Community involvement works where enforcement fails: conservation success through community-based management of Amazon river turtle nests

Darren Norris [Corresp., 1, 2, 3] , **Fernanda Michalski** [2, 3, 4] , **James P Gibbs** [5]

1 School of Environmental Sciences, Federal University of Amapá, Macapá, Amapá, Brazil
2 Ecology and Conservation of Amazonian Vertebrates Research Group, Federal University of Amapá, Macapá, Amapá, Brazil
3 Postgraduate Programme in Tropical Biodiversity, Federal University of Amapá, Macapá, Amapá, Brazil
4 Instituto Pró-Carnívoros, Atibaia, São Paulo, Brazil
5 Department of Forest and Environmental Biology, State University of New York (SUNY), Syracuse, New York, United States

Corresponding Author: Darren Norris
Email address: darren.norris@unifap.br

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 lawful protection regulations had no effect on nest harvesting. In contrast, during one year when community-based management approaches were enacted harvest levels dropped nearly threefold to a rate (26%) that is likely sufficient for river turtle population recovery. Our findings support previous studies that show how community participation, if appropriately implemented, can facilitate effective natural resource management where law enforcement is limited or ineffective.

1 Short title:

2 Amazon river turtle protection

4 Title:

5 Community involvement works where enforcement fails: Conservation success through community-

6 based management of Amazon river turtle nests

8 Authors: Darren Norris[1,2,3*], Fernanda Michalski[2,3,4], James P. Gibbs[5]

9 [1] School of Environmental Sciences, Federal University of Amapá, Rod. Juscelino Kubitschek Km 02,

10 68903-419 Macapá, Brazil

11 [2]Ecology and Conservation of Amazonian Vertebrates Research Group, Federal University of Amapá,

12 Rod. Juscelino Kubitschek Km 02, 68903-419 Macapá, Brazil

13 [3] Postgraduate Programme in Tropical Biodiversity, Federal University of Amapá, Rod. Juscelino

14 Kubitschek Km 02, 68903-419 Macapá, Brazil

15 [4] Instituto Pró-Carnívoros, Atibaia, São Paulo, Brazil

16 [5]Department of Forest and Environmental Biology, State University of New York, 404 Illick Hall, 13210

17 Syracuse, NY, USA

19 Corresponding author: Darren Norris*

20 E-mail: darren.norris@unifap.br

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 lawful protection regulations had no effect on nest harvesting. In

contrast, during one year when community-based management approaches were enacted harvest levels

dropped nearly threefold to a rate (26%) that is likely sufficient for river turtle population recovery. Our

findings support previous studies that show how community participation, if appropriately

implemented, can facilitate effective natural resource management where law enforcement is limited or

ineffective.

Introduction

Law enforcement can be an important tool for biodiversity conservation (Hilborn et al. 2006; Keane et al. 2008).Yet without motivation for compliance, punitive governance actions (including enforcement) are unlikely to succeed (Dietz et al. 2003; Keane et al. 2008; Ostrom 2015) and can even be counter-productive by generating conflicts with local communities (Dietz et al. 2003). The reality is that successful governance through effective external enforcement is the exception not the rule (Ostrom 2015). Further work is urgently required to produce practical guidelines for the optimal use of enforcement measures in biodiversity conservation (Dietz et al. 2003; Keane et al. 2008).

Developing effective conservation solutions is complicated for protected areas managed under multiuse governance regimes (Lambin et al. 2014; Nolte et al. 2013; Pfaff et al. 2015; Richards et al. 2017).Rules governing human behavior are at the heart of every system of common pool / multiuse resource management (Ostrom 2015; Salo et al. 2014). Within these scenarios governance is the art of motivating stakeholders to follow established rules and is necessary (but not always sufficient) for management success (Salo et al. 2014). 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). Integrating conservation and development projects can represent a successful, hybridized approach despite governance and enforcement being particularly challenging in mixed-use/common pool resource areas (Dietz et al. 2003).

Sustainable-use protected areas 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). Such areas are a primary example of general attempts to integrate communities and protected areas to generate conservation solutions. Local community-based management can be effective for the conservation of common pool resources (Campos-Silva & Peres 2016) although perennially struggle in practice with the

61 massive spatial scale at which they are often intended to achieve success, physical and intellectual

62 isolation, dearth of funding, and lack of political will (Peres 2011).

63   River turtles represent an important common pool resource across temperate and tropical

64 regions (Dudgeon et al. 2006) and are a focus of local community-based management in the Amazon.

65 Aquatic turtles are one of the most endangered groups of vertebrates (Gibbon et al. 2000), with some

66 52% of river turtles listed in some form of "threatened" by the IUCN (Böhm et al. 2013). River turtles

67 represent provisioning (food, source of income) and cultural services for local populations across the

68 globe (Eisemberg et al. 2011; Harju et al. 2017; Mittermeier et al. 2015). River turtles therefore present

69 informative and highly pertinent examples of the challenges facing conservation of common pool

70 resources in a rapidly changing world (Dietz et al. 2003; Gibbon et al. 2000; Harju et al. 2017;

71 Mittermeier et al. 2015).

72   Anthropogenic impacts including overexploitation have led to the decimation of many river turtle

73 populations across the Amazon region (Castello et al. 2013; Mittermeier 1978; Smith 1979). Despite

74 recent changes driven by region wide development (Piperata et al. 2011) the eggs and meat of side-

75 necked turtles (Podocnemididae) continue to be a widespread component in the diet of both rural and

76 urban peoples across Amazonia (Harju et al. 2017; Parry et al. 2014). Continued high demand for

77 Amazon river turtles generates high expectations for, and sharp debate about governance-effective

78 management approaches necessary to ensure the conservation of these species (Páez et al. 2015).

79   The most commonly adopted management approaches for Amazon river turtles involve actions

80 around the protection and conservation of nesting areas, nests and hatchlings during this critical life

81 phase when individual turtles are highly concentrated on exposed river sands accessible to people

82 (Harju et al. 2017; Mittermeier 1978; Páez et al. 2015; Vogt 2008). Nesting areas emerge episodically

83 with seasonal lowering of river levels and can shift from one season to the next so are typically

84 common-pool resources for which management actions necessarily include a variety of governance

85   mechanisms to ensure compliance (Salo et al. 2014). Mechanisms can be enforcement-focused and

86   punitive or they can target engagement with local stakeholders. The application of enforcement and

87   engagement (independently or in combination), depends heavily on the local context to secure both

88   participation and compliance (Dietz et al. 2003; Ostrom 2015; Salo et al. 2014).

89   The social, cultural and environmental diversity across Amazonia means that there remain few

90   examples comparing the relative efficacy of different governance approaches in the conservation

91   management of river turtles. How do we know what actually works? What combination of stakeholder

92   engagement, constructive participation, incentivization and external enforcement actually translate into

93   improved population status for river turtles and increased sustainability of resource use for local

94   stakeholders?

95   Herein we address these questions by presenting a recent harvest history of yellow-spotted river

96   turtle nests along 33 km of river situated between two Amazon sustainable-use protected areas. We

97   compare the exploitation of river turtle nests along the river segment during years when "protection"

98   emphasized only law enforcement via parties external to the local community versus when conservation

99   effort focused only on community engagement for the collaborative management of turtle nesting

100   areas. This "quasi-experiment" in the form of a temporal comparison among years with strongly

101   contrasting management approaches enabled us to evaluate the relative success of community

102   involvement versus enforcement for a sustaining a shared-pool resource in a protected area.

