Sustainable wildlife extraction and the impacts of socio-economic change among the Kukama-Kukamilla people of the Pacaya-Samiria National Reserve, Peru.

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Abstract

Throughout the tropics, hunting and fishing are critical livelihood activities for many Indigenous peoples. However, these practices may not be sustainable following recent socio-economic changes in Indigenous populations. Aiming to understand how human population growth and increased market integration affect hunting and fishing patterns, we conducted semi-structured interviews in five Kukama-Kukamilla communities living along the boundary of the Pacaya-Samiria National Reserve, in the Peruvian Amazon. Extrapolated annual harvest rates of fish and game species by these communities amounted to 1,740 t and 4,275 individuals (67 t), respectively. At least 23 fish and 27 game species were harvested. We found a positive correlation between village size and annual harvest rates of fish. Catch-per-unit-effort (CPUE) analyses indicated local depletion of fish populations around larger, more commercial communities. CPUE of fish was lower in more commercial communities and fishermen from the largest village travelled farther into the reserve, where CPUE was higher. CPUE of game species was negatively correlated with village size only when measured as number of hunted individuals, and not as biomass. Larger, more commercial communities targeted larger, economically-valuable species. This study provides evidence that human population growth and market-driven hunting and fishing pose a growing threat to wildlife and Indigenous livelihoods through increased harvest rates and selective harvesting of vulnerable species.

Keywords: Sustainability; Hunting; Fishing; Protected area; Amazon.

Introduction

In tropical forests, hunting and fishing are crucial to the livelihoods of Indigenous peoples as a source of protein and income (East et al., 2005). Unfortunately, a growing number of studies suggest current harvests of a variety of species exceed sustainable levels, causing widespread population declines and local extinctions (Abernethy et al., 2013; Castello et al., 2014; Morcatty & Valsecchi, 2015; Parry & Peres, 2015). As a result, the sustainability of hunting and fishing has become the subject of considerable concern among ecologists, anthropologists, protected area managers and conservationists alike. This has sparked a debate surrounding the presence of Indigenous peoples in protected areas, between those who view them as a direct threat to biodiversity and as conservation allies (da Silva et al., 2005; Ohl-Schacherer et al., 2007). In-depth monitoring of hunting and fishing is a key prerequisite to promoting the sustainable use of natural resources, avoiding extinctions of important species while preserving the rights of Indigenous people to land, traditions, and culture.

The decreasing sustainability of hunting and fishing practices has been attributed in part to the rapid growth in Indigenous populations and their integration in the market economy. These trends have triggered powerful socio-economic changes, leading to an increasing demand for wildlife products from both the rural and urban populations and a growing economic incentive to hunt and fish commercially (McSweeney & Jockisch, 2007; Ohl-Schacherer et al., 2007; Suarez et al., 2009; Fa et al., 2015). Simultaneously, improved technologies and transportation have enhanced the capacity of a growing number of hunters and fishermen to capture prey, including in previously inaccessible areas (Wilkie et al., 2000; Godoy et al., 2010; Foerster et al., 2012). However, empirical studies have revealed mixed and even positive effects of socio-economic development on wildlife harvesting (Lu, 2007). For example, opportunities for permanent and well-paid jobs combined with a preference among wealthier households for alternative protein sources like store-purchased meat can lead to a reduction in wildlife harvesting (Wilkie & Godoy, 2001; Gray et al., 2015; Vasco & Sirén, 2016). Understanding the complex interactions between socio-economic factors and extractive activities in a variety of social, cultural, and natural contexts remains imperative, especially given the need to alleviate poverty among Indigenous peoples.

In the Peruvian Amazon, hunting and fishing constitute integral components of the Kukama-Kukamilla culture. This Indigenous group harvests a large variety of natural resources from their surrounding areas that include the Pacaya-Samiria National Reserve (PSNR). In the past, a strict protectionist system in this reserve provoked a backlash of rampant poaching and over-exploitation by the local people (Bodmer et al., 2008). In the late 1990s, a new reserve administration adopted a co-management approach that permitted low levels of hunting and fishing. Since then, populations of key species have been increasing in the reserve, including threatened species such as the woolly monkey *Lagotrhix* spp., lowland tapir *Tapirus terrestris* and paiche *Arapaima gigas* (Bodmer & Puertas, 2007).

In this study, we aimed to explore how socio-economic factors influence the hunting and fishing patterns of the Kukama-Kukamilla people. While most studies have explored the impacts of socio-economic conditions between households, we explored the impacts at the community level. Through the use of semi-structured interviews, we tested the hypothesis that larger communities with greater access to the economic market exert higher pressure on wildlife and target more commercially valuable species. These communities are expected to be affected by higher levels of wildlife depletion, with preferred species disappearing near villages, triggering shifts in harvested species spectra. Our study provides important insights for conservation management into the factors that underpin sustainable resource use, specifically the risk of human population growth and market-driven hunting and fishing brought about by rural development.

Study area

Our study was carried out in the PSNR, which covers an area of 2,080,000 ha in the Department of Loreto, in the north-eastern Peruvian Amazon. It is bordered by two tributaries of the Amazon River, the Ucayali and Marañón rivers, and encompasses the two major drainage basins of the Pacaya and Samiria rivers. The reserve is characterised by massive hydrological fluctuations that occur between the high-water (October to May) and low-water (June to September) seasons (Kvist et al., 2001).

The majority of inhabitants are descendants of the Tupi-Guarani speaking Kukama-Kukamilla people and more recent immigrants of Caucasian and Indigenous origin (Gow, 2007). Their main livelihood activity is fishing, which is most productive during the low-water season, when fish become trapped in the shrinking water bodies. Nonetheless, migrations of fish feeding on fallen fruit in the *várzeas* (white-water flooded forests) make some fisheries productive during the high-water season (Kvist et al., 2001). The Kukama-Kukamilla also engage in opportunistic hunting, primarily during the high-water season, when the terrestrial fauna is concentrated on the non-inundated *restingas* (levees) (Bodmer et al., 1998).

Approximately 100,000 people in over 200 communities are currently living along the boundary of the PSNR (INRENA, 2009). We selected five Kukama-Kukamilla villages located at the mouth of the Samiria River, which were divided into two distinct areas: a) San Martín de Tipishca, Nuevo Arica and Bolivar lie on the shores of the Tipishca Lake; and b) San José de Samiria and Leoncio Prado are located along the Marañón River (Fig. 1). These villages ranged from 40 to 120 households (Table 1), and differed in their exposure to the market economy. The communities of the Marañón River supply produce to the urban markets of Loreto by selling to freezer vessels or directly to market vendors.

