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The role of scientists at the human-nature interface on MaB protected areas

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Abstract

According to the theory of social metabolisms, human-nature interaction can generate "waste" that can act as environmental passives. The impact of scientists' interaction with nature during their field researches is rarely ever discussed on literature. In this paper, we evaluate the externalities produced by scientific research on fauna based on a zoning system of a Man and Biosphere Reserve (MaB) in order to determine incompatibilities. We assume that the MaB zoning systems could prevent the generation of this type of waste done by scientists. We systematized all documents referred to Ñacuñán MaB Reserve in Argentina (60 years of records) and created a digital library. Afterward, we spatialized the investigations related to fauna and contrasted them with the current zoning system. The results showed that most of the researches were manipulatives and were conducted at the transition zone, followed by the northern core zone. Scientists do not always respect the activities allowed by zone. Sampling sites are frequently selected according to the proximity of their accommodation rather than to the permitted activities. Therefore, it is necessary to formulate new policies to avoid scientists' liabilities and to encourage the build of knowledge and research on less studied zones, to promote conservation and sustainable development of MaB reserves.

Keywords: externalities; fauna; scientific waste; socio-ecological systems; zoning

Resumen

El rol de los científicos en la interface hombre-naturaleza en las áreas protegidas MaB

Según la teoría de los metabolismos sociales, la interacción humano-naturaleza puede generar "residuos" que pueden actuar como pasivos ambientales. El impacto de los científicos que interactúan con la naturaleza en sus investigaciones de campo, raramente es discutido en la literatura. En este artículo, evaluamos las externalidades producidas por los científicos en sus investigaciones sobre fauna en función del sistema de zonificación de las Reservas del Hombre y la Biosfera (MaB) con el objetivo de determinar incompatibilidades. Suponemos que los sistemas de zonificación de MaB podrían evitar la generación de este tipo de residuos por parte de los científicos. Para ello se sistematizaron todos los documentos referidos a la Reserva MaB Ñacuñán en Argentina (más de 60 años de registros) y se creó una biblioteca digital. Luego espacializamos las investigaciones referidas a fauna y se contrastaron con el sistema de zonificación actual. Los resultados

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mostraron que la mayor parte de las investigaciones fueron manipulativas y se localizaron en la zona de transición, seguida de la zona del núcleo norte. Los científicos no siempre respetaron las actividades permitidas por zona, seleccionando sus sitios de muestro en función de la proximidad a su alojamiento. Por ello es necesario formular políticas para evitar las responsabilidades de los científicos y para orientar la generación de conocimientos en las zonas menos estudiadas a efectos de promover la conservación y el desarrollo sustentable de las Reservas MaB.

Palabras clave: externalidades; fauna; basura científica; sistemas socio-ecológicos; zonificación

1. Introduction

Nature, humans, and the interaction between them have been addressed historically by different disciplines over the last four decades. From the Science of Conservation Biology point of view, the conception of excluding human beings from protected natural areas (PNA) ruled. Humans considered themself as a factor of disturbance. Nevertheless, in the mid-1980s, a different point of view began to emerge. Under this incipient new paradigm scientists recognized that mankind had already modified what they had previously called natural systems, and conservation strategies that search for the protection of a pristine state of ecosystems were untenable (Primack et al., 2001). Nowadays, Conservation Biology stands over a new paradigm where humans and nature are integrated with each other under the premise of sustainable management of natural systems (Kates et al., 2001). The concept of socio-ecological systems arises within this framework. It integrates disciplines that belong to both natural and social sciences, and seek new proposes of sustainable interaction models between man, nature and socio-economical systems at different spatial and temporal scales (Berkes & Folke, 2003; Ostrom, 2009).

According to the socio-ecological theory of social metabolisms, when these interactions occur, humans generate a process of appropriation of the goods and services offered by nature in order to satisfy a need —appropriation phase. This phase continues with the transformation and circulation of these goods and services and ends with the excretion of waste into the natural environment (Toledo, 2008; 2013). These are called environmental passives or externalities. They concern the effects produced by anthropogenic activity on the environment because of the human-nature interaction. When people who cause the damage does not assume or compensate for it, it is referred as a negative externality. This generates an environmental debt that ends up falling on society (Valenzuela, 1991; Russi & Martínez-Alier, 2014). A recent review of this theory highlights the modern capitalism as the main disruptive driver of this human-nature interaction, based on a feedback interaction between this binomial instead of just one direction (the effect of human to nature), redefining this theory as a metabolic rift (Napoletano et al., 2015). Indeed, this theory sheds light on the current prevailing contradiction between the transformation of socio-ecological conditions to maximize profits and the ability to promote sustainable human development (Foster, 2013). The concept of metabolic rift has hardly been incorporated in environmental geographic studies and, because of this, the different spatial configurations caused by this rupture (Napoletano et al., 2019) are still unknown for most socio-ecological systems (Napoletano et al., 2015; 2019). For this reason they promote a more integrative socio-ecological-geographical approach by pointing that the use of spatial tool derived from the geographical discipline (such as the Geographical Information Systems) are needed to understand this theory on the real territory (Napoletano et al., 2015).

