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A Holistic Approach Including Biological and Geological Criteria for Integrative Management in Protected Areas

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Abstract Biodiversity hotspots and geosites are indivisible parts of natural heritage. Therefore, an adequate spatial delimitation and understanding of both and their linkages are necessary in order to be able to establish conservation policies. Normally, biodiversity hotspots are a typical target for those policies but, generally, geosites are not taken into account. Thus, this paper aims to fill this gap by providing an easily replicable method for the identification and integration of the geosites and the biodiversity hotspots in a Network for Integrative Nature Conservation that highlights their linkages. The method here presented has been applied to Urdaibai Biosphere Reserve situated in southeastern of the Bay of Biscay. The obtained results indicate that some geosites that are not directly related with biodiversity hotspots remain unprotected. Thus, from the study carried out, it can be stated that we conserving just the biodiversity hotspots is not enough to conserve the whole natural heritage of a protected area, as some plots interesting due to their relevant geoheritage remain unprotected. Therefore, it is necessary to fully integrate geosites into the planning documents of protected areas as a part of an ecosystem approach. The ecosystem approach recognizes the integrity of abiotic and biotic elements in nature conservation policies. Moreover, the proposed framework and the innovative methodology can be used as an easy input to identify priority areas for conservation, to improve the protected areas conservation planning, and to demonstrate the linkages between biodiversity hotspots and geosites.

Keywords Biodiversity hotspot · Geosites · Urdaibai Biosphere Reserve · Conservation planning · Protected Areas

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Introduction

The need for biodiversity conservation is internationally recognized. The Convention on Biological Diversity has called for a reduction in the rate of biodiversity loss by 2020, via the Strategic Plan for Biodiversity 2011–2020, which includes the Aichi Biodiversity Target. However, biodiversity hotspots, in many cases, are intricately linked to geological processes that are part of the geodiversity (Hudson and Inbar 2012) and some of them, of the geoheritage.

Geodiversity is defined as the variety of geological (rocks, minerals, fossils, soils) and geomorphological (landforms) features and the diversity of active geological processes. It includes their assemblages, relationships, properties, interpretations and systems (Gray 2004). The geoheritage is constituted by the overall sum of geosites. Geosities are defined as key areas showing geological features that allow the understanding of the origin and evolution of the Earth, including geomorphological processes, past climates and paleobiological evolution. They can be characterized by a combination of characteristics like representativeness, integrity, rarity, and published scientific data that allow present and future research to produce meaningful scientific knowledge of how the geosphere works and interacts with other Earth systems as biosphere, hydrosphere or atmosphere (scientific value). Sometimes, they can also be characterized by another combination of characteristics of a geological site like the didactic potential, vulnerability, fragility, accessibility, safety, logistics, and observation conditions that justify its use for educational activities (educational value). Likewise, they can be characterized by a combination of characteristics like scenery, interpretative potential, vulnerability, fragility, accessibility, safety, and uniqueness that justify its use for tourism and leisure activities (geotourism value). They may be determined as the most relevant manifestations of geodiversity and their identification, classification and protection are the major driver for geoconservation (Gray 2004; Erikstad et al. 2008; Brilha 2016).

During the last years, several methods to assess geosites have been developed (Cendrero 1996; Carcavilla et al. 2007; Brilha 2016) in order to provide objective tools for geoconservation. The concepts of geoconservation, geodiversity and geosites have gained national and international acceptance and usage. For example, geosites have been recognized by the International Union for Conservation of Nature (IUCN) (Resolutions WCC-2008-Res-4040 and WCC-2012-Res-5048 adopted during the 2008 and 2012 IUCN World Conservation Congress, respectively) and by the European Council of Ministers (Recommendation Rec. 2004-3). Actually in Europe, several countries (i.e. UK, Spain, Portugal, Italy, Poland and Ireland) have included geosites in some of their regional and local policy planning documents (Gray 2008). However, there is still not any European Directive directly related to geoconservation (Carcavilla et al. 2009). Therefore, key locations (geosites) for unveiling and understanding the geological history of the Earth, are under increasing risk of total or partial deterioration due to natural processes or human activities. Many of these places are situated in protected areas; however, they still are mostly unknown by their managers.

The IUCN defines a protected area as a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley 2008). In this definition, the use of the term Nature is stated to refer to both, biodiversity and geoheritage, as both are indivisible parts of nature. Consequently, in order to achieve the long-term conservation of nature in protected areas, it is necessary to identify their biodiversity hotspots and geosites (Pimm et al. 2014).

Moreover, the conservation policies for biodiversity hotspots and the ones for geosites have usually been disconnected, since they have often been understood as separate entities. Consequently, there has been a lack of spatial integration and recognition of their relationships (Gray et al. 2013; Hudson and Inbar 2012). This is especially notable in those geological outcrops and soils, landforms or active geological processes that present a strong influence on biodiversity hotspots. Therefore, management planning of any protected area, undoubtedly, requires a holistic approach that should integrate biodiversity hotspots, geosites and their relationships in order to ensure their adequate conservation (Hjort et al. 2012; Parks and Mulligan 2010). In this way, some authors propose to create a Network for Integrative Nature Conservation to highlight these linkages by the integration of the existing network of biodiversity hotspots with a network of geosites (Matthews 2014).

The Biosphere Reserve designation has been selected as a case study of protected area because it is globally considered as a territorial laboratory for the implementation of planning approaches where best practices are tested and exported (UNESCO 1995). Concretely, Urdaibai Biosphere Reserve (UBR) has been chosen ,because it presents a relevant biodiversity hotspot network and a valuable list of geosites (Mendia et al. 2010; Mendia and Monge-Ganuzas 2011). Moreover, the Use and Management Plan of UBR (PRUG/EKEG), approved in 1993 and modified in 2003, is actually under revision so the results of this holistic method are likely to be used to help redefine its conservation targets and spatial delimitation. This method can be extrapolated to the international community in charge of the planning and management of protected areas.

