Community involvement succeeds where enforcement fails: Conservation success through community-based management of Amazon river turtle nests around Brazilian sustainable-use protected areas (#23748)

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Community involvement succeeds where enforcement fails: Conservation success through community-based management of Amazon river turtle nests around Brazilian sustainable-use protected areas

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Law enforcement is widely regarded as a cornerstone to effective natural resource management. Practical guidelines for the optimal use of enforcement measures are lacking particularly in areas protected under sustainable and/or mixed use management regimes and where legal institution are weak. Focusing on the yellow-spotted river turtles (*Podocnemis unifilis*) along 33 km of river that runs between two sustainable–use reserves in the Brazilian Amazon as an illustrative example, we show that two years of patrols to enforce protection regulations had no effect on nest harvesting (with high nest harvest rates: 61%); whereas during one year when community management approaches were enacted there was nearly a threefold reduction in harvest levels to a rate (26%) within the realm of biological feasibility in terms of population viability. Our findings support previous studies that show how community participation, if appropriately implemented, serves as a cornerstone to effective natural resource management, especially where law enforcement is limited or ineffective.

Short title: Amazon river turtle management

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Community involvement succeeds where enforcement fails: conservation success through community-based management of Amazon river turtle nests around Brazilian sustainable-use protected areas

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Keywords

Integrated management; Protected area; Reptile; Monitoring; Amazon conservation; Human impact; Natural resource management; Nest harvest; Turtle conservation.

Abstract

Law enforcement is widely regarded as a cornerstone to effective natural resource management. Practical guidelines for the optimal use of enforcement measures are lacking particularly in areas protected under sustainable and/or mixed use management regimes and where legal institution are weak. Focusing on the yellow-spotted river turtles (*Podocnemis unifilis*) along 33 km of river that runs between two sustainable–use reserves in the Brazilian Amazon as an illustrative example, we show that two years of patrols to enforce protection regulations had no effect on nest harvesting (with high nest harvest rates: 61%); whereas during one year when community management approaches were enacted there was nearly a threefold reduction in harvest levels to a rate (26%) within the realm of biological feasibility in terms of population viability. Our findings support previous studies that show how community participation, if appropriately implemented, serves as a cornerstone to effective natural resource management, especially where law enforcement is limited or ineffective.

Introduction

Enforcement can be effective for conservation under many circumstances for some species (Hilborn et al. 2006; Keane et al. 2008). Rules governing human behavior are at the heart of every system of natural resource management, however, without compliance, enforcement cannot be successful (Dietz et al. 2003; Keane et al. 2008; Ostrom 2015). Success ultimately depends on the ability of managers to influence the behavior of resource users, and enforcement via external parties can play a vital role in the conservation of natural resources. Yet at the same time external enforcement may generate unnecessary conflicts with local communities (Dietz et al. 2003) and there are increasing examples where self-regulating community based management can be equally if not more effective than external enforcement in preventing the over exploitation of natural resources (Campos-Silva & Peres 2016; Nepstad et al. 2006). Models of enforcement have been important in predicting how individual incentives can be modified to improve compliance but further work is urgently required to produce practical guidelines for the optimal use of enforcement measures in conservation (Dietz et al. 2003; Keane et al. 2008).

Developing effective conservation solutions is further complicated when protected areas are managed under different governance regimes, the relative effectiveness of which in avoiding loss to biodiversity and ecosystem services has been the subject of recent debates (Lambin et al. 2014; Nolte et al. 2013; Pfaff et al. 2015; Richards et al. 2017). It has been suggested that there are two primary approaches to wildlife conservation: the generation of economic benefits from wildlife to local communities, so that protecting wildlife is in their interest, and the enforcement of protected areas. The weaknesses of this overly simplistic, bimodal vision have been widely documented (Fletcher et al. 2016; Ostrom 2015; Reed et al. 2016). The focus has shifted to the implementation of myriad multiuse initiatives including integrated conservation and development projects. However, governance and enforcement is particularly challenging in these mixed-use/common pool areas (Dietz et al. 2003), where meeting the needs of multiple stakeholders is theoretically appealing but can often generate conflicts between different user/consumer groups, that have adverse effects on conservation objectives (Dietz et al. 2003).

Effective external enforcement is the exception not the rule (Ostrom 2015). In the Amazon the ability to remotely and continuously monitor deforestation has enabled the successes of protected areas to be evaluated, however recent studies show how enforcement may be ineffective when disturbances/violations are hard to detect and/or reliably classify/identify (Richards et al. 2017). Additionally, many cases are not as clear cut or easy to monitor as deforestation (Peres et al. 2006), and there is increasing realization that with the continued expansion of human populations and consequent conversion of natural habitats the impact of hard-to-detect disturbances such as hunting can act synergistically to limit the effectiveness of protected areas as a conservation measure in the 21st century (Barlow et al. 2016; Peres et al. 2006). Increasing community involvement has been proposed as the main solution to improve protected area effectiveness when faced with such hard to detect disturbances of common pool resources (Ostrom 2015).