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Within the paradigm of socio-ecological systems, the MaB reserve program from the United Nations Educational Scientific and Cultural Organization (UNESCO) promotes the creation of this protected areas, wich includes people, nature and their interaction (Jaeger, 2005). Specifically, this international program has three major objectives based on sustainable development: the conservation of biodiversity and its processes, the sustainable development of the communities that inhabit them and the support on research, education and ongoing training (Köck & Grabherr, 2014). To achieve this objectives, MaB reserves should have an appropriate zoning scheme on territory for each protected area where certain activities are allowed or prohibited: 1) core areas devoted to long term conservation; 2) buffer zones; 3) transition zones where sustainable development is promoted (UNESCO, 2008). Considering the challenges of maintaining the functions of MaB reserves conservation and sustainable development, it is a current aim to strengthen the social and biological interactions among the three zones —buffer, core and transition zones— expresed on the territory and promoting the connectivity of biodiversity between them (Stoll-Kleemann & O’Riordan, 2017). This global target was clearly stated as the first action of the Lima Action Plan, which indicates that MaB reserves are models that contribute to the implementation of the Sustainable Development Goals (SDGs) (UNESCO, 2017). Thus, MaB reserves can be used as a model to test and apply interdisciplinary approaches at the human-nature interface in order to understand and manage changes and interactions within this social-ecological system (Reed & Price, 2020).

In South America there are 130 MaB reserves at 12 countries (UNESCO, 2018). Fifteen of them are present in Argentina (MAyDS, 2018), where social actors and protected ecosystems have different characteristics depending on each PNA. Most of the research programs are based on local and Indigenous Communities inhabiting the MaB reserves, that highlights the role of traditional and local knowledge in ecosystem management (UNESCO, 2017). This is the case for certain programs referring to the use of flour of *Prosopis flexuosa* for coking native meals in Argentina (Campos et al., 2017), the development of ecotourism by local communities in the Ría Celestún Biosphere Reserve in Mexico (Pinkus-Rendón & Pinkus-Rendón, 2015) or the international promotion of fishing and cropping products —with seal of origin— by local communities based on indigenous knowledge in the Shinan Dadohae Biosphere Reserve in Korea (Lee et al., 2010). Nevertheless, not only Indigenous Peoples inhabit these protected areas; scientists are the second most important social actor on these MaB reserves. They oversee the research programs that lead to managers to make their political and social decisions. Despite of their importance on this socio-ecological system, the consequences of scientist-nature interaction have not been fully addressed. A previous study made in the savanna ecosystem situated in a Brazilian PNA reports several effects of scientific activity in the environment (Saito, Ribeiro Gomes & Almeida, 2011). This emphasizes the need to include this social actor into the socio-ecological interaction studies of PNA. Although there is literature on the externalities generated by other activities -such as tourism in natural ecosystems (Tapia Mella & Zahra, 2012; Das & Chatterjee, 2015; Ximbo, 2017)- there is practically no data referring to those produced by scientists themselves.

The Ñacuñán MaB Reserve —located at the Monte Desert biome— was the first PNA created in the Province of Mendoza in Argentina in 1961, with the intention of protecting the most representative plant community of this biome, the *Prosopis flexuosa* forests (Ojeda et al., 1998). In 1986, Ñacuñán Reserve became part of the MaB Program from UNESCO, since it integrates two key social actors that interacts with nature: inhabitants and scientists. Although the interaction between nature and inhabitants has previously been addressed by several studies —such as Delugan & Torres (1996) and Torres et al. (2010) — so far the links between nature and scientists have not been approached. There is no knowledge about the impact of scientific research or the compliance with current legislation on PNAs regarding this desert ecosystem in particular —where vulnerability is higher than in tropical ones.

Therefore, our main objective is to analyze the interaction processes of the socio-ecological system of Ñacuñán MaB Reserve, particularly addressing the way in which scientists relate to nature on territory. On the bases of the theory proposed by Napoletano et al. (2015) of the necessary intersection between sociology, ecology, and geography to understand metabolic rifts or metabolic social processes, we hypothesized that the zoning system of the MaB reserves could spatially organize the scientists-nature interaction, and thus reduce or prevent potential externalities of scientific activity. At the same time, in the framework of this reciprocal relationship it is inferred that scientists research related to fauna is mostly located in the transition zone —the most accessible area— while the core and influence zones do not have the proper scientific background research to guarantee their status. To tackle the latter, two general objectives were proposed: 1) Create a digital library to be familiar with the latest scientific knowledge of this PNA; and 2) Analyze potential externalities after scientists finish with their research programs. Inside the second main objective we proposed four specific objectives: a) Determine how the spatial distribution of sampling sites varies according to the zoning areas; b) Examine the variation in the number of sites where researchers conducted extractive and/or manipulative activities among different zones; c) Quantify the number of sites with biodegradable and/or non-biodegradable marks used during research; d) Evaluate the quantity and location of extracted and not extracted brands after finishing their research project. The conceptual integration of the information obtained from these objectives could be used by managers and decision makers to improve zoning system of the PNA based on current scientific knowledge.

