Traditional Ecological Knowledge on wildlife as a subsidy for Ecosystem-based Management in Brazilian protected areas

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Abstract
Ecosystem-based Management (EBM) has been a widespread approach focusing management actions on maintaining a healthy, productive and resilient ecosystem, particularly in protected areas. Despite success in other countries, this approach is poorly studied and rarely used in Brazilian protected areas (PA) – most of them showing conflict between traditional people (e.g., Caiçaras) and PA managers due to these people use of natural resources, such as wild animals. Although hunting is prohibited in most part of Brazil, it may be allowed within sustainable-use PA, if managed to ensure both resource conservation and people subsistence. In this paper, we explore the use of Traditional Ecological Knowledge (TEK) of local communities as a subsidy to develop EBM focusing on wildlife within PAs in Brazil. We carried out semi-structured interviews with 39 residents and four local experts from a Caiçara community living within a PA in the Atlantic Forest of southeastern Brazil in order to understand their use and knowledge of wildife. We also carried out semi-structured interviews with 10 managers and staff of this PA to assess their willingness to take TEK into account an EBM plan. The community has its own management system, known and respected by the locals, in which hunting is allowed only during winter months (March to July), when game is fat and not reproducing. Caiçara often leave fruit in the woods to fatten the animals during the winter. Their main interests in wildlife include a source of food, medicinal use and as Pets. Conflicts emerging from wildlife inside Caicara communities relates to disturbances of vegetable gardens, consumption of domestic animal and human fear. Based on the prevalence of use and conflicts 10 species were selected to further explore TEK related to them for EBM. These include: the mammals paca (Cuniculus paca), agouti (Dasyprocta leporina), opossum (Didelphis sp), armadillo (Dasypus sp.), coati (Nasua Nasua), deer (Mazama americana), collared peccary (tajacu peccary), monkey (Sapajus nigritus) and ocelot (Leopardus sp.); the birds guan (Penelope obscura), macuco (Tinamus solitarius), toucan (Ramphastos sp.); and the reptile tegu lizard (Tupinambis merianae). Seven out of the ten PA staff interviewed believe TEK is an important factor to consider for management; they also understand that it is necessary to make new management arrangements and provide alternatives to hunting for local communities in order to ensure the wildlife conservation and local livelihoods. Main suggestions for management include formalize local Caiçara hunting rules through legal agreements; create other necessary rules under a systemic view; clearly define species that can be hunted and those that need conservation measures or population studies; and propose participatory community monitoring, using the community as partners in protecting animals from other threats such as poachers and wildlife traffickers. Wildlife uses and conflicts in Brazilian PAs are real issues and cannot be neglected. Our study highlights TEK relevance in providing critical information for EBM in protected areas in Brazil.

Keywords: Terrestrial vertebrates, Conservation, Hunting, Local Knowledge, Caiçara Community; Brazil

INTRODUCTION

Ecosystem-based Management (EBM) emerged as a response to natural resources management practices that achieve little success. While management theories and approaches focused on a few species, predetermined numbers for withdrawal (quotas) and ways to control environmental changes, their limitations highlighted the urgent need for more successful solutions and models for natural resources management (Holling & Meffe 1996). With the recent understanding of ecosystems as complex adaptive systems, since the 90's, EBM has been gaining attention regarding protected areas management (Slocombe 1998; Hooker &

Gerber 2004; Arkema *et al*. 2006). EBM approach postulates focus management efforts in maintaining a healthy, productive and resilient ecosystem in face of disturbance, thus ensuring the maintenance of biodiversity and ecosystem services provision (Slocombe 1993; McLeod *et al.* 2005; Chapin *et al.* 2009; McLeod & Leslie 2009).

The authors suggest that we should adopt a flexible management strategy, aiming to maintain the capacity of ecosystems to absorb disturbance and reorganize, preserving essentially its structure and function (Walker *et al.* 2004; McLeod & Leslie 2009). A successful EBM needs to be based on principles compatible with those of the local community, as well as to be integrative, comprehensive and participative by involving different groups of actors and their goals. Still, there is the need to work with complexity, to be dynamic in order to accept change, as well as transdisciplinary, applicable and adaptive, progressing with system and knowledge changes (Slocombe 1993; Slocombe 1998).

In Brazil, protected areas are historically poorly (or sometimes not at all) managed. In relation to the management of wild animals, the scenario is not different. Hunting has been a forbidden activity since 1967 (Brazilian Federal Law n° 5.197), allowed only for subsistence matters (since 1998, with the Brazilian Federal Law nº 9.605), which poses a very controversial issue. Nowadays, because there are no subsistence or management options for local communities, hunting monitoring is inefficient and laws are controversial, between others issues (Wallauer 2003), wild animals are stuck in a Tragedy of the Commons, as open access resources (Hardin 1968). However, Brazil has a large number of traditional and local communities that hold an extensive body of ecological knowledge, including the knowledge about wild animals. In addition, traditional communities around the world have been practicing sustainable use of wild animals for generations through rules and management that avoid indiscriminate use (Feeny *et al.* 1990). An example are the traditional communities of Caiçaras who live along the Brazilian southeastern coast, both inside and around protected areas.

Caiçara people are mostly farmers and fishermen who interact with the environment through agriculture, small-scale fishery, hunting and wild fruits gathering (Diegues *et al.* 1999; Marcilio 2006). In these communities, particularly in the remote ones, hunting is a secondary source of protein, still important as a nutrition supplement (Hanazaki *et al.* 2009). In Brazil, cultural motivations and food insecurity are the main reasons for the persistence of hunting activities, despite being illegal (Alves *et al.* 2009). Moreover, Caiçaras consider wild animals as resources, for medicine or handicraft, and as enemies, when they feed on domestic animals or threaten human health (Seixas & Begossi 2001). These interactions and the knowledge resulting from them are known as Traditional Ecological Knowledge (TEK).

