and biodiversity mappers of the ecological tradition. He described the latitudinal and altitudinal distributions of vegetation zones and was one of the first scientists to use maps to generate and test scientific hypotheses. At the turn of 19th and 20th century, in the wake of Charles Darwin's ideas about the need to consider the complex interplay between organisms and their environment, mapping the distribution of biodiversity took hold among naturalists, to the extent that Ernst Haeckel (1834–1919) coined both the terms "ecology" and "chorology"; the latter defined as "…the science of the geographic and topographic spread of organisms" (Williams and Ebach, 2008). However, it is only since the end of the 1960s that biodiversity mapping and cartography has raised much interest (Domon et al., 1989), of which several researchers began to devise schemes to divide the landscape into functional units of significance for conservation and/or resource development.

Although the use of maps in paper format has now sharply declined, ecology still relies on digital cartographic documents that can be used both to investigate those spatial and temporal phenomena pertaining to the natural world (Pedrotti, 2013) and to answer conservation questions at hand. Biodiversity maps are now extensively adopted for protecting biodiversity and the operation of many conservation programmes is inherently spatial. As of December 2016, the World Database on Protected Areas (UNEP-WCMC and IUCN, 2016) reported that 14.8% of terrestrial and inland water areas are covered by protected areas, while 5.1% of the global ocean surface and 12.7% of coastal and marine areas under national jurisdiction are covered by marine protected areas. To date, the designation of protected areas is regarded as "the most common human response to human-induced ecosystem degradation" (Woodley, 1997), to the extent that the addition of 25% of land to the 15% already protected (resulting in 40% of land protected) has been recently proposed to face an unprecedented change in global biodiversity (Leclère et al., 2020).

The pervading application of biodiversity maps has been bankrolled by progress in tools, modelling techniques (e.g., Species Distribution Models), and software such as Geographic Information Systems (GIS) (Burrough, 2001), along with the growing availability of high-quality spatial data from a variety of remote sensing sources (Moudrý et al.,

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https://doi.org/10.1016/j.biocon.2020.108843
Received 2 May 2020; Received in revised form 28 September 2020; Accepted 22 October 2020
Available online 5 November 2020
0006-3207/

2019). Our capacities for biodiversity mapping have now reached standards that seemed impossible until not long ago (Rocchini et al., 2016), making remote sensing and GIS one of the major technological revolutions that ecology has witnessed and has been partaker of (Chave, 2013). For instance, the map of tree density at a global scale has been able to estimate the global number of trees to approximately 3.04 trillion (Crowther et al., 2015), while the map of soil nematode abundance and functional group composition at a global scale showed that $4.4 \pm 0.64 \times 10^{20}$ nematodes (with a total biomass of approximately 0.3 gigatonnes) inhabit surface soils across the world (van den Hoogen et al., 2019).

At present, the widely accepted object of biodiversity mapping among ecologists is to produce a "correct" rational model of the terrain, building on the cartographic assumption that "the objects in the world are real and objective, and that they enjoy an existence independent of the cartographer; that their reality can be expressed in mathematical terms; that systematic observation and measurement offer the only route to cartographic truth; and that this can be independently verified"(Harley, 1989).

Overall, high technological performances, dominant scientific paradigms, and cartographic assumptions make biodiversity maps appear to be reliable, legitimate, and truthful picture of the natural world (Dalton and Stallmann, 2018; Hazen and Harris, 2007), or to employ Rorty's (1979) phrase "a mirror of nature".

2. Critical cartography

While ecologists yield to the temptation of objectivity and accuracy, geographers have already not been on the same page for several years. During the late 1980s and early 1990s, *critical cartography* questioned the hegemonic description of mapmaking as a progressive, value-free, and neutral transcription of nature, in an effort to reconsider maps as subjective, socially constructed, and ideological forms of power (Harley, 1989; Monmonier, 1991; Pickles, 2004; Turnbull and Watson, 1993; Wood et al., 2010). In "Deconstructing the map", one of the most revealing texts of *critical cartography*, Harley (1989) suggests how even scientific maps are a product not only of the "rules" of the order of geometry and reason, but also of the norms and values of the order of social tradition – such as those of ethnicity, politics, or religions. One example among all, the reason why the "North" is traditionally up on maps, is a result of its historical and cultural process, which is closely connected with the global rise and economic dominance of northern Europe. Initially, the "East", being the direction of the rising sun, was placed at the top of the map (hence the origin of the very word "orientation").

