Towards Sustainable Harvest of Sideneck River Turtles (*Podocnemis spp.*) in the Middle Orinoco, Venezuela

by

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Dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor
of Philosophy in the Department of
Environment in the Graduate School
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ABSTRACT

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Abstract

Despite 21 years of protection, sideneck river-turtles (*Podocnemis expansa, P. unifilis and P. vogli*, arrau, terecay and galápago, respectively), an important food resource for riverine communities (ribereños) in the Middle Orinoco, have not recovered. To determine the most effective conservation alternative for recovery, we conducted semi-structured interviews of ribereños and determined their attitudes towards turtle conservation; we collected discarded turtle remains in riverine communities to estimate the level of turtle harvest; and constructed a population model to study the effect of reduced survival and future extraction on arrau turtle population growth. We found that ribereños blame continued commercial extraction for the lack of turtle population recovery. Ribereños have a desire to participate actively in conservation and, despite feeling alienated by governmental officials charged with protecting turtles, prefer to be included in conservation efforts. However, ribereños also fear retaliation from turtle poachers. We found widespread turtle harvest along the Middle Orinoco centered on juvenile arrau turtles, and adult female terecay and galápago turtles. In our population model, reducing harvest causes an increase in population growth. A 10% increase in survival causes rapid exponential growth in arrau turtles. The population continues to grow in over 70% of projected scenarios with limited harvest from a recovered stock. Due to the widespread distribution of turtles and their harvest, we recommend increasing ribereño participation in conservation activities, closing outsider (non-ribereño) access to the resource, increasing enforcement against illegal commercial harvest, instating

possession limits for subsistence harvest, and promoting localized captive breeding of faster maturing terecay and galápago turtles to satisfy desire for turtle consumption.

Contents

Abstract iv

List of Tables x

List of Figures xii

Acknowledgements xvi

DEDICATION xviii

1. SIDENECK TURTLE HARVEST 1

  1.1 Introduction 2

  1.2 Methods 5

    1.2.1 Study area 5

    1.2.2 Harvest 6

    1.2.3 Capture 8

    1.2.4 Harvest vs. Capture 9

  1.3 Results 10

    1.3.1 Harvest 10

    1.3.2 Capture 15

    1.3.3 Harvest vs. Capture 18

  1.4 Discussion 23

    1.4.1 Harvest 23

    1.4.2 Capture 25

    1.4.3 Harvest vs. Capture 26

  1.5 Conclusions 30

2. SIDENECK TURTLE CONSERVATION; THE *RIBEREÑO'S* PERSPECTIVE. 32

2.1 Introduction....33
2.2 Methods....36
2.2.1 Study area and interview participants....36
2.2.2 Interview design and analysis....38
2.2.2.1 Summary of interview responses....39
2.2.2.2 Classification and Regression Tree Models....39
2.3 Results....40
2.3.1 Ribereños and their communities....40
2.3.2 Turtles....43
2.3.2.1 Consumption....43
2.3.2.2 Abundance....44
2.3.2.3 Conservation....46
2.3.3 CART Models....49
2.4 Discussion....53
2.5 Conclusions....55
3. MODELING GIANT SIDENECK TURTLE POPULATION RECOVERY AND SUSTAINABLE HARVEST....59
3.1 Introduction....60
3.2 Methods....62
3.2.1 Demographic Parameters....63
3.2.1.1 Egg and Hatchling Survival....63
3.2.1.2 Juvenile, Subadult, and Adult Survival....64
3.2.1.3 Fecundity....66
3.2.1.4 Age at maturity....67

3.2.2 Population Model 67
3.2.3 Management Simulations..70
3.2.3.1 Population recovery 70
3.2.3.2 Sustainable Harvest..72
3.3 Results 72
3.3.1 Demographic Parameters 72
3.3.1.1 Egg and Hatchling Survival 72
3.3.1.2 Juvenile, Subadult, and Adult Survival 73
3.3.1.3 Fecundity 73
3.3.1.4 Age at maturity...74
3.3.2 Population Model 75
3.3.3 Management Simulations..79
3.3.3.1 Population Recovery 79
3.3.3.2 Sustainable Harvest..80
3.4 Discussion 81
3.4.1 Demographic Parameters 81
3.4.2 Population Model 82
3.4.3 Management Simulations..83
3.4.3.1 Population Recovery 83
3.4.3.2 Sustainable Harvest..85
3.5 Conclusions...85
4. CONCLUSIONS 87
Appendix A 94
BIBLIOGRAPHY...99