TEK is known as the accumulation of knowledge, practices and beliefs about the relationship of living organisms with one another and with the environment (Berkes 1999, p. 7). Currently, TEK is recognized as positive for biodiversity conservation and for increased resilience of socio-ecological systems (Berkes & Folke 1998; Berkes *et al.* 2000). This happens partially because TEK is a dynamic, cumulative and adaptable to changes knowledge, which is built by experience, making it possible to monitor, interpret and respond to ecosystem dynamics (Berkes 1999). For EBM, the recognition of the interactions between traditional communities and wild animals, and the TEK accumulated based on them, are imperative for an effective and socially just management of protected areas, especially in areas that are poorly developed (Reichel-Dolmatoff 1976; Slocombe 1993; Slocombe 1998; Berkes & Folke 1998; Curtin & Prellezo 2010; Leme & Begossi 2013). In this sense, this research aimed to generate information from TEK raised in a Caiçara community, in order to support the development of an EBM approach, focused on wild animals in a protected area on southeastern Brazilian coast.

STUDY AREA

We conducted this study in the Caiçara community of Praia do Sono, located within the Juatinga State Ecological Reserve (JSER) in the municipality of Paraty, Rio de Janeiro state, Brazil. Restricted access to the community (reached only by boat or trail) resulted in a historically intense use of natural resources. The community of Praia do Sono has 314 inhabitants, which is equivalent to 22% of JSER population. JSER is a no-take protected area with over 1500 inhabitants (Silveira & Brandão 1991). Since 2010 JSER has been undergoing a re-categorization process to adapt to federal legislation (Lei Federal nº 9.985 de 2000) which may modify the relationship of communities with subsistence resources such as wild animals. Currently, there is a manager for the area, but there is no place for community participation or for a local management council.

DATA COLLECTION

We collected the data between October 2013 and June 2014, making use of three types of interviews: **i)** Semi-structured interviews with 39 Caiçara family units to investigate economic damages, threats to human health, uses, management and conservation of fauna in the community; **ii)** Structured interviews with seven key informants of the community (only men between 23 and 84 years), for correlation between popular (used in the community) and scientific (from a survey conducted in the area) names; **iii)** Semi-structured interviews with four key informants of the community (only men between 45 and 84 years), to investigate TEK on biology and ecology of 13 wild animals identified in the first interview as important to be managed in the Reserve (**Table 1**). Data also include informal conversations and direct observation of community activities.

We analyzed data through a qualitative-quantitative methodology, which includes coding, organization and triangulation of qualitative data, as well as descriptive statistics of the quantitative data (Seixas 2005). All information collected is discussed according to the Ecosystem-based Management approach framework (Slocombe 1993).

Table 1 - Thirteen wild animals selected as relevant to the conservation and management in JSER and the criteria for their selection

Species	Criteria for selection
Mammal	
Cuniculus paca, Dasyprocta leporina, Didelphis sp. Nasua nasua e *Pecari tajacu*	Highly nominated as game animals; Hunted because of damages to agriculture and animal husbandry.
Dasypus sp. e Mazama americana	Highly nominated as game animals; Indicated as in alarming population decline
Sapajus nigrittus	Indicated as in alarming population decline
Leopardus sp.	Hunted because of damages to animal husbandry and fear; Because of its ecological function
Bird	
Penelope obscura e Tinamus solitaries	Highly nominated as game animals; Indicated as in alarming population decline
Ramphastos sp.	Demanded as pet; Nominated as game animal
Reptile	
Tupinambis merianae	Hunted because of damages to agriculture and animal husbandry; Evidence of abnormal population growth; Nominated as game animal.

RESULTS AND DISCUSSION

Uses, treats and damages

The use of wild animals as food is still an intensely practiced activity and an important source of protein, highlighting its relevancy to Ecosystem-based Management (EBM). Religious, handicraft and pet uses are practically non-existent, while those regarding medicinal purposes uses manly lizard-Tegu (*Tupinambis merinae*), which is an abundant species in the region (**Table 2**). Yet, current use of home remedies has decreased considerably as now access to Paraty municipality is easier and the younger generation is increasingly losing touch with TEK.

Terrestrial wild vertebrates historically consumed in community of Praia do Sono are mammals (58.5% of mentions), birds (25.5%), reptiles (13.5%) and amphibians (2.5%) (**Table 2**). Because they are game animals, they are greatly threatened, which highlights the need to have their populations monitored. Interactions between hunters and these species facilitate registration of their population abundance, for example, through participatory monitoring (Constantine *et al.* 2008). Feeding on wild animals, before JSER implementation, was considered relevant by 92.3% of households interviewed. Currently, five people understand that there is still hunting for food in the community and in JSER, especially during winter, when tourism is scarce and families have no money to buy food. In contrast, twenty people believe that hunting is an almost or even completely abandoned practice in Praia do Sono. It is worth noting that legalization of traditional hunting and implementation of management are not incentives to practice, but an acknowledgment of actual activities and an attempt to ensure conservation of biodiversity and Caiçaras communities.

