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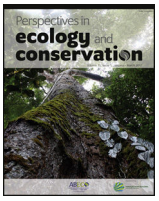

Policy Forums - Rewilding South American Landscapes

Community-based population recovery of overexploited Amazonian wildlife

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ABSTRACT

The Amazon Basin experienced a pervasive process of resource overexploitation during the 20th-century, which induced severe population declines of many iconic vertebrate species. In addition to biodiversity loss and the ecological consequences of defaunation, food security of local communities was relentlessly threatened because wild meat had a historically pivotal role in protein acquisition by local dwellers. Here we discuss the urgent need to regulate subsistence hunting by Amazonian semi-subsistence local communities, which are far removed from the market and information economy. Following positive examples from community-based management of aquatic and terrestrial resources, we advocate that hunting practices, based on modern scientific principles firmly grounded in population ecology, represent a strong window of opportunity to recover viable populations of previously overexploited wildlife.

Introduction

The Amazon basin experienced a dramatic process of 20th-century overexploitation of a wide range of both terrestrial and aquatic species, partly resulting from the international hide trade. Large-bodied vertebrates, such as black caiman (*Melanosuchus niger*), giant otter (*Pteronura brasiliensis*), manatee (*Trichechus inunguis*), giant air-breathing fish (*Arapaima gigas*) and white-lipped peccary (*Tayassu pecari*) succumbed to steep population declines due to overhunting and overfishing (Antunes et al., 2016; Fig. 1). Vertebrate overexploitation can lead to abrupt ecological changes that degrade the resilience and ecosystem services of Amazonian environments (Doughty et al., 2013; Peres et al., 2016). Moreover, population declines and local extirpation of game species can substantially reduce food security for Amazonian forest and floodplain dwellers, given that animal protein is a limiting resource across the Amazon basin (Headland and Bailey, 1991). Strategies to minimize habitat loss and reverse wildlife population declines — to ensure both the critical role of these species in ecosystem functioning and provide a safety net for local communities — represent an urgent conservation priority.

Protected areas worldwide arguably represent the key cornerstone in preventing or mitigating further habitat degradation and biodiversity loss (Bruner et al., 2001; Coetzee et al., 2014). However, tropical countries are typically under sharp financial duress and lack human resources to substantially implement protected area management (e.g. Campos-Silva et al., 2015). For instance, Brazil's ~1.6 million km^2 State of Amazonas, the subnational political unit controlling the largest tropical forest area on Earth, currently counts on only three staff employed to manage all 42 state protected areas, representing only 0.07 employee per reserve, or a mean reserve area of nearly 6.3 Mha per park manager. Novel approaches to both strengthen and diversify biodiversity conservation strategies are therefore critically needed.

In low-governance countries, decentralizing state-controlled natural resource management, including formal alliances with local communities, can substantially strengthen surveillance systems, reduce costs and improve effectiveness (Somanathan et al., 2009). Positive examples from community-based management arrangements have been documented in many natural ecosystems (Gibson and Marks, 1995; Cinner et al., 2012a,b; Somanathan et al., 2009). However, developing a legal regulation framework and robust