Accordingly, *critical cartography* claims that "text" is certainly a better metaphor for maps than "mirror of nature". Maps, just like texts, are "construction employing a conventional sign system", where such system must be produced within and accepted by social tradition and it is as arbitrary as the letters of the alphabet (Turnbull and Watson, 1993). Similarly, maps are always selective, and they do not and cannot display all there is to know about any given piece of an environment. The mapmaker omits those features of the world that lie outside the purpose of the immediate discourse (Harley, 1989). It follows that cartography is inherently a rhetorical text, since the steps in making a map – selection, omission, simplification, classification, the creation of hierarchies, and "symbolization", are inherently rhetorical (Harley, 1989).

Likewise, *critical cartography* denounces how maps are necessarily reflective of and productive of power (Wood et al., 2010). In this regard, Harley (1989) considered two areas of power: external and internal power of cartography. On the one hand, power exerted over or through maps always responds to external needs (external power). Behind most cartographers there are patrons or contractors such as monarchs, ministers, state institutions that have all initiated programmes of mapping for their own ends and for the maintenance of state of power. On the other hand, power exercised by cartographers themselves as a force for change and "embedded in the map text" is defined as "internal power", where cartographers manufacture power. The key to internal power is thus cartographic process: the ways maps are compiled and the categories of information selected, the way they are "generalized" and the rules of abstraction applied, the ways the elements of the landscape are formed into hierarchies and the various rhetorical styles are employed to represent the landscape. Through maps the world is disciplined and normalized, where all the technical processes involved in map making represent acts of control over its image. Although the map is never the reality, in such ways it has the power to legitimate and disseminate a new state's view of reality (see Monmonier, 1991). To employ Sonenberg's (1989) phrase, "it has always been this way with map makers… they have traced lines and lived inside them".

In a nutshell, in their intentions (external power) as much in their performative applications (internal power), maps signify subjective and socially constructed human purposes rather than mirroring nature (Harley, 1989; Searle, 2004).

3. The need for a critical approach in biodiversity mapping

At present, much of the debate surrounding biodiversity mapping focuses on how to approach the problem of inconsistent data and how the notion of biodiversity can best be modelled (Bowker, 2000; Hazen, 2009; Skidmore et al., 2015) in an effort to devise better approximations between raw data and the map image and to render the most truthful and neutral picture of nature (Pickles, 2004). Too often, our maps prove that things are the way we see them and there is no alternative to what we hold as true. Biodiversity maps are taken for granted and generated from a fixed perspective, thus the scientific-technological western perspective. On the one hand, this conviction is the consequence of a common way of being human, since we tend to live in a world of certainty, of undoubted perceptions; but, on the other hand, in the "western" ecology tradition, we are also trained to avoid the healthy epistemic challenge of knowing how we know, or mapping how we map (Maturana and Varela, 1992). Principles and process at the root of map making are mostly overlooked, ecologists widely perceive maps as mirrors of nature, and c*ritical cartography* has not yet pervaded the practice of biodiversity mapping. The subjective human purpose that maps signify as the forms of power they convey are poorly acknowledged among ecologists and commonly concealed by the great authority of objectivity or dominant scientific paradigms. Ignoring such aspects can be detrimental to an effective "spatialization" of conservation practices, precluding the possibility of identifying alternative spatial strategies or to question biodiversity maps.

Here I attempt to apply some of the assertions of *critical cartography* to the biodiversity mapping practice, in an effort to acknowledge and eventually question our assumptions of (biodiversity) mapping. Two dominant metaphors will be provided to shed light on those cognitive processes involved in map making and confute the objectivity of maps. In support of this, an historical journey into human cartographic diversity will show the varieties of maps that have been developed by different human societies in response to different purposes. Finally, discussing the current pitfalls of biodiversity mapping for conservation, the neutrality of maps will be challenged and the power they convey practically illustrated. This paper emphasizes the need to leave behind the belief of an "objective" approach for biodiversity mapping and conservation goals, as opposed to an alternative mapping approach (i.e., "counter maps"), providing viable alternatives to mitigate or face rapid biodiversity loss in a more "systemic" way.