103

Materials and Methods

104

Ethics statement

105

106   Ethical approval was not required for our noninvasive study, as we did not collect any biological samples

107   nor interfere with the behavior of the study species. Permission to collect observational data from river

108   turtle nesting areas was provided by research permit number IBAMA/SISBIO 49632-1 and 49632-2 to DN

109 and FM, issued by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). Interviews

110 and meetings with local residents were approved by IBAMA/SISBIO (permits 45034-1, 45034-2, 45034-3)

111 and the Ethics Committee in Research from the Federal University of Amapá (UNIFAP) (CAAE

112 42064815.5.0000.0003, Permit number 1.013.843).

113

114 **Study area**

115 The study was conducted along 33 km of the Falsino River, in the state of Amapá, Brazil (N 0.77327, W

116 51.58064; Fig. 1). This river segment runs between two sustainable-use protected areas, the Amapá

117 National Forest and the Amapá State Forest (hereafter "FLONA" and "FLOTA" respectively). Both are

118 National Forests, but only the FLONA (VI – "Protected area with sustainable use of natural resources") is

119 designated within the IUCN Protected Area Classification (UNEP-WCMC & IUCN 2018). This particular

120 stretch of river is 61 km from the nearest town and suffers relatively low anthropogenic influence (de

121 Oliveira et al. 2015; Norris & Michalski 2013), hosting just 3 - 6 houses during our study.

122 The regional climate is classified by Köppen-Geiger as "Am" (Equatorial monsoon) (Kottek et al.

123 2006), with an annual rainfall greater than 2000 mm (ANA 2016). The driest months are September to

124 November (total monthly rainfall < 150 mm) and the wettest months (total monthly rainfall > 300 mm)

125 from February to April (S1 Fig in (Paredes et al. 2017)).

126

127 **Background on river turtle management approaches**

128 The conservation and commercial exploitation of *Podocnemis unifilis* in Brazil contrasts with other South

129 American countries. Conservation actions primarily aimed at protecting nests were initiated at a time of

130 military rule (early 1970's) and have continued through democratization (1970's – 1980's) and into the

131 21st century (Alho 1985; Páez et al. 2015; Vogt 2008). Today management actions are developed within

132 international (*Podocnemis unifilis* is listed on CITES Appendix II, to which Brazil is a contracting party

133   since 1975) and national laws. For example Brazilian Federal law (Lei 5.197 of 3 January 1967) prohibits

134   the capture of wild turtles. The commercialization of farmed *Podocnemis unifilis* products including

135   meat, eggs and hatchlings is legally (under certain circumstances) and technically possible but these

136   actions are regulated by a complex and ambiguous suit of Brazilian Federal and State laws.

137   In our study area the management approaches aimed at conserving the species along the rivers

138   bordering the protected areas have varied over the last decade. Few alternative sources of revenue exist

139   for the local riverine populations in the area particularly as other widely commercialized species such as

140   the Giant South American Turtle (*Podocnemis expansa*) and the arapaima (*Arapaima gigas*) are not

141   present. Interviews with local landowners confirm that these species have not been present for at least

142   the last 60 years. Yet it is not possible to be certain whether this absence comes from historic

143   overexploitation or biogeographic limits to the species distribution. Although surrounded by

144   sustainable-use protected areas the continued survival of the traditional riverine communities is further

145   complicated by mercury contamination of fish stocks (Venturieri et al. 2017) and hydroelectric

146   expansion (Norris et al. 2018) that degrade the natural resources upon which they depend.

147   The need for direct conservation action to ensure the survival and recovery of *Podocnemis unifilis*

148   populations comes from anthropogenic pressures (primarily overexploitation e.g. hunting and nest

149   harvesting) originating from both a nearby town (Porto Grande, current population ca. 10,000 (IBGE

150   2010)) and the local riverine communities including approximately 50 families that live along the rivers

151   upstream from Porto Grande (Norris & Michalski 2013). The FLONA was created in 1989, and local

152   community members report that the first FLONA manager may have attempted nest translocation and

153   protection activities prior to 2009. Subsequently, in 2012, the organ responsible for the management of

154   the FLONA (ICMBio) implemented nest translocation and protection in an artificial nesting area

155   constructed at the ICMBio base, located at the entrance of the Falsino River (Fig. 1). A small number of

156   community members received payment to participate in the monitoring and protection of these nests.

157   The locals report that this action was of limited success as more than half of the translocated nests did

158   not survive and there was no funding to continue activities in subsequent years.

159   With the publication of the FLONA management plan in 2014 it became feasible (management

160   plans are a legal pre-requisite for many governance actions associated with Brazilian protected areas) to

161   adopt actions focusing on compliance of existing legislation. With a continued increase in infractions

162   (e.g. illegal hunting) a decision was made by ICMBio managers to initiate external enforcement actions.

163   The enforcement was conducted in 2015 and 2016 by the specialist Environmental Police task force

164   ("Batalhão de Polícia Militar Ambiental"). Funding for enforcement actions came from a collaboration

165   with the neighboring strictly protected (IUCN Category II) Tumucumaque National Park ("Parque

166   Nacional Montanhas do Tumucumaque"). Enforcement was provided to patrol navigable rivers that flow

167   along the borders of the sustainable-use areas (FLONA and FLOTA) and the National Park, i.e., rivers that

168   provide access to the strictly protected National Park. The National Park receives funding for such

169   activities from the Amazon Region Protected Areas (ARPA) program, whereas the sustainable-use areas

170   do not receive funding for any enforcement actions.

171   Enforcement patrols included between four to six people and were conducted along more than

172   160 km of rivers that surround the protected areas, including the 33 km study area. Enforcement patrols

173   focused on checks for illegal activities around the protected areas (such as hunting and the possession of

174   illegal arms) and included stopping boats to check fishing nets, the fish, the boat contents and question

175   boat crews. The enforcement activities also included stops at beaches to check for illegal activities

176   including hunting. During the enforcement period, the police team was based on the ICMBIO base (Fig.

177   1). One member of the police team was also stationed permanently at the base to monitor and question

178   and/or search any boats that passed this strategic location. Although there was a broad remit for the

179   enforcement patrols (i.e. they were targeting a range of illegal activities) their timing was synchronized

180   with the river turtle nesting season, which was a tactical management decision that aimed to use

181   external enforcement to increase legal compliance and reduce illegal nest harvests and thereby increase

182   the survival of river turtle nests and production of hatchlings along the rivers.

183   In 2017 a community-based management approach was undertaken, inspired by a request from

184   the local community itself. The decisions as to the actions adopted (e.g. the where, who, what and how)

185   came after two large meetings with the local landowners and ICMBio managers. The community

186   management activities were focused on landowners living along the Falsino River who participated in

187   nest protection activities (predator exclusion devices were placed on top of the river turtle nests to

188   avoid natural predation (Fig. S1)). Activities were focused around strategic nesting areas that were the

189   larger nesting areas (> 4 m^2) hosting most of the nests in the 33 km study area (accounting for 90 % of

190   nests in 2011). During the nesting season, local landowners monitored the nesting areas twice a week,

191   taking note, and protecting any new turtle nests with predator exclusion devices (Fig. S1). Local

192   landowners did not receive any payment for participation, but received training, gasoline and materials

193   necessary from an ongoing research project

194   (http://sites.nationalacademies.org/PGA/PEER/PEERscience/PGA_168063). Researchers contacted the

195   landowners every two weeks to receive updates of the nest monitoring.

196

197   **Nesting area surveys**

198   We assessed nesting success during four nesting seasons (2011, 2015, 2016 and 2017) along the same

199   33 km river segment (Table 1). This sequence of monitoring seasons represented a temporally

200   structured quasi-experiment that included one reference season with no enforcement and no

201   community management (2011), two in which external enforcement of existing protection regulations

202   was undertaken (2015, 2016) and one in which a community-based nest protection program was

203   enacted (2017). These temporal differences in management actions along the same river segment

204   enabled us to contrast the relative success of external enforcement and community-based management

205   in protecting river turtle nests.