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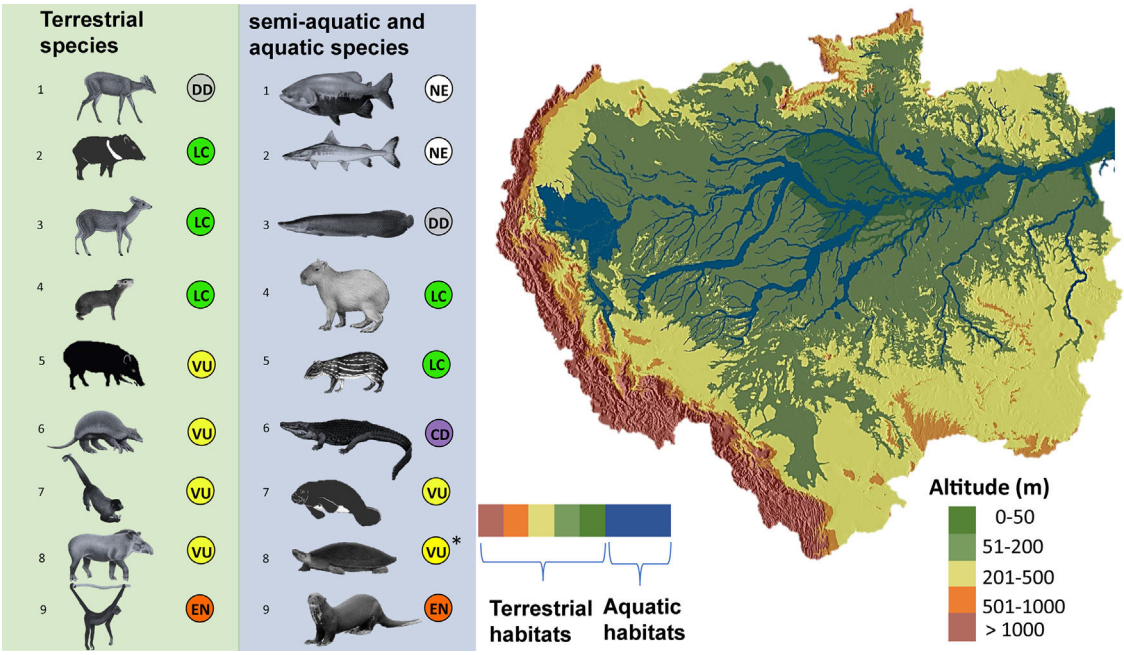

Fig. 1. Main species exploited and their habitats. A profile of key wildlife resources harvested for both subsistence and trade from either terrestrial or aquatic ecosystems across the entire hydrological boundary of the Amazon basin. Exemplar species of terrestrial (including strictly terrestrial and arboreal) and aquatic (including semi-aquatic) vertebrates are shown in the green and blue vertical columns, respectively. Circles denote the current IUCN conservation status of each species according to the latest update (IUCN, 2017). Green (Least Concern) and purple (Conservation Dependent) symbols represent low-risk species; yellow (Vulnerable) and orange (Endangered) symbols represent threatened species; grey symbols represent Data Deficient species and white symbol represent species that were not assessed. The elevational range of Amazonia is shown on the map, including strictly terrestrial and seasonally flooded areas, and permanent water bodies. Numerical codes denote the following species groups: Terrestrial: (1) Grey brocket deer, *Mazama gouazoubira*; (2) Collared peccary; *Pecari tajacu*; (3) Red brocket deer, *Mazama americana*; (4) Black agouti, *Dasyprocta fuliginosa*; (5) White-lipped peccary, *Tayassu pecari*; (6) Giant armadillo, *Priodontes maximus*; (7) Woolly monkey, *Lagothrix* sp.; (8) Lowland tapir, *Tapirus terrestris*; (9) Spider monkey, *Ateles* sp.; Aquatic: (1) Tambaqui, *Colossoma macropomum*; (2) Dourado catfish, *Brachyplatystoma rousseauxii*; (3) Arapaima, *Arapaima gigas*; (4) Capybara, *Hydrochoerus hydrochaeris*; (5) Lowland paca, *Cuniculus paca*; (6) Black caiman, *Melanosuchus niger*; (7) Amazonian manatee, *Trichechus inunguis*; (8) Freshwater turtles, *Podocnemis* spp.; and (9) Giant otter, *Pteronura brasiliensis*. *Three species of freshwater turtles: South American river turtle (*Podocnemis expansa* – Conservation Dependent); Yellow-spotted river turtle (*Podocnemis unifilis* – Vulnerable) and six-tubercled Amazon river turtle (*Podocnemis sexturbeculata* – Vulnerable). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

management tools are critical to empower and consolidate these arrangements. Here, we discuss pragmatic approaches to effectively achieve the conservation of viable populations of Amazonian wildlife through community-based management initiatives.