Food preferences and animal appreciation, as well as taboos and informal institutions of restriction are cultural concepts that promote wildlife conservation directly or indirectly (Colding & Folke 2001). In community of Praia do Sono we found preferences for herbivorous (e.g. agouti, paca) and tastier (e.g. brocket deer, collared peccary) animals. Unappreciated animals are the ones considered less tasty (e.g. Capuchin monkey and ocelot) or that cause aversion (e.g. frogs). Others, though, are thought as having a good relationship with the community (e.g. lizards – do not bother and eat insects –, birds – sing beautifully). Food taboos found due to food chain (e.g. lizards and opossum – feed on garbage), threats to human health (porcupine – skin inflammation), toxic substances (e.g. snakes – poison), symbolism such as predictions of bad luck (e.g. turkey vulture - *Coragyps atratus*- and black vulture - *Cathartes aura*) and religious customs (e.g. animals that are caught in specific traditional traps).

Table 2. Citations regarding uses of wild animals by Caiçaras and regarding threats and damages caused by wild animals to Caiçaras (n = 39): feeding uses (Fee); religious uses (Rel); medicinal uses (Med); craft uses (Craf); pet uses (Pet); damage to agriculture (Agr); damage to animal husbandry (Hus) and threat to human health (Thh).

Popular names in Brazil	Scientific names*	Uses					Threats and demages		
		Fee	Rel	Med	Craf	Pet	Agr	Hus	Thh
Mammals									
Cutia	*Dasyprocta leporina*	**22**	**-**	**1**	**-**	**3**	**9**	**-**	**-**
Paca	*Cuniculus paca*	**18**	**-**	**-**	**-**	**-**	**6**	**-**	**-**
Tatu	*Dasypus novemcinctus* e *Euphractus sexcinctus*	**16**	**-**	**-**	**1**	**3**	**-**	**-**	**-**
Gambá	*Didelphis sp.*	**14**	**-**	**1**	**-**	**-**	**-**	**27**	**-**
Coati	*Nasua nasua*	**12**	**-**	**1**	**-**	**3**	**-**	**-**	**-**
Porco-do-mato	*Pecari tajacu* e *Tayassu pecari*	**7**	**-**	**1**	**-**	**-**	**4**	**-**	**-**
Cachorro-do-mato	*Cerdocyon thous*	**5**	**-**	**-**	**-**	**-**	**-**	**2**	**-**

Popular names in Brazil	Scientific names*	Uses					Threats and demages		
		Fee	Rel	Med	Craf	Pet	Agr	Hus	Thh
Tamanduá	*Tamandua tetradactyla* e *Myrmecophaga tridactyla*	**4**	**-**	**2**	**-**	**-**	**-**	**-**	**-**
Macaco	*Alouatta guariba clamitans, Brachyteles arachnoides, Callithrix aurita e Sapajus nigritus*	**4**	**-**	**1**	**-**	**7**	**-**	**-**	**-**
Capivara	*Hydrochoerus hydrochaeris*	**4**	**-**	**1**	**-**	**-**	**10**	**-**	**-**
Veado	*Mazama americana*	**4**	**-**	**-**	**-**	**-**	**2**	**-**	**-**
Mão-pelada	*Procyon cancrivorus*	**4**	**-**	**-**	**-**	**-**	**2**	**2**	**-**
Ouriço	*Coendou spinosus*	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Preguiça	*Bradypus variegatus*	**3**	**-**	**1**	**-**	**-**	**-**	**-**	**-**
Onça/Jaguatirica	*Leopardus tigrinus, L. pardalis, Puma yagouaroundi, Puma concolor e Panthera onca*	**2**	**-**		**2**	**-**	**-**	**8**	**17**
Lontra	*Lutra longicaudis*	**-**	**-**		**-**	**-**	**-**	**2**	**-**
Birds									
Jacu	*Penelope obscura*	**18**	**-**		**-**	**-**	**-**	**-**	**-**
Macuco	*Tinamus solitarius*	**8**	**1**		**-**	**-**	**-**	**-**	**-**
Jurita	Columbidae	**6**	**-**		**-**	**-**	**-**	**-**	**-**
Tucano	*Ramphastos vitellinus* e R. *dicolorus*	**6**	**-**		**1**	**3**	**-**	**-**	**--**
Sabia	*Turdus sp.e Mimus saturninus*	**5**	**-**		**-**	**-**	**-**	**-**	**-**
Uru	*Odontophorus capueira*	**4**	**-**		**-**	**-**	**-**	**-**	**-**
Inhambu	*Crypturellus obsoletus* e *C. tataupa*	**4**	**-**		**-**	**-**	**-**	**-**	**-**
Saíra	*Tangara sp.*	**-**	**-**	**-**	**-**	**18**	**-**	**-**	**-**
Sabiá	*Turdus sp. e Mimus saturninus*	**-**	**-**	**-**	**-**	**15**	**-**	**-**	**-**
Periquito	*Brotogeris tirica*	**-**	**-**	**-**	**-**	**13**	**-**	**-**	**-**
Papagaio	*Amazona sp.* e de outras regiões	**-**	**-**	**-**	**-**	**9**	**-**	**-**	**-**
Coleiro	*Sphorophila sp.*	**-**	**-**	**-**	**-**	**4**	**-**	**-**	**-**
Trinca Ferro	Saltator similis	**-**	**-**	**-**	**-**	**4**	**-**	**-**	**-**
Tiê sangue	*Ramphocelus bresilius*	**-**	**-**	**-**	**-**	**3**	**-**	**-**	**-**
Curió	*Sphorophila angolensis*	**-**	**-**	**-**	**-**	**3**	**-**	**-**	**-**
Gavião	Acciptridae	**-**	**-**	**-**	**-**	**-**	**-**	**5-**	**-**
Reptiles									
Lagarto-teiú	*Tupinambis merianae*	**20**	**-**	**24**	**-**	**-**	**-**	**12**	**-**
Serpentes	-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**4**
Serpentes venenosas	-	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**24**
Tartaruga/ cágado	Chelonia	**7**	**-**	**2**	**1**	**-**	**-**		**-**
Anphibians									
Sapos e rãs	Nura	**5**	**-**		**-**	**-**	**-**	**-**	**-**

*Probable scientific names taken from a fauna survey carried out in the area and correlated through structured interviews with key informants.

