Conservation and Society 13(3): 254-264, 2015

Article

Participatory Monitoring and Management of Subsistence Hunting in the Piagaçu-Purus Reserve, Brazil

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Abstract

The Sustainable Development Reserve (RDS) model in Brazil provides legal context for monitoring wildlife with the involvement of local populations in gathering data and developing strategies for sustainable use. We present results of one year of self monitoring by hunters in five communities within the RDS-PP, discuss how the observed patterns reflect local hunting regulations, and suggest how this information could be incorporated into a formal management system. In addition to the offtake data, we interviewed hunters, inquiring about informal community hunting norms and agreements, and analysed the content of 19 rules in the reserve's management plan. 509 hunting events were recorded by 37 of the 104 families present (35%). Self monitoring permitted the evaluation of temporal and spatial fluctuations of hunting activities, notably regarding ease of canoe transport during the high-water season. Though communities have been apprehensive about developing regulations for subsistence hunting, one of the communities had developed a set of formal rules. Hunting for commercial sale to outsiders and restrictions on external hunters are concerns shared by the local population and the reserve management agencies. Such data and understanding are crucial to the management of protected areas in the Brazilian Amazon, where governance is often limited.

Keywords: subsistence hunting, protected areas, co-management, riverine populations, institutional arrangements, self monitoring, Piagaçu-Purus Reserve, Brazilian Amazon

INTRODUCTION

Hunting and other forms of wildlife use generate complex impacts in socioenvironmental systems, both from the point of view of the game species (Peres 2000; Levi et al. 2009; Endo et al. 2010) and the hunter (Bulmer 1967; Urton 1985; Robinson and Redford 1991; Shepard 2002). Management of such dynamic systems depends on institutional structures built around adaptive, participatory measures (Armitage et al. 2009) that provide a shared understanding between the parties involved in decision-making about wildlife use (Watson 2013). As more protected areas in Latin America have included local people in the decision-making processes, it has become increasingly important to build management systems that incorporate local knowledge and experiences (Berkes et al. 2000).

Hunting has been formally prohibited in Brazil since 1967 (Brazilian Federal Law No 5197, 1967), however it remains an essential element in the livelihoods of diverse indigenous and

Access this article online	
Quick Response Code:	Website: www.conservationandsociety.org
	DOI: 10.4103/0972-4923.170399

non-indigenous populations, especially in the Amazon (Peres 2000; Robinson and Bennet 2000). This gross contradiction between legislation and practice, literally relegating hunting to the realm of criminality, hindered any attempt at wildlife management in Brazil for decades. However a new opportunity has emerged in the context of the National System of Protected Areas, which gives inhabitants of Sustainable Development Reserves (RDS) the right to use natural resources and participate in management (SNUC 2000). Local knowledge and management practices are contemplated in the drafting of each RDS's Protected Area Management Plan, which 'establishes zoning and standards governing the land use and management of natural resources' (Brazilian Federal Law No 9985 of 2000, Article 2).

Participatory, adaptive management of wildlife use in protected areas requires efficient monitoring systems (Torgler et al. 2000) in order to understand patterns, track changes, and revise and update regulations. The goal is to contribute to the livelihoods of people who depend on wildlife harvest without endangering animal populations or their ecological functions. Monitoring programme should be designed to address impacts at appropriate temporal and spatial scales, while involving both scientific experts and local resource users (Ferraz et al. 2008; Luzar et al. 2011). Community-based monitoring is particularly relevant in countries where investment in research is limited. Participatory systems may shorten decision-making time frames (Danielsen et al. 2009), promote local autonomy in resource management (Constantino et al. 2012) and strengthen community resource rights (Funder et al. 2013).

Though the actual degree of local participation varies, numerous hunting studies in South America have demonstrated the importance of involving local populations in data collection, analysis, and even research design (Souza-Mazurek et al. 2000; Noss et al. 2004; Townsend et al. 2005; Marinelli et al. 2007; Constantino et al. 2008; Valsecchi 2012). By training hunters to record their own offtake, the spatial and temporal coverage of monitoring increases by several orders of magnitude over what is typically feasible for individual researchers during a single field season (Shepard et al. 2012). Such results, if reliable, can clarify the relative importance of different species to local users, predict ongoing impacts, provide robust comparisons of different hunting strategies across different environments and seasons, and also create a collaborative environment for developing management protocols (Campos-Rozzo and Ulloa 2003).

The RDS model in Brazil provides a legal context for developing systems for monitoring wildlife use, in which, local populations are protagonists in gathering data and developing strategies for sustainable use. This study presents the results of one year of self monitoring by hunters in Piagaçu-Purus, discusses how the observed patterns reflect informal local hunting regulations, and suggests how this information could be incorporated into a formal management system. The study was carried out in five *terra firme* (terra firme=portion of land that does not flood in the high-water season) communities within the RDS Piagaçu-Purus in the Brazilian state of Amazonas.

MATERIALS AND METHODS

Study site

The Piagaçu-Purus Sustainable Development Reserve (RDS-PP), created in 2003 by the State Government of Amazonas, is located along the Lower Purus River between the Purus-Madeira and Purus-Juruá watersheds (Figure 1), starting 223 km upstream from the city of Manaus. The region was heavily exploited for terrestrial and aquatic animals during the first half of twentieth century. Hunting remains an important subsistence activity for *caboclo*[1] residents of the RDS-PP and is practised in almost all communities of the reserve (Terra 2007; Muhlen 2008). According to Terra (2007), hunting plays a role equal to that of fishing and subsistence agriculture in nine communities of the RDS-PP. Over 50 species of terrestrial vertebrates are hunted, especially large ungulates and medium to large rodents. Hunters in these communities usually carry cartridge shotguns with calibres ranging from 16 to 32, but 20 calibre is preferred. The shotguns are mainly inherited from relatives or purchased secondhand among acquainted hunters. Ammunition are mostly prepared manually by hunters using gunpowder and lead shots bought or traded with fluvial merchants (*regatões*), fishing boats, or in city markets.