Lessons from aquatic resources

Impressive cases of sustainable use and population recovery of aquatic vertebrates have been shown in Brazilian Amazonia. *A. gigas*, the world's largest scaled freshwater fish, was historically decimated at most sites across entire Amazonian floodplains (Veríssimo, 1895), but community-based fishery management have led to a gradual recovery of wild populations (Castello et al., 2009; Petersen et al., 2016; Campos-Silva and Peres, 2016). Local communities, under strict collaborative arrangements with government agencies, NGOs and academia, have co-designed a number of spatially-explicit fisheries zones accommodating the interests of multiple stakeholders, resulting in locally protected and subsistence lakes used by small-scale fisherfolk, and lakes used by commercial fishing boats. Protected lakes can safeguard arapaima populations 30-times larger than similar-sized unprotected lakes (Campos-Silva and Peres, 2016). This ensures annual sustainable harvest quotas (up to 30% of total adults counted by the local managers in the previous year) commercialized locally, which protect not only this target species but several overexploited taxa, such as freshwater turtles, caimans and other high-value fish species, all of which have increased at managed sites (Miorando et al., 2013; Arantes and Freitas, 2016; Campos-Silva and Peres, 2016). Beyond marked demographic outcomes, community-based management provides unprecedented socioeconomic welfare for rural floodplain communities, enhancing their direct income, standards of living, and social organization (Campos-Silva and Peres, 2016).

Another pertinent example is the community-based protection of fluvial sand beaches, focusing on the conservation of freshwater *Podocnemis* turtles (*P. expansa*, *P. unifilis* and *P. sexturbeculata*). This was spearheaded by the Amazon Chelonian Program, a governmental initiative launched in the early 1970s, based on mapping of remaining large breeding populations of *P. expansa*, which in many cases had already been protected by local communities. This strategy consists of protecting beaches and breeding females along major rivers during the turtle reproductive season, thereby deterring poachers from raiding both eggs and adult females (Andrade, 2015; Campos-Silva, 2016; Pezzuti et al., 2017). *Podocnemis* turtles have gradually recovered across many areas of lowland Amazon (Cantarelli et al., 2014; Andrade, 2015; Camillo et al., 2012). Although population outcomes are impressive, the social benefits are still timid due to the absence of tangible socioeconomic gains delivered to local beach guards, although this embryonic program is on a positive trajectory (Projeto Médio Juruá, unpubl. data; Pezzuti et al., 2017).

Terrestrial game hunting: a management imperative?

We recognize different types of hunting, including commercial, recreational, trophy and population culls, but given our collective experience, we will largely focus on the issue of subsistence hunting, unavoidably with a strong Amazonian bias. This encompasses traditional livelihoods in Amazonian countries, for whom subsistence hunting is a daily necessity to meet animal protein needs, including indigenous groups, *caboclos*, *ribeireños*, *quilombolas*,

rubber tappers, Brazil-nut collectors, and to a lesser degree more market-integrated *caiçaras* in coastal Atlantic forests of southeastern Brazil.

Terrestrial game species provide critical animal protein to millions of Amazonian forest dwellers, particularly in the wet (high-water) season when fisheries catch-per-unit effort is less cost-effective (Peres, 2000; Endo et al., 2016). Drawing up enforceable guidelines for subsistence hunting should therefore become a priority to define new game management strategies to ensure food security for subsistence Amazonians.

In contrast to aquatic resources, formal management of terrestrial game species is still virtually non-existent. The absence of appropriate wildlife management guidelines for subsistence hunting partly results from absent state institutions and a generally biased interpretation of legal instruments. Although harvest-sensitive species, such as large-bodied ateline monkeys, tapir, and white-lipped peccaries (Peres et al., 2016; Bodmer et al., 1997), are more vulnerable and can be more easily overhunted, Amazonia still harbours large animal populations, where species resilient to hunting have always supported sustainable harvests (Ohl-Schacherer et al., 2007). Furthermore, traditional techniques are more efficient and less costly alternatives to conventional research and monitoring methods and should be used to manage target species (Valsecchi et al., 2014; El Bizri et al., 2016).

Effectively achieving sustainable hunting for all game species within a forest landscape is a nontrivial proposition, but new analytical approaches and positive examples are becoming widely available (Child, 2009; Levi et al., 2011; Shaffer et al., 2017). However, as hunting is still formally defined as illegal, there are no opportunities to develop spatial harvesting protocols, including hunting zones within sustainable-use, extractive and indigenous reserves, which could ensure demographic dividends through immigration from neighbouring no-take areas. Additionally, any possibility of aggregating value-added revenues to wildlife products cannot be legally considered so far. Next, we examine all official documents, including the Brazilian Constitution and subsequent Laws and Decrees to assess how hunting regulation based on exploitation theory could support wildlife conservation efforts.