Data collected shows that many animals no longer consumed, used to be so in the past. This change in the use of animals in the community of Praia do Sono was mainly caused by the increase of community income due to tourism, which reduced the need to consume less appreciated species. Development of food taboos has very positive consequences for the persistence of populations that are not consumed, but can negatively affect species that become more targeted for consumption. Still, abandonment of hunting practices regarding some

animals, or as a whole, reflect the loss of TEK, possibly leading to an indiscriminate use of fauna and lack of monitoring (Folke *et al.* 2007; Gadgil *et al.* 1993).

To 89.7% of households interviewed, at least one animal species damages or has damaged some of the community's subsistence activities. Despite its prohibition, agriculture is still practiced in the Reserve, and 48.7% of the households confirmed the existence of some damage in agriculture caused by mammals (**Table 2**). In order to avoid the farm losses, 17.9% of households reported that some people in the community prefer to kill the animals. With regard to damage occurring in animal husbandry, 74.3% of households claim that at least one species of wild animal causes damage, especially mammals, and 17.9% admitted that community members kill the animals as a way to solve the problem. Both agriculture and animal husbandry are prohibited in JSER zone, although there is no supervision to this concern. If JSER re-categorization lead to the creation of a sustainable protected area, these two activities may become allowed again in the study area, which certainly will raise community dissatisfaction concerning wild animals.

Among households surveyed, 76.9% pointed that animals are considered dangerous or cause fear (**Table 2**). Solutions cited for "harmful" species control were killing snakes (n=9) and running or scare away big wild cats (n=5). With respect to snakes, among the 66.6% households who reported being afraid of the animal (n=26), 65.3% confirm that community as a whole kill snakes (n=16), of which 50% claimed to kill only poisonous ones (n=8). It is true that snakes threat human health and should be avoided. However, bites resulting from this interaction are rare (personal communication – JSER official), while killing is recurring. Therefore, larger studies are advised to understand the impacts of these deaths to snakes populations. Community discontentment with big cats is motivated by perceptions that do not correspond to reality, providing that attacks from such animals against humans are not reported in the protected area (personal communication – JSER official). Local removal of predators can result in a cascading effect on the lower levels of the food chain, changing its entire composition, including vegetation (Redford 1992; Estes *et al.* 1998; Crowder & Norse 2008). The importance of wild cats as top predators (Redford 1992) and the alarming size of their populations (Chiarello *et al.* 2008) cause great concern when considered predatory attitudes that, although resulting from intrinsic cultural relations and inherent human behavior, have no basis in real facts.

Currently, mitigation field regarding threats and damage caused by wildlife to human populations is considerably developed, particularly regarding to carnivores. Some solutions proposed in scientific literature to minimize damages to animal husbandry are: protecting domestic animals, especially young, old or pregnant ones, at night and in areas near forests; decrease hunting of carnivores' natural preys (so they can find more food in their natural habitats); and offer economic and fiscal incentives to locals who suffered economic losses (Marchini 2010; ICMBio 2013). Hunting carnivores motivated by fear highlights the need of public environmental education to demystify feline species behavior (since American species rarely attack people), and to raise awareness of their ecological roles to local and regional ecosystems (Marchini 2010; ICMBio 2013). When we consider a hunting management that aims sustainability for wild animal species and local communities, some abdications must be made on both sides, by environmental agencies and Caiçara communities. We have to find ways to minimize the impacts on populations of wild animals by preventing management actions, which are already very complex, from becoming processes even more complicated.

We identified, on JSER, other impacts that appear to have significant consequences in populations of wild animals, but are difficult to consider in a management plan. Domestic dogs and cats live freely by the beach and in the forests in the community of Praia do Sono, threatening the protected area's biodiversity, especially regarding mammals and birds. These sorts of impacts are widely reported in scientific literature (Reed & Merenlender 2011; Hughes

& Macdonald 2013; Ziller & Dechoum 2014; Rangel & Neiva 2014; Sampaio & Schmidt 2014) and should be prime concern for management in the Reserve. We also identified sport-hunting activities and withdrawal of wild animals to supply exotic culinary and wildlife trades (especially birds). To solve negative effects resulting from these activities, solutions presented so far consist in increasing surveillance by environmental agencies and encouraging Caiçaras and tourists to denounce this kinds of activities.

Traditional traps, weapons and hunting techniques

In community of Praia do Sono, the mains instruments used to capture wild animals are: *mundéu*, snare trap, Brazilian indigenous slingshot, ordinary slingshot and rifle. These traps and weapons are used by other Caiçara and indigenous communities in Brazil (Alves & Carvalho 2008; Hanazaki *et al.* 2009; Pereira & Schiavetti 2010; Pinto 2011). *Mundéu* (**Figure 1.A**) is a Brazilian indigenous trap, very similar to deadfalls traps used by North-American indigenous. This trap resembles to a cage made with bamboo, filled with heavy stones in its sealing, armed to fall on wild animals and capture them. Fruits are used to attract animals into the trap, primarily mammals, birds and reptiles of medium-sized. We analyze *Mundéu* as being a low impact trap to game populations, when used traditionally, because its characteristics allow only few individuals to be captured each day. The snare trap (**Figure 1.B**) consists of a rope knotted in a loop and placed in the sand, used mainly to catch birds attracted by baits placed in the middle of the loop. We analyzed this trap as causing low impact on animal populations, when used in a moderate way, due to the time that each animal takes to be capture.