Methods

Data collection

We conducted 122 semi-structured interviews, which accounted for 34.9% of households within the study area, between June-August 2013 (Table 1). The use of semi-structured interviews was the preferred data collection method, as they allow emphasis on specific topics depending on the interviewees' knowledge and experience (Rubin & Rubin, 2005). Recall bias was expected to be minimal, as quantitative information asked was simple and activities are regular and highly seasonal (Golden et al., 2013). Since all households were found to be dependent on hunting and/or fishing, we adopted a convenience sampling approach, selecting the most accessible households (Patton, 2002). We targeted male heads of households for interviews, but in some cases interviewed women instead, either because they too participated in hunting or fishing, or they had acquired detailed information about harvests through cooking. We obtained prior informed consent from participants before conducting interviews.

The social sensitivity of the topic being explored may have created some bias in the data resulting from the under-representation of harvests. Where possible, we used participant observation to verify interview responses. We informed interviewees that no information gathered would be used against them and that survey information would be anonymised.

Data analysis

We obtained household harvest rates of fish by asking fishermen to state the total average biomass of fish caught per day, during high- and low-water seasons separately. This was extrapolated to annual harvest rates by multiplying each estimate of average daily yield for each season by 182.5 (6 months). A limitation of using interviews to collect harvest data was that fishermen were unable to state the quantity of each species harvested, because they measure the weight of the entire catch. We therefore recorded the percentage of households that harvest each species, using these data as proxies for relative harvest rates. We obtained annual household harvest rates of game species by asking hunters to state the average number of wild animals hunted per year for each species, as hunting is less frequent than fishing. This was converted to biomass using body weight data reported by Peres and Dolman (2000), Ohl-Schacherer et al. (2007), Cardoso et al. (2012), and Mayor et al. (2015). We determined community-level harvest rates of fish by multiplying average annual household harvest rates by the number of households in each community, and in the case of game species, by the percentage of households that engage in hunting.

We used these data to estimate catch-per-unit-effort (CPUE). The assumption behind CPUE as an indicator of sustainability is that hunters and fishermen must increase their efforts in areas with depleted populations to achieve the required meat and fish return rates. A difference in CPUE is assumed to reflect a difference in actual prey density or abundance (Rist et al., 2010). We calculated CPUE of fish as Y/H and CPUE of game species as I/D and B/D, where Y is the total daily yield of fish harvested; H is the number of hours a day fishermen leave their nets in the water (the most common method); I and B are the total number of individuals and biomass of games species hunted annually, respectively; and D is the number of days a year hunters are active. We averaged across households to obtain community-level CPUE estimates.

We calculated the distance travelled on hunting and fishing trips using reports of average time travelled. Based on information given by a local informant, we estimated that 6 km were travelled in 1 hour in *peque peque* (motorized canoe) and 4 km on foot. Since hunters limit their activities to within 2 km of the river, distance travelled was multiplied by four to obtain the size of the total catchment area (Begazo & Bodmer, 1998). The corresponding catchment area was drawn around the channels and lakes of the Samiria and Marañón rivers and divided into zones of low, medium, and heavy exploitation, using the maximum distances travelled by the top 25% and 50% percentiles as the thresholds (Fig. 2). Given our project's social science dimension and use of interviews, we determined that this measure of relative exploitation was appropriate (Brodizio & Chowdhury, 2010; Hawken & Munch, 2012). We used Welch's analysis of variance and the Kruskal-Wallis H test to compare distance travelled on hunting and fishing trips between communities. The Pearson's rank correlation coefficient allowed us to examine the relationship between CPUE and distance travelled as an indication of local resource depletion (Fa et al. 2006; Laurance et al. 2006).

We used multiple linear regressions to investigate the effects of socio-economic variables on community-level harvest rates and CPUE. We included village size as a continuous variable and market exposure as a categorical variable in all models, using season as an additional categorical variable in the analyses of fishing data. The response variables were log-transformed to account for non-normal distributions. We estimated the significance of variables by dropping them from the full model and using likelihood ratio tests to compare nested models. We examined variations in the species compositions of harvests, termed the 'harvest profile', using Principal Components Analysis (PCA). Results were considered significant for $P < 0.05$. Statistical analyses were undertaken in R version 3.3.1 (R Core Team, 2016).

Results

All households in the study area fished daily throughout the year. In 57% of households, fishing was supplemented with hunting. 77% of hunters were active less than 10 days a year, and only one hunted as often as 18 days a year. The total biomass of wildlife harvested annually by the five communities was ~1,807 t (Table 1). The majority of fishermen (96%) reported travelling in *peque peque* for no more than 6 hours, whereas 39% of hunters undertook trips of several days, travelling over 6 hours to reach remote *restingas* inside the reserve. The mean distance travelled by fishermen and hunters was 11.2 (±4.1) km and 44.0 (±11.1) km, respectively. The distance travelled on hunting trips did not differ between communities ($H_{(4)} = 5.70$, $P = 0.22$), but fishermen from Nuevo Arica and San Martín de Tipishca travelled farther than fishermen from other villages (*Welch's* $F_{(4,29.67)} = 18.21$, $P < 0.001$). The combined hunting and fishing catchment area for all communities covered ~576 km^2 (Fig. 2). There was a positive correlation between the distance travelled into the reserve and CPUE of fish during the low-water season (Pearson $r_{s(120)} = 0.22$, $P = 0.017$), but not the high-water season (Pearson $r_{s(120)} = 0.17$, $P = 0.07$). No significant correlation existed between distance travelled and CPUE of game species for number of individuals (Pearson $r_{(69)} = 0.19$, $P = 0.88$) or biomass (Pearson $r_{s(69)} = 0.14$, $P = 0.24$).

The communities of the Samiria basin collectively harvested 1,740 t of fish annually (96.3% of biomass extracted), comprising 23 fish species (Table 2). The most widely caught species was *Prochilodus nigricans*, a species of both commercial and subsistence importance. There was substantial variation in harvest profiles between communities (Fig. 3). In San José de Samiria and Leoncio Prado, fishermen harvested a large proportion of small, commercial species such as *Leporinus* spp., as well as larger species like *Hoplias malabaricus.* In San José de Samiria, smaller, less economically valuable species like *Oxydoras niger* and *Leiarius marmoratus* also made up a significant proportion of their catch. The communities of the Tipishca Lake depended on the most abundant species, including *Liposarcus pardalis*, *Pygocenturs* spp. and *Serrasalmus* spp. We found evidence that the paiche, a species of conservation concern, was also caught.