Integrating communities and protected areas to generate conservation solutions is challenging but has generated successes for wildlife in terrestrial (Peres 2011; Pfaff et al. 2015) and aquatic environments (Campos-Silva & Peres 2016; Harju et al. 2017). Integration can be implemented in various forms (Ostrom 2015). One of the most simple is via the recognition/designation of areas (e.g. zonation) where local communities are able to developed sustainable activities. One such example is the sustainable-use areas that have rapidly expanded in number and area across the Brazilian Amazon through the 21st century (Bernard et al. 2014; Peres 2011; Pfaff et al. 2015). The size, isolation, lack of funding and lack of political will have all been cited as limiting factors for the effective management of natural resources within these sustainable–use areas (Peres 2011). Yet recent studies show how local community-based management can be effective for conservation under these circumstances (Campos-Silva & Peres 2016).

Turtles are one of the most endangered groups of vertebrates (Gibbon et al. 2000). Indeed some 52% of freshwater turtles are threatened by unprecedented anthropogenic changes in the 21st century

(Böhm et al. 2013). River turtles represent provisioning (food, source of income) and cultural services for local populations across the globe (Eisemberg et al. 2011; Harju et al. 2017; Mittermeier et al. 2015). Turtles therefore represent informative and highly relevant examples of the challenges facing conservation of common pool resource in a rapidly changing world (Dietz et al. 2003; Gibbon et al. 2000; Harju et al. 2017; Mittermeier et al. 2015).

Here we present the recent history of yellow-spotted river turtle nest harvest along 33 km of river located between two Amazon sustainable-use protected areas. To evaluate the relative effects of enforcement and community involvement we compare the harvest of river turtle nests along the river segment during years with enforcement versus years with only community management. This comparison enables us to contrast the relative success of these alternative approaches for the conservation of the species in sustainable-use protected areas.

Materials and Methods

Ethics statement

Ethical approval was not required for our noninvasive study, as we did not collect any biological sample nor interfere with the behavior of the study species. Permission to collect observational data from river turtle nest-areas was provided by research permit number IBAMA/SISBIO 49632-1 and 49632-2 to DN and FM, issued by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). Interviews with local residents were approved by IBAMA/SISBIO (permits 45034-1, 45034-2, 45034-3) and the Ethics Committee in Research from the Federal University of Amapá (UNIFAP) (CAAE 42064815.5.0000.0003, Permit number 1.013.843).

Study area

The study was conducted along 33 km of the Falsino River, in the state of Amapá, Brazil (N 0.77327, W 51.58064; Fig 1). This river section runs between two sustainable-use protected areas, the Amapá

National Forest and the Amapá State Forest (hereafter "FLONA" and "FLOTA" respectively). Both are National Forests, but only the FLONA (VI – "Protected area with sustainable use of natural resources") is designated within the IUCN Protected Area Classification (UNEP-WCMC & IUCN 2018). This particular stretch of river is 61 km from the nearest town and suffers relatively low anthropogenic influence (de Oliveira et al. 2015; Norris & Michalski 2013), having between 3 and 6 houses over the study years.

The regional climate is classified by Köppen-Geiger as Am (Equatorial monsoon) (Kottek et al. 2006), with an annual rainfall greater than 2000 mm (ANA 2016). The driest months are September to November (total monthly rainfall < 150 mm) and the wettest months (total monthly rainfall > 300 mm) from February to April (S1 Fig in (Paredes et al. 2017)).

Management approaches

We assessed nesting success during four nesting seasons (2011, 2015, 2016 and 2017) along the same 33 km river stretch. These seasons included one with no enforcement and no community management (2011), two in which external enforcement of existing protection regulations was undertaken (2015, 2016) and one in which a community-based nest protection program was enacted (2017). These temporal differences in management actions along the same stretch of river enable us to contrast the relative success of enforcement and community based management in protecting river turtle nests.

The enforcement was conducted by the specialist Environmental Police task force ("Batalhão de Polícia Militar Ambiental"). Funding for enforcement actions came from a collaboration with the neighboring strictly protected (IUCN Category II) Tumucumaque National Park ("Parque Nacional Montanhas do Tumucumaque"). Enforcement was provided to patrol navigable rivers that flow along the borders of the sustainable-use areas (FLONA and FLOTA) and the National Park, i.e. rivers that provide access to the strictly protected National Park. The National Park receives funding for such activities from the Amazon Region Protected Areas (ARPA) program, whereas the sustainable-use areas do not receive funding for any enforcement actions. Patrols included between four to six people and were conducted along more than 300 km of rivers that surround the protected areas, including the 33 km study area. Enforcement patrols focused on checks for illegal activities around the protected areas (such as hunting and the possession of illegal arms) and included stopping boats to check fishing nets, the fish caught and speaking with people. The enforcement activities also included stops at beaches to check for illegal activities including hunting. During the enforcement period, the police team was based on the ICMBIO base, at the entrance of the Falsino River, where the community based management activities were subsequently implemented (Fig 1). One member of the police team was also stationed permanently at the base to monitor and question and/or search any boats that passed this strategic location.