BIOGRAPHY 108

List of Tables

Table 1. Shell size of male sideneck turtles caught in the Middle Orinoco from 1998-2008. Values are geometric mean (mm) and minimum-maximum. The appearance of secondary sexual characteristics (u-shaped anal notch and engrossed and elongated tail) allows external sex determination in males. We distinguished between females and juveniles by size using the geometric mean male size; we assume turtles larger than the mean with a v-shaped anal notch were females. 9

Table 2. Sideneck turtles harvested in the Middle Orinoco during the 2007-2008 dry season. Values correspond to geometric mean curved length (curved carapace length and curved plastral length -intergular scute to anal notch-), size range and sample size in parentheses. Sex ratio in females:males, star indicates significantly skewed ratio (χ^2, $p < 0.005$). Total harvest ranges from the largest total of either plastrons or carapaces to the addition of both in an effort to account for shells coming from the same turtle. 15

Table 3. Sideneck turtles captured in the Middle Orinoco during the 2008 dry season. Values correspond to geometric mean curved length (curved carapace length and curved plastral length -intergular scute to anal notch-), size range and sample size in parentheses. Sex ratio in females:males, star indicates significantly skewed ratio (χ^2, $p < 0.0005$). Carapaces and plastrons correspond to the same (live) turtle. Plastral length was not taken for all individuals, which accounts for sample size differences. 16

Table 4. Proportion of sideneck turtles harvested and captured in overlapping fishing area north of the Arrau Wildlife Refuge, Middle Orinoco (values in percentages). 18

Table 5. Sideneck turtles harvested and captured during 2007-2008 dry season from the overlapping fishing area north of the Arrau Turtle Wildlife Refuge. Values correspond to geometric mean curved length (curved carapace length and curved plastral length - intergular scute to anal notch), size range and sample size in parentheses. Sex ratio in females:males, star indicates significantly skewed ratio (χ^2, $p < 0.0005$). Carapaces and plastrons correspond to the same (live) turtle for captures; not all captured arrau plastrons were measured, accounting for sample size differences. 19

Table 6. Demographic characteristics of interview participants (n=65)...........................42

Table 7. Social institutions found in riverine communities along the Middle Orinoco. 43

Table 8. Causes of arrau turtle demise and unsuccessful recovery as perceived by ribereños. 46

Table 9. How Ribereños perceive conservation: definition, responsibility and personal incentives for wildlife protection. 47

Table 10. Recommendations from ribereños for improving arrau conservation program and how they can contribute. 48

Table 11. Arnstein's ladder of citizen participation. Modified from Arnstein (1969) and Sokolova (2005). 56

Table 12. Demographic parameters for female arrau turtles from the Middle Orinoco, Venezuela. 73

Table 13. Matrix results for Monte Carlo simulation of Middle Orinoco arrau turtle stochastic population model. Values correspond to average and 95% confidence limits. 78

List of Figures

Figure 1: Nesting female population in the Middle Orinoco determined from direct observation or estimated from nest counts (one nest per female) or egg production. The Middle Orinoco included several nesting beaches from the cities of Puerto Páez to Caicara. Currently most nesting (~98%) occurs on Playitas, the main nesting beach within the Wildlife Refuge. Historically important nesting beaches now account for less than 2% of nesting (data compiled from Humboldt 1820; Licata & Elguezabal 1997; Marín 2010; MARNR 1999; MINAMB 2008; Mogollones et al. 2010; Mosqueira-Manso 1945; Ramírez 1956)... 3

Figure 2. Map of study area displaying name and location of riverine communities, the Arrau Turtle Wildlife Refuge, and the in-water sampling area in the Middle Orinoco, Venezuela. The overlapping fishing area corresponds to in-water sampling area located outside of the refuge boundaries. 8

Figure 3. Per capita harvest of sideneck turtles in Middle Orinoco riverine communities. 11

Figure 4. Size of harvested arrau turtles in each riverine community scaled to per capita harvest. Each box contains the lower data extreme, first quartile, median, third quartile and upper data extreme (outliers are included in whiskers). The width of the box equals per capita harvest for each community. Communities are listed in south to north, up-river to down-river, order with the Arrau Turtle Wildlife Refuge approximately in the middle. .12

Figure 5. Percent harvest of arrau, terecay and galápago turtles scaled to total turtle harvest per community in the Middle Orinoco. 14