The reported total annual harvest of game species in the study area was ~4,275 individuals, equating to ~67 t (3.7% of biomass extracted) and comprising 27 species (Table 3). Mammals were the most frequently extracted group, making up 55.8% of all hunted individuals and 74.0% of hunted biomass, followed by birds (24.9%; 2.9%) and reptiles (19.3%; 23.1%). The most frequently hunted species were the white-lipped peccary *Tayassu pecari*, paca *Cuniculus paca* and brown agouti *Daysprocta variegata*. The majority of biomass harvested came from large-bodied animals, mainly the white-lipped peccary, lowland tapir, and black caiman *Melanosuchus niger*. The Amazonian manatee *Trichechus inunguis*, which is strictly protected, was hunted occasionally. As with fish harvest, we found that game harvest profiles varied substantially between communities (Fig. 4). In San José de Samiria and San

Martín de Tipishca, hunters harvested a larger proportion of large-bodied species, such as the lowland tapir, the South American river turtle *Podocnemis expansa* and the white-lipped peccary, whereas the other communities harvested a larger proportion of small primates and wetland birds.

The multiple linear regressions revealed a significant positive relationship between village size and annual harvest rates of fish (Table 4, Fig. 5). However, village size had no effect on CPUE of fish ($F = 0.96$, $P = 0.37$). There was also no effect of market exposure on harvest rates of fish ($F = 4.60$, $P = 0.08$), but commercial communities had a significantly lower CPUE of fish (Table 4, Fig. 6). As expected, season had a significant effect on harvest rates and CPUE of fish, both of which were higher in the low-water season (Table 4). Neither market exposure nor village size had a significant effect on harvest rates of game species (all $P > 0.47$), and there was no significant effect of market exposure on CPUE of game species, both when measured as individuals ($F = 0.39$, $P = 0.59$) and biomass ($F = 0.01$, $P = 0.94$). The linear models revealed a negative effect of village size on CPUE of game species when measured as individuals (size coefficient = -0.01 ±0.003, $t_{1,3} = -3.9$, $P = 0.03$, Fig. 7), but this effect was not present when measured as biomass ($F = 1.73$, $P = 0.32$).

Discussion

Our study adds to the growing body of research that suggests that socio-economic factors influence wildlife harvesting by Indigenous peoples (Smith & Wishnie, 2000; Lu, 2007; Godoy et al., 2010). Specifically, the patterns of hunting and fishing by the Kukama-Kukamilla people of the PSNR reveal the potential threat of increased market integration and a rising human population. The data presented in this study include a number of potential sources of variation that we did not control for, including environmental variables such as habitat quality, which may have limited the statistical power of the analyses. Furthermore, the small sample size of only five communities means caution must be taken when interpreting the results of the significance tests. However, since data points represent aggregates of household-level data, they reflect many more underlying observations, and we believe this allows us to make reliable inferences.

We discovered evidence of resource depletion in more commercial communities, reflected in a lower CPUE of fish. This could explain why harvest rates were similar across communities. If over-fishing had decreased fish populations, this would have reduced the profitability of fishing and perhaps limited commercial fishing activity (Vasco & Sirén, 2016). Nevertheless, the net pressure of commercial fishing on depleted resources is likely greater than the pressure exerted by non-commercial communities on relatively un-depleted fish stocks. In San José de Samiria and Leoncio Prado, fishermen targeted small, economically valuable species, indicating possible over-exploitation of larger species. This trend is observed in the nearby markets of Iquitos, where the sale of cheaper, smaller and faster-growing species has risen since the 1980s, while the sale of larger species has declined (Garcia et al., 2008; Atwood et al., 2015). The large proportion of less economically valuable species in harvests from San José de Samiria could reflect an increasing reliance on these species for subsistence.

As expected, larger communities exerted greater pressure on fish resources through increased harvest rates. We therefore expected to see similar signs of resource depletion in these communities. Nonetheless, community size had no significant effect on fish CPUE. However, fishermen from San Martín de Tipischa, the largest village, together with those from Nuevo Arica, travelled farther on fishing trips than those from neighbouring communities, and during the low-water season CPUE was higher farther into the reserve. This is consistent with the paradigm that Neotropical people are central-place foragers, travelling greater distances in search of preferred prey species as wildlife populations become locally depleted (Levi et al., 2009; 2011). Thus, fishing in previously un-exploited sites inside the PSNR could be masking resource depletion in the Tipishca Lake. Fishermen from San Martín de Tipishca also harvested small, abundant fish species, which may be able to sustain the larger human population.

The results of our study provided no clear evidence of a decline in game populations in the PSNR. Although CPUE of individuals was lower in larger communities, this likely reflects selective harvesting rather than resource depletion, since CPUE of biomass was similar across communities (Mayor et al., 2015). As observed in other communities in the Peruvian Amazon (Zapata-Ríos et al., 2009; Sirén & Wilkie, 2016), in San José de Samiria and San Martín de Tipishca, hunters harvested large-bodied prey species, including ungulates, large primates and reptiles. Encounter rates of these species in the forest are relatively low due to naturally low population densities (Peres & Lake, 2003; Espinosa et al., 2014), so hunters are likely targeting them for their greater meat harvests. The strong presence of preferred species in the harvest profiles of the Kukama-Kukamilla suggests that wild meat harvests are currently supplied by a relatively un-depleted source. This could be indicative of a source-sink dynamic, with immigration of game species from the un-hunted core zone of the reserve sustaining harvests in the catchment area (Navaro et al., 2000; Ohl-Schacherer et al., 2007).

Nevertheless, large-bodied game species are particularly vulnerable to over-exploitation due to slow reproductive rates (Mayor et al., 2017). The continued harvest of vulnerable species by the Kukama-Kukamilla people will likely cause significant population declines in the PSNR and a shift in prey selection toward a broader range of smaller, less-preferred species, following the general trend observed throughout the Amazon (Naranjo & Bodmer, 2007; Peres & Palacios, 2007; Constantino, 2016). The region has also been experiencing more extreme droughts and seasonal flooding in recent decades, which could exacerbate the impacts of unsustainable wildlife extraction by limiting resources for wildlife and causing direct mortality of animals (Bodmer et al., 2017). The recent sharp decline in populations of the white-lipped peccary throughout its range, for which non-anthropogenic impacts are suspected, will put further pressure on alternative and more vulnerable prey species (Fragoso, 2004; Richard-Hansen et al., 2013; Mayor et al., 2015).