The community based management originated in 2017 from a request from the local community and came after two large meetings with local landowners. The community management activities were focused on landowners living along the Falsino river who participated in nest protection activities (plastic predator exclusion devices were placed on top of the river turtle nests to avoid natural predation (Fig. S1). Activities were focused around strategic nesting areas. These were larger areas (> 4 m^2) with most (90% of the nests in the study area). During the nesting season, the landowners were patrolling the beaches, taking note, and protecting new turtle nests when they find it. Researchers contacted the landowners every two weeks to receive updates of the nest monitoring.

Nest-area surveys

To quantify levels of nest harvesting a series of nesting area surveys (Norris et al. 2018) were conducted between September and December in all study years. These months correspond to low water and include the complete nesting and first half of the hatching season in the study area (D. Norris pers. obs.). Nesting data from 2011 were obtained from a previous study (Arraes 2012). In 2015, 2016, and 2017 we then repeated the methodologies applied in 2011, as briefly summarized here, with full details available in Norris et al. (2018). To locate river turtle nests we conducted monthly (interval of 20 – 30 days between visits) surveys of all nesting areas. These searches were conducted together with local residents with over

30 years of knowledge of nesting areas and took place independently of any enforcement or community based management activities. Naturally depredated nests were identified by the presence of broken eggshells and/or remains of partially eaten eggs outside the nest, disturbed/uncovered nests surrounded by animal tracks and the presence of wildlife excavation marks. Human removal was identified when nests were found open (without sand cover), with a mean depth used by the river turtles (~ 10-15 cm), but without eggs or partially eaten eggshells. Human removal was also usually associated with signs of human activities, such as footprints, fire, charcoal, and campsite on the nest sites.

Data analysis

We used the number of nests harvested by humans as the response to compare the effects of external enforcement and community involvement. The contrast in nest harvest proportions between years 2011, 2015 and 2016 enabled us to test the hypothesis that enforcement generated differences in harvest rates. To test the hypothesis that increased enforcement was associated with reduced harvest levels we examined Spearman correlation between the amount of boat fuel (liters of petrol) used by patrols as our index of enforcement effort and the proportion of nests harvested. The contrast in nest status between years 2015, 2016 and 2017 enabled us to test the hypothesis that community based management resulted in lower harvest rates compared with enforcement.. Graphs and descriptive analysis were undertaken within R language and environment for statistical computing (R Core Team 2017).

Results

Harvest rates were high (averaging 61%) in enforcement years, whereas the lowest (26%) harvest level occurred when there was no enforcement patrols along the river (Fig 2). Although harvest levels in enforcement years did differ statistically compared with 2011 (proportion test, P = 0.04184), the continually high harvest rates mean that this statistical difference has little biological relevance. There was no association between enforcement effort and harvest rates (Spearman S = 12.1, P = 0.7892).

Contrary to our expectation that harvest levels would decline with enforcement, we found that a threefold increase in effort (675 to 1665 liters) was associated with a 33% increase in harvest levels between 2015 and 2016.

The lowest harvest was recorded in 2017 when there was no enforcement but community management was implemented. The CBM harvest rate in 2017 (26%) differed significantly from the years (2015 and 2016) with enforcement (proportion test, $P < 0.0001$) and the year (2011, 75%) with no enforcement and no CBM (proportion test, $P < 0.0001$).

Discussion

Our findings strongly suggest that enforcement has little effect on river turtle nest harvesting. Additionally, multiple lines of evidence suggest that there is no direct cause and effect relationship between enforcement effort and nest harvest rates. In contrast, community management was associated with a significant reduction in nest harvest rates. Yet, the community management project did not directly target human removal of turtle nests. So why then was there such a sharp reduction in nest harvest?

It is important to note that the management project was inspired by the community members. The community had expressed concern regarding environmental degradation in the area including the loss of turtle nests, and the increasing amount of rubbish along the river at the beaches /nesting areas. Protecting the nests temporarily against natural predators was a way that community members could actively participate not only in caring for the turtle nests but also the surrounding environment. As human harvesting was not specifically targeted these actions had general support and conflicts were not generated. The lack of conflicts is also explained by the fact that community members do not depend on river turtle nests for their daily nutritional requirements or economic well-being (Norris & Michalski 2013).

Providing payments for protecting nests and/or the selective harvest of nests that would otherwise be flooded have been used to engage local communities in the management of river turtle nests (Caputo et al. 2005). Different to such studies, we did not provide any financial rewards for participation, nor did we translocate nests for headstarting incubation nor harvest selected nests. Seasonal differences in our study area compared with that of Caputo et al. (2005) partly explain the difference in approach. In our study area, peak nesting (mid to late October) takes place approximately two months before river levels rise (mid to late December), which means many embryos are in advanced stages of development and the eggs are not suitable for harvest when levels rise. This is because locals prefer fresh eggs, with harvesting activities also peaking around October. The uncertainty in future effects of climate change, changes in flow rates due to development patterns (e.g. hydropower developments (Timpe & Kaplan 2017)), deforestation, and their synergistic effects on wildlife species and human populations are therefore a challenge for the implementation of conservation solutions. Such uncertainties reinforce the need for solutions to be tailored to the local context.