The RDS-PP circumscribes two indigenous reserves (TI Lago Ayapuá and TI Itixi Mitari), and is bordered to the south by the Abufari Biological Reserve (REBIO) and Nascentes do Lago Jari National Park (PARNA), forming a mosaic of protected areas governed by several different co-management regimes. The reserve is comprised of both flooded forests and upland *terra firme* landscapes; fully 56% of the area of the reserve is *terra firme*. The 834,243 ha reserve is divided into seven administrative sectors, representing management units with a certain degree of ecosystem (hydrological cycles, vegetation types) and socioeconomic (demographics, land use) homogeneity. The reserve contains 57 communities and 4,000 residents who fish, hunt, and practice small-scale agriculture and extractivism (Deus et al. 2003; Instituto Piagaçu 2010).

Since its creation, the RDS-PP seeks to conciliate natural resource use with socioenvironmental sustainability through participatory zoning of the territory (e.g., defining non-take vs. intensive use areas), and elaboration of rules to regulate use and access to resources. The process is overseen by the Management Council, composed of 15 government representatives and 19 civil society representatives including local leaders of the administrative sectors and trade unions[2]. Although compliance and monitoring are formally the residents' duty and the government's responsibility, most such protected areas in Brazil rely on non-governmental organisations or universities to carry out these functions (Seixas and Vieira,

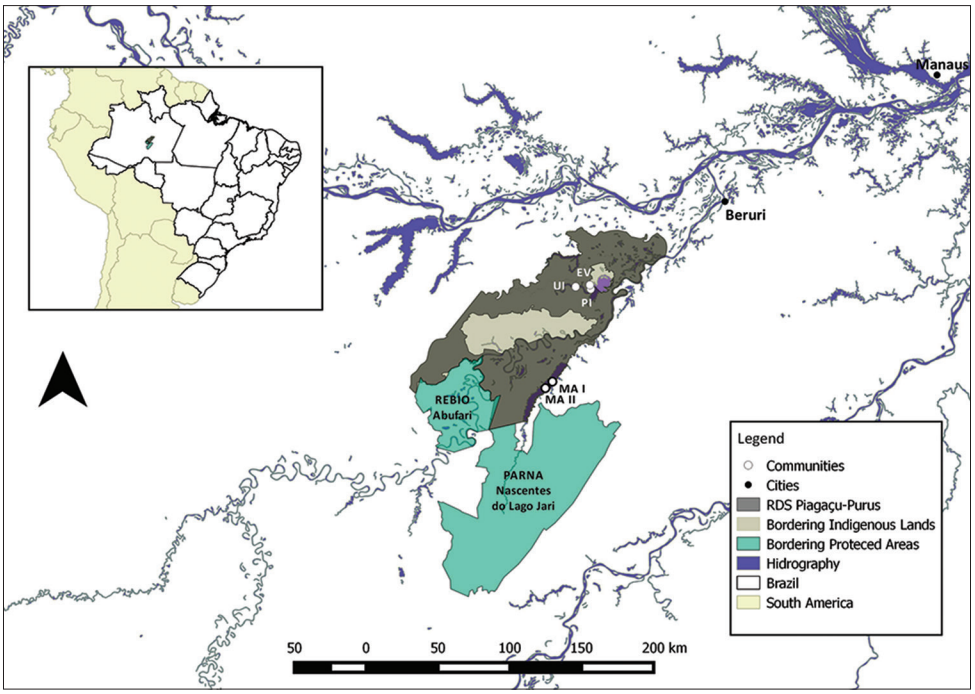

Figure 1

Location of the RDS Piagaçu-Purs and the five communities of the study: (UI) Uixi, (EV) Evaristo, (PI) Pinheiros, (MA I) Mari I, and (MA II) Mari II

2014). RDS-PP is no different, and monitoring is carried out mostly by the Piagaçu Institute. The process of zoning and regulating natural resource use in the reserve began in 2004 through a partnership between Piagaçu Institute and the Centre for Protected Areas of Amazonas State (CEUC/SDS). This initial survey concentrated on fishing resources in communities in the northern part of the reserve. The zoning process is still in progress, and aims to specify areas by sector for subsistence use, commercial management, and protection. During this process proposals are initially collected from each community, then a sector-wide unified proposal is discussed for approval by the Management Council. Currently the formal management plan for the southern part of the reserve is being finalized, and will require validation by the reserve's Management Council and approval by state authorities.