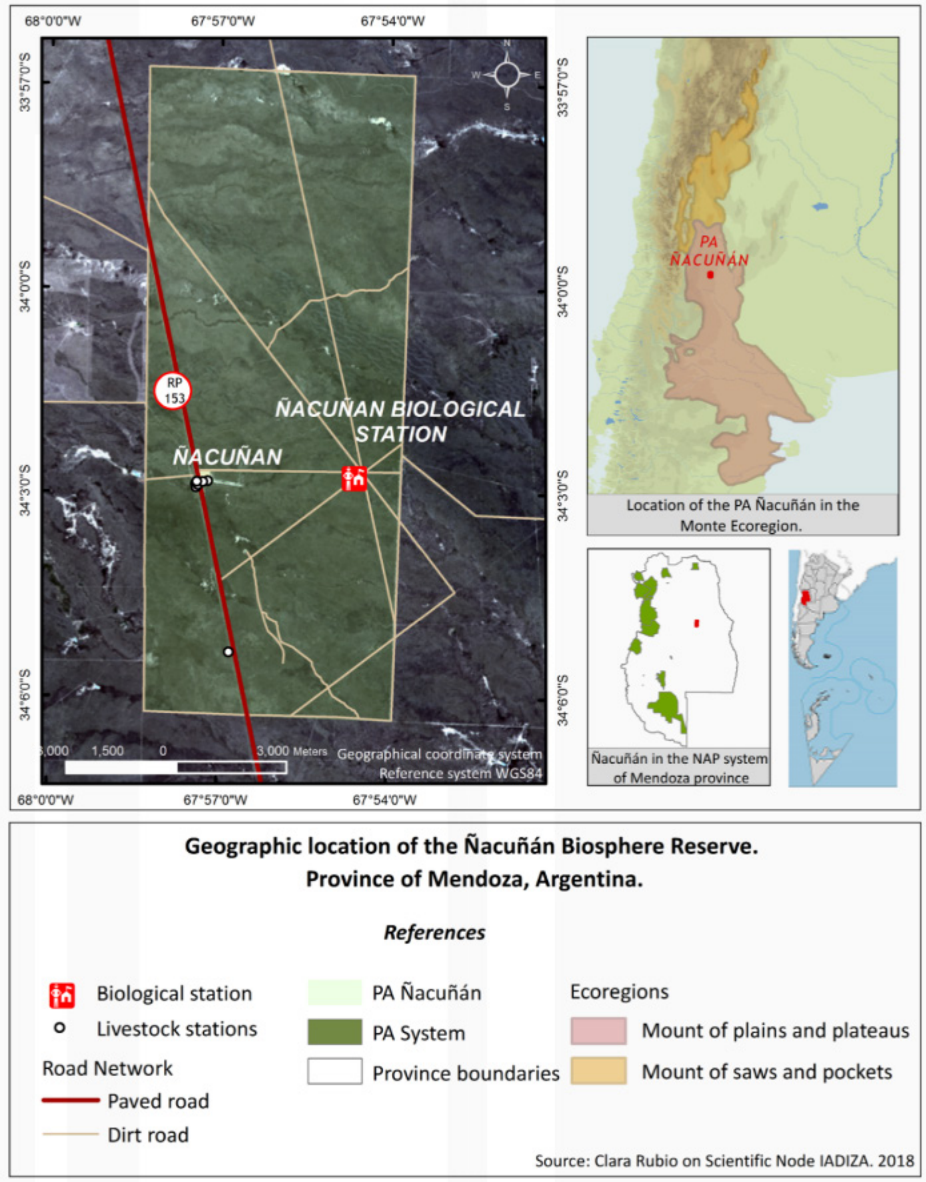
2. Methodologhy

2.1. Study area

The Ñacuñán MaB Reserve is in the center-west of Mendoza province in Argentina (34° 03' S and 67° 58' W). It comprises 12300 hectares (Boshoven & Tognelli, 1995) and is located at the Monte Desert Biome (Figure 1). The climate is semiarid and strongly seasonal, with hot wet summers with mean temperatures > 20° C and cold dry winters with mean temperatures < 10° C (Claver & Roig-Juñent, 2001). Mean annual rainfall is 342,4 mm; wet season rainfall averages 262,56 mm and dry season 79,20 mm.

The Argentine Institute of Research of Arid Zones (IADIZA), part of the Argentinian National Council of Scientific and Technological Research (CONICET), managed this PNA since its creation in 1961 until 2010, when a co-management program began along with the Directorate of Natural and Renewable Resources (DRNR) under Provincial government in Mendoza. Fifty years of research institute management have turned Ñacuñán Reserve into one of the most and best studied PNA in Argentina (Claver & Roig-Juñent, 2001). Park rangers have been in the protected area from 2010 to today —there were no park rangers before this date— and a co-management committee was created to make decisions regarding the activities allowed on the protected area.

Figure 1. Geographic location of Ñacuñán MaB Reserve, Province of Mendoza, Argentina.



Source: Rubio, M.C. on Scientific Node IADIZA, 2018.