We found that the involvement of a relatively small number of key personnel had a broad impact and that a positive community perception (of doing the right thing) was sufficient to ensure engagement. Previous studies show that harvest and consumption of nests is not random within or between rivers (Escalona & Fa 1998; Hernández et al. 2010; Norris & Michalski 2013). Harvest rates are not spatially uniform, increasing at beaches closer to towns and in more accessible river sections (Escalona & Fa 1998; Hernández et al. 2010; Pignati et al. 2013). Additionally neighbors consumption was the strongest of 12 environmental, spatial and social variables used to explain patterns of nest consumption in the local community (Norris & Michalski 2013). A detailed understanding of the local context and spatially explicit monitoring of nesting beaches and community activities is therefore required to ensure the success of any community based management of river turtle nests.

Local communities living along Amazon rivers have increasing access to alternative food sources (de Jesus Silva et al. 2017; Piperata et al. 2011) and depend less on relatively limited seasonal supplies to meet their nutritional requirements (de Jesus Silva et al. 2017). Human nest predation and egg consumption has long been recognized as both a threat (reducing recruitment and population size) and opportunity (a valuable resource, which generates stakeholder involvement in conservation) for the conservation and management of *P. unifilis* populations (Caputo et al. 2005; Mittermeier 1978; Smith 1979). However, with riverine communities likely to become progressively less dependent on turtle eggs as a food source (Piperata et al. 2011), conservation activities need to be developed that do not rely simply on the preservation of nests for subsequent commercialization. Our results suggest that indirect benefits and intrinsic values placed by local communities can be as important as economic gain for the development of successful conservation actions aimed at maintaining natural resources.

Human harvest is ubiquitous across the species range (Escalona & Fa 1998; Hernández et al. 2010; Landeo 1997; Smith 1979; Vogt 2008), and without management the levels of human harvest of river turtle nests are typically > 50% (Table 1) and can reach 100% at nesting areas [(Bermúdez-Romero et al. 2010; Hernández et al. 2010; Lipman 2008), D Norris pers. obs., 2016]. Although we found high harvest levels prior to community management, we expect that these observed proportions represent minimum values. This is because nests sites can be hard to detect as they may be concealed post-harvest by harvesters. It therefore seems plausible that differences in detectability could explain at least part of the variation (harvest levels ranged from 55% to 75%) in the proportion of nests removed in the years prior to the community management in 2017.

Fewer nests were found during the years with enforcement patrols (2015 and 2016), and we hypothesize that these reductions can be attributed to the increased and/or more careful concealment of harvested nests as a response to the presence of the enforcement patrols. The harvest of nests falls within a grey area of the protected area governance and legislation. The river is outside of the protected area border, Brazilian legislation allows for the harvest of natural resources to meet basic (nutritional) needs. Although both the existing governance regime and legislation is often ambiguous and unclear, local residents are within their rights to consume the river turtle nests, so why would concealment increase with the presence of enforcement? The most likely explanation is that nest harvest was not carried out by the local residents. Although interviews reveal that more than 50% of local residents eat turtle eggs, the locals remain close (typically < 500 m) to their houses (Norris & Michalski 2013). Community members cite harvest for commercial exploitation by outsiders (town residents) as the main cause of nest removal.

The needs of different users can generate conflicts in common pool resources (Ostrom 2015). Our findings from the first year of community-based management were overwhelmingly positive and the expected conflicts did not occur. There appears to be a strong degree of respect and understanding of environmental problems within the local communities. The community based management was implemented after seven years of research and has developed with the local communities. As such, our findings suggest that engagement and good will are most important results that explain the success of the first year. There is obviously no guarantee that this will continue, and there is a need to continually engage and work with local communities within an adaptive management framework with the capacity to respond to socio-economic changes as well as new and unforeseen challenges.

Conclusions

Although our findings come from the first year of community management the clear reduction in river turtle nest harvest shows that a focus on community involvement generates immediate benefits for conservation within multiuse protected areas. Our findings suggest that the presence of community members monitoring and protecting against natural predators was sufficient to deter the harvest by outsiders without generating any obvious conflicts. As such we conclude that the good will, understanding, and perceptions of the local communities are the vital/keystone components for the success of conservation activities within the sustainable-use protected areas.

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References

ANA. 2016. Sistema de Informações Hidrológicas - HidroWeb. *Available at http://hidroweb.ana.gov.br/* (accessed 20 July 2016).

Barlow J, Lennox GD, Ferreira J, Berenguer E, Lees AC, Nally RM, Thomson JR, Ferraz SFdB, Louzada J, Oliveira VHF, Parry L, Ribeiro de Castro Solar R, Vieira ICG, Aragão LEOC, Begotti RA, Braga RF, Cardoso TM, Jr RCdO, Souza Jr CM, Moura NG, Nunes SS, Siqueira JV, Pardini R, Silveira JM, Vaz-de-Mello FZ, Veiga RCS, Venturieri A, and Gardner TA. 2016. Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. *Nature* 535:144-147. 10.1038/nature18326

Bermúdez-Romero AL, Hoyos-Rodríguez M, Álape-Sánchez DE, Morales-Betancourt MA, and Solano C. 2010. Tortugas Charapa y Taricaya (*Podocnemis expansa* y *Podocnemis unifilis*), un recurso de conservación prioritario. In: Bermúdez-Romero AL, Trujillo F, Solano C, Alonso JC, and Ceballos-Ruiz L, eds. *Retos locales y regionales para la conservación de la fauna acuática del sur de la Amazonia colombiana*. Bogotá: Corpoamazonia, Instituto Sinchi, Fundación Omacha y Fundación Natura, 111-127.