In accordance with the systems view of life (Capra and Luisi, 2014), to perform problem solving in complex systems, a shift in perspective is necessary, where systems must be observed from a broad perspective that includes seeing overall structures, patterns, and cycles in systems, rather than seeing only specific events or parts in the system. In order to modify our perspective, system science also implies that epistemology – the understanding of the process of knowing or mapping the process of mapping – has to be explicitly included in the investigation of natural phenomena. Biodiversity maps, addressing complex issues, are not exempt from epistemological analysis. As the twenty-first century unfolds, it is becoming more and more evident that to face the major problems of our time – energy, the environment, climate change, food security, financial security - we need such a shift in our perceptions, our values, our thinking (Capra and Luisi, 2014).

4. Beyond objectivity: cognitive processes in mapping

The need for human beings to represent the earth's surface dates back to thousands of years. The consciousness of the world involves monitoring for novelty for both unanticipated events in time and unexpected objects and conditions in space, which might constitute hazards or afford opportunities (Lewis, 1987). Therefore, "spatialization" was probably the "first and most primitive aspect of consciousness" (see Jaynes, 1976) since, in accordance with the "Personal Construct Theory", to ensure survival and success, "a person must anticipate events by construing their replications" (see Kelly, 1955).

Survival and success also depended on cooperation between individuals and within society, as well as on the ability to communicate between individuals and within a group, in order store and transmit information (Lewis, 1987). Hence, this led to the development of several forms of language and conventions, including those for communicating spatial information.

In short, the function of a map is to replicate and eventually transfer through conventional sign systems any spatial consciousness about the environment to anticipate objects and conditions in space.

Two metaphor will be hereunder discussed to explain those cognitive processes involved in replicating the spatial consciousness, and thus to demonstrate both the impossibility for maps to be an objective mirror of nature and the subjective human purpose they signify: "*the space peculiar to each animal as soap bubbles*" by the biologist Jakob von Uexküll (1926) and the "*captain sailing through an uncharted channel*" by the philosopher and theoretician of radical constructivism Paul Watzlawick (1984).

4.1. The soap bubbles

> "*The space peculiar to each animal, wherever that animal may be, can be compared to a soap bubble which completely surrounds the creature at a greater or lesser distance. The extended soap bubble constitutes the limit of what is finite for the animal, and therewith the limit of its world; what lies behind that is hidden in infinity*."
>
> von Uexküll (1926)

According to Jakob von Uexküll (1926), the most important thing in the soap bubble metaphor is not that organisms are encased within a bubble, but that each organism cannot have a pure unmediated experience of the environment since it is limited to what is accessible to it in relation to its sensorimotor system. von Uexküll describes the female tick (*Ixodes ricinus*) life cycle, claiming that: "Out of the vast world which surrounds the tick, three stimuli shine forth from the dark-like beacons, and serve as guides to lead her unerringly to her goal" (von Uexküll, 1934). This is to say that nearly everything in the external world around the tick has no significance to it, except for heat, butyric acid (sweat), and smooth skin.

Specifically, he demonstrates that the environment (*umwelt*) derives from an intricate and subjective process of active construction (Feiten, 2020): an organism constructs a world for itself by turning physical and social stimuli into patterns of neuronal excitation which constitute signs. It follows that each organism maps its own environment, and it is plausible that there are just as many environments (including maps) as organisms (map makers). There are several evident examples in the animal world where organisms develop their own spatial cognition and would have no significance to individuals beyond immediate cognitive grasp. Wolves leave scent marks at regular intervals along well-established routes and concentrate most at route junctions and near the edges of their territories (Peters and Mech, 1975), or the round and waggle dance performed by honeybees on returning to the hive, indicating to other hive members the direction and distance at which nectar has been found (see von Frisch, 1967).