This study aims to provide an easily replicable method for the identification, delimitation and integration of the whole natural heritage (biodiversity hotspots and geosites) in planning and policy documents of protected areas. Thus, the specific objectives of the study are: (1) identify and delimitate the biodiversity hotspots, the geosites and their spatial congruence in UBR; (2) propose a new integrated method to achieve an integrative conservation planning for protected areas; and (3) compare the previously existing conservation network and the newly proposed to determine the consequences of the integration of new natural heritage elements for conservation.

Methods

Geographical and Geological Setting

The UBR is located in the Basque Country, southeastern Bay of Biscay (43°19´ N, 2°40´ W) (Fig. 1). It is delimited by the Oka River hydrographic basin and occupies an area of 220 km^2. It has a population of approximately 45,000 inhabitants.

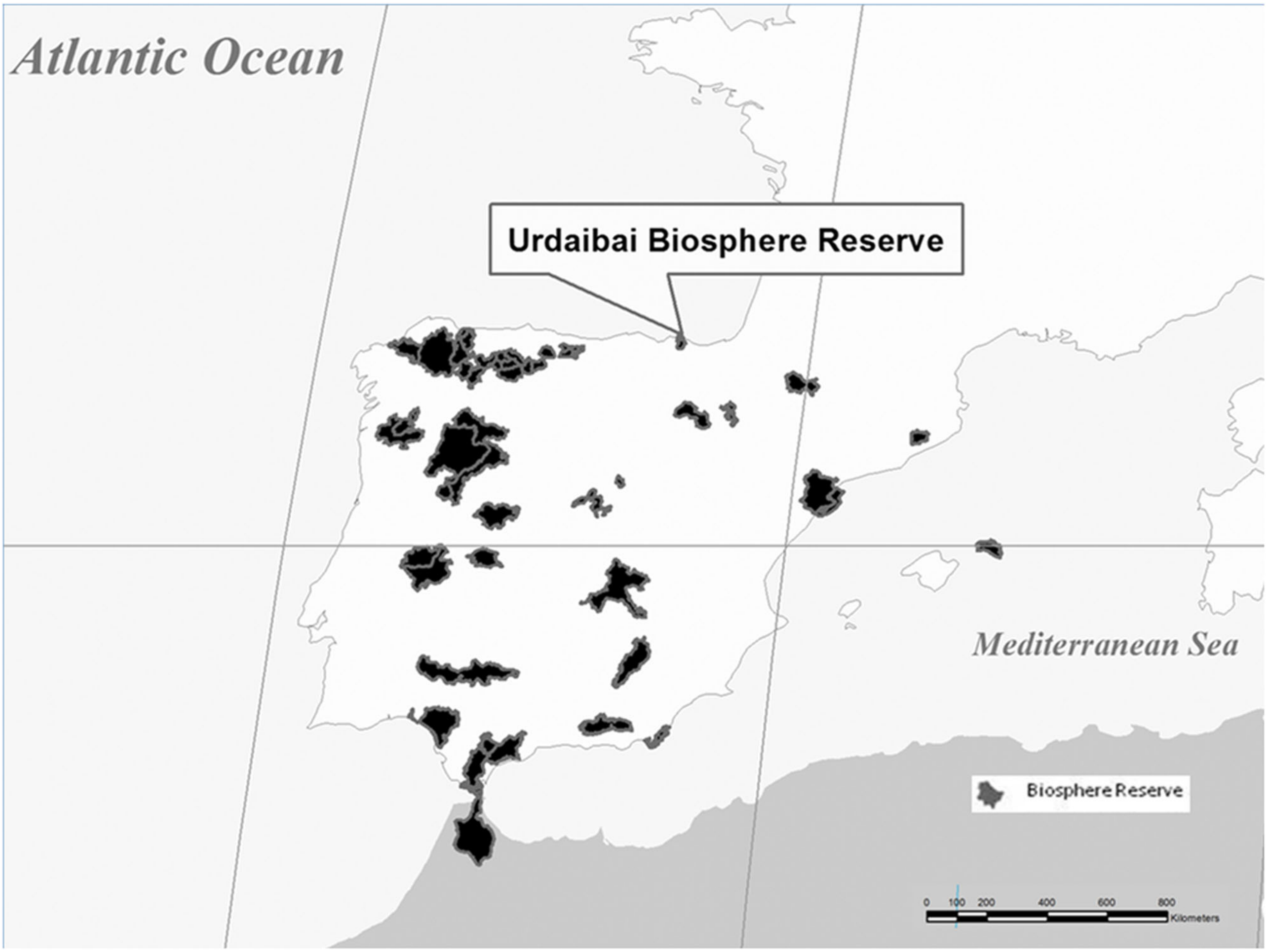

Fig. 1 Location of the UBR and other Spanish Biosphere Reserves in the context of the biogeographical regions

The UBR is located in the geologic framework of the Basque-Cantabrian basin. Its geological materials are mainly sedimentary despite some volcanic (Upper Cretaceous basalts, pyroclastic and epiclastic rocks) and subvolcanic outcrops (Triassic basalts with ophitic texture) dotted around its territory. They cover an age range from the Triassic to the Quaternary (250 million years of the Earth history). Most of the area is covered by Cretaceous sedimentary rocks (marls, sandstones and calcareous rocks) full of fossils like rudists, orbitolines, corals, sponge, etc., except its southern part where Paleocene-Eocene calcareous flysch deposits crop out. Quaternary sediments appear as a result of a variety of active geological processes such as the fluvial processes produced by Oka River and its tributaries, the karstic processes associated with limestone outcrops and the estuarine and marine processes that occur in the nearshore.