For this study, five communities situated in *terra firme* habitat were chosen, preselected based on their significant documented consumption of game animal meat (Terra 2007; Muhlen 2010). The communities of Uixi, Pinheiros and Evaristo are located in the Ayapuá sector, while Mari I and Mari II are located in the Jari-Arumã sector of the reserve (Figure 1). In the Ayapuá sector, the most recent settlement dates to the mid twentieth century, when a merchant settled to exploit rubber trees *Hevea brasiliensis* and Brazil nut *Bertholletia excelsa* (Agnello 1966). Older villages, mostly involved in the rubber trade in the early twentieth century, had grown gradually through the century as commercial exploitation of fish and wildlife intensified. In the 1960s, hunting was banned by the Brazilian Federal Law, but measures of control were only enforced after the creation of Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute of Environment and Renewable Natural Resources; IBAMA) in 1989. By this period, exploitation of natural resources began to decline, although it still represented the main income source for these populations. Nowadays, Brazil nut harvest and small-scale commercial fishing are the two main sources of income in Ayapuá. Uixi is the oldest and largest community in this sector, with 150 adult residents formally recognised in the 1980s, while Pinheiros and Evaristo have 90 and 12 residents, respectively. In the Jari-Arumã sector, the most recent settlement was established in the early twentieth century, associated with the exploitation of rubber, wildlife, and rosewood *Aniba rosaeodora*. Today, most of their income is derived from banana and manioc (cassava flour) agriculture. Mari I has 60 adult residents while Mari II has only 15. Mari I was formally recognized in the 1990s and Mari II was created from a dismemberment of Mari I in 2006 over religious (Catholic/Protestant) differences.

Data collection methods and analysis

Data on game animal harvest were collected in the five study communities between November 2011 and December 2012, taking advantage of the wildlife monitoring programme already put in place by the Piagaçu Institute. The voluntary programme sought residents willing to fill out self monitoring forms. All residents of the five communities were invited to participate during community meeting and individual house visits. Among 104 households visited, more than 70% were initially interested in the monitoring, but after a year,

only 37 families actually returned information about their hunting events. Most hunters had little schooling, but in every household there is at least one literate person (usually the wife or a school-aged child) who took responsibility for filling out the monitoring sheets. Participants were trained and monitoring sheets were collected in the field by Institute researchers at intervals no greater than 45 days. Individual accompaniment was carried out by a researcher visiting households periodically. In two communities (Uixi and Mari I) we also counted on one resident in each community who voluntarily took responsibility for concentrating the data. At the end of the monitoring year, meetings were held in each participating community to present the data and discuss results. Every monitor attended the meetings, allowing for a discussion of various limitations that were found in the data, for example, the extent to which monitoring underestimated actual hunting returns.

Participating families recorded the following information for each hunting event: 1) date, 2) time of departure and arrival, 3) number of hunters, 4) location of hunt, 5) success or failure, 6) number of animals taken by species 7) sex of animals; 8) if the hunt was independent or associated with other everyday activities (e.g., fishing, agriculture), 9) whether the meat was destined for subsistence or sale, and 10) means of transportation (e.g., walking, canoe). The data sheets used in this study was inspired by those used in other published studies (Souza-Mazurek et al. 2000; Noss et al. 2004; Townsend et al. 2005; Ohl-Schacherer et al. 2007) and further adapted and refined during community workshops in 2009. The sheets are illustrated with iconic representations of animals and other information, allowing people with minimal formal education to annotate basic data such as species and quantity.

In addition to the data on game offtake, we also carried out semi-structured interviews with knowledgeable hunters identified through snowball sampling (Bailey 1987) as indicated by other community members. We asked them to tell us more detailed information about traditional hunting norms and informal community rules and agreements. We also carried out content analysis (Bailey 1987) of the formal rules presented in the reserve's nearly complete management plan. We evaluated the proposed formal zoning maps for the Jari-Arumã sector to see how well they reflected field data. Finally, hunting data were evaluated for their potential utility in refining the measures proposed in the current management plan.

RESULTS

Self monitoring of hunting

In all, 74 of the 104 families (71%) from the five communities agreed to participate in self monitoring. Of these, about half successfully completed data sheets about hunting activities (Table 1). Between November 2011 and December 2012, a total of 509 hunting events were recorded by 37 families, representing 35% of the total families. 50 records describe unsuccessful hunting events, while 459 records describe successful hunting events (Table 1).

Table 1

Summary of households, number of participating monitors, and hunting events recorded

Community	Families	Proposed monitors	Effective monitors	Hunting events	
				Successful	Total
Uixi	42	25	11	197	206
Pinheiros	29	19	9	91	113
Evaristo	5	3	2	16	18
Mari I	22	21	15	155	172
Mari II	6	6	0	0	0
Total	104	74	37	459	509

The effective monitors (those who successfully completed data sheets) tended to be the most respected hunters in each community. In Mari I, the support of one resident regarded locally as one of the best hunters, and who had previously collaborated on other wildlife research, was essential for continued monitoring throughout the year. His personal support was clearly responsible for the high proportion of effective monitors in this community (15 of 22 total families). Uixi, the largest community, had a relatively lower participation of effective monitors (11 of 42 total families), but once again these were considered the most successful hunters of the community. In Uixi, the sharing and selling of game meat between neighbours is common, and appears to contribute to the emergence of specialized hunters who provide wildlife meat for those who spend more time in other harvesting activities. Animals are usually sold by 'quarters' for the medium sized species, or by kilo for large bodied mammals, with a maximum price equivalent to about USD 1 per kg. Payment in these cases is understood by community members not as profit per se but as compensation for the hunter's expenses, such as ammunition and fuel.

There were only two effective monitors in Evaristo, but these were again the two best hunters, responsible for distributing game meat to all families. In Pinheiros, the nine effective monitors also participated in other research and extension programmes promoted by Piagaçu Institute, likely contributing to their willingness to participate. All six families of Mari II agreed to participate in the monitoring, but none returned any hunting data. They claimed to have lost the data sheets during a heavy flood in 2012, when most were forced to move from their homes.