Overall, our results indicate that the forests of the PSNR are able to provide important food supplements for the Kukama-Kukamilla people. However, hunting and fishing in some villages appears to be approaching critical thresholds, threatening the natural capital of the reserve. Around the world, the combination of human population growth and increased market integration of Indigenous peoples is linked to a downward spiral of local species extinctions and a diminishing supply of crucial protein and income. In this context, the sustainable management of natural resources represents a crucial opportunity for biodiversity conservation where protected areas and Indigenous territories overlap (Zimmerman et al., 2001). Development professionals, protected area managers, and conservationists need to help maintain low hunting and fishing pressure by diversifying and enhancing existing livelihood strategies, thereby reducing poverty in rural communities and conserving vulnerable species (Bodmer & Lozano, 2001; Bassett, 2005; Gandiwa, 2011). Community-based management is needed to monitor the impacts of socio-economic and climatic change, and to ensure the long-term sustainable use of forest species, both inside and outside protected areas.

Author contributions

REB and MK designed the data collection methods and REB provided logistical support in the field. MK collected and analysed the data and wrote the first draft of the manuscript. JCA, MK, CE, REB and PM edited the manuscript to produce the final draft. AB produced the maps.

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Biographical sketches

Maire Kirkland conducts research into the sustainable use of natural resources. Cristina Eisenberg works on food-web relationships, sustainable natural resources use, and ecological restoration globally, with a focus on Indigenous communities. Andy Bicerra, Richard E. Bodmer and Pedro Mayor are involved in wildlife research and biodiversity conservation in the Neotropics. Jan C. Axmacher explores patterns of biodiversity in China and the UK.

Table 1. Details of interviews and community-level household harvest rates in the five Kukama-Kukamilla communities located at the mouth of the Samiria River. The amount of meat available for consumption was calculated as 70% of biomass extracted (Hill et al., 1984; Roos et al., 2007). The values for individuals were calculated based on an average household size of 6.

Community	San Martín de Tipishca	Nuevo Arica	Bolivar	Leoncio Prado	San José de Samiria
Number of families	120	50	40	90	50
Number interviewed (%)	29 (24.2%)	28 (56.0%)	9 (22.5%)	30 (33.3%)	26 (52.0%)
Total harvest per year (t)					
Fish	679.64	222.26	359.32	327.95	151.26
Game	15.01	14.42	8.40	9.94	10.70
Total meat	694.65	236.68	367.72	337.89	161.96
Total harvest per household per year (t)					
Fish	5.66	4.45	8.98	3.64	3.03
Game	0.21	0.51	0.37	0.19	0.38
Total meat	5.87	4.96	9.35	3.83	3.41
Total meat available for consumption					
Per household per year (t)	4.11	3.47	6.55	2.68	2.39
Per individual year (t)	0.68	0.58	1.09	0.45	0.40
Per individual per day (kg)	1.88	1.59	2.99	1.22	1.09

Table 2. Fish species harvested by the Kukama-Kukamilla people, showing the proportion of households harvesting each species during high- and low-water seasons.

Species		Percentage of households (%)	
Scientific name	Local name	High	Low
Characiformes			
Prochilodus nigricans	Boquichico	83.33	77.12
Hoplerythrinus unitaeniatus	Shuyo	60.83	41.18
Mylossoma duriventre	Palometa	26.67	45.00
Hoplias malabaricus	Fasaco	26.67	28.57
Triportheus spp.	Sardina	25.00	22.69
Leporinus spp.	Lisa	15.83	22.69
Brycon spp.	Sabalo	5.83	5.74
Pygocenturs/Serrasalmus spp.	Piraña	14.17	17.65
Potamorhina latior	Yahuarachi	6.67	4.20
Colossoma macropomum	Gamitana	0.83	0.83
Perciformes			
Satanoperca jurupari	Bujurqui vaso	15.00	23.33
Astronotus ocellatus	Acarahuazú	9.17	26.27
Cichla monoculus	Tucunaré	0.83	6.67
Siluriformes			
Liposarcus pardalis	Carachama	64.17	51.28
Pseudoplatystoma tigrinum	Tigre zúngaro	4.17	5.83
Pimelodus blochii	Bagre	3.33	4.17
Pseudoplatystoma fasciatum	Doncella	3.33	2.50
Hoplosternum spp.	Shirui	2.50	0.83
Hypopthalmus edentatus	Maparate	0.83	1.67
Sorubim lima	Shiripira	0.83	0.00
Oxydoras niger	Turushuqui	0.83	0.83
Leiarius marmoratus	Achara	0.83	0.83

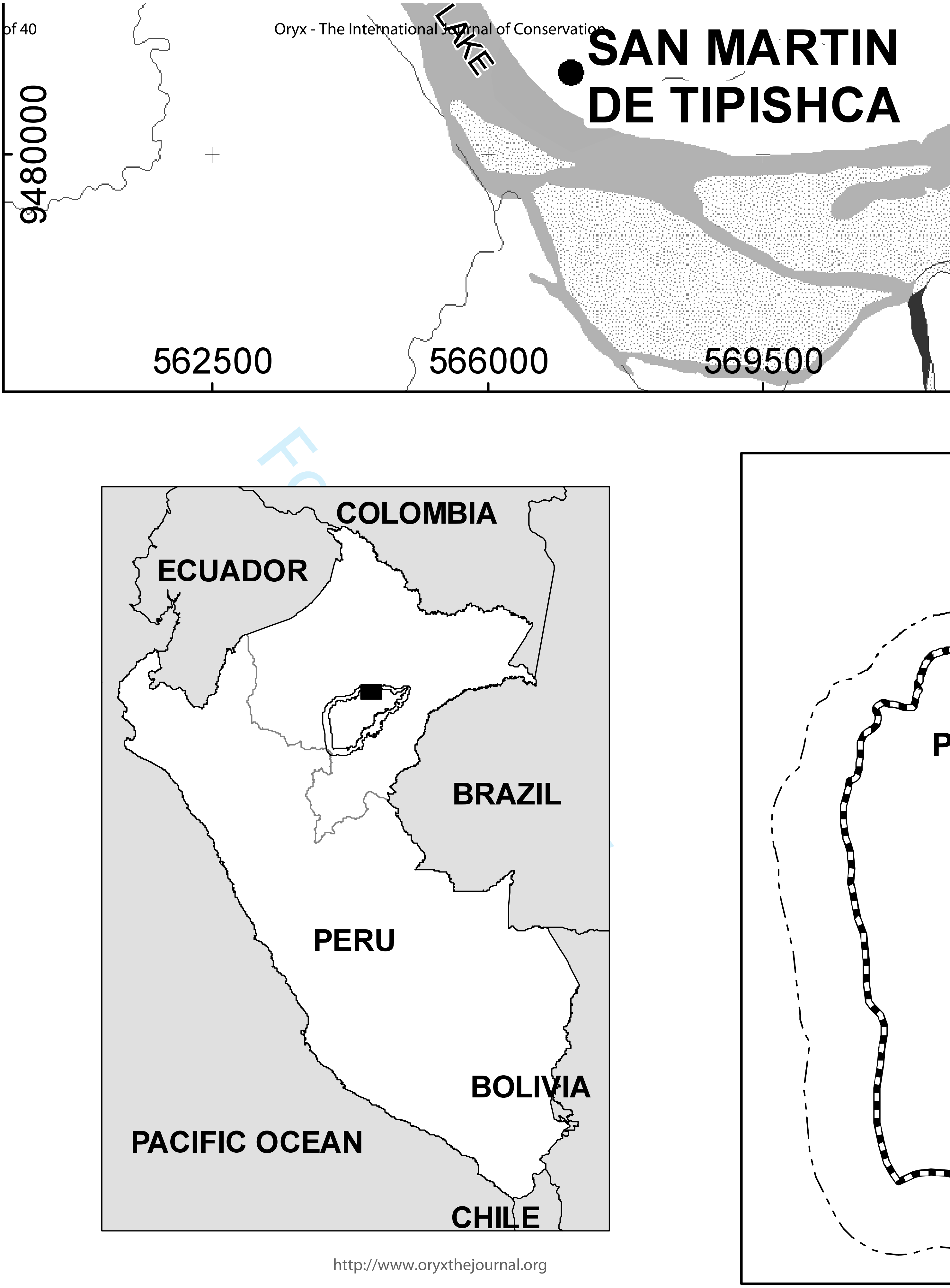
Table 3. Annual harvest rates of game species by the Kukama-Kukamilla people, showing the number of individuals and biomass harvested per household per year.