206   To quantify levels of nest harvesting a series of nesting area surveys (Norris et al. 2018) were

207   conducted between September and December in all study years. These months correspond to low water

208   and include the complete nesting and first half of the hatching season in the study area (D. Norris pers.

209   obs., 2016). Nesting data from 2011 were obtained from a previous study (Arraes 2012). In 2015, 2016,

210   and 2017 we then repeated the methodologies applied in 2011, as briefly summarized here, with full

211   details available in Norris et al. (2018). To locate river turtle nests we conducted monthly (interval of 20

212   – 30 days between visits) surveys of all potential nesting areas including river banks and islands along

213   the 33 km section by navigating along the river in a motorized boat at a constant speed (ca. 10 km/h).

214   When potential nesting areas were identified through visually searching river banks and circling

215   islands we stopped to search for turtle nests. We identified potential areas where environmental

216   conditions matched those described in the literature (Escalona & Fa 1998; Norris et al. 2018; Pignati et

217   al. 2013) and/or those found at the nesting areas from 2011. Nesting areas were mapped with a

218   handheld GPS to calculate the size of the available nesting area (Escalona & Fa 1998; Norris et al. 2018).

219   These searches were conducted together with local residents with decades of knowledge of nesting

220   areas and took place independently of any enforcement or community-based management activities. To

221   minimize possible observer biases related to the searches of turtle nesting areas and nests we

222   maintained at least one observer in the team constant while conducting searches in all years (2011,

223   2015, 2016, and 2017). Naturally depredated nests were identified by the presence of broken eggshells

224   and/or remains of partially eaten eggs outside the nest, disturbed/uncovered nests surrounded by

225   animal tracks and the presence of wildlife excavation marks. Human removal was identified when nests

226   were found open (without sand cover), with a mean depth used by the river turtles (~ 10-15 cm), but

227   without eggs or partially eaten eggshells. Human removal of eggs was also usually associated with signs

228   of human activities, such as footprints, fire, charcoal, and campsite on the nesting areas.

229

230   **Data analysis**

231   We used the proportion of nesting areas and proportion of nests harvested by humans as response

232   variables to compare the effects of external enforcement and community involvement. The contrast (2-

233   sample test for equality of proportions with continuity correction) in nest harvest proportions between

234   years 2011, 2015 and 2016 enabled us to test the hypothesis that enforcement generated differences in

235   harvest rates. To test the hypothesis that increased enforcement was associated with reduced harvest

236   levels we examined Spearman correlation between the amount of boat fuel (liters of petrol) used by the

237   enforcement patrols as our index of enforcement effort and the proportion of nesting areas and nests

238   harvested. If enforcement was effective for the management of the river turtles we predict that the

239   harvest (proportion of both nesting areas and nests harvested) should decline with increasing

240   enforcement effort (represented by liters of petrol used). The contrast (2-sample test for equality of

241   proportions with continuity correction) in nest status between years 2015, 2016 and 2017 enabled us to

242   test the hypothesis that community-based management resulted in lower harvest rates compared with

243   enforcement. All descriptive analysis and graphics production were undertaken within the R language

244   and environment for statistical computing (R Core Team 2017; Wickham 2009).

245

246   **Results**

247   Harvest rates were high in enforcement years (averaging 76% and 61% for area and nest harvest

248   proportions respectively), whereas the lowest harvest level occurred when no enforcement patrols

249   occurred along the river (42% and 26% harvest of areas and nests respectively, Table 1, Fig. 2). The nest

250   harvest rate declined during years of law enforcement compared to the 2011 reference level (Table 1,

251 Fig. 2); although nest harvest levels in one enforcement year (2015) did differ compared with 2011 (2-

252 sample test for equality of proportions , P = 0.02508), the continually high harvest rates (55% and 67%,

253 2015 and 2016 respectively, Fig. 2) imply this statistical difference was of little biological relevance.

254 There was no association between enforcement effort and harvest rates over the four years (Spearman

255 rho = 0.11, P = 0.895 and Spearman rho = 0.50, P = 1.00 for nest and area harvests respectively). We

256 estimated that a twofold increase in enforcement patrol effort (155 to 355 liters) between 2015 and

257 2016 had no significant effect on area or nest harvest rates (Table 1, 2-sample test for equality of

258 proportions P = 0.3381 and 0.7485 for nest and area harvest respectively). This substantially increased

259 patrolling effort was associated with only a small reduction in the proportion of areas harvested (82% to

260 70%), yet also a 33% increase in nest harvest levels (55% to 67%, Table 1, Fig. 2).

261 Notably the lowest nest harvest was recorded in 2017 when there was no enforcement but

262 community management was implemented (Table 1, Fig. 2). Prior to community-based management the

263 majority of nesting areas and nests were harvested (Table 1, Fig. 2). This pattern was inverted with

264 community-based management as the majority of nesting areas and nests remained unharvested in

265 2017 (Table 1, Fig. 2). The community-based management harvest rate in 2017 (42% and 26% harvest of

266 areas and nests respectively) differed significantly from the years (2015 and 2016) with enforcement

267 (Table 1, 2-sample test for equality of proportions, $P < 0.0001$ for both areas and nest harvest

268 proportions). The portion of nests harvested under community-based management (26%) also declined

269 significantly compared with the reference year (2011, 75%) with no enforcement and no community-

270 based management (Table 1, 2-sample test for equality of proportions, $P < 0.0001$).

271

272 **Discussion**

273 Our findings strongly suggest that law enforcement patrols as a nest protection strategy have little

274 effect on river turtle nest harvesting. Additionally, multiple lines of evidence suggest that there is no

275   direct cause and effect relationship between enforcement effort and nest harvest rates. In contrast,

276   community management was associated with a significant reduction in nest harvest rates.

277   A first year (egg and hatchling) survival rate of 0.2 is typical for population growth in river turtles

278   (Iverson 1991; Pike et al. 2008; Zimmer-Shaffer et al. 2014). Although we found that nest harvest rates

279   did decline during years with enforcement compared with the 2011 reference level, nest harvest levels

280   remained so high that they are likely to be unsustainable for populations even under the best-case

281   scenario of no adult harvest. For example, harvest rates increased in the second year of enforcement to

282   67%. This implies that no more than an additional 13% of the original nest cohort could die as hatchlings

283   before first year survival would fall below the 0.2 survival threshold and the population would enter a

284   decline phase. Such a low hatchling mortality rate is unlikely considering the challenges for survival of

285   this small and relatively fragile stage (Iverson 1991) and the diversity of aquatic predators in Amazon

286   rivers. Therefore our findings suggest that the governance of river turtle management plans with

287   external enforcement was ineffective in the area studied.

288   The use of external enforcement has been widely applied and documented for the governance of

289   forestry and fisheries management across Amazonia (Lambin et al. 2014; McGrath et al. 2015; Nepstad

290   et al. 2006; Nolte et al. 2013; Peres et al. 2006; Richards et al. 2017). In Brazil such enforcement is also

291   widespread (McGrath et al. 2015; Richards et al. 2017) and both the local traditional riverine

292   communities and townspeople in our study area are familiar with the actions of external enforcement

293   agents. Our findings strongly suggest that the enforcement mode as applied in our study area was not

294   suitable to detect and/or deter illegal nest harvesting activities. The enforcement approach was typical

295   for Amazon waterways and relied heavily on diurnally operated, motorized boat patrols. Female turtles

296   generally lay eggs at night, and in our study area locals report that harvesters often wait at nesting areas

297   overnight and collect nests almost immediately as eggs are laid. This means that harvesters are unlikely

298   to be detected by the diurnal enforcement patrols. Additionally, as harvest rates increased in the second

299   year it is also possible that the harvesters became more familiar with the enforcement patrols and more

300   confident in their ability to avoid interdiction.