Considering only effective monitors, each family hunted an average of 13 times per year (SD = 10.6), or approximately one hunting event per month. One hunter reported only a single hunting event, while the greatest return was reported by a hunter with 48 records. On average, Uixi recorded 19 hunting events per family per year while Mari I, Pinheiros, and Evaristo recorded roughly half that amount, with 11, 10, and nine hunting events/family/year, respectively.

Of the 459 successful hunts, only three were marked 'for sale' and nine were marked both 'for consumption' and 'for sale', and the rest were marked only 'for consumption'. In the

two cases, where a jaguar or puma was hunted, the monitor wrote in 'self defence' as the justification for the kill, rather than marking one of the two options presented in the form: 'for consumption' or 'for sale'.

In Ayapuá sector, Uixi recorded 47 different hunting locations, Pinheiros recorded 35 and Evaristo, three. Of these 85 hunting locations, 23% were mentioned in seven or more hunting events. Though these communities are relatively close to each other, only seven hunting grounds overlapped. Mari I community in the Jari-Arumã sector reported using 32 hunting grounds, six of which included seven or more hunting events. Currently no formal land zoning proposals exist for the Ayapuá sector. However, residents of two of the three communities in this study agreed to protect a specific area at the head of Lake Ayapuá. Proposals for conservation areas and commercial and subsistence use areas have already been received from each community of the Jari-Arumã sector. There is agreement over approximately 50% of the area proposed for protection among three of the seven communities, including Mari I and Mari II. Two of the six hunting locations, most used by Mari I, are located within the protection area that three of the communities in this sector proposed, suggesting that community members already include hunting vulnerability in their criteria for management priorities. Indeed, the people of Mari I had already proposed a specific measure to regulate the use of a certain stream with especially high hunting pressure. Conflict emerged in an area of overlap with a subsistence area proposed by a fourth community, which did not feel the necessity to impose protected area since it is bordered to the south by a more strictly protected area, the REBIO Abufari. The disagreement between proposals reflects conflicts over resource use among users in the sector. A sector-wide unified proposal is required to solicit approval from the Management Council.

Overall 30 animal species were recorded, with 13 species of mammals, 10 reptiles, and seven birds (Table 2).

Of the 459 successful hunting events, 951 individual animals were killed, which corresponds to an average of two animals per hunting event. However, of the total number of hunting events (N = 509), more than half (53%) represented only a single animal, while 18% (N = 91) represented events with two animals, mainly spotted paca *Cuniculus paca,* white-lipped peccary *Tayassu peccary* and collared peccary *Peccary tajacu.*

Table 2

Offtake by species and community during a year of monitoring

Species		Community				
Scientific name	**Common name**	**Evaristo[a]**	**Pinheiros[a]**	**Uixi[a]**	**Mari I[b]**	**Total**
Cuniculus paca	Spotted paca	0	19	82	74	175
Tayassu pecari	White-lipped peccary	13	23	109	9	154
Dendrocygna autumnalis	Black-bellied whistling-duck	0	95	8	14	117
Pecari tajacu	Collared peccary	2	11	82	8	103
Cairina moschata	Muscovy duck	5	8	26	41	80
Mitu tuberosa	Razor-billed curassow	0	4	30	17	51
Podocnemis unifilis	Yellow-spotted river turtle	0	1	37	10	48
Dasyprocta fuliginosa	Black agouti	1	21	7	7	36
Lagothrix cana	Geoffroy's woolly monkey	2	0	19	13	34
Dasypus sp.	Armadillo	1	13	7	11	32
Mazama sp.[c]	Deer	3	4	10	9	26
Phalacrocorax brasilianus	Neotropic cormorant	0	14	3	0	17
Penelope jacquacu	Spix's guan	0	0	6	6	12
Tinamus sp.	Tinamou	2	7	1	1	11
Podocnemis expansa	South american river turtle	0	0	0	11	11
Tapirus terrestris	South american tapir	0	0	7	2	9
Hydrochaeris hydrochaeris	Capybara	0	3	3	0	6
Sapajus apela	Black-capped capuchin	0	1	3	1	5
P. onca or *P. concolor*[d]	Puma	0	0	1	3	4
C. crocodilus or *M. niger*[d]	Caiman	0	0	2	2	4
Peltocephalus dumerilianus	Big-headed amazon river turtle	0	0	0	4	4
Psophia leucoptera	Pale-winged trumpeter	0	0	0	3	3
Chelonoidis denticulate	Yellow-footed tortoise	0	1	2	0	3
Phrynops nasutus	Common toad-headed turtle	0	0	0	1	1
Leopardus pardalis	Ocelot	0	0	0	1	1
Accipter poliogaster	Gray-bellied hawk	0	1	0	0	1
Tigrisoma lineatum	Rufescent tiger-heron	0	1	0	0	1
Alouatta puruensis	Purús red howler monkey	0	0	0	1	1
Ardea cocoa	Cocoi heron	0	1	0	0	1
	Grand Total	29	228	445	249	951

[a]Communities in the Ayapuá sector. [b]Community in the Jari-Arumã sector. [c]Individuals of Mazama americana and Mazama nemorivaga are grouped and separated later by recall hunting. [d]Caiman and jaguar and puma are recorded in a generic way and individuals of these two species are grouped together.

The three hunting events with the largest number of individuals killed in the same event were black bellied whistling duck *(Dendrocygna autumnalis*), corresponding to 22, 16, and 15 individuals per event. These sporadic, high yield hunting events were responsible for increasing the overall average. However, offtake of aquatic reptiles may be underestimated, as these are considered locally primarily as fishing resources, rather than as game animals.