Figure 6. Size of captured arrau turtles inside and just north of the Arrau Turtle Wildlife Refuge. Each box contains the lower data extreme, first quartile, median, third quartile and upper data extreme (outliers are included in whiskers). The width of the box equals percent capture for each site corrected by sampling effort. Sites listed in south to north, up-river to down-river, order. Sites inside the wildlife refuge in grey. 17

Figure 7. Size comparison with kernel density distributions of captured and harvested sideneck turtles from the overlapping fishing area. The reference bands display differences between curves (equal to two standard errors). Captured and harvested shell size distributions were different for arrau carapaces ($p = 0$), juvenile ($p = 0$) and male plastrons ($p < 0.05$) and terecay carapaces ($p < 0.01$) and female plastrons ($p = 0$). Size distribution of female arrau plastrons and galápago carapaces were not different. Male terecay and galápago were not harvested, whereas juvenile terecay and galápago were not captured. We captured only one female galápago (245 mm PL)..............................21

Figure 8. Size comparison with kernel density distributions of captured and harvested sideneck turtles from the overlapping fishing area; pooled juvenile and female plastron data. The reference bands display differences between curves (equal to two standard errors). Vertical dotted lines indicate minimum nesting female size for arrau and geometric mean male size for terecay and galápago. Because terecay and galápago are also harvested while they nest, we consider mean male size approximates size at maturity for females. 22

Figure 9. Comparison of commercial (Hernández & Espín 2003) and subsistence harvest (present study) of arrau turtles in the Middle Orinoco, Venezuela. Larger harvested turtles are channeled towards commerce (p = 0)...24

Figure 10. Reanalysis of captured and harvested arrau turtles from Hernández and Espín (2003) using kernel density plots. Larger arrau are selected during harvest (p = 0). 27

Figure 11. Comparison of harvested arrau between Hernández and Espín (2003) and the present study using kernel density plots. Ribereños are consistent in size selection of harvested arrau (p = 0.09). 27

Figure 12. Nesting female population in the Middle Orinoco determined from direct observation or estimated from nest counts (one nest per female) or egg production. The Middle Orinoco included several nesting beaches from the cities of Puerto Páez to Caicara. Currently most nesting (~98%) occurs on Playitas, the main nesting beach within the Wildlife Refuge. Historically important nesting beaches, now account for less than 2% of nesting (data compiled from Humboldt 1820; Licata & Elguezabal 1997; Marín 2010; MARNR 1999; MINAMB 2008; Mogollones 2004; Mosqueira-Manso 1945; Ramirez 1956)..35

Figure 13. Map of study area displaying name and location of riverine communities visited and the Arrau Turtle Wildlife Refuge in the Middle Orinoco, Venezuela. 38

Figure 14. Frequency of arrau turtle consumption by ribereños in the Middle Orinoco. Historical, consumption of arrau turtles > 20 years ago, before they were banned and the wildlife refuge was created; Current, turtle consumption this dry season; Desired, turtle consumption if turtles were abundant and ribereños were allowed to consume them. ...44

Figure 15. Comparison between current and historical abundance of arrau turtles as perceived by ribereños (n=64). 45

Figure 16. Change in arrau turtle abundance in the past five years as perceived by ribereños (n=50). 45

Figure 17. Ribereños living close to the wildlife refuge report not consuming turtles. Ribereños living further from the refuge report consuming turtles 1-3 d/yr. Farmers, grazers and ribereños with other livelihoods who live far from the wildlife refuge report eating turtles 1-3 d/mo, while in the same area young fishers report eating turtle 1-3 d/yr

and older fishers report not eating turtles (model improvement = 0.52). Branch length represents proportion of variance explained. 50

Figure 18. How groups of ribereños perceive changes in juvenile abundance. Older ribereños living up river from the wildlife refuge report juvenile turtles are more abundant than 5 years ago. Ribereños living down river and far from the wildlife refuge report fewer juveniles than 5 years ago, whereas ribereños living closer to the refuge consider juvenile abundance has increased in the past 5 years (model improvement = 0.66). Branch length represents proportion of variance explained. 51

Figure 19. Groups of ribereños who perceive National Guards as being corrupt. Young ribereños who live close to the wildlife refuge perceive National Guards as being corrupt. Older ribereños living in Bolivar, close to the wildlife refuge also perceive National Guards as corrupt (model improvement = 0.42). Branch length of inset represents variance explained in each split. 52