Species Scientific name	Local name	Individuals (n/household/year)	Biomass (kg/household/year)
Artiodactyla			
Tayassu peccari	Huangana	2.97	103.99
Pecari tajacu	Sajino	0.62	15.58
Mazama americana	Venado colorado	0.30	6.09
Rodentia			
Cuniculus paca	Majáz	2.54	20.29
Dasyprocta variegata	Añuje	1.96	9.78
Cingulata			
Dasypus novemcinctus	Carachupa	1.61	9.65
Primates			
Alouatta seniculus	Coto	1.10	7.16
Sapajus apella	Mono negro	0.51	1.48
Cebus albifrons	Mono blanco	0.42	1.13
Saimiri boliviensis	Maquisapa	0.12	1.05
Ateles spp.	Fraile	0.09	0.08
Lagothrix spp.	Choro	0.03	0.25
Perissodactyla			
Tapirus terrestris	Sachavaca	0.57	79.13
Carnivora			
Nasua nasua	Achuni	0.20	1.01
Sirenia			
Trichechus inunguis	Vaca marina	0.04	17.39
Pelecaniformes			
Ardea spp.	Garza	1.22	1.46
Phalacrocorax brasilianus	Cushuri	1.00	1.50
Anseriformes			
Cairina moschata	Sachapato	1.16	3.48
Galliformes			
Pipile cumanensis	Pava	0.94	1.32
Penelope jacquaca	Pucacunga	0.71	0.92
Mitu tuberosa	Paujil	0.57	1.75

Tinamiformes			
Crypturellus undulates	Panguana	0.23	0.26
Testudinae			
Podocnemis unifilis	Taricaya	2.09	16.70
Chelonoidis denticulata	Motelo	0.77	6.14
Podocnemis expansa	Charapa	0.43	11.30
Crocodilia			
Melanosuchus niger	Lagarto negro	0.91	42.00
Caiman crocodylus	Lagarto blanco	0.32	9.57

Table 4. Results of the multiple linear regression analyses showing how community-level harvest rates and CPUE of fish are affected by village size, market exposure and season.