Of the game species hunted, only four are listed as threatened to some degree on the International Union for Conservation of Nature and Natural Resources Red List (IUCN 3.1): *Lagothrix cana*-Threatened, *Tapirus terrestris*-Vulnerable, *Tayassu pecari*-Vulnerable, and *Chelonoidis denticulata*-Vulnerable.

The data show that primate hunting is fairly limited overall. Hunters noted a preference for woolly monkey due to its flavour, while remaining species tend to be avoided either because of food taboos, or because of sense of unease at killing creatures so inherently human. There is no indication of over harvest of primate species. Many residents stated that once they had adopted any primate as a pet, they could not bring themselves to eat monkeys any more. References to infant monkeys' similarity to human babies and their human-like expressions and gestures were mentioned frequently by hunters to explain their avoidance of these species (Vieira 2013).

Of the total of 951 kills, the sex of 180 individuals was not identified in the records. Of these, 60% were events involving the black bellied whistling duck, which, like certain other bird species (*Mitu tuberosa*, *Cairina moschata*), does not exhibit profound sexual dimorphism. The main mammal species recorded (spotted paca, white-lipped peccary and collared peccary) showed sex ratio of 1:1. (Table 3).

Table 3

Sex ratio of the main species recorded (N>20 individuals killed)

Species	No. of kills	NI	F	M	Sex ratio*
Cuniculus paca	177	14	85	78	93
Tayassu pecari	154	0	74	80	108
Pecari tajacu	103	6	47	50	106
Cairina moschata	80	13	24	43	179
Mitu tuberosa	51	4	21	26	124
Podocnemis expansa	48	9	12	27	225
Dasyprocta fuliginosa	36	5	22	9	41
Lagothrix cana	34	1	13	20	154
Dasypus sp.	32	0	13	19	146
Mazama sp.	26	1	8	17	213
Total	711	53	308	350	NA

*Sex ratio is the ratio between the number of males for every 100 females.
NI: sex not identified; F: female; and M: male

The most commonly hunted species were spotted paca, white-lipped peccary, black bellied whistling duck, and collared peccary, a pattern similar to that found in other studies in the Amazon (Constantino et al. 2008; Valsecchi 2012). The relative importance of each species varied greatly depending on the hunting grounds, reflecting the travel method and the most common hunting techniques in each community (Table 4).

In Mari I, the most commonly taken species were spotted paca and muscovy duck, both associated with this communities frequent use of canoe transportation. Hunters mostly use canoes motorized with a small lawnmower style engine attached to a long propeller shaft (*rabeta*). They use boats to approach the best hunting spots, but continue by oar to avoid frightening the animals with engine noise. In these communities, most families spend the most part of the day engaged in agriculture and the production of manioc (cassava) flour. Hunting is preferentially carried out in canoes, either on the way to the cultivated plots in the early morning or at dusk, or else by spotlighting at night, especially when water level drops between July and September.

In the communities of the Ayapuá sector, hunters prefer to hunt during the day, often travelling by motorised canoe to the trail head of the hunting grounds. Hunting in groups to track white-lipped peccary herds is common, especially when water levels rise and the animals become stranded on *terra firme* islands. The black bellied whistling duck was hunted most often by members of Pinheiros, especially during the rainy season when they use hunting grounds in a flooded forest near the community where the ducks nest. Members of this community were also seen to hunt with dogs to flush black agouti *Dasyprocta fuliginosa,* armadillo *Dasypus* sp., and collared peccary *Pecari tajacu* from their burrows.

All communities hunted more often during the high-water period, between May and July, when hunting grounds are more easily accessible by canoe. However, the relative importance of different species varies throughout the year (Figure 2). Both in Ayapuá sector and in Mari I, the species showed the same pattern with respect to the average monthly water level and therefore the data are grouped. Larger game species are hunted more at high water levels while waterfowl are hunted more often during the dry months between November and February.

The neotropical cormorant *Phalacrocorax brasilianus* and the black bellied whistling duck were hunted mostly during the early high-water season, when they congregate to breed, and can be seen nesting or with chicks. The same pattern is found for muscovy duck, despite being hunted year round. Hunting patterns for tinamous *Tinamus* sp. and armadillos appeared unrelated to flood levels, since the hunting of these species

Table 4

Time of day and transportation method of hunting events by sector

	Period			Transportation			
Sector	Day	Night	Total*	On foot	Canoe	Canoe and on foot	Total*
Ayapuá	202	47	249	29	76	146	251
Jari	70	74	144	19	95	35	149

*Only non-opportunistic hunting events are included (n=439), and where complete information was available for this field