As mentioned before, Ñacuñán Reserve was created in order to protect the most representative plant community of this desert biome, the *Prosopis flexuosa* forests. These forests were subjected to intense extractive processes for decades, linked initially to the expansion of the railway in Argentina and later to the development of viticulture in the irrigated areas (Abraham & Prieto, 2000). To guard these forests, the Protected Natural Areas department (ANP) have on watch many fauna species most of them included in the national and / or international red list (e.g.: Ojeda, Chillo & Díaz Isenrath, 2012). There are also endemic species —such as the pichiciego (*Chlamidophorus truncatus*)—, vulnerable —*Dolichotis patagonum*, the 'mara'— endangered species —*Harpyhaliaetus coronatus*, the crowned eagle— and species of commercial value like ñandú (*Rhea americana*) (Claver et al., 1999). We focused this research on papers referring to fauna —not only related to *Prosopis* forest— because the conservation of wildlife is especially important in the PNA.

The PNA have a zoning scheme since 1979 and was later modified in 1995 according to the criteria established by UNESCO (Abraham, Claver & Boshoven, 2001). The scheme is concentric, conformed of a core conservation area surrounded by a buffer zone, which in turn is enclosed by a transition zone: 1) Core Zone: these areas are securely preserved sites to protect biological diversity, monitor minimally disturbed ecosystems and undertake nondestructive research and other low-impact usages. It is divided into northern (ZONCO) and southern (ZOSCO) core areas; 2) Buffer Zones: these areas usually surround or adjoin the core zone; its objective is to attenuate the effects of the alterations produced by man. Experimental and comparative studies on the area can be carried out, as well as environmental education, recreation and ecotourism. It is divided into northern (ZONAR) and southern (ZOSAR) buffer zones; 3) Transition Zone: This area comprehends the town where local community lives. At the transition zone it is allowed manipulative research, environmental education, cooperation between researchers and local people, ecotourism and sustainable development practices. Activities that involve processes of irreversible degradation are forbidden. It is currently divided into the southern experimental zone (ZOSEX) and the northern exploitation and demonstration zone (ZONAD).

2.2. Sampling design

Since our main objective is to evaluate the interaction process and its consequences at the human-nature interface, we used different approaches and tools from different scientific disciplines, such as historical reconstruction of the evolution of research —of over 60 years— interviews with scientists, Geographic Information Systems (GIS) and remote sensing, conservation biology and design of protected areas, among others. Hereafter, they are detailed according to the objective.

a) Objective 1: We generated a bibliographic database with all the papers, manuscripts, thesis, dissemination material, books, etc. referring to Ñacuñán MaB Reserve, from its creation to 2015. This bibliographic database not only includes scientific papers but also secondary sources as mentioned before. For each record, the following variables where included in the database: author/s, year of publication, title, type of source —scientific papers, dissemination magazines, books, thesis, congresses or workshops presentations and reports— volume, pages, editorial, and the web-link, if it had one. Most of these documents were in an analog format at IADIZA, so the Centralized Documentation Service of the CCT-Mendoza-CONICET proceeded to digitize them to be incorporated into the digital library. All papers recorded in 'El Desierto del Monte: La Reserva de Biósfera de Ñacuñán' (Claver & Roig-Juñent, 2001) book were included in the database. For papers later than 2001, an exhaustive web search was made using Google Scholar. We looked for key words as Ñacuñán and Desierto del Monte, both in Spanish and English. Afterward, we verified the database checking the permission record in the office in Ñacuñán, to make sure all projects were included.

b) Objective 2: Because of the vast number of records systematized in the previous stage, we decided to restrict our analysis to fauna, the most studied group with 126 papers published and recorded in the digital library. Only those papers that allowed us to obtain a georeferenced data from the sampling site were included. Each paper was considered a sample and the following variables were registered on every one: authors; sampling year; year of the paper; geographical coordinates (x, y) of the sampling points; the use of biodegradable or non-biodegradable marks; extraction or non-extraction of marks after finishing the study; the faunistic study group (i.e.: ants, mammals, etc.); the zoning category (core, buffer, transition) and habitat type where sampling points were registered (Prosopis forest; creosote bush; sand dunes or Bulnesia bush);

whether the study was extractive or not; and if there was a manipulation process of the studied object. In the cases where the geographical coordinates of the sampling sites were not consigned on the published paper, we requested it to the authors via e-mail or in person.

2.3. Data analysis

Objective 1: We analyzed the relative frequency of bibliographic records according to the type of source —index journals; thesis; books; technical reports; congress abstracts; dissemination articles; and projects— by using a Chi-squared test ($p<0.05$). In addition, we tested relative frequency of scientific research according to different taxas (Chi-squared test), to evaluate missing information meant for decision management according to the areas defined in the zoning scheme.