Regulating subsistence hunting: Brazilian legal instruments

A broad analysis of the Brazilian Constitution and subsequent Laws and Decrees shows that the right to hunt is often ensured as a legitimate right for local users. The Firearm Directive (Law 10826/2003) is the only national legal instrument that explicitly considers subsistence hunting, sanctioning that rural people who depend on hunting for their personal subsistence can possess a fire weapon, provided this is used under their capacity of subsistence hunters.

Although the "*use, persecution, destruction, hunting or harvesting*" of wildlife were banned by the Brazilian Faunal Protection Law (Law 5197 of 3rd January 1967, Article 1), hunting is permitted (or at least tolerated) by the Environmental Crimes Law (Law 9605 of 12th February 1998) whenever carried out as a "*necessity, to satiate the hunger of the agent or his/her family*" (Article 37). The Brazilian Faunal Protection Law was also not designed to prohibit hunting indiscriminately, since regulatory provisions clearly state that officially authorized sustainable hunting can occur as long as "*regional peculiarities allow the exercise of hunting, with permission established by the Federal Attorney Office*" (Article 1, §1). Article 24 of the 1988 Brazilian Constitution declares that both the federal and state governments are charged with the mission of overseeing natural resource management including hunting as well as exploitation of freshwater and marine fisheries.

Traditional peoples are defined as culturally differentiated groups that utilize natural resources within their territories to maintain their socio-cultural ancestry (Beltrán, 2000). Hunting is an economic activity as ancient as the arrival of the first Amazonians, over 10,000 years ago (Roosevelt et al., 1996). Indigenous groups have exclusive rights to hunting and fishing within their territories, as explicitly recognized through the Indigenous Statute (Law 6001/1973). For all other traditional ethnic groups, the most important legal instruments concerning traditional hunters' territorial rights to access natural resources within their territories include the 169 International Convention (Art. 15 and 23), the National Policy for the Sustainable Development of Traditional Peoples (PNPCT, Decree 6040/2007), the National System of Protected Areas (SNUC, Law 9985/2000), and Decree 592/1992 from International Covenant on Civil Rights.

Amazonian traditional peoples are typically not fully market-integrated, so that wildmeat is a crucial component of their protein needs (Peres, 2000; Lawrie, 2016). Fundamental legal principles of Brazilian Society also hold the State to account in providing adequate food for its citizens, respecting cultural diversity, and ensuring sustainable resource use. Given this legal framework, there are no reasons for environmental authorities and the police to criminalize hunting for subsistence. As long as hunting is still interpreted as an illegal activity by decision makers, there will be no opportunities to develop wildlife management tools through community-based approaches.

Although we recognize the urgent need for hunting regulation, we advocate that rules of engagement should be built under a participatory mechanism involving all users, stakeholders and researchers. We highlight that the controversial Wildlife Management Law proposal (6268/2016), which was recently submitted by federal legislator Valdir Collato — a staunch advocate for agribusiness interests in the National Congress — is entirely misdirected and fails to address the plight of both the vast majority of wildlife resources in Brazil and their legitimate users. This is merely a top-down initiative focused on sports hunting to suppress invasive species, which can raid croplands. In fact, this legal proposal makes a mockery of any notion of user participation based on tried-and-tested population ecology principles, and fails to address management imperatives for extractive communities who really depend on wildlife resources.

Assumptions for successful community-based conservation programs

Based on learned lessons from the historical ecology of Amazonian extractive industries, human accessibility to wildlife is a key determinant of animal population resilience (Antunes et al., 2016). Spatiotemporally explicit harvest zoning is a critical step in wildlife production models. Given that game population ecology in different regions remains poorly known, 'no-take' areas are particularly promising management tools, particularly in terms of the fraction of a population represented by any given level of offtake (Milner-Gulland and Akçakaya, 2011; Joshi and Gadgil, 1991). Establishment 'no-take' areas between highly dispersed human settlements may replenish hunting catchments through source-sink dynamics (Novaro et al., 2000; Levi et al., 2009). Participatory zoning (take and no-take zones) has been encouraged by recent Brazilian policies in extractive reserves (SNUC; Brasil, 2000) and indigenous territories (PNGATI; Brasil, 2012), leading to early signs of population recovery for even those species most decimated by the Amazonian hide trade (Silveira and Thorbjarnarson, 1999; Castello et al., 2009; Dos Santos Lima et al., 2014; Souza, 2015; Campos-Silva and Peres, 2016; Pimenta, 2016).