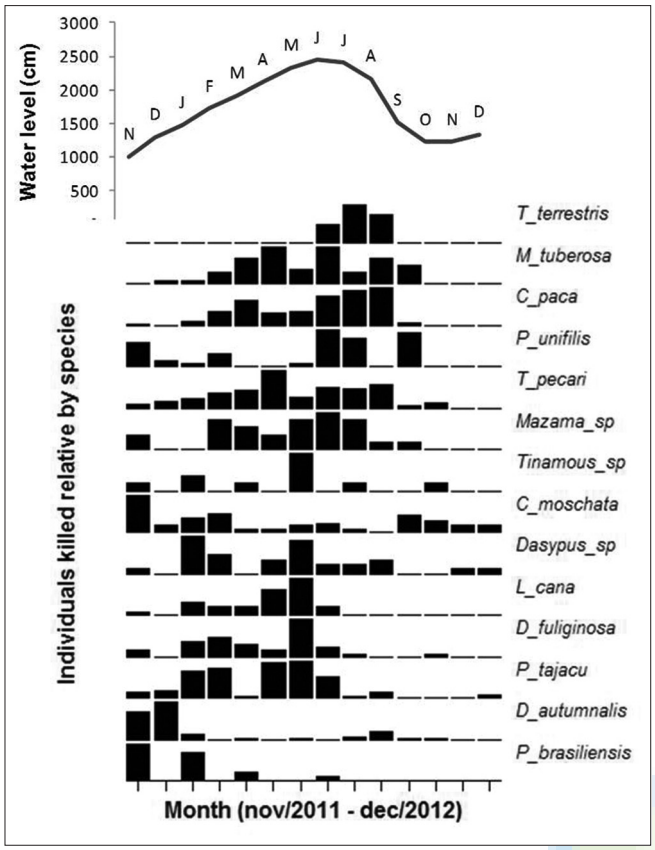

Figure 2
Monthly offtake (November 2011 to December 2012) and average monthly water level. For scientific names see Table 2

is largely opportunistic. All other species were hunted more during high-water months. White-lipped peccary and deer were hunted routinely during peak flood months (between May and July). Collared peccary, black agouti and woolly monkeys are the most important game species at the beginning of the high-water season and are replaced by tapir, spotted paca, and yellow spotted river turtles as the high-water season advances. Overall seasonal variation in offtake appears associated mostly with accessibility as a result of water levels, but finer variations also appear to reflect phenological cycles, particularly related to food availability. As one hunter noted,

> [Hunting] is better when the land starts drying out than when it starts flooding. When the water level starts dropping fallen fruits float on the water. They float around until they reach the river banks. The water starts dropping and the fruits come ashore. Then the game comes in and eats that fruit, whether it's a peccary, paca, or a tapir. July and August are good months for hunting those animals (hunter from community Mari I).

Rules governing wildlife use

In Brazil, there are no legal measures regulating the use of wildlife, aside from the general prohibition in the 1967 law. The management plan of the Piagaçu-Purus reserve is based on Article 37, paragraph I of the Environmental Crimes Law (Brazilian Federal Law No. 9605, 1998) that supports subsistence hunting of bush meat. The law states that killing an animal is not a crime when it is required to satisfy the hunger of the hunter or his family, providing a somewhat precarious legal loophole for developing management strategies in protected areas. In contrast to the restrictiveness and unidimensionality of Brazilian legislation, we observed a rich set of informal institutions and traditional rules regulating hunting in the study communities, including generalised cultural norms and consciously adopted rules. We explore food taboos and other cultural norms elsewhere (Vieira et al. 2013, unpublished data), focusing our analysis here on conscious rules, that have been formalised to some degree in written documents.

Development of the management plan for the RDS-PP resulted in the adoption of 31 rules governing the use of aquatic wildlife and 19 rules governing the use of terrestrial wildlife, as stipulated by residents, with Piagaçu Institute and CEUC/SDS acting as intermediaries. The set of rules is valid only for subsistence hunting[3] and only if approved by the Management Board and the protected area governing body (State Centre for Protected Areas, CEUC/SDS). The rules governing the use of terrestrial wildlife were created in a participatory planning workshop held in 2009 by representatives from all administrative sectors of the RDS-PP. Some of these rules draw from existing informal rules already in place in the communities, while others represent management strategies suggested by those intermediating the meeting.

Though communities have been apprehensive about developing regulations for subsistence hunting, one of the study communities had already developed a set of formal rules. In 2012, Uixi community residents convened a meeting to regulate wildlife use in the community. The meeting minutes (Table 5) describe a set rules limiting hunting on commemorative occasions, namely small or large religious festivals. Two rules were developed to control access by outside users: teachers and visitors. A specific planning measure was included for the hunting of spotted paca *Cuniculus paca* depending on the sex of the animal and the season. The month of August is considered among locals to be an important time in the reproduction cycle of the species, a time when the species is also more accessible, and hence vulnerable to indiscriminate spotlight hunting. The minutes also establish an expiration date for the rules, lending them an adaptive character.

The remaining communities have no written rules, although one rule is consensually acknowledged among the residents interviewed: 'Selling game meat to outsiders is forbidden'. Meanwhile, buying and selling hunting products among neighbours is tolerated to maintain social ties in the community. In Mari I, a group of residents who often hunt together cited a specific measure regulating hunting locations in which hunters rotated hunting along a set of streams for a defined time period. There is some degree of agreement between these home grown community rules and the formal rules in the management plan. However the management plan specifically bans outsiders from