Von Uexküll's ideas are now supported by the more recent cognitive theory of Enaction (see Varela et al., 1992): "cognition is not the representation of a pre-given world by a pre-given mind but is rather the enactment of a world and a mind on the basis of a history of the variety of actions that a being in the world performs". In short, "there can only be an individuality that copes, relates and couples with the surroundings, and inescapably provides its own world of sense" (Weber and Varela, 2002), or its own map of the environment.

4.2. The captain who sails through an uncharted channel

> '*A captain, who on a dark, stormy night has to sail through an uncharted channel, devoid of beacons and other navigational aids, will either wreck his ship on the cliffs or regain the safe, open sea beyond the strait. If he loses ship and life, his failure proves that the course he steered was not the right one. One may say that he discovered what the passage was not. If, on the other hand, he clears the strait, this success merely proves that he literally did not at any point come into collision with the (otherwise unknown) shape and nature of the waterway; it tells him nothing about how safe or how close the disaster he was at any given moment.… It would not be too difficult to imagine that the actual geographical shape of the strait might offer a number of safer and shorter passages*'.
>
> Watzlawick (1984)

What emerges from this metaphor is that elaborating a map does not say anything about the environment. The only knowledge is that it was a map suitable for our purpose or intentions (i.e., safely navigating the channel). In this sense, a map has to be meant as just one of many possible constructions of several environments, the suitability of which is merely dependent on our purposes or criteria. Consequently, a map is a result of perceived anomalies that produce dissatisfaction with existing conceptions since the "real" world manifests itself exclusively in that area where our construction breaks down (von Glasersfeld, 1984). A map will, therefore, never "match" some objective world outside, but rather "fits" the constructor's criteria (von Glasersfeld, 1984). However, differently from the "soap bubble" metaphor, this metaphor also emphasizes the structured probing of the environment by the knower, leading to the "perturbation relative to some expected result", and then leads to a new understanding and the possibility of building different or more viable replicates (maps) (von Glasersfeld, 1989).

5. Cartographic diversity: a journey into different human purposes and practices

Notably, as a consequence of man's millennial presence on the planet and his need to replicate, share, and transfer spatial information, the number of cartographic solutions adopted so far is remarkable. There have been no limits to the varieties of maps that have been developed historically in response to different purposes, aiming at different goals, and embodying different assumptions about what is cartographic practice (Harley, 1989). In this regard, Woodward and Lewis (1998) described three different but not mutually exclusive categories of "Cartography": cognitive, performance, and material cartography. However, we can generalize that more complex forms of maps (the inscription of spatial knowledge) tend to arise within higher organised or bureaucratic societies (Wood, 1994).

5.1. Cognitive cartography

This category refers to the maps that people apparently carry in their heads as mnemonic devices in forms of thought or images (Woodward