	Estimate ± SE	*t*	*P*
Harvest rates			
(Intercept)	3.42 ±0.35	9.74	0.000
Size	0.01 ±0.00	2.66	0.033
Low-water season	1.25 ±0.26	4.80	0.002
CPUE			
(Intercept)	-0.80 ±0.14	-5.73	0.001
Commercial	-1.10 ±0.17	5.73	0.001
Low-water season	1.61 ±0.17	6.77	0.000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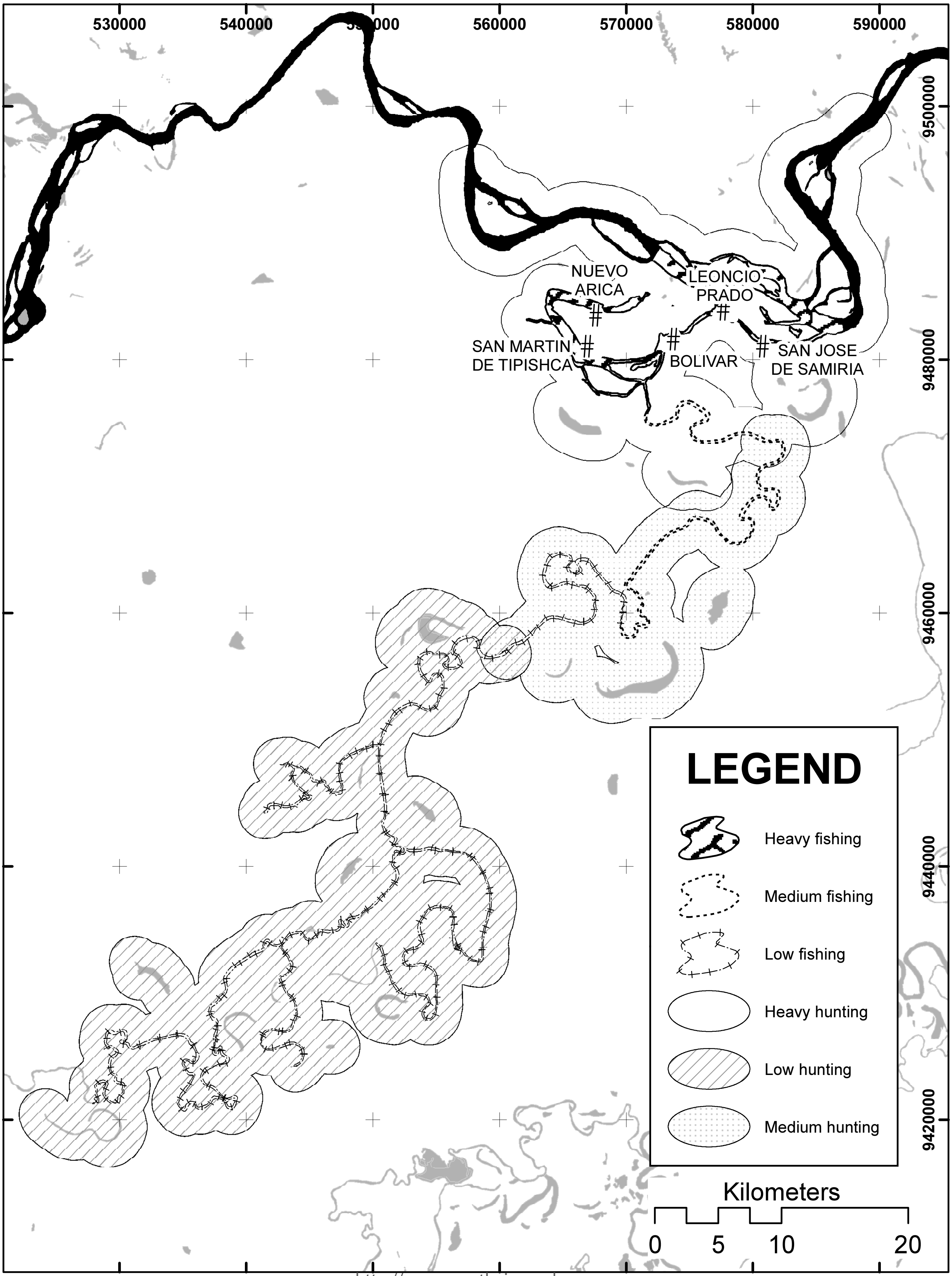
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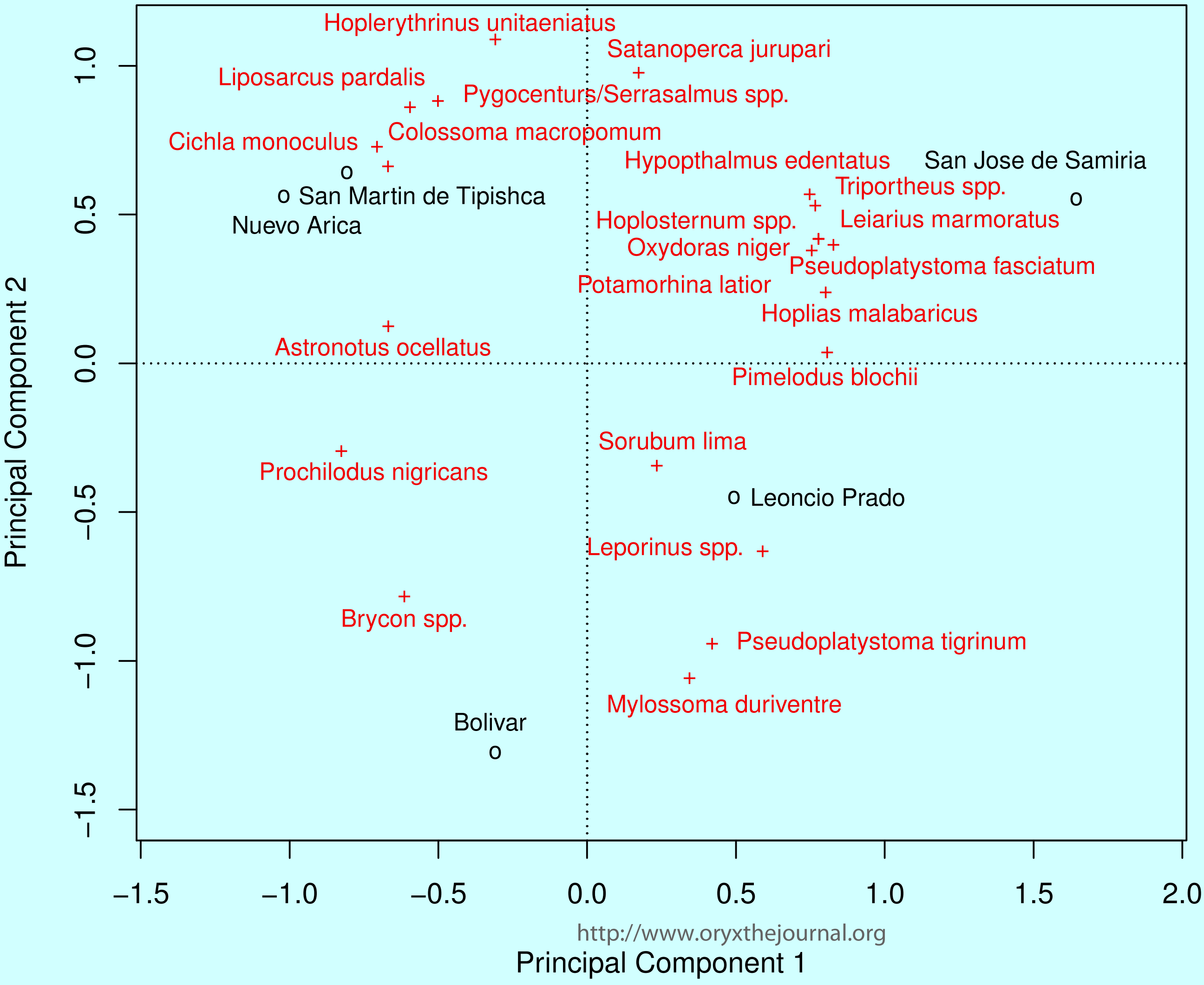
Hoplerythrinus unitaeniatus
Satanoperca jurupari
Liposarcus pardalis
Pygocenturs/Serrasalmus spp.
Colossoma macropomum
Cichla monoculus
Hypopthalmus edentatus
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Hoplosternum spp.
Leiarius marmoratus
Oxydoras niger
Pseudoplatystoma fasciatum
Potamorhina latior
Hoplias malabaricus
Astronotus ocellatus
Pimelodus blochii
Sorubum lima
Prochilodus nigricans