In 1984, this area was declared Biosphere Reserve by UNESCO. Later, in 1989, the Basque government enacted the Law 5/1989 on the Protection and Management of the Urdaibai Biosphere Reserve in order to protect its Core Zone (2651 ha) that is a biologically rich wilderness area and contains three special areas of conservation (SACs): the Oka estuary and its surrounding littoral (ES2130007); its fluvial system network (ES2130006); and the Cantabrian evergreen-oak forests (ES2130008). This zone also contains a special protection area that covers the estuary, the littoral and their surrounding areas (ES0000144). Likewise, the PRUG/EKEG of UBR, according to the Statutory Framework of the World Network of Biosphere Reserves (UNESCO 1995), establishes the zonation of the rest of the UBR: the Buffer zone (5413 ha) which is a less ecologically sensitive and more resilient natural area that serve as a cushion for the Transition Zone (14,093 ha); and the Transition Zone, situated on the periphery of the UBR, which is the least ecologically sensitive and is mainly used for economic development. The PRUG/EKEG of UBR as well regulates in detail the human uses that can be done in each Zone. As has been mentioned above, this Plan was approved in 1993, modified in 2003, and actually is under revision. The 28 % of the UBR is also included in the European Natura 2000 Network.

To sum up, the PRUG/EKEG of UBR has been established in order to implement a sustainable development model that tries to conserve the natural heritage of UBR and at the same time, provides benefits to the surrounding human communities.

Identification of the Biodiversity Hotspots

A GIS-based approach (ArcGIS 10, ESRI 2010) was designed to identify spatially the most biologically relevant areas referred to as biodiversity hotspots. The identification of biodiversity hotspots has been an effective method for prioritizing conservation issues (Grant and Samways 2011) as they represent areas with the highest biological value (Sloan et al. 2014). These areas are usually defined by one or more species-based metrics (number of species-species richness; number of species restricted to a particular area—endemic species richness; and number of rare or threatened species). However, considering only species diversity may not be sufficient to fully capture all levels involving biodiversity (Marchese 2015). Therefore, in this study, an integrative approach that quantifies different levels of biodiversity was used. The value of biodiversity was calculated as a function of plant richness, habitat quality and existence of a legally protected feature (Onaindia et al. 2013a, b), using Raster Calculator tools provided by Spatial Analyst in ArcGIS.

$$B = f(r, q, p)$$

Where: B = Biodiversity; r = plant richness, as the number of native vascular plant species, q = habitat quality; p = the degree to which the land is legally protected.

The environmental unit was used as a quantification unit and according to the European Nature Information System habitat classification, 16 environmental units were defined at 1:10,000 scale (see Table 1). Subsequently, values from 1 to 3 based on plant richness and habitat quality was assigned to these environmental units (Table 1).

To calculate the number of vascular plant species, only native species were taken into account. Thus, alien and invasive species were avoided. The number of native vascular plant species in each environmental unit were calculated based on the literature (Amezaga et al. 2004; Arnáiz and Loidi 1982; Benito and Onaindia 1991; Calviño-Cancela et al. 2012; Dech et al. 2008; Loidi and Herrera 1990; Loidi et al. 1997; Onaindia 1986, 1989; Onaindia et al. 1991; Onaindia and Mitxelena 2009; Peña et al. 2011; Rodríguez-Loinaz et al. 2011). Obtained values were rescaled from 1 to 3, using equal intervals from the maximum value to the minimum value: >54 = 3, 27–53 = 2, and <26 = 1. The habitat quality was estimated as a function of the suitability of each environment unit for providing habitat for biodiversity (Terrado et al. 2016). It was used as an indicator of biodiversity because the loss of habitat structure generally leads to a decline in species richness and biomass. Forests, coastal habitats, estuarine habitats, rocky areas and heaths were the environment units that presented the highest habitat suitability for native species. According to these criteria, the assigned value for each environmental unit was the following: 3 = forests, coastal habitats, estuarine habitats, rocky areas and heaths; 2 = grasslands and forest plantations and 1 = the most transformed ecosystems (crops, artificial soil, quarries…).

The presence of previously delimited protected areas (Basque Government 2016) in the territory at 1:25,000 scale was also included in the database. In this case, the presence of an area protected by European Directives was valued as 3, the presence of an area protected by regional laws was valued as 2 and the rest of the areas as 1 (Peña et al. 2015).

Finally, the biodiversity value was calculated by adding the values of the three described components. All components were considered equally relevant, covering complementary aspects of biodiversity; therefore, they were given equal weights within and among them.

Table 1 Environmental units used to calculate biodiversity value and value assigned to each one for plant species richness and habitat quality

Environmental units	Number of native vascular plant species	Plant species richness	Habitat quality
Coastal habitats	42	2	3
Estuarine habitats	35	2	3
Grasslands	49	2	2
Shrubs and heaths	25	2	3
Riparian forests	70	3	3
Beech forests	73	3	3
Mixed-oak forests	79	3	3
Cantabrian evergreen-oak forests	72	3	3
Broadleaves plantations	61	3	2
Eucalyptus plantations	12	1	2
Coniferous plantations	61	3	2
Rocky areas	10	1	3
Orchards and crops	0	1	1
Invasive species	0	1	1
Quarries	0	1	1
Artificial soil (parks, cities, village)	0	1	1

Plant species richness = number of native vascular plant species. The number of native vascular plant species in each environmental unit was calculated based on the literature

Identification of Geosites

In order to identify geoheritage with scientific, educational and touristic value, an inventory of the geosites of UBR with local, national or international relevance was performed (Mendia et al. 2010). The selection of the potential geosites consisted of: (1) a literature review of all geological data published about UBR and the advice of experts that have developed research in the area; (2) a definition of various geological frameworks; and (3) a characterization of the geosites representative of each geological framework.

The geological frameworks were defined according to the geological and geomorphological maps for the Basque Country at 1:25,000 scale (Basque Government 2016), and to the advice from geoscientists as follows: (1) geological materials (rocks and fossils representative of a geological age or event); (2) tectonic structures; (3) geomorphological landforms; and (4) active littoral, karstic, and fluvial processes. Thus, a list of potential geosites for each geological framework was obtained. Subsequently, a systematic fieldwork was carried out by 13 geoscientists (experts in the geology of the region) for the qualitative assessment of each potential geosites, based on the following criteria: (1) Representativeness: concerning the appropriateness of the geosites to illustrate a geological feature or processes which are essential for the interpretation of the regional geology; (2) Integrity: related to the present conservation status of the geosites, taking into account both natural processes and human activities; (3) Singularity: the geosites have served as an unusual geological example or have been representative of an uncommon process; and (4) Scientific knowledge: based on the existence of scientific data about each geosite.