Objective 2: First, we spatialized all records of geographic location of the sampling sites. In some cases, researchers reported the GPS points, while in others they reported an area in a sketch. In the latter, we identify these points accurately using Google Earth, to be able to georeferenced them. We used the zoning map of Ñacuñán Reserve published by IADIZA-CONICET Provincial Scientific Node digital data repository (SIG-Desert, 2018). All reported geographic coordinates were transformed to the sexagesimal format, using the reference system WGS 84 (World Geodetic System). Additionally, in order to perform the corresponding geospatial analysis, the coordinates were converted to flat coordinates and referred to the POSGAR 98 system. For these analyses we used the free and open access QGIS software. At each site (x, y coordinates), a relational table of attributes was associated with the following variables:

1) Presence (or not) and the type of (biodegradable or not) mark at the sampling site: B/BIO (presence of biodegradable mark); B/NBIO (presence of non-biodegradable mark); NB (no mark); and ND (no data).

2) Removed (or not removed) mark after finishing the study: YES (if the mark was removed), NO (if the mark was not removed), NA (not applicable; there was no marks).

3) Was there fauna material extraction? YES or NO.

4) Were there manipulative activities at the sampling site? YES or NO

We used Chi squared test to search for differences on these sampling points attributes on the PNA.

3. Results

3.1. Objective 1

After the extensive research and bibliographic digitalization, 360 documents were obtained, generated between the creation of the PNA in 1961 and 2016. This turned the digital library of Ñacuñán MaB Reserve into the first one of its kind in Mendoza. Sixty one percent [5]of the bibliographic reports recorded were papers published in index journals, followed by thesis and books (10 % each), technical reports and congress abstracts (7 % each), dissemination articles (4 %), and pro-

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[5] https://www.mendoza-conicet.gob.ar/portal/iadiza/paginas/index/areas-experimentales

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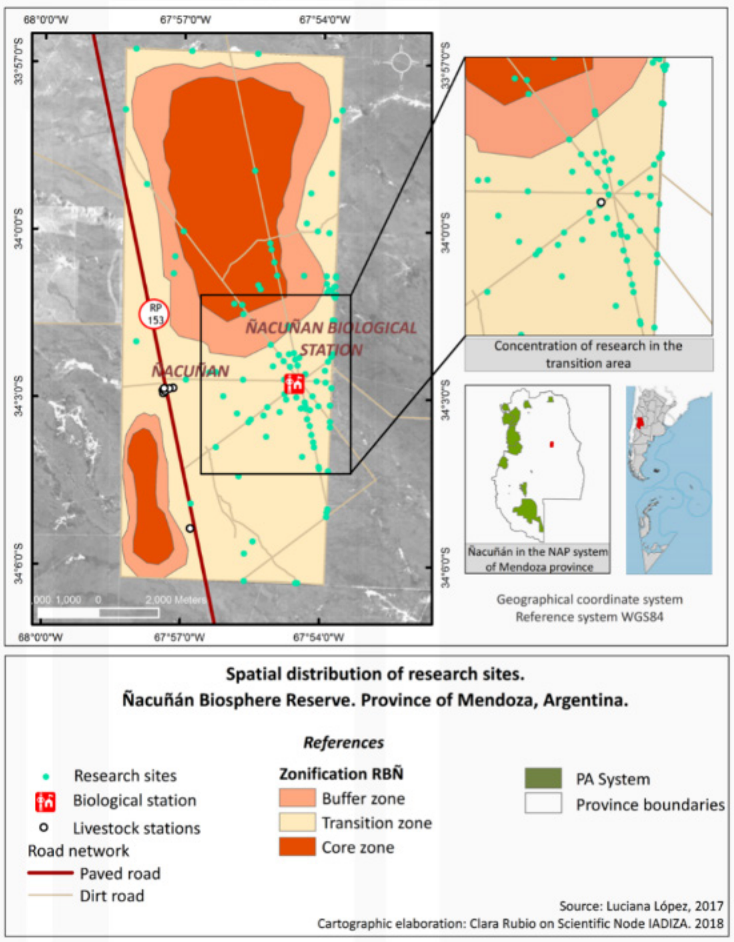
jects (1 %; χ^2= 653,54; p<0,0001). Most reported taxa were mammals (N = 126; 43,6 %) —small ones being the most represented among this group (69,09 %). Birds were the second most represented group (34,12 %), followed by insects (19,8 %), reptiles (1,5 %); and arachnids (0,8 %; χ^2= 92,41; p<0,0001).

3.2. Objective 2

Objective 2a) When we analyzed how the sampling sites spatial distribution of the investigations varied according to the areas defined in the PNA zoning scheme, we found that the largest number of research sites were located in the transition zone (N=185) and secondly in the core zone (N = 30; χ^2= 259,32; p <0,0001) (Figure 2). At the same time, 56 % of the sites of study were in the vicinity of the experimental station where scientists stay during the field work —within a radius of less than 3 km (area demarcated in Figure 2). The map shows the high density of projects in the area of influence of the biological station.