A  B 

Figura 1. A. *Mundéu* (source: Hanazaki et al. 2009). B. Snare trap (source: http://triboescoteira.blogspot.com.br/).

Brazilian indigenous slingshot (**Figure 2.A**) and ordinary slingshot (**Figure 2.B**) are, both, weapons made of a stick in the shape of a "Y" and an "U", respectively, with an elastic tied to its edges. In community of Praia do Sono, these weapons are rarely used by adults, yet much used by children to shoot birds as a hobby. We analyzed these weapons as causing low impact on wild animal populations because of its low capacity to cause damage to animals and because children mainly use it. Unlike the instruments shown, the rifle (**Figure 2.C**) can be used indiscriminately for a long period, which may result in a greater impact on fauna populations, so we conclude that it is not desirable to encourage its use (Levi *et al.* 2009).

The impact that the traps have on wild populations is a key issue to be assessed on an EBM. It is essential to be clear what injury each instrument can cause to wild populations and, in a scenario were management hunting exists, which of these instruments use should be

encouraged or prohibited for traditional hunters. On this subject, we highlight two things to be considered. Although the traps have been classified as low-impact, when we wonder about species that are endangered, any impact on their populations can mean a major threat (Alvard *et al.* 1997; Bodmer *et al*. 1997). Moreover, in Brazil, the use of traps and weapons to hunt wild animals increases the penalty on the offender (since hunting is prohibited) under the Federal Law of Environmental Crimes (Brazilian Federal Law nº 9.605 de 1998).



Figure 2. A. Brazilian indigenous slingshot (source: Camila Islas 2014). B. Ordinary slingshot (source: ranchodostropeiros.blogspot.com). C. Espingarda (source: http://www.vetagris.com.br/)

A technique traditionally used in the community to attract wild animals is the provision of food in certain places of the forest, near hunting traps, for condition animals to feed nearby and also to fatten them to be hunted in the future (Sanches 2001; Araújo *et al.* 2008). This activity is also practiced in other Brazilian communities (Sanches 2001; Araújo *et al.* 2008; Rock-Mendes *et al.* 2005) and can be considered a traditional practice that sponsor biodiversity, as discussed by Berkes & Folke (1998). In community of Praia do Sono it was common to plant fruit trees specifically to fattening fauna. This type of activity, developed over generations of socioecological interactions, can increase environmental carrying capacity regarding wild populations. Small-scale agriculture historically held on Praia do Sono worked in the same way, although many times conflicts were generated because animals feed on crops. As discussed above, agriculture practice is currently prohibited and its gradual abandonment is resulting in a decrease of ecosystems capacity to support wild populations, as reported by informants. As JSER can change to a sustainable protected area category, agriculture can be allowed again and these questions argued above will need to be discussed for the new management plan.

Biology and Ecology of Wild animals

Key informants' TEK (from interview iii) reveals behaviors that are common to all thirteen animal species more deeply investigated (**Table 1**). TEK gathered from informants indicates a reproductive behavior of fauna, which consists of animals gaining weight in winter to lose it in summer during breeding season. In any management plan, the protection of animals in breeding season is one of the most significant strategies to ensure the replacement of animals in the wild at same rate, or higher than that before their removal (Bodmer *et al.* 1994;. Hooker & Gerber 2004; Ezcurra *et al.* 2009). Thus, it is essential to increase supervision on hunting, both traditional (for subsistence, practiced for Caiçaras) and illegal (sport and professional) practices, and on withdrawals of animals for wildlife trade during breeding season. In scientific literature, we found that animals such as opossum, paca and agouti may have more than one reproductive event per year (Gonçalves *et al.* 2014). However, a protection at least four-month-

long each year (breeding season of other species) already contributes to the replacement of these species in nature.

Another pattern reported by informants refers to the larger body size of males compared to females of the same species. According to experts on wild animals, this pattern is valid to almost all animal species, especially mammals. When compared with literature, this information is consistent for vertebrate species (Fairbairn 1997), in particular for animals like capuchin monkey, opossum and collared peccary (Cáceres & Monteiro-Filho 1999; Reis *et al.* 2006; Gonçalves *et al.* 2014). In an EBM, we should consider a prevalent hunt of males, since reproductive success of females is limited by its physiology, while the reproductive success of males is determined by access to females (Clutton-Brock 1988). However, sex ratio should not be ignored, because a very low number of males can result in fewer fertilized females and affect the recruitment of the species (Bodmer *et al.* 1994).

Still regarding body sizes, based on the theory of optimal foraging (Pyke *et al.* 1978) between different game species, and – considering human behavior –, smaller species are hunted at the expense of larger ones, only when their catch is much easier (Robinson & Bennett 2000). In other words, hunters, in general, only hunt certain small species of animals when the cost benefit relationship equals or exceeds the average return (Leme & Begossi 2013). This pattern has been found in tropical forests, where, in some human communities, most of consumed game meat comes from a small number of large species (Redford & Robinson 1987; Peres 2000; Robinson & Bennett 2000), while in other communities, the largest animals represent only 40% of consumed species (Bennett & Robinson 2000). In community of Praia do Sono, in the absence of large animals, such as brocket deer and tapir, small and medium sized animals are the most hunted ones, as agouti and coati. In this cost benefit relationship, we should also consider the effects of preferred meats. For an EBM, we should also consider that animals with higher biomass result in greater benefit for families that feed on them and, in this sense, fewer animals have to be hunted to meet communities' needs of nutrition (Robinson & Bennett 2000). However, large animals have slow growth strategies and invest in few reproductive events, which generates slow replacement of individuals (Peres 2000; Robinson & Bennett 2000). The withdrawal of large animals from nature can also affect predators that feed on them, therefore, needing to hunt more individuals to meet predators food demand (Dirzo & Miranda 1990; Redford 1992; Chiarello *et al.* 2008.).