Other critical features of community-based management systems include strong leadership, harvesting quotas, social cohesion and locally-enforced protected areas (Gutiérrez et al., 2011), as well as respect by wildlife managers to cultural aspects and local rules. Strengthening social capital, linked with incentives and rules to promote resource conservation and enhanced local welfare remains a challenge that can be co-managed by government agencies, NGOs and academia. The Brazilian government should play a central role, creating effective tools to regulate the activity, rewarding highly compliant local communities and penalizing non-compliance. Arapaima management is a very informative example, whereby high-compliance communities promote population recovery through time, in which high levels of engagement translates into higher harvesting quotas and tangible social benefits (Campos-Silva and Peres, 2016).

Governmental agencies and NGOs can also create economic instruments to subsidize the initial costs of community-based initiatives, as illustrated by innovative approaches to manage aquatic resources. These traditional communities have always been neglected from public policies, so they hardly have financial autonomy to kickstart new projects of this magnitude. Finally, the academic sector can operate as a barometer, assessing outcomes and trends in community arrangements (e.g. www.projetomediojurua.org), or implementing extension projects that support local capacity-building (e.g. pedepincha.com.br).

Future directions

Regulation and management of subsistence offtake is imperative to ensure both food security for forest dwellers and wildlife resources on which they depend. National policies addressing indigenous and extractive reserves, such as PNGATI and SNUC, provide existing legal instruments to accomplish some pilot management programs, especially in protected areas with high governance. Through both robust data acquisition, monitoring and analysis, these programs will contribute to our understanding about the effects of hunting on animal populations and provide management guidelines for decision makers.

We are far off from designing an adequate conservation plan for Amazonian wildlife that can be effectively enforced. Although aquatic resources succumbed to the brunt of the impact of past extractive industries, they have shown much higher recovery rates that are consistent with harvesting models. These initiatives consist of a rare window of opportunity to develop a meaningful conservation program for historically overexploited vertebrate fauna, which should be subsidized by government agencies and NGOs. The federal government also should create a platform to improve the dialogue between researchers, policy-makers and users in general to establish an integrated action framework. Universities and research institutes should prioritize the evaluation of existing hunting arrangements, attempting to design and co-implement sustainable harvest models. Finally, greatly improving resource management strategies will also rest on the creation of strictly-protected areas, including the proper implementation of existing sustainable-use reserves that should no longer be underfunded and understaffed.

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References

Andrade, P.C.M., (Thesis) 2015. Manejo Comunitário de Quelônios (Família Podocnemididae *Podocnemis unifilis*, *P.sextuberculata*, *P.expansa*) no Médio Rio Amazonas e Juruá. Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas.

Antunes, A.P., Fewster, R.M., Venticinque, E.M., Peres, C.A., Levi, T., Rohe, F., Shepard, G.H., 2016. Empty forest or empty rivers? A century of commercial hunting in Amazonia. Sci. Adv. 2, e1600936.

Arantes, M.L., Freitas, C.E.C., 2016. Effects of fisheries zoning and environmental characteristics on population parameters of the tambaqui (*Colossoma macropomum*) in managed floodplain lakes in the Central Amazon. Fish. Manag. Ecol. 23 (2), 133–143.

Beltrán, J. (Ed.), 2000. Indigenous and Traditional Peoples and Protected Areas: Principles, Guidelines and Case Studies. IUCN/WWF International, Gland, Switzerland and Cambridge, UK/Gland, Switzerland, xi+133 pp.

Bodmer, R.E., Eisenberg, J.F., Redford, K.H., 1997. Hunting and the likelihood of extinction of Amazonian mammals. Conserv. Biol. 11 (2), 460–466.

Brasil, 2000. Lei n° 9.985, de 18 de julho de 2000. Sistema Nacional de Unidades de Conservação da Natureza – SNUC.

Brasil, 2012. Decreto N° 7.747, de 5 de Junho de 2012. Política Nacional de Gestão Territorial e Ambiental de Terras Indígenas – PNGATI.

Bruner, A.G., Gullison, R.E., Rice, R.E., Da Fonseca, G.A., 2001. Effectiveness of parks in protecting tropical biodiversity. Science 291 (5501), 125–128.