Leoncio Prado
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Brycon spp.
Pseudoplatystoma tigrinum
Mylossoma duriventre
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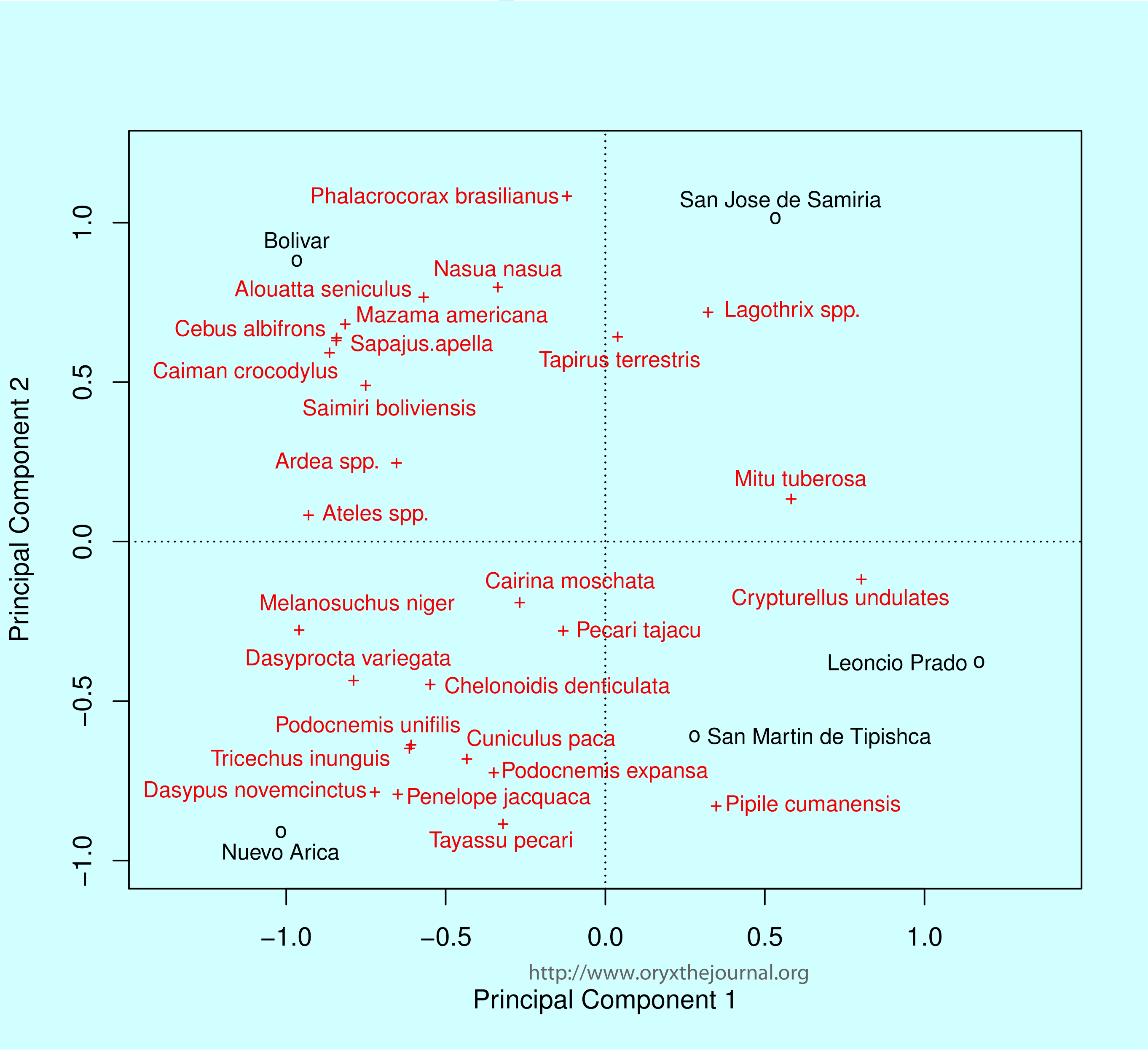
Phalacrocorax brasilianus
San Jose de Samiria
Bolivar
Nasua nasua
Alouatta seniculus
Lagothrix spp.
Mazama americana
Cebus albifrons
Sapajus.apella
Tapirus terrestris
Caiman crocodylus
Saimiri boliviensis
Ardea spp.
Mitu tuberosa
Ateles spp.
Cairina moschata
Melanosuchus niger
Crypturellus undulates
Pecari tajacu
Dasyprocta variegata
Leoncio Prado
Chelonoidis denticulata
Podocnemis unifilis
Cuniculus paca
San Martin de Tipishca
Tricechus inunguis
Podocnemis expansa
Dasypus novemcinctus
Penelope jacquaca
Pipile cumanensis
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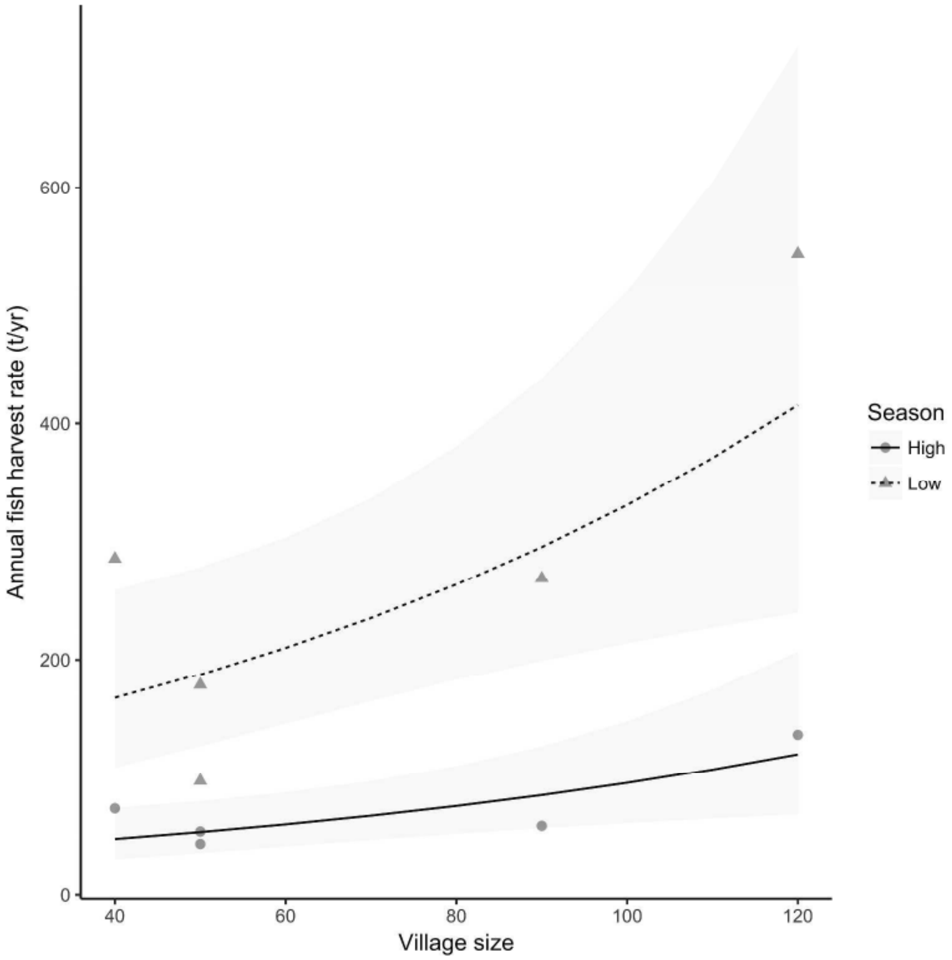