In short, hunting of animals with larger body sizes within the same species (FitzGibbon 1998) and between species can lead to a selective pressure for smaller body sized individuals and species, which can affect their reproductive capacity and their functions in ecosystems, such as dispersion of large seeds (Peres 2000; Fritz *et al.* 2009; Estes *et al.* 2013). In addition, overexploitation of certain species can promote reduction of biodiversity, alter ecosystem resilience and affect availability of food resources for human populations that depend on wildlife to ensure their food sovereignty (FitzGibbon 1998; Robinson & Bennett, 2000). Therefore, it is preferable, for a successful management, that the hunting withdrawal of individuals from ecosystems to be diverse, regarding species and individuals of the same species, prioritizing animals with rapid growth strategy (Robinson & Bennett 2000).

In this context, considering the thirteen species selected in this study as specially relevant to JSER management and their specific characteristics (**Table 3**), we conclude that animals such as opossum, coati, collared peccary and macuco, which generate a considerable number of cubs per reproductive event (> 5), should have less impact on ecosystems when they are removed by hunting, because their replacement is faster. For animals such as paca, agouti and brocket deer, which conceive fewer animals per year, it is advisable to restrict the number of individuals that can be hunt (FitzGibbon 1998; Robinson & Bennett 2000). Although Caiçaras from community of Praia do Sono consume medium-sized animals, with high reproductive rate, as coati, opossum and collared peccary, they also consume animals as agouti,

paca and brocket deer, which can cause, according to data collected, considerable impacts on populations of *Mazama americana*, for example.

Table 3 - Summary of Traditional Ecological Knowledge gathered from key informants (n=4) about the thirteen wild animals defined as specially relevant to JSER management: scientific name (SN) and popular name in Brazil (NPB), conservation status (CS), existence of sexual dimorphism (SD), lonely or group behavior (L or G), reproductive rate (RR), type of power (A), Habitat (H)

SN and NPB	CS	SD	L or G	RR	FD	H
Dasyprocta leporina cutia	Almost threatened	Yes	Alone/couple	Low	Frugivore	Forest
Cuniculus paca paca	Vulnerable in the state	Yes	Alone/couple	Low	Frugivore	Forest
Didelphis sp. gambá	Least concern	Yes	Alone/couple	High	Omnivore	All
Dasypus sp. tatu	Least concern	Yes	Alone	Medium	Insectivoro us	hillside
Nasua nasua Coati	Vulnerable in other state	Yes	Group 10 to 20	High	Frugivore	All
Mazama americana veado	In danger in the state	No	Alone	Low	Herbivore	Forest
Pecari tajacu porco-do-mato	Vulnerable in the state	Yes	Group 10 to 30	High	Frugivore e herbivore	Forest
Sapajus nigritus macaco	Least concern	Yes	Group 10 to 30	Low	Frugivore e herbivore	Forest
Leopardus sp jaguatirica	Vulnerable	No	Alone	Low	Carnivore	Forest
Penelope obscura jacu	Insufficient data	Yes	Alone or group	High	Frugivore	Forest
Tinamus solitarius macuco	Insufficient data	Yes	Alone or group	High	Frugivore	All
Ramphastos sp. tucano	Insufficient data	Yes	Group 10 to 30	High	Frugivore	All
Tupinambis merianae lagarto	Not threatened	Yes	Alone	High	Omnivore	All

Population fluctuations of animals and their threat status are also key issues for EBM, mainly due to the functional role that these populations play in ecosystems (Slocombe 1993; Crowder & Norse 2008; Curtin & Prellezo 2010). Considering the 39 households surveyed, there were 110 mentions about population fluctuations of wild animals in the region, being 4.5% related to animals in general, 40.9% to mammals, to 23.6% birds, 24.5% to reptiles and 6.3% to amphibians. Regarding each taxon citations, 57.7% mentioned population decrease or disappearance of some species of mammal in the region, 69.2% of birds, 7.4% of reptiles and 42.8% of amphibians. It is consensus among Caiçaras wild animals' experts that agouti, capybara (*Hidrochoerus Hidrochaeris*) and lizard-tegu populations have increased in the last years in the region, what provides the opportunity to centralize hunt in these species over others that are threatened in JSER area, such as brocket deer and capuchin monkeys. In a management of wildlife is necessary to avoid extreme situations. In this case, wild animals populations cannot have their density decreased to the point that they have no relevance for ecosystems and hunting (Bennett & Robinson 2000).

Hunt, even when practiced traditionally, can cause impact in threatened wildlife populations, especially if we neglect inherited characteristics of species (Robinson & Redfort 1991; Redford 1992; Peres 2000; Crowder & Norse 2008). Thus, it is important to create rules that consider this information and which are understood and legitimized by the community (Slocombe 1993; Chapin et al 2009a.). With respect to brocket deer, many inhabitants of Praia

do Sono have this awareness, feeling sorry for the excessive hunting of the species and their population decrease and they agree that there should be some kind of protection to the animal.

Other reason why one should consider to protect game species from population decrease is to prevent extraction certain of sites known by hunters as source of species, either by legal means or by developing some informal rule within the own community, for the recovery of wildlife populations (Bennett & Robinson 2000). Bennett & Robinson (2000) suggest that local rules for protected this areas ("source" ones) are the only tools that can ensure persistence of game animals populations in places with little financial and human resources.