Bernard E, Penna L, and Araújo E. 2014. Downgrading, downsizing, degazettement, and reclassification of protected areas in Brazil. *Conservation Biology* 28:939-950. 10.1111/cobi.12298

Böhm M, Collen B, Baillie JEM, Bowles P, Chanson J, Cox N, Hammerson G, Hoffmann M, Livingstone SR, Ram M, Rhodin AGJ, Stuart SN, van Dijk PP, Young BE, Afuang LE, Aghasyan A, García A, Aguilar C, Ajtic R, Akarsu F, Alencar LRV, Allison A, Ananjeva N, Anderson S, Andrén C, Ariano-Sánchez D, Arredondo JC, Auliya M, Austin CC, Avci A, Baker PJ, Barreto-Lima AF, Barrio-Amorós CL, Basu D, Bates MF, Batistella A, Bauer A, Bennett D, Böhme W, Broadley D, Brown R, Burgess J, Captain A, Carreira S, Castañeda MdR, Castro F, Catenazzi A, Cedeño-Vázquez JR, Chapple DG, Cheylan M, Cisneros-Heredia DF, Cogalniceanu D, Cogger H, Corti C, Costa GC, Couper PJ, Courtney T, Crnobrnja-Isailovic J, Crochet P-A, Crother B, Cruz F, Daltry JC, Daniels RJR, Das I, de Silva A, Diesmos AC, Dirksen L, Doan TM, Dodd CK, Doody JS, Dorcas ME, Duarte de Barros Filho J, Egan VT, El Mouden EH, Embert D, Espinoza RE, Fallabrino A, Feng X, Feng Z-J, Fitzgerald L, Flores-Villela O, França FGR, Frost D, Gadsden H, Gamble T, Ganesh SR, Garcia MA, García-Pérez JE, Gatus J, Gaulke M, Geniez P, Georges A, Gerlach J, Goldberg S, Gonzalez J-CT, Gower DJ, Grant T, Greenbaum E, Grieco C, Guo P, Hamilton AM, Hare K, Hedges SB, Heideman N, Hilton-Taylor C, Hitchmough R, Hollingsworth B, Hutchinson M, Ineich I, Iverson J, Jaksic FM, Jenkins R, Joger U, Jose R, Kaska Y, Kaya U, Keogh JS, Köhler G, Kuchling G, Kumlutaş Y, Kwet A, La Marca E, Lamar W, Lane A, Lardner B, Latta C, Latta G, Lau M, Lavin P, Lawson D, LeBreton M, Lehr E, Limpus D, Lipczynski N, Lobo AS, López-Luna MA, Luiselli L, Lukoschek V, Lundberg M, Lymberakis P, Macey R, Magnusson WE, Mahler DL, Malhotra A, Mariaux J, Maritz B, Marques OAV, Márquez R, Martins M, Masterson G, Mateo JA, Mathew R, Mathews N, Mayer G, McCranie JR, Measey GJ, Mendoza-Quijano F, Menegon M, Métrailler S, Milton DA, Montgomery C, Morato SAA, Mott T, Muñoz-Alonso A, Murphy J, Nguyen TQ, Nilson G, Nogueira C, Núñez H, Orlov N, Ota H, Ottenwalder J, Papenfuss T, Pasachnik S, Passos P, Pauwels OSG, Pérez-Buitrago N, Pérez-Mellado V, Pianka ER, Pleguezuelos J, Pollock C, Ponce-Campos P, Powell R, Pupin F, Quintero Díaz GE, Radder R, Ramer J, Rasmussen AR, Raxworthy C, Reynolds R, Richman N, Rico EL, Riservato E, Rivas G, da Rocha PLB, Rödel M-O, Rodríguez Schettino L, Roosenburg WM, Ross JP, Sadek R, Sanders K, Santos-Barrera G, Schleich HH, Schmidt BR, Schmitz A, Sharifi M, Shea G, Shi H-T, Shine R, Sindaco R, Slimani T, Somaweera R, Spawls S, Stafford P, Stuebing R, Sweet S, Sy E, Temple HJ, Tognelli MF, Tolley K, Tolson PJ, Tuniyev B, Tuniyev S, Üzüm N, van Buurt G, Van Sluys M, Velasco A, Vences M, Veselý M, Vinke S, Vinke T, Vogel G, Vogrin M, Vogt RC, Wearn OR, Werner YL, Whiting MJ, Wiewandt T, Wilkinson J, Wilson B, Wren S, Zamin T, Zhou K, and Zug G. 2013. The conservation status of the world's reptiles. *Biological Conservation* 157:372-385. 10.1016/j.biocon.2012.07.015

Campos-Silva JV, and Peres CA. 2016. Community-based management induces rapid recovery of a high-value tropical freshwater fishery. *Scientific Reports* 6:34745. 10.1038/srep34745