Camillo, C.S., dos Santos, O.M., de Sousa, I.S., de Queiroz, H.L., 2012. Community-based freshwater turtle conservation in middle Solimões River, AM, Brazil. UAKARI 8 (1), 33–44.

Campos-Silva, J.V., da Fonseca Junior, S.F., Peres, C.A., 2015. Policy reversals do not bode well for conservation in Brazilian Amazonia. Nat. Conserv. 13 (2), 193–195.

Campos-Silva, J.V., (PhD Thesis) 2016. Manejo Participativo nas Várzeas Amazônicas e seus Efeitos Multi-tróficos. Universidade Federal do Rio Grande do Norte, Natal, Brazil.

Campos-Silva, J.V., Peres, C.A., 2016. Community-based management induces rapid recovery of a high-value tropical freshwater fishery. Sci. Rep. 6.

Cantarelli, V.H., Malvasio, A., Verdade, L.M., 2014. Brazil's *Podocnemis expansa* conservation program: retrospective and future directions. Chelonian Conserv. B 13 (1), 124–128.

Castello, L., Viana, J.P., Watkins, G., Pinedo-Vasquez, M., Luzadis, V.A., 2009. Lessons from integrating fishers of *Arapaima* in small-scale fisheries management at the Mamiraua reserve, Amazon. Environ. Manage. 43, 197–209.

Child, B., 2009. Conservation in transition. In: Child, B., Suich, H., Spenceley, A. (Eds.), Evolution and Innovation in Wildlife Conservation: Parks and Game Ranches to Transfrontier Conservation Areas. Earthscan.

Cinner, J.E., Daw, T.M., McClanahan, T.R., Muthiga, N., Abunge, C., Hamed, S., . . . Jiddawi, N., 2012a. Transitions toward co-management: the process of marine resource management devolution in three east African countries. Glob. Environ. Change 22 (3), 651–658.

Cinner, J.E., McClanahan, T.R., MacNeil, M.A., Graham, N.A., Daw, T.M., Mukminin, A., . . . Campbell, S.J., 2012b. Comanagement of coral reef social-ecological systems. Proc. Natl. Acad. Sci. U. S. A. 109 (14), 5219–5222.

Coetzee, B.W., Gaston, K.J., Chown, S.L., 2014. Local scale comparisons of biodiversity as a test for global protected area ecological performance: a meta-analysis. PLoS ONE 9 (8), e105824.

Dos Santos Lima, D., Marmontel, M., Bernard, E., 2014. Reoccupation of historical areas by the endangered giant river otter *Pteronura brasiliensis* (Carnivora: Mustelidae) in Central Amazonia, Brazil. Mammalia 78 (2), 177–184.

Doughty, C.E., Wolf, A., Malhi, Y., 2013. The legacy of the *Pleistocene megafauna* extinctions on nutrient availability in Amazonia. Nat. Geosci. 6 (9), 761–764.

El Bizri, H.R., Araújo, L.W.S., Araújo, W.S., Maranhão, L., Valsecchi, J., 2016. Turning the game around for conservation: using traditional hunting knowledge to improve the capture efficiency of Amazon lowland pacas. Wildl. Biol. 22, 1–6.

Endo, W., Peres, C.A., Haugaasen, T., 2016. Flood pulse dynamics affects exploitation of both aquatic and terrestrial prey by Amazonian floodplain settlements. Biol. Conserv. 201, 129–136.

Gibson, C.C., Marks, S.A., 1995. Transforming rural hunters into conservationists: an assessment of community-based wildlife management programs in Africa. World Dev. 23, 941–957.

Gutiérrez, N.L., Hilborn, R., Defeo, O., 2011. Leadership, social capital and incentives promote successful fisheries. Nature 470 (7334), 386–389.

Headland, T.N., Bailey, R.C., 1991. Introduction: have hunter-gatherers ever lived in Tropical Rain Forest independently of agriculture? Hum. Ecol. 19 (2), 115–122.

IUCN, 2017. The IUCN Red List of Threatened Species. Version 2017-1, http://www.iucnredlist.org (downloaded 12.05.17).

Joshi, N.V., Gadgil, M., 1991. On the role of refugia in promoting prudent use of biological resources. Theor. Popul. Biol. 40 (2), 211–229.