Table 5

Written rules for the use of wildlife by communities in the study

Written rules
Source: Management plan
Hunting activity is permitted in the RDS-PP only for the subsistence of the local residents
The sale of game meat to non-residents of the RDS-PP including fishermen, merchants, tour operators, tourists, and visitors is prohibited
Hunting as a source of income for residents of the reserve is prohibited
Hunting by people who do not live within the RDS-PP is prohibited
Residents of each community are encouraged to hunt within their respective hunting grounds, respecting the zoning and rules specific to each sector
Residents are encouraged to not use dogs for hunting, respecting rules specific to each sector
The use of traps of any kind for hunting in the RDS-PP is expressly prohibited
Killing of animals not used for food (e.g. jaguar, otter, porpoise), is prohibited except in self-defence
Killing of any pregnant female animal is prohibited
Killing birds and collecting eggs and/or chicks, especially muscovy ducks and black-bellied whistling-ducks, during breeding season is prohibited
Killing immature individuals of any animal species is prohibited
Killing any animal species in large numbers in a single hunting event is prohibited. Specific number (quotas) may be discussed and specific rules agreed upon in each sector
Capture and collection of species listed among the endangered species according to IBAMA and the IUCN is permitted only for research purposes with the prior authorization by the managing government bodies
Raising tethered or caged forest animals in captivity is prohibited
The use of slingshots to harm or kill animals is prohibited, and the parents of minors are responsible
The local community shall be entitled to take up to 3 kg of game meat on long journeys for the purpose of consumption along the journey
The consumption of larger quantities of turtle meat and other animals on commemorative occasions (celebrations) is permitted, but sale of the meat is prohibited
Hunters who fail to comply with a rule will have their game meat confiscated and distributed to the rest of the local community
It was established that in case any rule is disrespected, the offender's weapon will be confiscated for 90 days for first-time offences and for 180 days for repeat offences
Source: Uixi meeting minutes
It was decided that 100 kg is the limit for a small church communal event in the year 2012
For large events 350 kg was agreed upon, to occur once per year
For teachers three days hunting per week was agreed upon
Visitors can hunt up to 20 kg, but cannot take yellow-spotted river turtle
In August, residents decided they may only kill one spotted paca female per week
This document is valid for three years
Any community member found breaking the law in this agreement will be banned to hunt

RDS-PP: Piagaçu-Purus Sustainable Development Reserve; IBAMA: Instituto Brasileiro do Meio Ambiente; IUCN: International Union for Conservation of Nature

hunting, while Uixi proposed regulations for specific groups of outsiders (teachers and visitors).

DISCUSSION

Spotted paca was the species with the highest number of recorded kills, and two communities have proposed specific regulatory measures for this species: Uixi proposed a bag limit of a single female for the critical month of August, while Mari I has put into place a stream rotation system. These, and other local suggestions, will be incorporated into the formal RDS-PP management plan. No community control measures were found associated with the hunting of white-lipped and collared peccaries, but under the management plan sector specific quotas may be set.

Black bellied whistling ducks and muscovy duck represent the third and fifth most hunted species. These ducks are often hunted during the breeding period. Although there are specific rules in the management plan regarding hunting waterfowl during the breeding period, this period also represents greater accessibility for hunters. Seasonal data is useful in monitoring hunting controls relevant to a species' reproductive cycle if complementary data on the reproductive biology of the species exists (Moller et al. 2004). However the local peoples' difficulty in distinguishing between male and female birds hinders the development of management measure based on reproductive biology. One of the weaknesses of the current monitoring system is that data on the age and reproductive status of individuals was not collected, important data that could be added in future monitoring activities. These examples represent known deficiencies that could be incorporated into the monitoring system.

The most problematic aspect of self monitoring results involves illegal hunting practices, such as commercial sale or transportation of bush meat, the use of traps, the keeping of wild animals as pets in captivity or sale of wildlife, and the killing of endangered animals, all practices prohibited by Brazil's Environmental Crimes Law (Brazilian Federal Law No. 9605 of 1998).

The reported killing of the South American tapir *Tapirus terrestris,* one of the only hunted species regarded as Threatened by IUCN (3.1), is low but probably underestimated once hunters are aware of its special protection by Law. Among the local population there is a series of beliefs and practices involving the 'care' (*zelo*) of salt licks where tapirs concentrate, apparitions of spiritual beings for those who disobey these norms, and an avoidance of tapir meat as *reimoso* (reimoso=unwholesome) for those in vulnerable states such as illness or pregnancy. These sociocultural norms appear to act, at least in part, as regulatory measures to restrict the consumption of this vulnerable species. These beliefs and practices will be explored in a separate article, and represent an especially rich area for understanding hunting in its full socioenvironmental richness and reconciling formal reserve planning with informal management practices (Vieira 2013).

The sale and transport of bush meat is both a legal and conceptual problem. The local sale of meat among neighbours and transportation of meat for family sustenance during long trips is formally prohibited by Brazilian law (Brazilian Federal Law No. 9605, 1998, the Environmental Crimes Law), however, these are common practices in the reserve, in fact, transportation of limited quantities of meat for long trips is a local rule that may be incorporated in the official management plan. Such legal contradictions further complicate the formal regulation of hunting in the reserve, and will need to be resolved in the long term. However, at the current time, hunting and sale to outsiders and restrictions on external hunters are more immediate concerns shared by the local population and the external regulatory rules.

The reserve monitoring plan prohibits hunting dogs, however, some communities continue to use them, generating conflict in some localities. Dogs are known for their ability to corner game species but also to scare animals away. Conflicts regarding hunting with dogs were also observed by Koster (2008) in Nicaragua, and this aspect may require special attention in monitoring.

Although all community members were invited to participate in self monitoring, recognised hunters were the ones who most effectively returned monitoring data. This, in part, reflects their pride in their social status as good hunters, but also suggests their recognition of the importance of the resource (Souza-Mazurek et al. 2000; Noss et al. 2004; Ohl-Schacherer et al. 2007). Self monitoring represents a vast increment in data collection effort at a much reduced cost over the typical single researcher hunting study (Souza-Mazurek et al. 2000; Noss et al. 2004; Ohl-Schacherer et al. 2007; Constantino et al. 2008; Demelas 2012; Valsecchi 2012). Data collection by the hunters themselves allows immediate recording of hunting events, an advantage over recall methods that are known to lose accuracy after more than a 24 hour time lapse (Dufour 1995). The data presented here is certainly an underestimate of total offtake for the region, but by validating the data retrospectively, and knowing precisely how many families were and were not monitored, it is possible to obtain a rough estimate of the overall offtake numbers.