The application of these criteria involves the removal of the potential geosites that do not comply with the previously established criteria. For the selection of geosites, they considered the following: (1) those occurrences that better represented the geological material, structure, landform or process, (2) those that have been in the best conservation status; (3) those that have showed rare features; and (4) those that have had originated scientific data or publications. The 13 geoscientists have also assigned vulnerability and fragility values for the geosites following the criteria stated by Fuertes-Gutiérrez and Fernández-Martínez (2012) (Table 2).

Subsequently, each geosite was mapped and quantitatively assessed for its scientific, educational and touristic values (Mendia et al. 2010). For the quantitative assessment, only the scientific value has been taken into account. Thus, established educational and touristic values of the geosites used for their designation was avoided, as the main aim of this work has been to establish areas that need to be protected. With the aim of assessing the scientific value of the geosites, four criteria were followed (Mendia et al. 2010; Mendia and Monge-Ganuzas 2011): (1) representativeness: capacity of the site to illustrate geological elements or processes; (2) key locality: recognition of the geosite by national or regional scientific literature; (3) integrity: related to the present conservation status of the geosite; the better the integrity, the higher the scientific value; and (4) singularity: a small number of similar geosite in the study area increases the scientific value. Each geosite was ranked 1, 2 or 3 points in accordance with the indicators for each criterion (Table 3). The final scientific value was an average of the four criteria. All criteria were considered as intrinsically related to the geological characteristics of the geosite, so the same importance was given to all of them.

Moreover, each geosite was quantitatively assessed for both, vulnerability and fragility using four criteria (Mendia et al. 2010; Mendia and Monge-Ganuzas 2011). The first two criteria were related to the intrinsic characteristics of the geosites (fragility) and the other two were related to its vulnerability to human actions. The used criteria were the following: (1) fragility to natural actions: reflects the possibility of loss of geological elements in the site as a consequence of natural actions (susceptibility to erosion, intensity of erosional agents, environmental changes, etc.); (2) fragility because of the size of the geological element: small elements are more likely to be damaged; (3) accessibility: reflects the conditions of access to the site for the general public. A site with easy access is more likely to be damaged by misuse of visitors than one with difficult access; and (4) vulnerability to urban development and proximity to areas or activities with potential to cause degradation: urban areas.

Each geosite was ranked 1, 2 or 3 points in accordance with the indicators for each criterion (Table 4). The final vulnerability and fragility value was an average of the four criteria. All criteria were equally related to the deterioration of the geosite. Thus, it was considered that the relative importance of them was the same and all criteria were given the same weight. A site had maximum vulnerability and fragility when its main characteristic geological elements had a high probability of being damaged either by natural or human induced actions. Finally, a critical and detailed analysis of the results was done in order to avoid contradictions between the final scientific value and the vulnerability and fragility value.

Both values were not computed together in a single formula to obtain a final score because they are independent of each other. The value of a geosite is not directly related to its vulnerability and fragility. Clearly, the conjugation of the value of both aspects is essential for establishing priorities in any conservation and/or management strategy (Mendia et al. 2010; Mendia and Monge-Ganuzas 2011; Brilha 2016). Thus, in this study, geosites with the highest

Table 2 Geosite identifications, geological framework, area, scientific value and vulnerability and fragility value

	Geosite ID	Geological frameworks	Area (Ha)	Scientific value	Vulnerability and fragility value
1	Black Flysch of the Matxitxako Cape	Materials	26,54	3	1
*2	Matxitxako boulder and cobble beach	Litoral landform	8,58	2	3
*3	Olistolith of the Aritxatxu beach	Materials	2,59	3	3
*4	Bermeo raised abrasion platform (+30)	Litoral landform	5,20	3	1
5	Errotatxu river basin	Fluvial landform	35,92	2	2
*6	Mundaka Rasa (+10)	Litoral landform	3,10	2	1
*7	Lumachelle of the Ondartzape beach	Materials	2,34	3	3
8	Lumachelle of Mundaka	Materials	1,80	2	3
9	Ophite of the Gernika diaper	Materials	14,99	3	1
*10	Sandindere island	Litoral landform	0,48	2	1
*11	San Pedro cave	Karstic system	1,02	2	3
*12	Cockpit-style karst landscape of Atxapunta	Karstic system	32,87	2	1
*13	Triassic red clay of Urkitxepe, Busturia	Materials	0,36	2	3
*14	Mape river channel	Fluvial landform	229,57	2	2
*15	Malluku doline, Murueta	Karstic system	30,56	2	1
*16	Murueta quarry	Materials (abandoned quarry)	0,69	2	2
*17	Arrola sinkhole	Karstic system	0,04	2	2
18	Forua quarry and Atxaga cave	Karstic system	10,86	2	1
19	Pillow lavas and pyroclastic breccia of Baldatika	Materials	24,65	2	1
20	Pillow lava flow of Abaliz	Materials	5,27	3	1
*21	Oka river incision	Fluvial landform	5,45	2	2
22	Gorozika quarry	Materials	1,99	2	2
23	Cretaceous/Tertiary boundary of Urrutxua	Materials	2,16	3	3
24	Oka and Golako river channels	Fluvial landform	2064,79	2	2
25	Aquifer of Gernika	Materials (resources)	5465,56	2	2
26	Pyroclastic breccia of Ajangiz	Materials	5,51	2	2
27	Pillow lava and lobated flow of Uarka	Materials	2,10	3	1
28	Gernika diapir	Tectonic structure	1030,24	3	1
29	Aretxalde II cave	Karstic system	0,04	3	3
*30	Cockpit-style karst landscape of Ereñozar	Karstic system	424,86	3	1
31	Oma-Basondo and Bolunzulo dolines	Karstic system	75,09	2	1
*32	Santimamiñe cave	Karstic system	0,23	3	3
*33	Olalde karst spring	Karstic system	0,19	3	3
34	Bollar doline	Karstic system	52,62	2	1
35	Red limestone of Ereño (Red quarry)	Materials (abandoned quarry)	5,85	3	1
*36	Oxina cave (Oxina-Argatxa system)	Karstic system	4,86	2	3
*37	Cockpit-style karst landscape of Atxarre	Karstic system	27,77	3	1
38	Anbeko polder	Materials (agricultural resource)	36,05	1	2
*39	Jurasic limestone of Kanala	Materials	3,55	2	3
*40	Oka river upper estuary	Litoral landform	597,62	3	2
41	Oka river lower estuary	Litoral landform	214,31	3	2
42	Laida beach and Mundaka bar	Litoral landform	61,35	3	2
*43	Cretaceous platform facies of Laida	Materials	0,55	2	3
*44	Talus facies of Laida	Materials	1,49	3	3
*45	Abrasion platform/boulder Antxonazpia cobble	Litoral landform	9,69	2	1
*46	Laga beach	Litoral landform	19,45	3	2
47	Laga ophites	Materials	5,74	2	1
*48	Platform-talus facies and paleokarst of Asnarre	Materials and litoral landform	3,19	3	2
*49	Karst and Ogoño cape	Litoral landform	80,36	3	1
*50	Landslide deposit of Elantxobe	Litoral landform	31,20	2	1
*51	Izaro island	Litoral landform	14,32	3	1