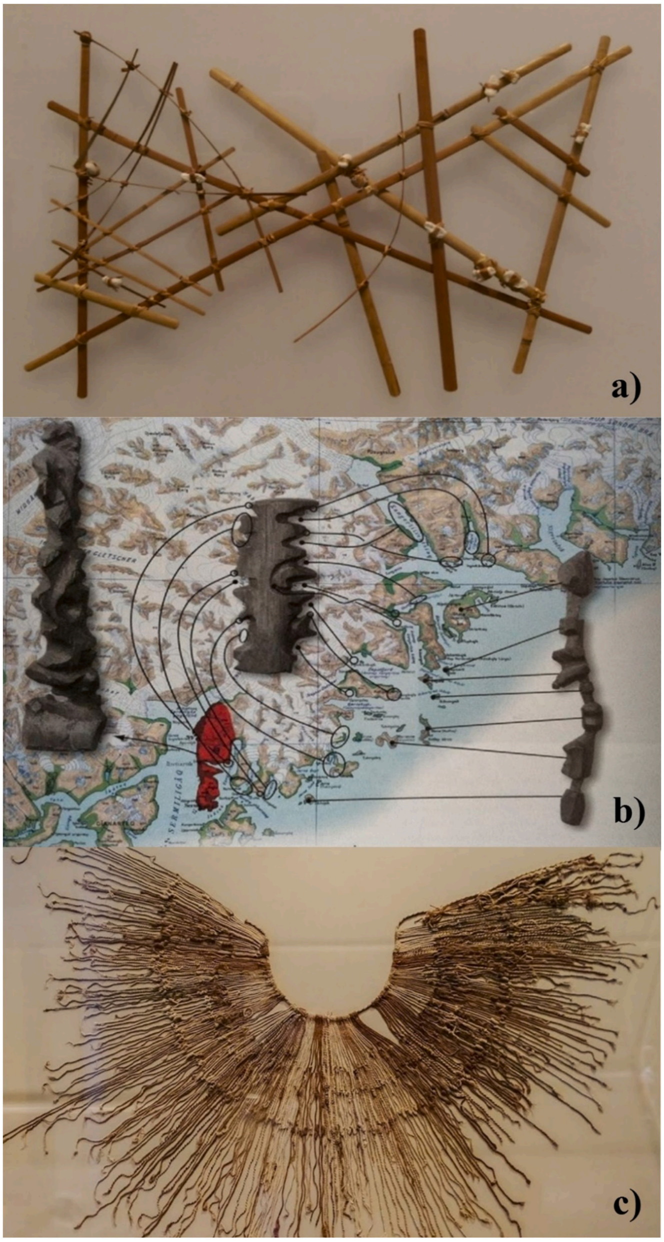

Fig. 1. Examples of material cartography: (a) shell charts (From the collection of the Phoebe A. Hearst Museum of Anthropology at the University of California, Berkeley. Photo by Jim Heaphy); (b) carved wooden maps (from "Topografisk Atlas Grønland" in Guttesen and selskab, 2000); (c) khipu (from the National Museum of the American Indian. Photo by James Tanner).

and Lewis, 1998). Neuroscientists have long investigated how animal brains store and process spatial information. It is now acknowledged that mammalian brains are equipped with "Place cells" and "Grid cells" in the hippocampus and the entorhinal cortex respectively; the former are involved in creating an internal neural map of a particular environment, while the latter are involved in measuring movement distances, thus providing a metric to the spatial map in the hippocampus (Leutgeb et al., 2005; see O'Keefe and Nadel, 1978).

However, these mental maps — either in their primitive or most evolved cultural forms — surprisingly allow travel across significant distances. Pacific Islanders are superb navigators who found their way without consulting any instruments or charts at sea after spending days or sometimes many weeks out of sight on land (Finney, 1998). Gladwin (1970) reported how traditional navigation was still practiced in the Caroline Islands of Micronesia.

5.2. Performance cartography

In many societies, ephemeral performances also fulfil the function of a map. Such performance may take the form of a non-material oral, visual, or kinesthetic social act, such as a gesture, ritual, chant, procession, dance, poem, story, or other means of expression or communication, and whose primary purpose is to define or explain spatial knowledge or practice (Woodward and Lewis, 1998). Indeed, material cartography might be a disadvantage in societies where maps were designed to grasp the ever-changing rhythms of nature and territory.

One of the most popular examples of ephemeral solutions comes from Aboriginal culture. We are now aware that Aboriginal people could know about and travel across unknown, even distant, territory. Bruce Chatwin's (1987) best-selling popularisation *The Songlines* has created an international recognition of the distinctive relationship between traditional Aboriginal songs and the mythic pathways that connect places over vast distances in Australia. In Australia, sites are connected not only in myth but also by sequences of verses in long song series. One individual will only know one section of the songlines; however, through exchange and negotiation, the travel of Ancestors can be connected to form a network of dreaming tracks that act as a form of a map (Sutton, 1984). Aborigines typically performed, invoked, and exchanged these songs in religious ceremonies, and their knowledge is, in fact, combinable because it is in the form of narratives of journey across the landscape.