Self monitoring over a one-year period also permitted the evaluation of temporal and spatial fluctuations of hunting activities, and ethnographic observation and interviews revealed the social, ecological and logistical justifications for these variations. However, the current monitoring system did not track hunting events to precise geographic coordinates. This improvement to the data collection protocol might improve accuracy of the zoning process currently underway in the reserve.

CONCLUSIONS

Several authors have noted conditions that facilitate the success of community-based monitoring programmes: 1) the importance of the biological resource for local populations, 2) community rights to manage resource usage, 3) community political organisation and the presence of leaders, and 4) collaboration among decision makers (Constantino et al. 2012). Many, if not all, of these conditions are met in the study communities in the RDS-PP. Wildlife is indeed an important food resource, and hunters themselves proved to be the most successful monitors. All communities have local administrative leaders, however, in communities where the population is not concentrated near the administrative centre, monitoring was hindered. In some cases, local leaders and assistants trained by other research programmes were instrumental partners in implementing the hunting monitoring system.

The study highlights a number of challenges to participatory monitoring and wildlife co-management. The first, observed in many other conservation initiatives (Humavindu and Stage 2014), is financial sustainability. The Piagaçu Institute monitoring programme study was designed to minimize costs by involving effective stakeholders, and thus, avoiding the need for paid monitors. However, it will still require external inputs to continue developing. Once local residents appropriate the monitoring system, external dependence tends to drop (Funder et al. 2013), but conflicting management rights will complicate this process in the RDS-PP.

Wildlife use represents a more subtle income source for residents when compared to fisheries and agriculture, and is less a matter of concern among users, a fact reflected in the somewhat limited initiatives at wildlife regulation. In addition, no measures of rules enforcement were observed. However, RDS-PP has a community surveillance system for fisheries that could serve as a model for evaluating and adapting hunting regulations.

The conflicting legal status of hunting in Brazilian law discourages local wildlife management by hunters, since their rights are still very restricted. As a consequence, informal rules that conflict with formal rules tend to be overlooked or given a blind eye. One example in this case was the prevalence of wild meat sales in the informal exchange economy, banned by the current management regulations, but tolerated, and in fact common in some communities. Without sufficient understanding of the local socioenvironmental context, the imposition of contradictory or illogical external regulations could render local management ineffective and unenforceable while also stifling local capacity to resolve conflicts.

Despite disagreements between certain formal and informal rules regarding the sale and transport of bush meat, there was a greater degree of community agreement with rules involving seasonal restrictions, bag limits, and quotas. These provide examples of how to foster community-based management of wildlife combining of locally grounded measures with scientific data. Ongoing monitoring provides information that can feed back into a flexible, adaptive management plan including the testing and revision of practices and rules (Armitage et al 2009). Decisions made and enforced at the local level are more effective at responding to the socioenvironmental dynamics of ecosystems (Berkes et al. 2000). A system properly involving local people in monitoring these dynamics allows for constant adjustment and improvement.

We observed how local participation in data collection increased both the efficiency and the extent of data collection, while also enhancing local understanding about resource management. This, and other RDS in Brazil are proving to be productive laboratories for developing regulatory measures in collaboration with local communities, who have extensive traditional ecological knowledge about local resources and a vested interest in monitoring and managing their extractive activities. Together, these factors facilitated the implementation of an efficient pilot system in Piagaçu-Purus, with the potential for incremental adjustments, and data gathering to monitor compliance and support decision-making processes. Participatory monitoring, appropriately applied, generates useful spatial, temporal and quantitative data on hunting impacts while also deepening researchers' and administrators' understanding of local hunting practices and traditional forms of social and ecological control. Such data and understanding are crucial to the management of hunting in human-inhabited protected areas in remote tropical regions where governance is often limited (Yu et al. 2010).

ACKNOWLEDGEMENTS

This study is part of MV's master's degree which was completed in the Postgraduate Programme in Ecology of the National Institute for Amazon Research (INPA). The authors are grateful to the RDS-PP residents for their collaboration and to the Piagaçu Institute (IPi) and of Mamirauá Sustainable Development Institute (IDSM) for the scientific and logistic support. The authors are also thankful to the Rufford Small Grants Foundation for the financial support, and to the CNPq for MV's scholarship and to the IDSM for EM's scholarship.

NOTES

1. The term *caboclo* does not designate ethnic identity per se, but rather refers to a large part of the non-indigenous rural population of Amazonia descended from intermarriage and cultural and economic assimilation between remnant indigenous populations, Europeans and Afro-Brazilian settlers especially from northeastern Brazil (Murrieta, 1998).
2. Government entities include two responsible for indigenous affairs (FUNAI, SEIND), two involved in protected area management (ICMBio, SDS/CEUC), six representatives of local municipalities (Beruri, Anori, Tapauá), representatives of the health sector (FVS), fish management (MPA/SEPA-AM), forest and agricultural resources (IDAM) and the Military Police; civil society representatives include: two representatives of the local fishing sector (SINDARP, Beruri Fishing Colony), one representative of the local rural workers' syndicate (STTR) one regional non-governmental organisation (IPI) 13 local representatives from the different reserve sectors and two representatives of the indigenous territories circumscribed in the reserve; and finally the public-private organisation *Fundação Amazonas Sustentável* (FAS) that runs the *Bolsa Floresta* welfare programme for Amazonas state.
3. 'Subsistence hunting' does not have a formal definition in Brazilian legislation, but for the purposes of the Management Plan of the RDS-PP, it is understood following Article 37 of Federal Law No. 9605 of 1998.

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Received: December 2013; **Accepted**: November 2014