*Those geosites that overlapped with a hotspot of biodiversity

Table 3 Criteria, indicators, and parameters used for the quantitative assessment of the scientific value of geosites

Criteria/indicators of the scientific value	Parameters
A. Representativeness	
The geosite is the best example in UBR to illustrate elements or process, related with the geological framework under consideration.	3 points
The geosite is a good example in UBR to illustrate elements or process, related with the geological framework under consideration.	2 points
The geosite reasonable illustrates elements or process in UBR, related with the geological framework under consideration.	1 point
B. Key locality	
The geosite is recognized as a key locality by national and/or regional science to illustrate and understand the national and/or regional geology.	3 points
The geosite helps to illustrate and understand the regional geology but it isn't the best example in UBR.	2 points
The geosite doesn´t add more information that key localities to illustrate and understand the regional geology.	1 point
C. Integrity	
The geosite is very well preserved.	3 points
The geosite isn't so well preserved, some characteristics of the main geological element is altered o modified.	2 points
The geosite isn't well preserved, the characteristics of the main geological element is altered o modified.	1 point
D. Singularity.	
The geosite is the only occurrence of this type in UBR.	3 points
In UBR, there are five or ten examples of similar geosites.	2 points
In UBR, there are more than 10 examples of similar geosites.	1 point

scientific value, and vulnerability and fragility values were given top priority for management and conservation strategies.

Analysis of the Spatial Congruence Between Biodiversity Hotspots and Geosites

Once biodiversity hotspots and geosites were identified, they were spatially overlapped in order to analyze their spatial congruence and linkages. This spatial analysis also served to study the coherence and suitability of the previously existing zonation in the PRUG/EKEG.

Results

Biodiversity Hotspots

The 12 % of the UBR has been considered as biodiversity hotspot (Fig. 2a), being the natural forests the ecosystems that have presented the greatest contribution to these areas. Cantabrian evergreen-oak forests contributed the highest (54 %), followed by the mixed-oak forests (28 %). Other environmental units, such as coastal habitats and estuarine habitats, despite the small area they cover, have also been included as biodiversity hotspots due to their high biodiversity contents.

Unfortunately, a great part of the mixed-oak forests (58 %) has not been considered as biodiversity hotspot in the study because they are outside of Natura 2000 network and outside also of the Core Zone of the UBR. It means that they are not legally protected.

Consequently, all biodiversity hotspots which included those mixed-oak forests that are not taken into account by the current PRUG-EKEG, are proposed to be included into the Network for Integrative Nature Conservation (see Fig. 2a). These biodiversity hotspot areas represent 18 % of the UBR area in the proposal , a slight increase is seen if it is compared with the one delimited by the PRUG-EKEG.

Geosites

After the application of the described method, 51 geosites were designed in UBR (Table 2). The majority of them are situated in the coastline, the estuary and the karstic areas (Fig. 2b). These geosites have a local relevance. Besides, 38 of them have also a regional relevance as they are included in the Inventory of Geosite of the Basque Country. Moreover, the Oka estuary which included various geosites of local relevance (10, 38, 40, 41 and 42), has also an estate

Table 4 Criteria, indicators, and parameters used for the quantitative assessment of the vulnerability and fragility of geosites

Criteria/indicators of vulnerability and fragility	Parameters
A. Fragility to natural actions.	
The geosite is highly vulnerable to the environmental changes.	3 points
The geosite is lowly vulnerable to the environmental changes.	2 points
The geosite isn´t vulnerable to the environmental changes.	1 point
B. Fragility due to the size of the geological element.	
The size of geosite is less than 10,000 m^2.	3 points
The size of geosite is among 10,000 and 100,000 m^2.	2 points
The size of geosite is more than 100,000 m^2.	1 point
C. Vulnerability due to accessibility.	
Geosite highly accessible by car through a paved road.	3 points
Geosite accessible by car through a gravel road or on foot.	2 points
Geosite lowly accessible only on foot.	1 point
D. Vulnerability to urban development and proximity to areas/activities with potential to cause degradation.	
Geosite in areas with high possibility of urban development due to high proximity to urban areas.	3 points
Geosite in areas with low possibility of urban development due to low proximity to urban areas.	2 points
Geosite in areas without possibility of urban development.	1 point