5.3. Material cartography

Spatial representations may also be permanent or at least non-ephemeral. This category of material cartography, which comprises most artefacts we normally think of as "maps", also includes models, ceramics, drawings, paintings, textiles, descriptions or depictions of performances, and in situ records (Woodward and Lewis, 1998). As stated above, Micronesians have a well-deserved reputation for long-distance open sea voyaging without charts in canoes, deemed small by European standards. However, for purposes of memory and teaching, the Marshallese navigators designed charts made from the midribs of palm fronds and *Pandanus* splines, with shells as place markers for the atolls (Spennemann, 2005) ("stick charts"), as shown in Fig. 1a.

A second unusual example is found with carved wooden maps (Fig. 1b), which were made by nineteenth-century Eskimos in Greenland to represent coasts and island chains. Eskimos were able to draw quite detailed topographic plans of large coastal areas with little spatial distortion (Bagrow, 1948) in order to safely navigate and fish across fjords. The Inka *khipus* also depict the people's world in a way that enhances spatial understanding. *Khipus* are knotted-string devices based on the hierarchical organisation of data through a decimal system, whereby information is positioned according to ones, tens, and hundreds (Gartner, 1992). Not only could they record historical events, census and tribute information, and calendrical information, but also geographical narratives, and they also served as maps. *Khipus* are composed of a primary cord and a set of attached secondary strings or pendant (Fig. 1c). The regularly spaced position of knots, the colour, thread type and weave, knot directionality, and other variables are potentially important in interpreting *khipus* and providing spatial information (Parssinen, 1992).

6. Beyond neutrality: current limitations of biodiversity mapping for conservation

With the emergence of *critical cartography*, scientists have begun to challenge our overreliance on contemporary mapping conventions and technologies or scientific paradigms for conservation practices (Hazen and Harris, 2007; Peluso, 1995).

Peluso (1995) reported how, in Indonesia, a set of forest maps were produced with the most up-to-date technologies and data (i.e., Satellite

Landsat data and aerial photographs) to support state land managers and international institutions, such as the FAO, World Bank, Worldwide Fund For Nature, and International Union for the Conservation of Nature. Nonetheless, these maps underestimated a lack of knowledge of forested-based population assertions and management of forest territories, and their actual patterns of forest and agricultural land use (extremely dynamic and mostly un-mappable) resulting in many years of timber exploitation and ecosystem degradation.

Following on from Peluso (1995), Hazen and Harris (2007) reported more such cases, which include three aspects that critically challenge the strong reliance on contemporary mapping technologies and conventions for territorially-focused conservation practice, namely: preferential mapping; unequal mapping; and the effectiveness and effects of mapped conservation spaces. Such aspects are reported here below, and enriched with more recent cases, illustrate how biodiversity maps, far from being neutral representation of nature, convey both external and internal power in their intentions as well as in their performative applications.

6.1. *Preferential mapping*

In this regard, the degree to which areas may be selected for protection owing to their relative "mappability" is relevant. For instance, marine ecosystems have not witnessed the same increase in protected areas over the past 30 years which occurred in terrestrial areas (Brooks et al., 2006; UNEP-WCMC and IUCN, 2016) as it is more difficult to map and manage ocean features (Steinberg, 2001). Similarly, even though ecosystem services (ES) have been identified as crucial for human well-being, their spatial locations are rarely considered in land-use decision, mainly because collecting spatial data for ES is not a straightforward process and mapping methods lack consistency (Darvill and Lindo, 2015; Nahuelhual et al., 2015). This is particularly true when cultural ES are at stake (e.g. spiritual/religious landscapes, inspirational landscapes, sense of place landscapes) since their quantification is hindered due to methodological challenges, such as difficulty in assessment owing to their non-market value, incommensurability, and intangibility (Sherrouse et al., 2011). Conversely, conservation practices might be weighted towards concepts and practices that are most readily expressed in map forms since mapping practices hold cachet scientifically and politically (for "power of maps", see Harris and Hazen, 2006; Nietschmann, 1995). This is the case of the "biodiversity hotspot" concept stating that eclipsing many other approaches has become a reigning scientific paradigm among conservationists. This is at the expenses of what Kareiva and Marvier (2003) refer to as "biodiversity coldspots" and regardless of its relevant limitations, especially for large carnivores requiring vast territories, which may not be particularly rich in species (Kareiva and Marvier, 2003; Marchese, 2015).