For animals that live in groups, such as collared peccary, coati and capybara, one must consider their hierarchical relationships, because, for some groups, it is a greater impact when the alpha male or female is hunted (Bennett & Robinson 2000) or when you have a concentrated hunt of the young ones (e.g. when they monitor the group or raze cubs) (FitzGibbon 1998). In these cases, it is essential to lean on TEK and scientific information to understand these relations and consider them in a hunting management. In the community of Praia do Sono key informants state that they can distinguish females from males of some wild animals species, but not all and not in all their age stages. Thus, as the identification and monitoring of wild populations is critical, as well as considering the age of hunted animals in this activities, interaction between managers and traditional hunters that possess TEK is essential, because, for example, when hunting is done by traps, the percentage of animals caught for each age group is generally correlated to their proportion in nature, reflecting the status of the population (Bodmer *et al.* 1997; Aquino *et al.* 2009). If only old animals of determined species are caught in traps, on detriment of young ones, it is possible that recruitment of this species is low. Therefore, monitoring of wild animals populations occurs naturally in hunters activities and this type of information are the key to decision-making regarding the management of wildlife.

Although it is very important to consider all information gathered about each species management, ecosystems are complex systems, which cannot be predicted just by knowing its parts. Thus, no matter what it is known about each species, when several factors are put into the equation, populations do not respond always as expected (Crowder & Norse 2008). Similarly, when a wild animal population suffers an impact from a predator population, the results of this interaction are felt not only by prey population, but also by all populations related them (Robinson & Redfort 1991; Crowder & Norse 2008). In this sense, interactions between species studied are a key issue for the EBM on JSER (Crowder & Norse 2008).

Accordingly, if an animal is preferred for hunting, there are greater pressures on its populations, which affects lower and higher levels of the food chain. Thus, for example, a human community ends up competing with big felines for the same prey. However, if other animals may also be preyed by big cats or the community, competition tends to decrease and both predators populations can be sustained (Wright 2003). Still, some species have greater adaptive capacity to impacts than others, due to physiological and behavioral characteristics, such as reproductive rate, feed preferences and sensitivity to habitat degradation, responding differently to predation, competition, mutualism and parasitism, for example (Robinson & Redfort 1991; Peres 2000; Crowder & Norse 2008). These different responses are not measured when we consider only connections between species (Crowder & Norse 2008). Top predators and ecosystem engineers are examples of species considered key species because their populations have greater impact on their communities and ecosystems (Robinson & Redfort 1991; Bennett & Robinson 2000; Crowder & Norse 2008), being especially relevant to EBM.

Other species and taxonomic groups to be considered in an Ecosystem-based Management

Besides the 13 selected species, three primate species stand to be managed: *Callithrix aurita, Brachyteles arachnoides* and *Alouatta guarita clamitans,* because of evidences provided by key informants on the decline of their populations caused by traditional and sport

hunting, as well as wildlife trade (RENCTAS 2001). *Puma concolor* and *Puma yagouaroundi* also need to be better studied, especially because there is little information about their populations, being indicated as decreasing locally, in the speech of informants, and in Brazil as a whole (Chiarello *et al.* 2008; Machado *et al.* 2008). At the top of the food chain, wild cats are the main actors of top down control (Crawshaw & Quigley 2002; Duffy 2003), so that those species have to be permanently monitored in management plans (Duffy 2003). Capybara (*Hydrochoerus Hidrochaeris*) also stands out for management because its population in JSER is reported as in constant increase, which may reflect in future problems for the protected area because this animal reproduces quickly (Alvarez & Kravetz 2006), its large body size results in few predators in the Atlantic Forest, while their groups can reach 40 animals, resulting in a high consumption of plants (Alvarez & Kravetz 2006; Martins *et al.* 2008).

We emphasize the importance of evaluating the follow species populations before discussion and implementation of a management plan in JSER, because all animals mentioned are impacted directly or indirectly by Caiçaras communities. Are they: *Tayassu pecari*, *Euphractus sexcinctus*, *Pteroglossus bailloni*, *Selenidera maculirostris*, *Tamandua tetradactyla*, *Myrmecophaga tridactyla*, *Sphiggurus villosus*, *Bradypus variegatus*, *Crypturellus obsoletus*, *Crypturellus tataupa*, *Patagioenas sp*. e *Leptotila sp.*, *Hydromedusa maximiliani*, *Acanthochelys radiolata*, snakes in general.

Traditional management rules

Generally speaking, there is only one traditional management rule in community of Praia do Sono, known as the "Caiçara rule" based on the reproductive behavior of the species discussed above, which 87.1% (n=34) of households interviewed reported to know. This rule postulates that during the winter months hunting is allowed for hunters from the community because it is the time when animals are not reproducing and their meat has better quality and greater fat accumulation. In summer, hunting is prohibited, as the animals begin to reproduce and give birth to their cubs, which results in a low quality meat and little body fat. In addition, hunt of cubs is considered by Caiçaras from Praia do Sono a serious offense and a violation of the sustainability of hunt. This rule is considered a time taboo, according to Colding & Folke (2001) and demonstrates the intricate socio-ecological relations resulting from TEK.

When questioned whether this rule is still known and legitimized in the community, 51.2% of households understand that the rule is legitimate. Informal institutions, known as restrictions that govern human interaction through verbal agreements (North 1990; Kiser & Ostrom 1982), as it is understood the “Caicara rule”, should be the leading basis for state agreements between managers and Caiçara communities for implementing EBM. As discussed previously, promoting wildlife protection during breeding season is one of the most important issues when considering the sustainability of wild animals populations and hunting itself, as reported by Caiçaras.