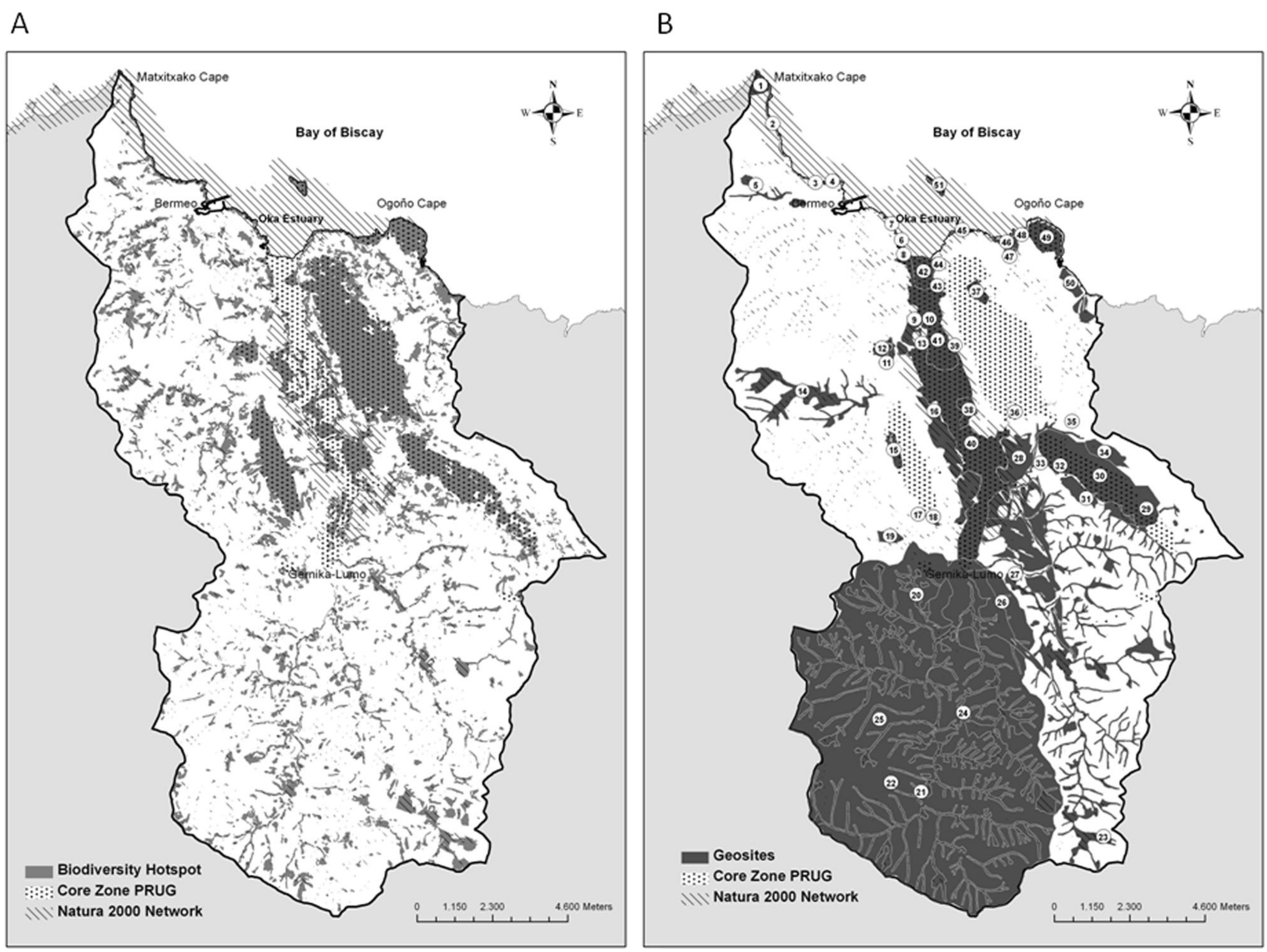

Fig. 2 **a** Biodiversity hotspots of UBR. **b** Geosites of UBR (their identification appears in Table 2)

and international relevance as it has been accepted to be included in the Inventory of elements that will be include in the International Geological Heritage through the Global Geosite project (IGME 2016).

On the one hand, the high degree of rock exposure in the littoral is the main factor that determines the high abundance of geosites in the coastline. Moreover, the variety of fluvial, estuarine and marine processes and landforms that take place near the Oka estuary and its surrounding littoral is the main cause of the determination of many geosites related to the estuary and the nearshore. On the other hand, the significant number of endokarstic and exokarstic elements in the limestone outcrops of the UBR make also conditional on the number of existing geosites.

The geosites take up almost half of the UBR area (49 %). Furthermore, 23 geosites obtained a high intrinsic value (value = 3) and 7 of them obtained also a high vulnerability and fragility value (value = 3). The geological materials group (rocks and fossils) was the most abundant group contributing to 20 geosites followed by littoral landforms and karstic systems groups, each contributing to 12 geosites (Table 2).

Furthermore, 63 % of the geosites present more than half of their area inside Natura 2000 network. Most of them belonged to the groups of geomorphological landforms (littoral landforms and karstic systems) and geological materials with 17 and 12 geosites, respectively. However, 19 geosites had more than half of the area outside of Natura 2000 network and outside also of the Core Zone of the UBR. They belonged mainly to geological materials, karstic system, and tectonic structure and are located mainly in the mixed-oak forests, the Cantabrian evergreen-oak forests and the coastal and estuarine habitats. All the geosites identified were proposed to be included into the Network for Integrative Nature Conservation.

Connection Between Biodiversity Hotspots and Geosites

The 34 % of the biodiversity hotspot area was overlapped with the geosites area. These areas grant interest for its high biodiversity and for its relevant geological characteristics. The 25 % of these areas were already included into the Natura 2000 network and 20 % into the Core Zone of the UBR (Fig. 3). The geosites that overlapped with biodiversity hotspots belonged mainly to the group of geomorphological landforms and active geological processes (Table 2). However, 6 % of the UBR area (16 % of the proposed Network for Integrative Nature Conservation) grants interest only for its high biodiversity, and 42 % (67 % of the proposed new Network for Integrative Nature Conservation) only for its relevant geological characteristics (Fig. 3). These latter corresponded to geosites belonging mainly to the group of geological materials, and tectonic structures that overlap mainly with grassland and hedges, coniferous plantations and artificialized soils.