301   The clear patterns observed are unlikely to be artifacts of the sampling approach used. There is no

302   evidence to suggest that differences observed in number of turtle nesting areas and nests were due to

303   observer bias during the searches as we maintained at least one observer in the team constant while

304   conducting searches in all years (2011, 2015, 2016, and 2017). Similarly, there is no evidence to suggest

305   the magnitude of the differences between years can be explained by natural variation in the number of

306   turtle females and therefore number of nests during the survey period. In fact, considering the well-

307   documented anthropogenic impacts on the wildlife community in our study area (Norris & Michalski

308   2013; Norris et al. 2018) it is more reasonable to expect a decline in the overall number of nests.

309   Nest harvests by humans is ubiquitous across the species range (Escalona & Fa 1998; Hernández

310   et al. 2010; Landeo 1997; Smith 1979; Vogt 2008); without management the levels of human harvest of

311   river turtle nests are typically > 50% (Table 2) and can reach 100% at nesting areas (Bermúdez-Romero

312   et al. 2010; Hernández et al. 2010; Lipman 2008) (D. Norris pers. obs., 2016). Although we observed high

313   harvest levels prior to community management, estimated nest harvest proportions are likely to

314   represent minimum values. This is because nests sites can be hard to detect as they may be concealed

315   post-harvest by harvesters. Therefore differences in detectability might explain at least partially

316   variation (harvest levels ranged from 55% to 75%) in the proportion of nests removed in the years prior

317   to the community management in 2017.

318   Fewer nests were found during the years with enforcement patrols (2015 and 2016), a pattern we

319   hypothesize can be attributed to the increased and/or more careful concealment of harvested nests as a

320   response to the presence of the enforcement patrols. The harvest of nests falls within a poorly defined

321   area of the protected area governance and legislation. The river is outside of the protected area border

322   and Brazilian legislation allows for the harvest of natural resources to meet basic (nutritional) needs.

323   Although both the existing governance regime and legislation is often ambiguous and unclear, local

324   residents are within their rights to consume the river turtle nests. Why, then, would nest harvest

325   concealment increase with the presence of enforcement? The most likely explanation is that nest

326   harvest was not carried out by the local residents. Although interviews reveal that more than 50% of

327   local residents eat turtle eggs, the locals remain close (typically < 500 m) to their houses (Norris &

328   Michalski 2013). Community members cite harvest for commercial exploitation by outsiders (town

329   residents) as the main cause of nest removal.

330   The community management project that was implemented did not directly target human

331   removal of turtle nests. So why then was there such a sharp reduction in nest harvest? It is important to

332   note that the community management project was inspired by the community members after previous

333   management and governance approaches did not provide outcomes desired either for species

334   conservation or local aspirations for community development. The community had expressed concern

335   regarding environmental degradation in the area including the loss of turtle nests (due to human harvest

336   (Norris & Michalski 2013) and the submersion of nesting areas by a newly installed hydroelectric dam

337   (Norris et al. 2018)), and the increasing amount of rubbish along the river at the beaches /nesting areas.

338   Protecting the nests temporarily against natural predators was a way that community members could

339   actively participate not only in caring for the turtle nests but also the surrounding environment. As nest

340   harvesting by humans was not specifically targeted these actions had general support and conflicts were

341   not generated. The lack of conflicts is also explained by the fact that community members do not

342   depend on river turtle nests for their daily nutritional requirements or economic well-being (Norris &

343   Michalski 2013).

344   Providing payments for protecting nests and/or the selective harvest of nests that would

345   otherwise be flooded have been used to engage local communities in the management of river turtle

346   nests (Caputo et al. 2005). Different to such studies, we did not provide any financial rewards for

347   participation, nor did we translocate nests for headstarting incubation nor sanction harvest of a subset

348   of nests. Seasonal differences in our study area compared with that of Caputo et al. (2005) partly explain

349   the difference in approach. In our study area, peak nesting (mid to late October) takes place

350   approximately two months before river levels rise (mid to late December), which means many turtle

351   embryos are in advanced stages of development and the eggs are not suitable for harvest when levels

352   rise. This is because locals prefer fresh eggs, with harvesting activities also peaking around October. The

353   uncertainty in future effects of climate change, changes in flow rates due to development patterns (e.g.

354   hydropower developments (Timpe & Kaplan 2017)), deforestation, and their synergistic effects on

355   wildlife species and human populations are therefore a challenge for the implementation of

356   conservation solutions. Such uncertainties reinforce the need for solutions to be tailored to the local

357   context.

358   We discovered that the involvement of a relatively small number of key personnel had a broad

359   impact and that a positive community perception (of doing the right thing) was sufficient to ensure

360   engagement. Previous studies show that harvest and consumption of nests is not random within or

361   between rivers (Escalona & Fa 1998; Hernández et al. 2010; Norris & Michalski 2013). Harvest rates are

362   not spatially uniform, increasing at beaches closer to towns and in more accessible river sections

363   (Escalona & Fa 1998; Hernández et al. 2010; Pignati et al. 2013). Additionally, patterns of consumption

364   are also aggregated within communities, with river turtle egg consumption by neighbors the strongest of

365   12 environmental, spatial and social variables used to explain patterns of river turtle egg consumption in

366   the local community (Norris & Michalski 2013). A detailed understanding of the local context and

367   spatially explicit monitoring of nesting beaches and community activities is therefore required to ensure

368   the success of any community-based management of river turtle nests.

369   Local communities living along Amazon rivers have increasing access to alternative food sources

370   including poultry (mainly chicken) and farmed fish (de Jesus Silva et al. 2017; Piperata et al. 2011) and

371   depend less on relatively limited seasonal supplies such as turtle eggs to meet their nutritional

372   requirements (de Jesus Silva et al. 2017). Human nest predation and egg consumption has long been

373   recognized as both a threat (reducing recruitment and population size) and opportunity (a valuable

374   resource, which generates stakeholder involvement in conservation) for the conservation and

375   management of *P. unifilis* populations (Caputo et al. 2005; Mittermeier 1978; Smith 1979). However,

376   with riverine communities likely to become progressively less dependent on turtle eggs as a food source

377   (Piperata et al. 2011), conservation activities need to be developed that do not rely simply on the

378   preservation of nests for subsequent commercialization.

379   Our results suggest that indirect benefits and intrinsic values placed by local communities can be

380   as important as economic gain for the development of successful conservation actions aimed at

381   maintaining natural resources. We did not adopt an approach of payments for riverine people during

382   the community-based management activities, and turtle nest harvest rates did decrease markedly when

383   compared with years with enforcement patrols. For these reasons we are confident to link the success

384   of the community-based management to riverine perceptions of intrinsic value of preservation of the

385   forest, rivers and the wildlife they support as shown in the meetings with landowners in our study.

386   The needs of different users can generate conflicts in common pool resources (Ostrom 2015). Our

387   findings from the first year of community-based management were overwhelmingly positive and the

388   conflicts anticipated did not materialize. In the region studied, there appears within the local community

389   to be a strong degree of respect for natural resources and an understanding of environmental problems.