Possibilities of an Ecosystem-based Management focused on hunting in JSER

In Brazil, restrictive legislation results in preventing the essential dialogue about wild animals hunt, for both conservation and management of wild animals and food sovereignty of communities. This situation generates misinformation, unfounded opinions and a disarticulated governments and communities. In our point of view, Caiçaras can be seen as one species in the food web of JSER, regulating populations of wild vertebrates, mainly by a top down control, for a considerable time, as discussed for other communities by Folke *et al.* (2007) and Gadgil *et al.* (1993). As the traditional management in Praia do Sono was developed through trial and error, as well as symbolic and prescriptive relationships willing to reduce their impact, it is

possible that these interactions result in positive regulations for wildlife (Reichel-Dolmatoff 1976; Berkes & Folke 1998; Berkes *et al.* 2000). Informal management rules, such as "Caiçara rule" for hunting, can provide recovery of populations impacted by predatory activities (Colding & Folke 2001). Community can also allow increase in wild animals populations, by providing food, and thu increasing environmental carrying capacity, by supplying fruits as bait or with agriculture, or decrease in uncontrolled populations through targeted hunting. Recognizing and managing this system including humans as its integral part is what EBM proposes (Slocombe 1993; Curtin & Prellezo 2010).

The dynamic between human population, TEK and wildlife is critical to a protected area as JSER, which intends to preserve a healthy ecosystem with all its functions, but lacks infrastructure for gathering information through biological surveys. Currently, a large part of modern conservation has focused on legitimate natural resources use and management by human populations in order to foster its protection (Robinson & Bennett 2000), a conception of management that is also found in EBM. We emphasize that a management that intends to use TEK as subside to decision-making must recognize the limitations of its use. Not always the information gathered is a clear record of reality, therefore, it is necessary to gather researchers and traditional community to guarantee that management goals are, beyond legitimized by all participants, assertive, in consistence with JSER reality and, thus, effective.

It is worth noting that population studies should be conducted to assess status of wildlife populations here studied before any decision-making aiming to modify dynamics already established. Finally, a major step of the management after the implementation of an EBM focused on wild animals should consist of a monitoring of actions (Tallis *et al.* 2010). In agreement with all discussed, a participatory monitoring, which consists in a continued ecosystem evaluation carried out within local communities, is a very helpful tool that can support implementation of EBM on JSER (Guijt 1998). Some obstacles that may be encountered when implementing EBM approach are the conventional management approaches, still very rooted in Brazilian governmental structure; the little engagement that local and traditional communities can present, because of the receive from environmental agencies; and the infrastructure of JSER, very limited when compared to its area and the number of people living in it.

CONCLUSION

Traditional Ecological Knowledge (TEK) once again demonstrates its relevance, even in a community where its erosion is evident. Within information raised in community of Praia do Sono, we found demands and subsidies for developing an Ecosystem-based Management (EBM) focused on terrestrial vertebrate fauna. The existence of traditional traps, a complex rule of hunting regulation, taboos and biological and ecological knowledge about wild animals are themselves evidences of the importance of hunting for the Caiçara community and their capacity to understand various aspects related to management of local natural resources. Quite often, these people are excluded from discussions related to management, because of their lack of scientific knowledge, which is contradictory to EBM approach.

Data raised point to a traditional hunting of wildlife that has persisted for several generations, being in theory and to some extent, sustainable, although, according to the informants, populations of some animals have decreased (e.g. paca, capuchin monkeys, brocket deer), while others have increased (e.g. Capybara, Lizard), requiring more studies to prove this result. Due to restrictive legislation, hunt turned out to be a taboo, where some pretend not to do, while others do not appear to see, resulting in a distorted idea that hunting is no longer important to food sovereignty of Caiçara people. Although there are differences in JSER Caiçara community's needs (because of different access to tourism and, consequently, to

income), it is urgent this reality to be highlighted and openly discussed in JSER and in Brazil, to prevent Caiçaras and other traditional and local communities with low income to suffer in name of conservation.

In this sense, EBM can contribute to provide management for JSER, especially regarding hunting, because it relies on a systemic view that only comes to benefit protected areas, by seeking to ensure stability of wildlife populations and a healthy ecosystem as a whole, warranting its resilience and, thus, a better ability to deal with future threats. In addition, the importance of socio-ecological relations on ecosystems and of local and traditional ecological knowledge are clear, which is an especially relevant approach to Brazilian protected areas, replete with diverse people and knowledge.

Thus, EBM is a necessary approach, mainly for JSER, which does not currently have any management focused on wildlife. This phase of re-categorization is the most opportune time for the results of this work to bring a real contribution for fauna management and food sovereignty in the Reserve, as this is a rare moment in which a no taken protected area opens possibilities to Caiçara's communities and significant changes can occur. However, for the use of wild animals by communities to be sustainable, it is necessary to conduct more studies, such as monitoring wild populations and evaluating the impact of the withdrawal of these animals.

Finally, we emphasize again the damages to protected areas management arising from negligence of the relationship among traditional and local communities, living in or around these areas, and the wildlife. Because, though the opinion of environmental agencies and Caiçaras communities are diverging, Caiçaras hunting of wild animals for feed and motivated by threats and damages that wildlife cause is a reality in JSER, and so is the feed need of the population, especially the most remote. EBM is an approach that brings, much more than techniques or ways of doing, a different way of thinking about natural resource management, a first step beyond conventional management still very found in Brazil.

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