Lawrie, R.A., 2016. Proteins as Human Food: Proceedings of the Sixteenth Easter School in Agricultural Science, University of Nottingham, 1969. Elsevier.

Levi, T., Shepard, G.H., Ohl-Schacherer, J., Peres, C.A., Yu, D.W., 2009. Modelling the long-term sustainability of indigenous hunting in Manu National Park, Peru: landscape-scale management implications for Amazonia. J. Appl. Ecol. 46, 804–814.

Levi, T., Shepard, G.H., Ohl-Schacherer, J., Wilmers, C.C., Peres, C.A., Yu, D.W., 2011. Spatial tools for modeling the sustainability of subsistence hunting in tropical forests. Ecol. Appl. 21 (5), 1802–1818.

Milner-Gulland, E.J., Akçakaya, H.R., 2011. Sustainability indices for exploited populations. Trends Ecol. Evol. 16, 686–692.
Miorando, P.S., Rebêlo, G.H., Pignati, M.T., Brito Pezzuti, J.C., 2013. Effects of community-based management on Amazon river turtles: a case study of *Podocnemis sextuberculata* in the lower Amazon floodplain, Pará, Brazil. Chelonian Conserv. Biol. 12 (1), 143–150.
Novaro, A.J., Redford, K.H., Bodmer, R.E., 2000. Effect of hunting in source-sink systems in the Neotropics. Conserv. Biol. 14, 713–721.
Ohl-Schacherer, J., Shepard, G.H., Kaplan, H., Peres, C.A., Levi, T., Yu, D.W., 2007. The sustainability of subsistence hunting by Matsigenka native communities in Manu National Park, Peru. Conserv. Biol. 21 (5), 1174–1185.
Peres, C.A., 2000. Effects of subsistence hunting on vertebrate community structure in Amazonian forests. Conserv. Biol. 14 (1), 240–253.
Peres, C.A., Emilio, T., Schietti, J., Desmoulière, S.J., Levi, T., 2016. Dispersal limitation induces long-term biomass collapse in overhunted Amazonian forests. Proc. Natl. Acad. Sci. U. S. A. 113 (4), 892–897.
Petersen, T.A., Brum, S.M., Rossoni, F., Silveira, G.F.V., Castello, L., 2016. Recovery of *Arapaima* sp. populations by community-based management in floodplains of the Purus River, Amazon. J. Fish Biol. 89 (1), 241–248.
Pezzuti, J.C.B., De Castro, F., McGrath, D., Miorando, P., Barboza, R.S.L., 2017. Local Conservationists. community conservation network of freshwater turtles in the Lower Amazon. Ecol. Soc. (in press).
Pimenta, N., (MSc Thesis) 2016. O Retorno das Ariranhas à Paisagem Baniwa. Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas.
Roosevelt, A.C., Da Costa, M.L., Machado, C.L., Michab, M., 1996. Paleoindian cave dwellers in the Amazon: the peopling of the Americas. Science 272 (5260), 373.
Shaffer, C.A., Milstein, M.S., Yukuma, C., Marawanaru, E., Suse, P., 2017. Assessing the sustainability of Waiwai subsistence hunting in Guyana with implications for co-management in Amazonian indigenous reserves. Conserv. Biol.
Silveira, R., Thorbjarnarson, J.B., 1999. Conservation implications of commercial hunting of black and spectacled caiman in the Mamirauá Sustainable Development Reserve, Brazil. Biol. Conserv. 88 (1), 103–109.
Somanathan, E., Prabhakar, R., Mehta, B.S., 2009. Decentralization for cost-effective conservation. Proc. Natl. Acad. Sci. U. S. A. 106, 4143–4147.
Souza, D.S., (MSc Thesis) 2015. Peixe-boi da Amazônia (Trichechus inunguis natterer 1883): mortalidade e uso do habitat na reserva de desenvolvimento sustentável Piagaçu-Purus, Amazônia central, Brasil. Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas.
Valsecchi, J., El Bizri, H.R., Figueira, J.E.C., 2014. Subsistence hunting of *Cuniculus paca* in the middle of the Solimões River, Amazonas, Brazil. Braz. J. Biol. 74 (3), 560–568.
Veríssimo, J.A., 1895. pesca na Amazônia, vol. 3. Livraria classica de Alves.