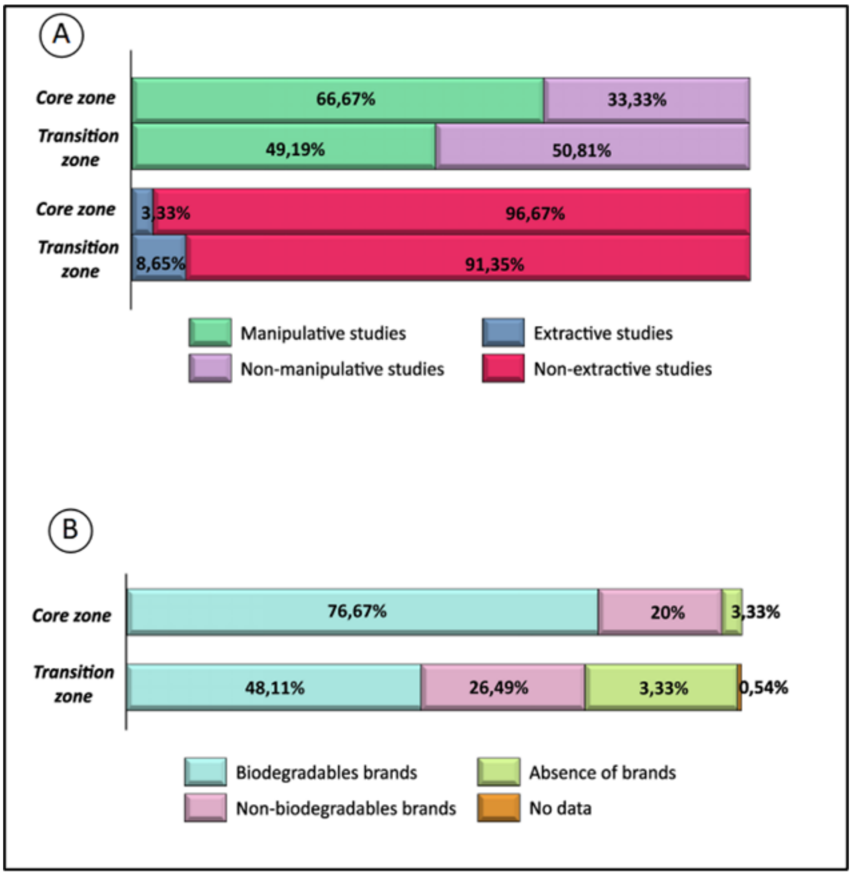
Figure 2. Ñacuñán Reserve zoning and distribution of the research sites (N = 220)



Source: López, L. (2017). Cartographic elaboration: Rubio, C. (2018).

Objective 2b) When we examined the variation in the number of sites where the researchers carried out extraction and / or manipulation activities, we found that most studies were manipulative (66,67 %) and non-extractives (96,67 %), both in the core and transition zone (manipulative = 49,19 %; non-extractive = 91,35 %) (Figure 3A). In the buffer zone, only five sites of study were recorded and just two of them were manipulative and non-extractive projects.

Figure 3. Type of research and marks used according to the MaB Reserve Zoning. 3A) Relative frequency of research sites with manipulative/non-manipulative studies and extractive/non-extractive studies; 3B) Relative frequency of research sites according to the type of marks used on each zone of Ñacuñán Reserve.



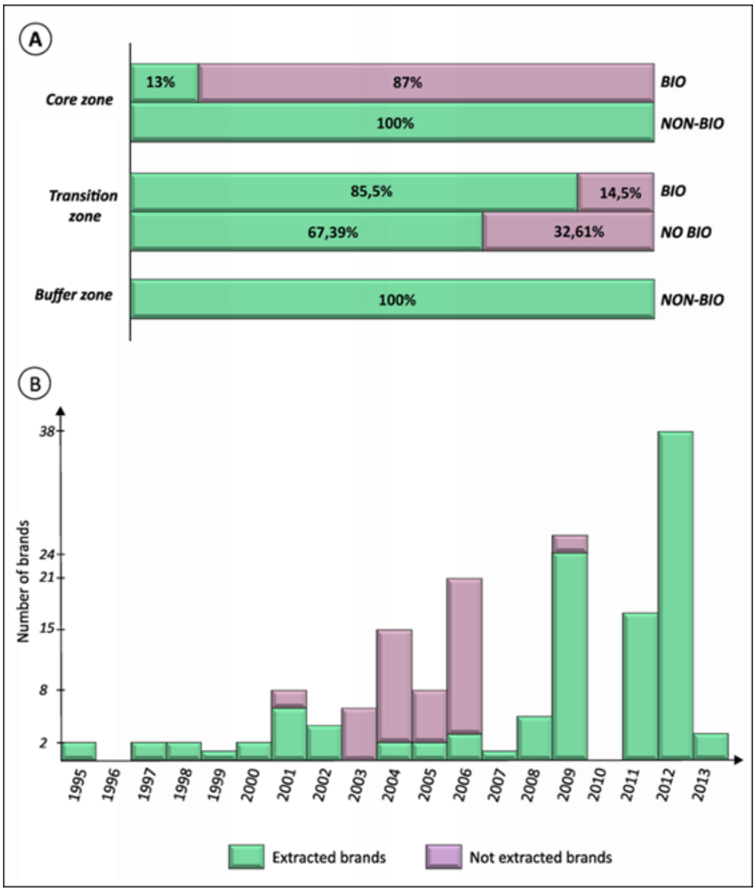
Source: Own elaboration

Objective 2c) The analyses of the investigations revealed that most of the marks used were biodegradable in the core zone (76,67 %; $\chi^2 = 22,7$, p<0,0001) (Figure 3B), as well as in the transition zone (48,11 %). Non-biodegradable marks were mostly recorded in the transition zone (24,86 %; $\chi^2 = 22,7$, p<0,0001) (Figure 3B). Non-biodegradable marks were used only in two of the five sites at the buffer zone, while no marks were used in the remaining ones.