Figure 5. The effect of village size on annual community harvest rates of fish in the five Kukama-Kukamilla communities located at the mouth of the Samiria River during the high- and low-water seasons. The lines are the predicted slopes from the linear regression model and the shaded areas represent 95% confidence intervals.

1425x1425mm (72 x 72 DPI)

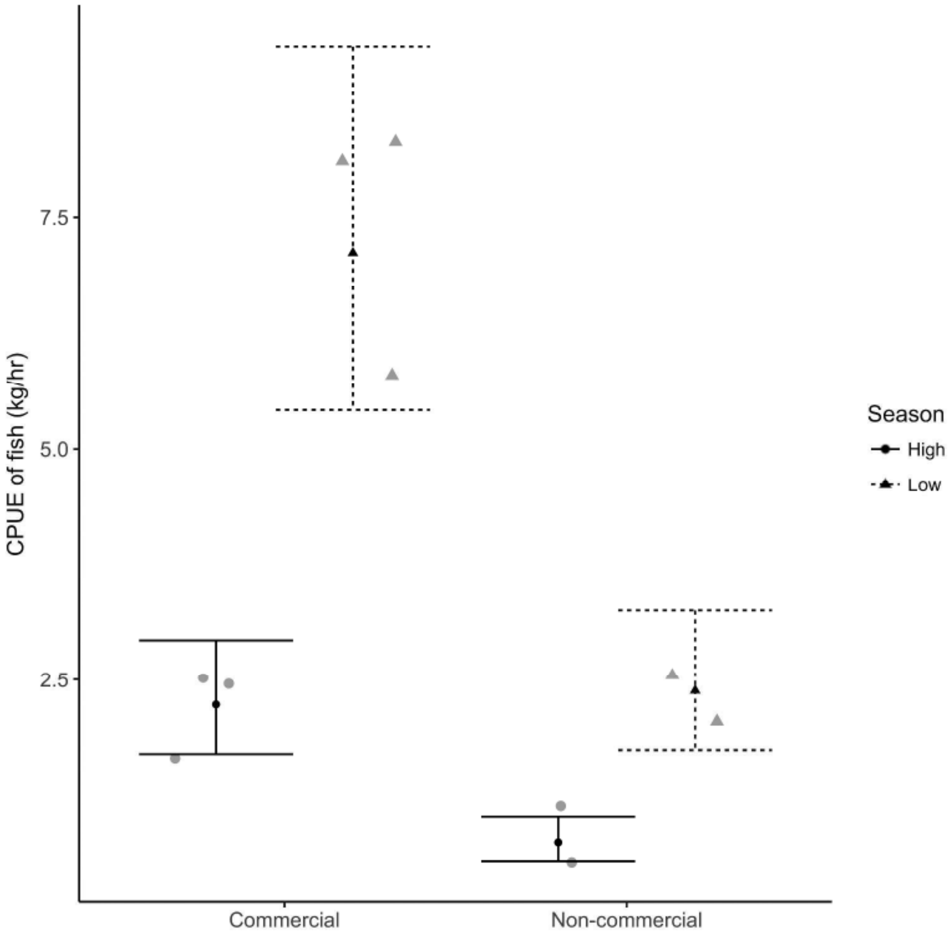

Figure 6. The effect of market exposure on CPUE of fish in the five Kukama-Kukamilla communities located at the mouth of the Samiria River during the high- and low-water seasons, with the predicted means from the linear regression model and 95% confidence intervals.

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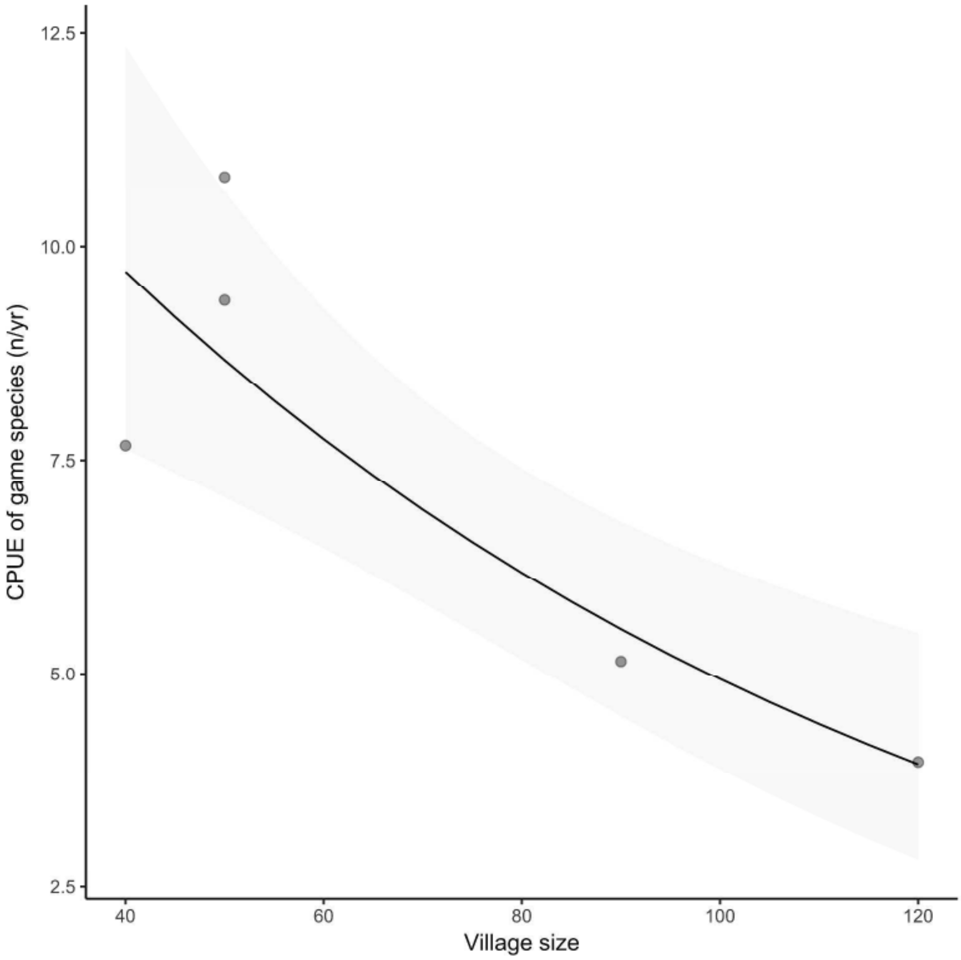

Figure 7. The effect of village size on CPUE of game species, when measured as the number of individuals, in the five Kukama-Kukamilla communities located at the mouth of the Samiria River. The lines are the predicted slopes from the linear regression model and the shaded areas represent 95% confidence intervals.

1425x1425mm (72 x 72 DPI)