6.2. *Unequal mapping*

Second, the mapping of diversity has often resulted in unequal outcomes for different social groups (e.g., Indigenous people), with livelihoods or forms of knowledge being excluded or marginalized (Díaz et al., 2018). Western or techno-scientific ideas are often preferred over traditional indigenous knowledge, even as this conveys a complex understanding of the ecosystem processes and has successfully maintained ecosystems over long periods (Berkes et al., 1998). Garnett et al. (2018) reported that indigenous people manage or have tenure rights over at least ~38 million km^2 in 87 countries or politically distinct areas on all inhabited continents. This represents over a quarter of the world's land surface and intersects about 40% of all terrestrial protected areas and ecologically intact landscapes (i.e., boreal and tropical primary forests, savannas, and marshes). Despite this, unsubstantiated claims about pastoralists competing with wildlife in Southwestern Niger have resulted in the total exclusion of local people from the territory (Turner, 1999). Maasai knowledge has been excluded from conservation efforts in Northern Tanzania, further marginalizing the Maasai and discouraging more flexible land-use management practices, of which local knowledge may be particularly well suited (Goldman, 2003). Many correlations between monitoring the boundaries of protected areas and violence against local populations have been also reported (Peluso, 1993). Nonetheless, from the 1980s onwards, and thanks to the new research avenues opened by critical cartography, mapping has also been massively appropriated by Indigenous peoples in repositioning themselves on national and word maps in order to get back or consolidate spaces of action and being (Desbiens et al., 2020).

6.3. *The effectiveness and effects of mapped conservation spaces*

Lastly, Hazen and Harris (2007) also discuss the effectiveness and effects of mapped conservation spaces. Most often, other areas outside protected areas are concurrently implied to be less worthy of protection (Boothby, 2002). For instance, they reported how Costa Rica is proportionally well protected compared to other Latin American countries; however, in the 1990s, it experienced the highest rates of deforestation among other countries. Besides, such mapping practices can also alter human perceptions of an area, resulting in new social and psychological associations: in 1872, Native American communities with long-term human use of land were displaced in order to create Yellowstone National Park and to comply with visions of pristine nature to feed the myth of wilderness. Similarly, Büscher and Fletcher (2019) propose a shift towards promoted areas rather than protected areas. They claim that a protected area, by its very definition, aims at protecting nature from people. This is about foraging nature–people dichotomies rather than celebrating the many inherent links between them. Finally, as cartographers necessarily honour compass direction, coordinate systems, or other aspects in creating maps (Monmonier, 1991), those dealing with biodiversity and conservation maps necessarily honour certain species or understanding of nature over others (Hazen and Harris, 2007).

7. Alternative maps vs objective maps

A lot has already been done to address the above-listed issues with an increasing awareness by conservation practitioners (Dudley et al., 2018). However, adopting a critical cartographic approach may represent an advantage in performing more effective and systemic biodiversity maps for conservation.

We can conclude that a map, whether in the form of cognitive, performance, or material, is nothing but a symbolical and eventually transferable replicate of the environment (e.g. rhetorical text) to anticipate objects and conditions in space. Such a replicate is enacted by the organism in accordance with its sensorimotor system, and the related norms and values deriving from the context and culture in which this replicate is produced. Concurrently, because of the impossibility for a map to "match" some objective world outside and the revisionist creative process of knowing, there can be several replicates of the same "external world" that fit different constructor's criteria or purpose, and that can be recursively modified to build a more viable replicate. The varieties of maps that have been developed historically in response to different purposes clearly illustrate how our "western" maps, far from being a transparent opening to the world, are but a particular human way of looking at the world. The above listed limitations of maps for conservation also indicate how maps have the power to disseminate a new state's view of reality and modify the environment accordingly. By way of conclusion, it follows that our maps cannot provide a neutral representation of biodiversity distribution for conservation practices since their production is either historically and socially situated (i.e. external power of maps) or it influences change by conveying particular ways of ordering the world (i.e. internal power of maps) (Noucher et al., 2019).