Caputo FP, Canestrelli D, and Boitani L. 2005. Conserving the terecay (*Podocnemis uinifilis*, Testudines : Pelomedusidae) through a community-based sustainable harvest of its eggs. *Biological Conservation* 126:84-92. 10.1016/j.biocon.2005.05.004

de Jesus Silva R, de Paula Eduardo Garavello ME, Nardoto GB, Mazzi EA, and Martinelli LA. 2017. Factors influencing the food transition in riverine communities in the Brazilian Amazon. *Environment, Development and Sustainability* 19:1087-1102. 10.1007/s10668-016-9783-x

de Oliveira IAP, Norris D, and Michalski F. 2015. Anthropogenic and seasonal determinants of giant otter sightings along waterways in the northern Brazilian Amazon. *Mammalian Biology - Zeitschrift für Säugetierkunde* 80:39-46. 10.1016/j.mambio.2014.07.006

Dietz T, Ostrom E, and Stern PC. 2003. The Struggle to Govern the Commons. *Science* 302:1907-1912. 10.1126/science.1091015

Eisemberg CC, Rose M, Yaru B, and Georges A. 2011. Demonstrating decline of an iconic species under sustained indigenous harvest – The pig-nosed turtle (Carettochelys insculpta) in Papua New Guinea. *Biological Conservation* 144:2282-2288. 10.1016/j.biocon.2011.06.005

Escalona T, and Fa JE. 1998. Survival of nests of the terecay turtle (Podocnemis unifilis) in the Nichare-Tawadu rivers, Venezuela. *Journal of Zoology* 244:303-312. 10.1111/j.1469-7998.1998.tb00034.x

Fletcher R, Dressler W, Büscher B, and Anderson ZR. 2016. Questioning REDD+ and the future of market-based conservation. *Conservation Biology* 30:673-675. 10.1111/cobi.12680

Gibbon JW, Scott DE, Ryan TJ, Buhlmann KA, Tuberville TD, Metts BS, Greene JL, Mills T, Leiden Y, Poppy S, and Winne CT. 2000. The Global Decline of Reptiles, Déjà Vu Amphibians. *BioScience* 50:653-666. 10.1641/0006-3568(2000)050[0653:TGDORD]2.0.CO;2

Harju E, Sirén AH, and Salo M. 2017. Experiences from harvest-driven conservation: Management of Amazonian river turtles as a common-pool resource. *Ambio*. 10.1007/s13280-017-0943-5

Hernández O, Espinosa-Blanco AS, May LC, Jiménez-Oraa M, and Seijas AE. 2010. Artificial incubation of yellow-headed sideneck turtle Podocnemis unifilis eggs to reduce losses to flooding and predation, Cojedes and Manapire Rivers, southern Venezuela. *Conservation Evidence* 7:100-105.

Hilborn R, Arcese P, Borner M, Hando J, Hopcraft G, Loibooki M, Mduma S, and Sinclair AR. 2006. Effective enforcement in a conservation area. *Science* 314:1266-1266. 10.1126/science.1132780

Keane A, Jones JP, Edwards-Jones G, and Milner-Gulland EJ. 2008. The sleeping policeman: understanding issues of enforcement and compliance in conservation. *Animal Conservation* 11:75-82. 10.1111/j.1469-1795.2008.00170.x

Kottek M, Grieser J, Beck C, Rudolf B, and Rubel F. 2006. World map of the Koppen-Geiger climate classification updated. *Meteorologische Zeitschrift* 15:259-263. 10.1127/0941-2948/2006/0130

Lambin EF, Meyfroidt P, Rueda X, Blackman A, Börner J, Cerutti PO, Dietsch T, Jungmann L, Lamarque P, and Lister J. 2014. Effectiveness and synergies of policy instruments for land use governance in tropical regions. *Global Environmental Change* 28:129-140. 10.1016/j.gloenvcha.2014.06.007

Landeo C. 1997. Factores limitantes de la población preeclosional de la taricaya *Podocnemis unifilis* en el río Manú. In: Fang TG, Bodmer RE, Aquino R, and Valqui MH, eds. *Manejo de Fauna Silvestre en la Amazonía*. La Paz, Bolivia: UNAP, 185-189.

Lipman AJ. 2008. An ecological approach to community-based conservation: Management of Podocnemis river turtles in Noel Kempff Mercado National Park, Bolivia. University of Georgia.