390   The community-based management was implemented after seven years of research and has been

391   developed with the local communities. Based on our findings we hypothesize that respectful and

392   practical engagement along with good will are the most important drivers in explaining the success of

393   the first year. There is obviously no guarantee that this will continue, and there is a need to continually

394   engage and work with local communities within an adaptive management framework with the capacity

395   to respond to socio-economic changes as well as new and unforeseen challenges.

396

397   Conclusions

398   Although our findings come from the first year of community management the clear reduction in river

399   turtle nest harvest illustrates that a focus on community involvement can generate immediate benefits

400   for conservation within multiuse protected areas. Our findings suggest that the presence of community

401   members monitoring and protecting against natural predators was sufficient to deter the harvest by

402   outsiders without generating any obvious conflicts about river turtle conservation. As such we conclude

403   that the good will, mutual understanding, and collaborative development of conservation initiatives

404   between local communities, researchers and conservationists are the vital/keystone components for the

405   success of conservation activities within the sustainable-use protected areas.

406

407   Acknowledgments

408   The Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) and the Federal University of

409   Amapá (UNIFAP) provided logistical support. We thank the staff at ICMBio (Ivan Machado de

410   Vasconcelos, Sueli Gomes Pontes) for their help in developing the community management activities

411   and providing data on the enforcement effort during the study period. We are grateful to various

412   volunteers, graduate and post-graduate students who have participated in data collection over the

413   years. We also thank Alvino Pantoja Leal, Cremilson, Cleonaldo and Cledinaldo Alves Marques for their

414   invaluable assistance during fieldwork.

415

416   References

417   Alho CJR. 1985. Conservation and management strategies for commonly exploited amazonian turtles.
418   *Biological Conservation* 32:291-298. https://doi.org/10.1016/0006-3207(85)90019-9
419   ANA. 2016. Sistema de Informações Hidrológicas - HidroWeb. *Available at http://hidroweb.ana.gov.br/*
420   (accessed 20 July 2016).
421   Bermúdez-Romero AL, Hoyos-Rodríguez M, Álape-Sánchez DE, Morales-Betancourt MA, and Solano C.
422   2010. Tortugas Charapa y Taricaya (*Podocnemis expansa* y *Podocnemis unifilis*), un recurso de
423   conservación prioritario. In: Bermúdez-Romero AL, Trujillo F, Solano C, Alonso JC, and Ceballos-
424   Ruiz L, eds. *Retos locales y regionales para la conservación de la fauna acuática del sur de la*
425   *Amazonia colombiana*. Bogotá: Corpoamazonia, Instituto Sinchi, Fundación Omacha y Fundación
426   Natura, 111-127.
427   Bernard E, Penna L, and Araújo E. 2014. Downgrading, downsizing, degazettement, and reclassification
428   of protected areas in Brazil. *Conservation Biology* 28:939-950. 10.1111/cobi.12298
429   Böhm M, Collen B, Baillie JEM, Bowles P, Chanson J, Cox N, Hammerson G, Hoffmann M, Livingstone SR,
430   Ram M, Rhodin AGJ, Stuart SN, van Dijk PP, Young BE, Afuang LE, Aghasyan A, García A, Aguilar
431   C, Ajtic R, Akarsu F, Alencar LRV, Allison A, Ananjeva N, Anderson S, Andrén C, Ariano-Sánchez D,
432   Arredondo JC, Auliya M, Austin CC, Avci A, Baker PJ, Barreto-Lima AF, Barrio-Amorós CL, Basu D,
433   Bates MF, Batistella A, Bauer A, Bennett D, Böhme W, Broadley D, Brown R, Burgess J, Captain A,
434   Carreira S, Castañeda MdR, Castro F, Catenazzi A, Cedeño-Vázquez JR, Chapple DG, Cheylan M,
435   Cisneros-Heredia DF, Cogalniceanu D, Cogger H, Corti C, Costa GC, Couper PJ, Courtney T,
436   Crnobrnja-Isailovic J, Crochet P-A, Crother B, Cruz F, Daltry JC, Daniels RJR, Das I, de Silva A,
437   Diesmos AC, Dirksen L, Doan TM, Dodd CK, Doody JS, Dorcas ME, Duarte de Barros Filho J, Egan
438   VT, El Mouden EH, Embert D, Espinoza RE, Fallabrino A, Feng X, Feng Z-J, Fitzgerald L, Flores-
439   Villela O, França FGR, Frost D, Gadsden H, Gamble T, Ganesh SR, Garcia MA, García-Pérez JE,
440   Gatus J, Gaulke M, Geniez P, Georges A, Gerlach J, Goldberg S, Gonzalez J-CT, Gower DJ, Grant T,
441   Greenbaum E, Grieco C, Guo P, Hamilton AM, Hare K, Hedges SB, Heideman N, Hilton-Taylor C,
442   Hitchmough R, Hollingsworth B, Hutchinson M, Ineich I, Iverson J, Jaksic FM, Jenkins R, Joger U,
443   Jose R, Kaska Y, Kaya U, Keogh JS, Köhler G, Kuchling G, Kumlutaş Y, Kwet A, La Marca E, Lamar
444   W, Lane A, Lardner B, Latta C, Latta G, Lau M, Lavin P, Lawson D, LeBreton M, Lehr E, Limpus D,
445   Lipczynski N, Lobo AS, López-Luna MA, Luiselli L, Lukoschek V, Lundberg M, Lymberakis P, Macey
446   R, Magnusson WE, Mahler DL, Malhotra A, Mariaux J, Maritz B, Marques OAV, Márquez R,
447   Martins M, Masterson G, Mateo JA, Mathew R, Mathews N, Mayer G, McCranie JR, Measey GJ,
448   Mendoza-Quijano F, Menegon M, Métrailler S, Milton DA, Montgomery C, Morato SAA, Mott T,
449   Muñoz-Alonso A, Murphy J, Nguyen TQ, Nilson G, Nogueira C, Núñez H, Orlov N, Ota H,
450   Ottenwalder J, Papenfuss T, Pasachnik S, Passos P, Pauwels OSG, Pérez-Buitrago N, Pérez-
451   Mellado V, Pianka ER, Pleguezuelos J, Pollock C, Ponce-Campos P, Powell R, Pupin F, Quintero
452   Díaz GE, Radder R, Ramer J, Rasmussen AR, Raxworthy C, Reynolds R, Richman N, Rico EL,
453   Riservato E, Rivas G, da Rocha PLB, Rödel M-O, Rodríguez Schettino L, Roosenburg WM, Ross JP,
454   Sadek R, Sanders K, Santos-Barrera G, Schleich HH, Schmidt BR, Schmitz A, Sharifi M, Shea G, Shi
455   H-T, Shine R, Sindaco R, Slimani T, Somaweera R, Spawls S, Stafford P, Stuebing R, Sweet S, Sy E,
456   Temple HJ, Tognelli MF, Tolley K, Tolson PJ, Tuniyev B, Tuniyev S, Üzüm N, van Buurt G, Van
457   Sluys M, Velasco A, Vences M, Veselý M, Vinke S, Vinke T, Vogel G, Vogrin M, Vogt RC, Wearn
458   OR, Werner YL, Whiting MJ, Wiewandt T, Wilkinson J, Wilson B, Wren S, Zamin T, Zhou K, and
459   Zug G. 2013. The conservation status of the world's reptiles. *Biological Conservation* 157:372-
460   385. 10.1016/j.biocon.2012.07.015
461   Campos-Silva JV, and Peres CA. 2016. Community-based management induces rapid recovery of a high-
462   value tropical freshwater fishery. *Scientific Reports* 6:34745. 10.1038/srep34745