Objective 2d) Finally, the analyses of the quantity and location of the marks removed (or not) from the PNA after the research project was completed showed that in the core zone 87 % of the biodegradable marks (20/23) still remained in the PNA after the end of the project —they were not extracted, while 100 % of the non-biodegradable marks were extracted. At the same time, 77 biodegradable marks (86,51 %) and 31 non-biodegradable marks (67,39 %) were extracted after the end of the project in the transition zone. Lastly, two sites registered non-biodegradable marks in the buffer zone, which were extracted at the end of the investigation (Figure 4A).

Regarding not-extracted biodegradable marks, the main material was wood (Figure 4A) and were located in the core zone (20 sites) and in the transition zone (12 sites). When revisiting the extraction/non extraction processes from the creation of the PNA to the present, there is a growing tendency to remove the marks from the field after finishing research projects, whether these are biodegradable or non-biodegradable marks (Figure 4B).

Figure 4. A) Research sites with extracted/not extracted marks, according to the type of brand used and its location in the zoning scheme of Ñacuñán Reserve. B) Temporal evolution of marks extraction process (according to the year of papers publication).



Source: Own elaboration

4. Discussion

Ecologists and conservation biologists mainly develop research programs in order to understand how different processes affect natural systems and hence to find a way to revert degradation developments towards the preservation of nature and the creation of schemes for their sustainable management. Nevertheless, research activity is rarely evaluated as a process that could negatively affect natural systems. Results obtained from this work allow us to understand and visualize the way scientists are related to their object of study, the form of this interaction and its consequences. Man and Biosphere reserves set as an excellent model since their zoning system allowed us to spatially evaluate human-nature interaction using SIG tools and the efficacy of zoning classification at once. Our results highlight the importance and necessity of a complete data base of research activity on MaB reserves —such as the one created for Ñacuñán MaB Reserve— as well as the accurate spatialization of sampling sites, in concordance with the experimental type designed to avoid inconsistencies with approved activities and scientific waste.

As mentioned before, one of the most remarkable tools for MaB reserves management is its zoning scheme. The zones delimitation and their diverse range of use/management are based on the prior knowledge of plants and animals' communities of the reserve (Courrau, 1999; Claver & Roig-Juñent, 2001; Ontivero et al., 2008). Nonetheless, managers do not always have enough

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information of the system when they bound the zones, triggering the need of a periodic revision for a successful management (Cuello, Claver & Rubio, 2016). The databases referring to the investigations carried out in a PNA should be considered an important tool to define the knowledge gaps and the management priorities of the area —particularly on MaB reserves.

The analysis of the spatial distribution of the fauna sampling sites allowed us to detect the absence of fauna studies within the core and buffer southern zones. This could be due to the difficulties to access these areas since there is only one footprint —in poor conditions— to approach the area (Kufner & Claver, 1997). Within the transition zone, the highest concentration of sampling sites was found around the biological station of the PNA, where researchers stay. More than 50 % were in a radius less than 3 km apart from the biological station, mainly associated with roadsides. This data highlights the need to promote research programs in habitats distant from the biological station, hence decisions makers can have accurate information to manage the PNA. By having broad information, the existing zoning scheme could be revised from a systemic point of view, prioritizing those biological variables considered adequate —e.g.: biodiversity, richness, functional diversity, key species, etc.— (Oltremari & Thelen, 2003; Barber, Miller & Boness, 2004). It is worth mentioning that these knowledge gaps find their correlation on a regional scale. Abraham et al. (2009) warn about the need to deepen the studies on ecosystems which belongs to the Monte ecoregion.

The different zones of MaB reserves have differential —permitted and forbidden— uses and activities in order to organize the territory (Cifuentes Arias, 1992). This zoning should be updated with the increase of novel knowledge, following the 'adaptive management' premise (Maass et al., 2010). In the case of Ñacuñán MaB Reserve, our results indicate that uses and activities carried out by researchers at diverse zones do not correspond entirely to those permitted in each of them. For example, at the core zone there were registered several research projects based on a manipulative or extractive type of fauna´s management, even though these are not allowed according to what is established in the Reserve Management Plan. In the buffer zone, experimental studies are allowed according to the management plan. In neither the original MaB document of zoning or the actual management plan are descriptions of the prohibited and accepted experimental studies. In order to contribute to the effective management of the MaB Reserve, it is necessary to clarify and make explicit the scientific activities allowed and prohibited according to current zoning, not only to guide scientists who wish to carry out research, but also local administrators and the rangers.