Discussion

The Network for Integrative Nature Conservation

Currently, a key challenge is to improve the integration of the most relevant natural heritage into environmental policy and to improve its implementation in order to ensure a more holistic and sustainable environmental management that could increase the benefits to the population (Gordon and Barron 2012). Therefore, in this study, the protection of the biodiversity hotspots and the geosites together through the establishment and management of an Integrative Nature Conservation Network has been proposed because it is the most efficient method for environmental conservation (Dingwall 2000). The proposed Integrative Nature Conservation Network presented in this study is a suitable example of integration of areas of environmental interest into conservation planning of protected areas. It includes biotic and abiotic elements with exceptional values that spatially: (1) many times overlap; but (2) others do not.

In the first case, the biodiversity hotspots identified consisted of natural forests, coastal habitats and estuarine habitats. As a large variety of active geological processes occur in those habitats, they have been characterized as geosites. Those active geological processes (geosites) are directly related to biological processess and determine the existing biodiversity hotspots. In fact, the dynamic of the geological systems determines the heterogeneity of the environment and creates mosaics of topography and dynamic environments that support a range of high biodiversity (Matthews 2014). For instance, analyzing the Cantabrian evergreen-oak forests, the littoral and the estuary it can be easily see that they have been designed as SACs, as a part of the Core Zone of the UBR and Natura 2000 network, and have also been covered by several geosites delimitation. This evidence could mean that some of the geosites would have been already protected by biologically induced criteria (Dingwall 2000; Weighell 2004), and that conserving biodiversity hotspots helps indirectly to conserve geosites (Parks and Mulligan 2010). However, this is not always true. For instance, the geosite 7 (Fig. 3) despite being located inside Natura 2000 network is being heavily threatened by fossil collectors, thus it has been considered as highly vulnerable. Unfortunately, the recently approved Management Plan for Natura 2000 in the Basque Country does not regulate anything in relation to these extractive activities. Therefore, the Integrative Nature Conservation Network proposed would have an associated regulation for

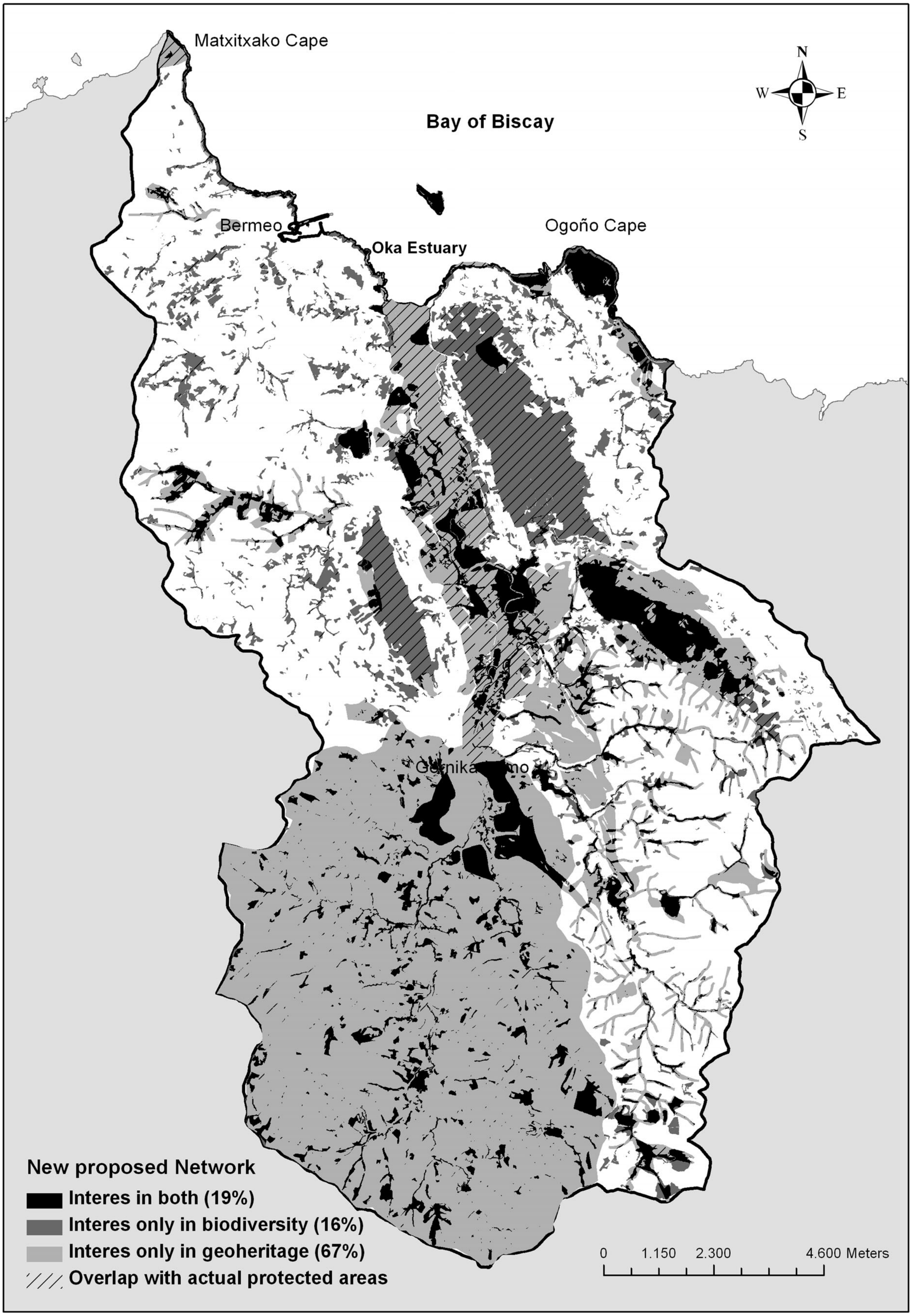

Fig. 3 Proposed network for integrative nature conservation

vulnerable or fragile geosites. Similar effective conservation measures for geosites have been proposed in other areas (Gray 2008). In fact, geosite 7 of UBR which presents a high scientific value, and a high vulnerability and fragility value need an urgent conservation priority in the PRUG-EKEG. The threatening factors of both, the biodiversity hotspots and the geosites, are often so different that conservation actions must really be done separately; however, can also often share management actions. In the case of the Biosphere Reserves, both should be considered in the delimitation of the Core Zone.