463 Caputo FP, Canestrelli D, and Boitani L. 2005. Conserving the terecay (*Podocnemis uinifilis*, Testudines :
464   Pelomedusidae) through a community-based sustainable harvest of its eggs. *Biological*
465   *Conservation* 126:84-92. 10.1016/j.biocon.2005.05.004
466 Castello L, McGrath DG, Hess LL, Coe MT, Lefebvre PA, Petry P, Macedo MN, Renó VF, and Arantes CC.
467   2013. The vulnerability of Amazon freshwater ecosystems. *Conservation Letters* 6:217-229.
468   10.1111/conl.12008
469 de Jesus Silva R, de Paula Eduardo Garavello ME, Nardoto GB, Mazzi EA, and Martinelli LA. 2017. Factors
470   influencing the food transition in riverine communities in the Brazilian Amazon. *Environment,*
471   *Development and Sustainability* 19:1087-1102. 10.1007/s10668-016-9783-x
472 de Oliveira IAP, Norris D, and Michalski F. 2015. Anthropogenic and seasonal determinants of giant otter
473   sightings along waterways in the northern Brazilian Amazon. *Mammalian Biology - Zeitschrift für*
474   *Säugetierkunde* 80:39-46. 10.1016/j.mambio.2014.07.006
475 Dietz T, Ostrom E, and Stern PC. 2003. The Struggle to Govern the Commons. *Science* 302:1907-1912.
476   10.1126/science.1091015
477 Dudgeon D, Arthington AH, Gessner MO, Kawabata Z-I, Knowler DJ, Lévêque C, Naiman RJ, Prieur-
478   Richard A-H, Soto D, and Stiassny ML. 2006. Freshwater biodiversity: importance, threats, status
479   and conservation challenges. *Biological reviews* 81:163-182. 10.1017/S1464793105006950
480 Eisemberg CC, Rose M, Yaru B, and Georges A. 2011. Demonstrating decline of an iconic species under
481   sustained indigenous harvest – The pig-nosed turtle (Carettochelys insculpta) in Papua New
482   Guinea. *Biological Conservation* 144:2282-2288. 10.1016/j.biocon.2011.06.005
483 Escalona T, and Fa JE. 1998. Survival of nests of the terecay turtle (Podocnemis unifilis) in the Nichare-
484   Tawadu rivers, Venezuela. *Journal of Zoology* 244:303-312. 10.1111/j.1469-
485   7998.1998.tb00034.x
486 Gibbon JW, Scott DE, Ryan TJ, Buhlmann KA, Tuberville TD, Metts BS, Greene JL, Mills T, Leiden Y, Poppy
487   S, and Winne CT. 2000. The Global Decline of Reptiles, Déjà Vu Amphibians. *BioScience* 50:653-
488   666. 10.1641/0006-3568(2000)050[0653:TGDORD]2.0.CO;2
489 Harju E, Sirén AH, and Salo M. 2017. Experiences from harvest-driven conservation: Management of
490   Amazonian river turtles as a common-pool resource. *Ambio*. 10.1007/s13280-017-0943-5
491 Hernández O, Espinosa-Blanco AS, May LC, Jiménez-Oraa M, and Seijas AE. 2010. Artificial incubation of
492   yellow-headed sideneck turtle Podocnemis unifilis eggs to reduce losses to flooding and
493   predation, Cojedes and Manapire Rivers, southern Venezuela. *Conservation Evidence* 7:100-105.
494 Hilborn R, Arcese P, Borner M, Hando J, Hopcraft G, Loibooki M, Mduma S, and Sinclair AR. 2006.
495   Effective enforcement in a conservation area. *Science* 314:1266-1266. 10.1126/science.1132780
496 IBGE. 2010. Censo demográfico 2010. *Available at*
497   *http://www.ibge.gov.br/home/download/estatistica.sht* (accessed 8 January 2013 2013).
498 Iverson JB. 1991. Patterns of survivorship in turtles (order Testudines). *Canadian Journal of Zoology*
499   69:385-391.
500 Keane A, Jones JP, Edwards-Jones G, and Milner-Gulland EJ. 2008. The sleeping policeman:
501   understanding issues of enforcement and compliance in conservation. *Animal Conservation*
502   11:75-82. 10.1111/j.1469-1795.2008.00170.x
503 Kottek M, Grieser J, Beck C, Rudolf B, and Rubel F. 2006. World map of the Koppen-Geiger climate
504   classification updated. *Meteorologische Zeitschrift* 15:259-263. 10.1127/0941-2948/2006/0130
505 Lambin EF, Meyfroidt P, Rueda X, Blackman A, Börner J, Cerutti PO, Dietsch T, Jungmann L, Lamarque P,
506   and Lister J. 2014. Effectiveness and synergies of policy instruments for land use governance in
507   tropical regions. *Global Environmental Change* 28:129-140. 10.1016/j.gloenvcha.2014.06.007
508 Landeo C. 1997. Factores limitantes de la población preeclosional de la taricaya *Podocnemis unifilis* en el
509   río Manú. In: Fang TG, Bodmer RE, Aquino R, and Valqui MH, eds. *Manejo de Fauna Silvestre en*
510   *la Amazonía*. La Paz, Bolivia: UNAP, 185-189.

511 Lipman AJ. 2008. An ecological approach to community-based conservation: Management of
512   Podocnemis river turtles in Noel Kempff Mercado National Park, Bolivia. University of Georgia.
513 McGrath DG, Castello L, Almeida OT, and Estupiñán GM. 2015. Market formalization, governance, and
514   the integration of community fisheries in the brazilian amazon. *Society & Natural Resources*
515   28:513-529. 10.1080/08941920.2015.1014607
516 Mittermeier RA. 1978. South America's river turtles: saving them by use. *Oryx* 14:222-230.
517   10.1017/S0030605300015532
518 Mittermeier RA, van Dijk PP, Rhodin AGJ, and Nash SD. 2015. Turtle Hotspots: An Analysis of the
519   Occurrence of Tortoises and Freshwater Turtles in Biodiversity Hotspots, High-Biodiversity
520   Wilderness Areas, and Turtle Priority Areas. *Chelonian Conservation and Biology* 14:2-10.
521   10.2744/ccab-14-01-2-10.1
522 Nepstad D, Schwartzman S, Bamberger B, Santilli M, Ray D, Schlesinger P, Lefebvre P, Alencar A, Prinz E,
523   Fiske G, and Rolla A. 2006. Inhibition of Amazon Deforestation and Fire by Parks and Indigenous
524   Lands. *Conservation Biology* 20:65-73. 10.1111/j.1523-1739.2006.00351.x
525 Nolte C, Agrawal A, Silvius KM, and Soares-Filho BS. 2013. Governance regime and location influence
526   avoided deforestation success of protected areas in the Brazilian Amazon. *Proceedings of the*
527   *National Academy of Sciences* 110:4956-4961. 10.1073/pnas.1214786110
528 Norris D, and Michalski F. 2013. Socio-economic and spatial determinants of anthropogenic predation
529   on Yellow-spotted River Turtle, *Podocnemis unifilis* (Testudines: Pelomedusidae), nests in the
530   Brazilian Amazon: Implications for sustainable conservation and management. *Zoologia* 30:482-
531   490. 10.1590/s1984-46702013000500003
532 Norris D, Michalski F, and Gibbs JP. 2018. Beyond harm's reach? Submersion of river turtle nesting areas
533   and implications for restoration actions after Amazon hydropower development. *PeerJ* 6:e4228.
534   10.7717/peerj.4228
535 Ostrom E. 2015. *Governing the commons*. Cambridge: Cambridge University Press.
536 Páez VP, Lipman A, Bock BC, and Heppell SS. 2015. A Plea to Redirect and Evaluate Conservation
537   Programs for South America's Podocnemidid River Turtles. *Chelonian Conservation and Biology*
538   14:205-216. 10.2744/CCB-1122.1
539 Paredes OSL, Norris D, de Oliveira TG, and Michalski F. 2017. Water availability not fruitfall modulates
540   the dry season distribution of frugivorous terrestrial vertebrates in a lowland Amazon forest.
541   *PLoS ONE* 12:e0174049. 10.1371/journal.pone.0174049
542 Parry L, Barlow J, and Pereira H. 2014. Wildlife harvest and consumption in Amazonia's urbanized
543   wilderness. *Conservation Letters* 7:565-574. 10.1111/conl.12151
544 Peres CA. 2011. Conservation in sustainable-use tropical forest reserves. *Conservation Biology* 25:1124-
545   1129. 10.1111/j.1523-1739.2011.01770.x
546 Peres CA, Barlow J, and Laurance WF. 2006. Detecting anthropogenic disturbance in tropical forests.
547   *Trends in ecology & evolution* 21:227-229. 10.1016/j.tree.2006.03.007
548 Pfaff A, Robalino J, Sandoval C, and Herrera D. 2015. Protected area types, strategies and impacts in
549   Brazil's Amazon: public protected area strategies do not yield a consistent ranking of protected
550   area types by impact. *Phil Trans R Soc B* 370:20140273. 10.1098/rstb.2014.0273
551 Pignati MT, Fernandes LF, Miorando PS, Ferreira PD, and Pezzuti JCB. 2013. Nesting Site and Hatching
552   Success of Podocnemis unifilis (Testudines: Podocnemididae) in a Floodplain Area in Lower
553   Amazon River, Pará, Brazil. *South American Journal of Herpetology* 8:175-185. 10.2994/SAJH-D-
554   13-00006.1
555 Pike DA, Pizzatto L, Pike BA, and Shine R. 2008. Estimating survival rates of uncatchable animals: The
556   myth of high juvenile mortality in reptiles. *Ecology* 89:607-611. 10.1890/06-2162.1