Our research shows that scientists began to remove marks used for their research projects mainly after year 2009, which coincides with the initial presence of park rangers in the PNA. Since there are no written protocols on how to proceed, the extraction of used marks depends on the sole discretion of each scientist. However, the presentation of a final report —including results and news from the project— is mandatory by provincial legislation —Ñacuñán Reserve is co-managed by IADIZA and the Provincial government (DRNR, 2012). Failing on submitting such report implies the rejection on further scientific research permissions for any natural ecosystem in the province of Mendoza. In the past, the absence of coordination between both institutions caused inadequate management regarding this administrative process. Yet, since 2010 the co-management committee works on establishing new management resolutions. The results obtained from this research will be the bases for the zoning system revision, which will be included in the update of the PNA management plan.

Based on the current paradigm of socio-ecological systems, we analyzed the relationship between scientists —as key social actors— and Ñacuñán Reserve —as a biological system— based on Social Metabolisms Theory. According to this premise, scientists construct a relationship with nature —mostly driven by an academic, ecological or conservationist concern— by appropriating nature to resolve their interests (e.g. exclusion for small mammals or birds, extraction of feces or animals, experiments on diet selection with exotic seed on field, etc.) and generating waste (Toledo 2008; 2013). Waste is visualized as the residues not extracted from nature by scientists after finishing their study and can be visualized as liabilities or environmental debts. Although wood stakes are biodegradable, they have a slow degradation process, which will vary on the wood type and environmental drivers (Blanchette et al., 1990). Plastic tapes are non-biodegradable waste and remains for longer periods than wood.

When dealing with this social-nature interaction, the understanding not only of this interaction in one direction, but in both, as proposed by Henry Lefrebvre, in the context of the current macroeconomic global model (Saito, 2017; Napoletano et al., 2019), allow us to understand our results in the context of a metabolic rift. In this sence, Lefrebvre recognizes the existence of a rupture between society and nature related to pollution processes, waste generation (Lefrebvre, 2009) and soil depletion and alteration of biogeochemical cycles on a planetary scale (Tsuru, 1970). According to the "externalities" or "wastes" of scientific activity –the main object of this research-, their understanding can be conceptualized under the process of reciprocal degradation between society and nature proposed by Marx (Foster et al., 2019). Lefrebvre (2014) states that results of the processes of control of nature, under the expansion of capitalism, lead to the alienation and destruction of the latter (Foster, Clark & York, 2010). It also recognizes other negative impacts such as fragmentation, dispersion, externalization and exclusion, both in natural and social systems. Despite in our research of scientific-nature interaction the generation of waste was a common behaviour, we also have observed most recently that scientist had change their relationship with nature by extracting marks or using biodegradable marks during the last years.

Finally, it is important to highlight that this PNA reports a large amount of contributions compiled on the digital library, strongly essential for making suitable management decisions. It is also necessary to improve the communication channels between the different social actors —managers, researchers, and decision makers— in order to make right decisions regarding planning and management of the PNA at a normative level (Dávila, 2010; UNESCO, 2015).

5. Conclusions

The integrative framework developed in our research, that includes the socio-ecological approach joint with geographical and spatial analyses, allow us supporting the theoretical proposal of Napoletano et al (2015), by reflecting the spatial expression of interactions that occurs between scientists and nature on MaB Protected Areas. This reinforces the need to continue strengthening the integration of the socio-ecological approach and critical geography, promoting new interdisciplinary horizons that can be deepened in the future.

The analysis of the interaction processes between the researchers and nature allowed us to partially verify the hypothesis raised in this work. It is relevant to highlight that although the MaB reserve zoning system constitutes a favorable regulatory framework to spatially organize scientific-nature interactions, it is not always respected by researchers who often incur in the origination of negative externalities or environmental liabilities. Particularly, regarding the hypothesis that

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fauna research is primarily located at the transition zone due to its greater accessibility, our results confirm this assertion and highlight the absence of a core-area defined by scientific knowledge to supports their status.

The impact generated by researchers at MaB Reserves is of great relevance to the sustainable management of the protected area system. Specifically, the case of Ñacuñán MaB Reserve gains relevance considering that it is co-managed by a research institute and a government entity, and because it constitutes the preferred research area for a significant number of local and foreign scientists —for more than 60 years to the date. The systematization of all the investigations carried out in a digital library, together with the creation of a geographic information system that gathers the fundamental variables of each one, provides essential information inputs for the identification of knowledge gaps in the socio-ecological system of the PNA. On this basis, and with the pursue of conservation of biodiversity and the sustainable development of ecosystems, the design of future research programs will be necessary for MaB Reserves. These programs should have the responsible participation of the scientific sector, supported by PNA managers and decision-makers in order to achieve the integration of local communities. Finally, we conclude that there is an important need to review the procedures carried out during the development of research projects in MaB Reserves and to ensure clear protocols in order to minimize and / or avoid the externalities of scientists.

Finally, it is important to highlight the great utility that this type of approach and analysis supposes for all MaB Reserves, since it contributes closely to the process of periodic updating of the zoning schemes established by UNESCO's MaB Program, by providing solid foundations oriented to the fulfillment of the guidelines of said program. The systematization of the scientific knowledge generated in each MaB Reserve could be replicated on a national scale, in order to create an integrated information system at the regional level, which allows defining conservation priorities from a systemic ecoregional approach.

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