Mittermeier RA. 1978. South America's river turtles: saving them by use. *Oryx* 14:222-230. 10.1017/S0030605300015532

Mittermeier RA, van Dijk PP, Rhodin AGJ, and Nash SD. 2015. Turtle Hotspots: An Analysis of the Occurrence of Tortoises and Freshwater Turtles in Biodiversity Hotspots, High-Biodiversity Wilderness Areas, and Turtle Priority Areas. *Chelonian Conservation and Biology* 14:2-10. 10.2744/ccab-14-01-2-10.1

Nepstad D, Schwartzman S, Bamberger B, Santilli M, Ray D, Schlesinger P, Lefebvre P, Alencar A, Prinz E, Fiske G, and Rolla A. 2006. Inhibition of Amazon Deforestation and Fire by Parks and Indigenous Lands. *Conservation Biology* 20:65-73. 10.1111/j.1523-1739.2006.00351.x

Nolte C, Agrawal A, Silvius KM, and Soares-Filho BS. 2013. Governance regime and location influence avoided deforestation success of protected areas in the Brazilian Amazon. *Proceedings of the National Academy of Sciences* 110:4956-4961. 10.1073/pnas.1214786110

Norris D, and Michalski F. 2013. Socio-economic and spatial determinants of anthropogenic predation on Yellow-spotted River Turtle, *Podocnemis unifilis* (Testudines: Pelomedusidae), nests in the Brazilian Amazon: Implications for sustainable conservation and management. *Zoologia* 30:482-490. 10.1590/s1984-46702013000500003

Norris D, Michalski F, and Gibbs JP. 2018. Beyond harm's reach? Submersion of river turtle nesting areas and implications for restoration actions after Amazon hydropower development. *PeerJ* 6:e4228. 10.7717/peerj.4228

Ostrom E. 2015. *Governing the commons*. Cambridge: Cambridge University Press.

Paredes OSL, Norris D, de Oliveira TG, and Michalski F. 2017. Water availability not fruitfall modulates the dry season distribution of frugivorous terrestrial vertebrates in a lowland Amazon forest. *PLoS ONE* 12:e0174049.

Peres CA. 2011. Conservation in sustainable-use tropical forest reserves. *Conservation Biology* 25:1124-1129. 10.1111/j.1523-1739.2011.01770.x

Peres CA, Barlow J, and Laurance WF. 2006. Detecting anthropogenic disturbance in tropical forests. *Trends in ecology & evolution* 21:227-229. 10.1016/j.tree.2006.03.007

Pfaff A, Robalino J, Sandoval C, and Herrera D. 2015. Protected area types, strategies and impacts in Brazil's Amazon: public protected area strategies do not yield a consistent ranking of protected area types by impact. *Phil Trans R Soc B* 370:20140273. 10.1098/rstb.2014.0273

Pignati MT, Fernandes LF, Miorando PS, Ferreira PD, and Pezzuti JCB. 2013. Nesting Site and Hatching Success of Podocnemis unifilis (Testudines: Podocnemididae) in a Floodplain Area in Lower Amazon River, Pará, Brazil. *South American Journal of Herpetology* 8:175-185. 10.2994/SAJH-D-13-00006.1

Piperata BA, Spence JE, Da-Gloria P, and Hubbe M. 2011. The Nutrition Transition in Amazonia: Rapid Economic Change and its Impact on Growth and Development in Ribeirinhos. *American Journal of Physical Anthropology* 146:1-13. 10.1002/ajpa.21459

R Core Team. 2017. R: A Language and Environment for Statistical Computing. 3.4.2. *Available at* https://www.R-project.org/.

Reed J, Van Vianen J, Deakin EL, Barlow J, and Sunderland T. 2016. Integrated landscape approaches to managing social and environmental issues in the tropics: learning from the past to guide the future. *Global Change Biology* 22:2540-2554. 10.1111/gcb.13284

Richards P, Arima E, VanWey L, Cohn A, and Bhattarai N. 2017. Are Brazil's Deforesters Avoiding Detection? *Conservation Letters* 10: 470–476. 10.1111/conl.12310

Smith NJH. 1979. Aquatic turtles of Amazonia: an endangered resource. *Biological Conservation* 16:165–176. 10.1016/0006-3207(79)90019-3

Timpe K, and Kaplan D. 2017. The changing hydrology of a dammed Amazon. *Science Advances* 3. 10.1126/sciadv.1700611

UNEP-WCMC, and IUCN. 2018. Protected Planet: The World Database on Protected Areas (WDPA). *Available at* www.protectedplanet.net (accessed 24 January 2018).

Vogt R. 2008. *Tartarugas da Amazonia*. Manaus: INPA.

Figure 1

Study area.

(A) State of Amapá in Brazil. (B) Location within Amapá. (C) Showing location of community managed *Podocnemis unifilis* nesting areas. Red solid line delimits the location of the Falsino river section with community management. Solid black square is the location of the ICMBio base that served as the enforcement base in 2015 and 2016. The nearest town – Porto Grande is shown by a solid red circle. Location of the FLONA sustainable-use protected area is shown in yellow.