557   Piperata BA, Spence JE, Da-Gloria P, and Hubbe M. 2011. The Nutrition Transition in Amazonia: Rapid
558   Economic Change and its Impact on Growth and Development in Ribeirinhos. *American Journal*
559   *of Physical Anthropology* 146:1-13. 10.1002/ajpa.21459
560   R Core Team. 2017. R: A Language and Environment for Statistical Computing. 3.4.2. *Available at*
561   *https://www.R-project.org/*.
562   Richards P, Arima E, VanWey L, Cohn A, and Bhattarai N. 2017. Are Brazil's Deforesters Avoiding
563   Detection? *Conservation Letters* 10: 470–476. 10.1111/conl.12310
564   Salo M, Sirén A, and Kalliola R. 2014. *Diagnosing wild species harvest: resource use and conservation*.
565   San Diego: Academic Press.
566   Smith NJH. 1979. Aquatic turtles of Amazonia: an endangered resource. *Biological Conservation* 16:165–
567   176. 10.1016/0006-3207(79)90019-3
568   Timpe K, and Kaplan D. 2017. The changing hydrology of a dammed Amazon. *Science Advances* 3.
569   10.1126/sciadv.1700611
570   UNEP-WCMC, and IUCN. 2018. Protected Planet: The World Database on Protected Areas (WDPA).
571   *Available at www.protectedplanet.net* (accessed 24 January 2018).
572   Venturieri R, Oliveira-da-Costa M, Gama C, and Jaster CB. 2017. Mercury Contamination within
573   Protected Areas in the Brazilian Northern Amazon-Amapá State *American Journal of*
574   *Environmental Science* 13:11-21. 10.3844/ajessp.2017.11.21
575   Vogt R. 2008. *Tartarugas da Amazonia*. Manaus: INPA.
576   Wickham H. 2009. *ggplot2: Elegant Graphics for Data Analysis*: Springer-Verlag New York.
577   Zimmer-Shaffer SA, Briggler JT, and Millspaugh JJ. 2014. Modeling the effects of commercial harvest on
578   population growth of river turtles. *Chelonian Conservation and Biology* 13:227-236.
579   10.2744/CCB-1109.1

580

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.

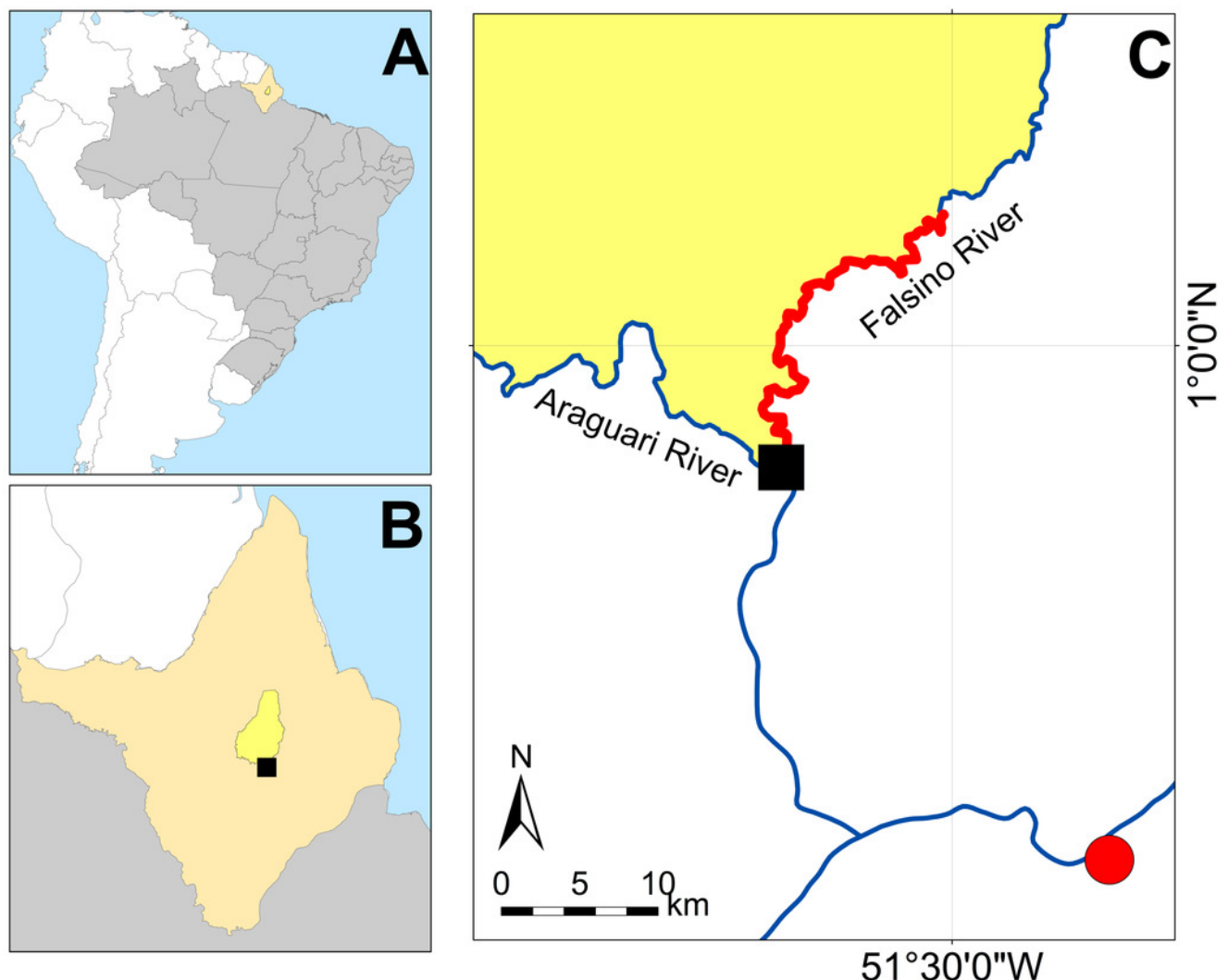



Figure 2

Four years of nest harvest.