Moreover, we have to bear in mind that there are still areas of reality

Table 1
A *vademecum* for biodiversity map makers and users: Alternative mapping vs objective mapping.

Alternative mapping	Objective mapping
Complete objectivity is neither an attainable nor a desirable goal	Complete objectivity is either an attainable or a desirable goal
Involve reflexive analyses of the way a map is constructed from a relative perspective	Tend to avoid reflexive analyses, resulting in a map constructed from an absolute perspective
A map reflects the mapper's criteria and purposes	A map reflects objective reality
Every map is both data and narrative	Every map is a faithful representation of the data
Recognises all forms (indigenous included) of Cartographic conventions	Recognises only "western" cartographic conventions
Incorporates cognitive, performance, and material cartography	Mostly incorporates material cartography
Not all contexts are best addressed with mapping	All contexts are potentially addressed with mapping
A map is just one replication out of the many existing environments	A map is the replication of a pre-given environment
An organism's relationship to environments are diverse and dynamic	An organism's relationship to environments are fixed and invariable
Maps are rated in terms of viability and accuracy	Maps are rated only in terms of accuracy
Every stage of mapping is important to enable change and reflection	Mapping is limited to outcomes
Bottom-up approach	Top-down approach
Accounts for the external and internal power of maps	Does not account for the power of maps

that cannot be mapped or put into figures: both in terms of objective limits, which our metrological systems cannot handle (metrology as the science of measurement), and in terms of moral, symbolic, and identity related limits (Noucher et al., 2019).

As a result, it is important to strive and rate maps not only in terms of scientific accuracy but also on their "viability", which is their range of application and how successful they are in achieving the aims for which they are drawn.

Such viability has already been addressed in an alternative set of maps, known among geographers as "counter" maps, or through Public Participation Geographic Information Systems (PPGIS). Counter-mapping recently took hold after springing from and reacting to a lineage of technologically facilitated, institutionalised, top-down knowledge. Counter mapping is supposed to use (spatial) data or knowledge to unite critical ideas and radical practice to explore and realise more viable alternative possibilities (Dalton and Stallmann, 2018). Peluso (1995) successfully adopted these maps to co-opt the cartographic conventions of the Indonesian state (see above), to legitimize the claims to the forests and rights to their use emanating from the colonised (the Dayak people indigenous to Kalimantan), and to counter the abuses committed by the state against their lands and lives. Similarly, PPGIS uses easily understood tools (e.g. paper and digital maps) that strive to include public values into decision making processes (Barndt, 1998). Participatory methods are used as a bottom-up approach that aims to empower those stakeholder groups involved in the process, by providing visual tools that helps them understand threats and conservation priorities (Fagerholm et al., 2012).

Accordingly, the following main points provided will characterize an alternative mapping approach as opposed to an objective one (Table 1). Such a Table is intended as a *vademecum* for biodiversity map makers and users to guide them in the devising of alternative maps.

8. Conclusion

This paper aims to promote healthy skepticism about biodiversity and conservation maps, not to support cynicism. This paper assists ecologists in reconsidering maps and biodiversity maps (even though based on up-to-date scientific assumptions) as subjective, socially constructed, and ideological forms of power, rather than objective, value-free, and neutral transcription of nature. As such, maps are inevitably affected by personal constructions, dominant culture, and sometimes ignorance, or scientific blindness.

Mapping biodiversity and designating protected areas now appear to be a matter of survival for human beings and "spatialization" is inevitably a part of the solution. However, the belief of an "objective" approach for biodiversity mapping should be abandoned in favour of an alternative mapping approach (i.e., "counter maps") that can provide viable alternatives to mitigate or face rapid biodiversity loss in a more "systemic" way. As such, a critical approach questioning our perspectives and cartographic assumptions has to be explicitly embedded in the future of biodiversity mapping, in an effort to consider maps not only as effective tools for managing our environment, but also as mirrors of our scientific western tradition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research was partially mentored by Vincent Kenny, whose priceless suggestions catalyzed my shift in perspective towards a systems view of life.

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