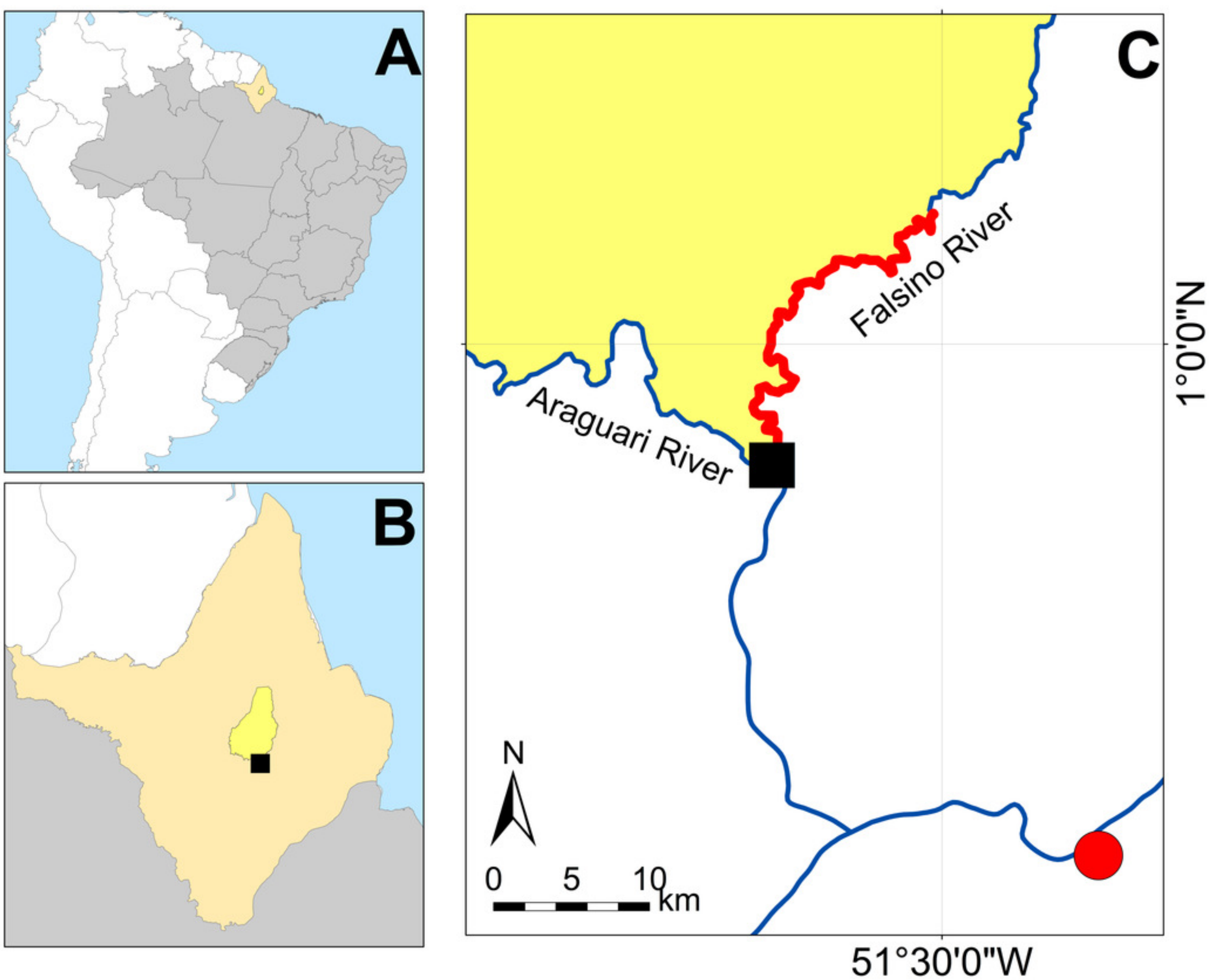

Table 1(on next page)

Nest harvest rates obtained from the literature.

Comparison of harvest rates of yellow-spotted river turtle nests with and without community based management. Means and confidence limits obtained via nonparametric bootstrap without assuming normality.

Type	Study duration	Harvest (%)	Nests		Location	Source
			Total	Harvest		
No community management	Single season	51.9	952	494	Manú, Peru	Landeo (1997)
	Single season	84.9	351	298	Nichare-Tawadu, Venezuela	Escalona & Fa (1998)
	Single season	50.9	165	84	Manapire & Cojedes, Venezuela.	Hernández et al. (2010)
	Single season	81.2	69	56	Bajo & Medio Putumayo, Peru	Bermúdez-Romero et al. (2010)
	Multi season	31.8	434	138	Iténez & Paraguá, Bolivia	Lipman (2008)
	Multi season	65.7	268	188	Falsino River, Brazil	Present study
Mean (±95% CI)		61.1 (46.4 – 75.4)				
With community management	Single season	28.2	383	108	Aguarico River, Ecuador	Caputo et al. (2005)
	Multi season	19.4	273	53	Taboleiro da Água Preta, Brazil	Pignati et al. (2013)
	Multi season	0.1	676	1	Iténez & Paraguá, Bolivia	Lipman (2008)
	Single season	26.4	144	38	Falsino River, Brazil	Present study
Mean (±95% CI)		18.5 (6.7 – 27.8)				

Figure 2

Four years of nest harvest

Harvest of *Podocnemis unifilis* nests along 33 km of river in Amapá State, Brazil. (A) Nest harvest during years with (white triangle) and without (black circles) community based management (CBM). Total number of nests in parentheses, the dashed horizontal line shows the median harvest from the three years without CBM. Horizontal grey shading represents the 95% confidence interval of harvest levels in the absence of CBM across the species range (see Table 1). (B) Proportion of river turtle nests harvested in four nesting seasons. (C) Enforcement effort during four river turtle nesting seasons.