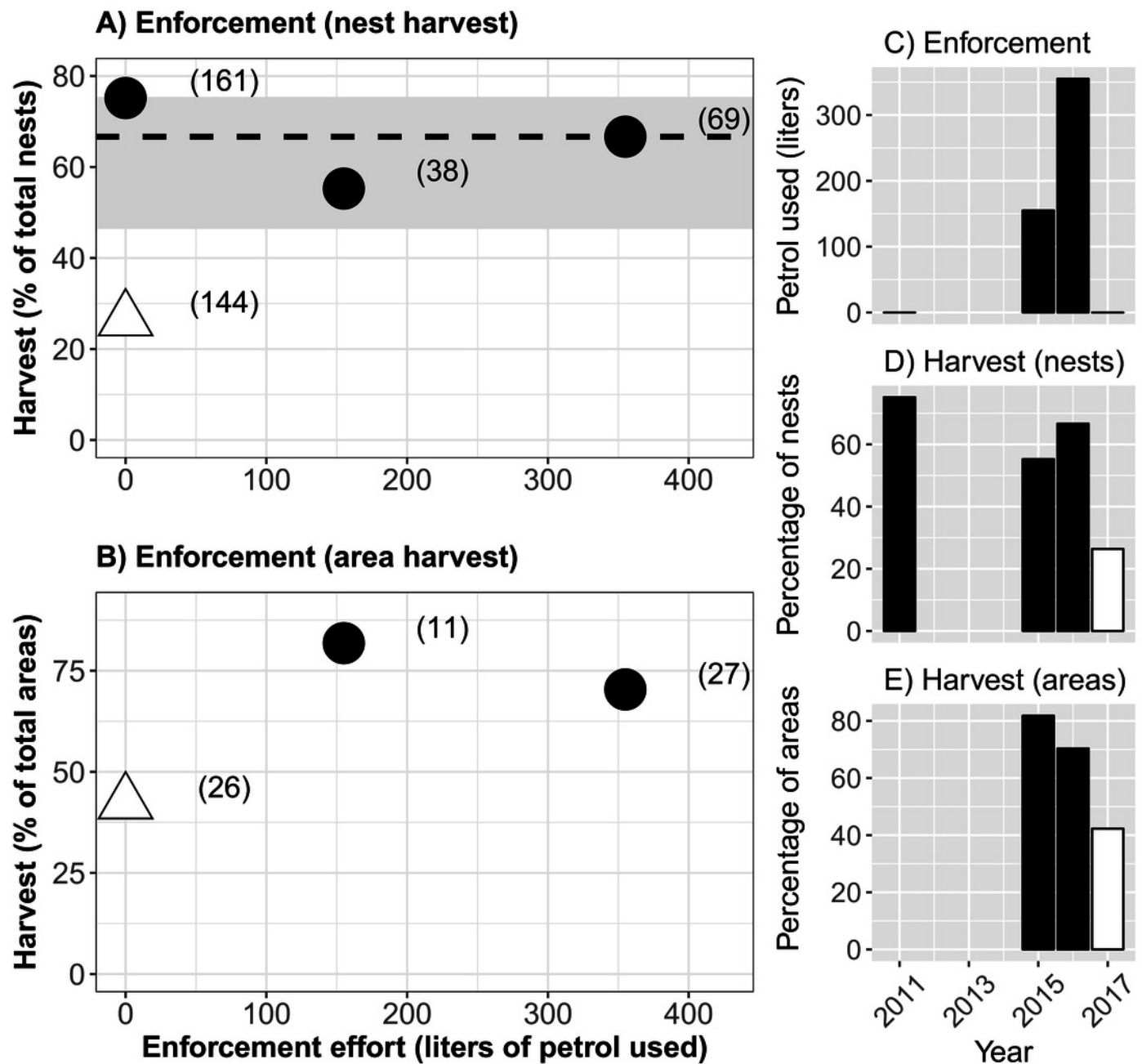
Harvest of yellow-spotted river turtle (*Podocnemis unifilis*) nests along 33 km of river in Amapá State, Brazil. (A) Nest harvest during years with (white triangle) and without (black circles) community-based management (CBM). Total number of nests in parentheses, the dashed horizontal line shows the 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 2). (B) Nesting areas with harvest during years with (white triangle) and without (black circles) CBM. Total number of areas in parentheses, the number of nests harvested per nesting area was not recorded in 2011. It was not possible to estimate confidence intervals for area harvest due to lack of reported results (see Table 2). (C) Enforcement effort during four river turtle nesting seasons. (D) Proportion of river turtle nests harvested in four nesting seasons. (E) Proportion of river turtle nesting areas harvested in four nesting seasons.

A) Enforcement (nest harvest)

B) Enforcement (area harvest)

C) Enforcement

D) Harvest (nests)

E) Harvest (areas)

Nest harvest along the Falsino River.

Harvest of yellow-spotted river turtle (*Podocnemis unifilis*) nests during four years along 33 km of the Falsino River. Estimates of survey and enforcement effort in years with different management approaches also included.

Year	CBM[a]	Enforce[b]	Total areas surveyed[c]	Total nesting areas (harvested, unharvested[c])	Total nests (harvested, unharvested)	Nests per area	Nest density[c, d]
2011	No	No		22	161 (121, 40)[e]	7.3	
2015	No	Yes (155)	87	11 (9, 2)[e]	38 (21, 17)[f]	3.5	83.9
2016	No	Yes (355)	79	27 (19, 8)[e]	69 (46, 23)[e, f]	2.6	50.7
2017	Yes	No	83	26 (11, 15)	144 (38, 106)	5.5	105.9

2   [a] If community-based management was applied.

3   [b] If external enforcement patrols were used, with effort (liters of petrol used) during the nesting season

4   in parentheses.

5   [c] Values not measured in 2011.

6   [d] Nests per hectare of nesting areas.

7   [e, f,] Denote years with the same proportion of harvest within columns. Pairwise comparisons between

8   years obtained using a 2-sample test for equality of proportions with continuity correction ($P_\alpha = 0.1$).

Nest harvest rates obtained from the literature.

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

Type	Study duration	Nesting areas[a]			Nests			Location	Source
		Harvest (%)	Total	Harvest	Harvest (%)	Total	Harvest		
No community management	Single season	-	-	-	51.9	952	494	Manú, Peru	Landeo (1997)
	Single season	71.4	7	5	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	-	5	-	31.8	434	138	Iténez & Paraguá, Bolivia	Lipman (2008)
	Multi season	76.1	19	15	65.7	268	188	Falsino River, Brazil	Present study
Mean					61.1				
(±95% CI)					(46.4 – 75.4)				
With community management	Single season	-	6	-	28.2	383	108	Aguarico River, Ecuador	Caputo et al. (2005)
	Multi season	100	1	1	19.4	273	53	Taboleiro da Água Preta, Brazil	Pignati et al. (2013)
	Multi season	-	4	-	0.1	676	1	Iténez & Paraguá, Bolivia	Lipman (2008)
	Single season	42.3	26	11	26.4	144	38	Falsino River, Brazil	Present study
Mean					18.5				
(±95% CI)					(6.7 – 27.8)				

2 [a] Means not calculated for area harvest rates due to small sample sizes. Dashes indicate when values

3 were not reported