In the second case, there is a variety of geosites that do not show spatial congruence with the biodiversity hotspots. It does not mean that high biodiversity is not related to geological active processes or features, but it indicates that conserving only biodiversity hotspots is not enough to conserve the relevant natural heritage present in a protected area. Those geosites belonged mainly to the group of geological materials, and tectonic structures. They can be considered as relevant areas to explain the geological processes that shape the landscape and support the biodiversity, and as secret windows to read many amusing chapters of the history of the Earth. Without an understanding of the Earth processes that have led to their formation and that are currently experiencing, the management of the biological aspects of protected areas will not be as effective as it should be (Matthews 2014). Therefore, both geosites and biodiversity hotspots must be identified and managed in conservation planning of at least the protected areas (Erikstad 2012).

In this way, in the case of the biodiversity hotspots, more than half of the mixed-oak forests of UBR are not identified as an issue to be protected despite its high biodiversity. This means that not only some of the geosites are situated outside of the conservative zonation proposed by the current PRUG-EKEG, but also some of the biodiversity hotspots. These native forests, dominated by *Quercus robur* L., with *Fraxinus excelsior* L. and *Castanea sativa* Miller, are the potential vegetation for about 80 % of the UBR (Onaindia et al. 2004). Throughout the 20th Century, they were heavily fragmented causing a significant loss of biodiversity (Rodríguez-Loinaz et al. 2011). However, their conservation is actually considered a priority by different stakeholders (Onaindia et al. 2013a, b). Thus, relevant changes should be introduced in the identification and delimitation of the current protected areas, and the proposed holistic methodology could help in this process.

This study demonstrates that although biodiversity hotspots and geosites are not often present in the same spatial delimitation, both components of the natural heritage have several spatial and functional linkages. Consequently, both should be integrated into protected areas planning as key issues, using an ecosystem approach that recognizes the integrity of abiotic and biotic elements and processes for nature conservation.

An Innovative Method for the Integrated Delimitation of Protected Areas: The Establishment of a Network for Integrative Nature Conservation

The presented methodology is a useful tool for the integrated delimitation of the natural heritage of protected areas. This method is fast, useful and easily replicable by managers as they can identify, map and prioritize areas of natural interest (Knight 2011). They can also include this information as part of the key spatial information for planning of protected areas (Fuertes-Gutiérrez and Fernández-Martínez 2012; Mendia and Monge-Ganuzas 2011). Many approaches currently exist for identifying priority areas for conservation on a global or regional scale (Allen 2008). However, the identification of small scale areas of interest, where ground level conservation activities occur, has largely been ignored. Arguably, it is at this level, where conservation management is most important (Grant and Samways 2011) and where this methodology should be used.

The proposed methodology is especially interesting to be used in protected areas as almost all of them hold geosites that are necessary to know and conserve (Carcavilla et al. 2009). In Spain, for example, there are 48 Biosphere Reserves, and nearly all of them contain relevant geological values that are usually unknown to site managers (Monge-Ganuzas and Martínez-Jaraiz 2013). Therefore, most of them are not included in their delimitation of areas of natural interest and are not included in their nature conservation planning. This is the reason why inventories of geosites are needed, not only at the national level (Spanish Law 42/2007 on Natural Heritage and Biodiversity) but also for individual protected areas.

Thus, identifying the biodiversity hotspots and geosites areas and their ranking according to different criteria (qualitative and quantitative) is a necessary prerequisite for the conservation of the whole natural heritage (Knight 2011). In the case of the biodiversity hotspots, the identification of areas of interest that are maybe under threat (Myers et al. 2000) is an effective method for prioritizing conservation activities (Grant and Samways 2011). In the case of geosites contrariwise, the scientific value and vulnerability and fragility value are suitable to define priorities for their conservation.

Geosites are not only unknown to the managers but also to the society in general. Therefore, it is necessary to spread the relevant value of geosites and its linkages to biodiversity and to explain as well that how they contribute to society. In this regard, it can be stated that effective conservation of geosites will depend on better public awareness, understanding and support (Matthews 2014).

Conclusions

Conserving areas of high biodiversity is not enough to conserve the whole natural heritage present in protected areas, as some areas are interesting for their relevant geoheritage as well. These areas may be scientific, educational, cultural, and recreational resources because therein, the role of geologic processes in shaping the landscape or explaining the history of the Earth can be seen. Therefore, it is necessary to fully integrate geosites into the planning of protected areas as part of an ecosystem approach that recognizes the integrity of abiotic and biotic processes for nature conservation. In this way, the Network for Integrative Nature Conservation proposed in this study is a suitable example of an easy method for the integration of different areas of natural interest in protected areas. The proposed framework and the innovative method can be used by the managers of protected areas as an input to identify and delimitate areas for nature conservation in order to improve their current conservation planning, to support land planning strategies at different spatial scales, and to demonstrate the linkages between biodiversity hotspots and geosites to the society.

Further work must be done in the future in order to understand the existing multiple relationships between biotic and abiotic elements of the environment, especially in relation with the geological active processes, such as landforms, rocky outcrops and substrate types that influence and control the ecological networks.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

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