Figure 20. Staggered-entry stage-based matrix model. *P* denotes survival and *F* denotes fecundity (pre-breeding census model). Subscripts designate initial and final stages involved in the transition. EH, egg/hatchling stage, $J_{1\text{-}6}$ juvenile stages, $A_{S,M \text{ or } L}$ small, medium or large adult stages. Adults have no terminal age. 69

Figure 21. Kernel density distribution of Middle Orinoco arrau turtle nesting-female size (n = 264, 1990-1998). 75

Figure 22. Intrinsic growth rate for the Middle Orinoco arrau turtle population derived from exponential regression applied to number of nesting females. Dotted lines represent 95% confidence intervals for the regression $y = 841.32e^{0.00005711.x}$ (r^2_{adj} = -0.05263). 76

Figure 23. Projected growth of nesting female arrau turtles in the Middle Orinoco under current management (equivalent to decreasing maximal growth model survival of juveniles and subadults by 17% and adults by 13%). Solid line represents the average and dotted lines represent confidence intervals of population growth for 1000 iterations. The population increases in 83% of the simulations. In 50 years, there are an average of 2,224 nesters..77

Figure 24. Matrix results for arrau turtle population model. Stable age distribution and elasticities are proportions (i.e.: scaled to sum 1). Reproductive value is relative to eggs. Whiskers represent 95% confidence intervals produced by the Monte Carlo simulation (1000 iterations). 78

Figure 25. Projected growth of nesting female arrau turtles in the Middle Orinoco after eliminating estimated commercial and subsistence harvest (equivalent to a 7% increase in juvenile and subadult survival in current growth model). Solid line represents the average and dotted lines represent confidence intervals of population growth for 1000

iterations. In 39 years there are an average of 10,000 nesters. The population grows in 95% of the simulations. 79

Figure 26. Projected growth of nesting female arrau turtles in the Middle Orinoco under double the current subsistence and no commercial harvest (equivalent to a 11% increase in juvenile and subadult survival in current growth model). Solid line represents the average and dotted lines represent confidence intervals of population growth for 1000 iterations. The population increases in 97% of the simulations. In 25 years, there are 10,000 nesters on average. 80

Figure 27. Projected growth of Middle Orinoco arrau turtle population with yearly harvest of 10,000 juvenile, subadult and adult turtles according to current harvest behavior. Solid line represents the average and dotted lines represent the confidence intervals of population growth for 1000 iterations. On average, the population continues to grow despite harvest, surpassing 60,000 nesting females in 15 years, less than 7% decrease in abundance. 81

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Joe S., all the Global Fellows I have known, Chris Oishi, Andy B…. and oh, goodness, I know there are more… but I only have two minutes left to finish this!

I love you all… THANK YOU for being there for me!

DEDICATION

“I did it!”

Hiro Kurosawa

A mi gente, que, en persona o virtuales, en alma y sentimiento, siempre han estado presentes ayudándome a terminar… a cumplir esta INMENSA meta.

Gracias!

To Bob and Sophia, you keep me going.

1. SIDENECK TURTLE HARVEST

1.1 Introduction

Turtles have long been an important food resource for humans. However, changes in human population size, modern harvest methods, and transculturization (cultural merging and convergence) have led to overexploitation in many turtle species (Klemens & Thorbajarnarson 1995; Thorbjarnarson et al. 2000). Such is the case for the Giant South American river turtle or *arrau* (*Podocnemis expansa*), estimated at over 330,000 nesting females in 1800 in the Middle Orinoco (Humboldt 1820), overexploitation reduced this population to less than two thousand nesting females by 1985 (MINAMB 2008) (Figure 1). With the demise of the arrau, preferred for its size, gregarious nesting, and large clutches, hunting pressure has increased for congenerics like the yellow-headed sideneck turtle or *terecay* (*Podocnemis unifilis*), and the savannah sideneck turtle or *galápago* (*Podocnemis vogli*) (Escalona & Fa 1998; Thorbjarnarson et al. 1993). All three species are listed in Appendix II of CITES (UNEP-WCMC 2009). The arrau is listed as critically endangered in Venezuela (Decreto N° 1486 1996; Rodríguez & Rojas-Suárez 2008) and lower risk / conservation dependent in the IUCN Red List (IUCN 2009). The terecay is listed as threatened in Venezuela (Rodríguez & Rojas-Suárez 2008) and vulnerable in the IUCN Red List (IUCN 2009). The galápago is listed as threatened in Venezuela (Rodríguez & Rojas-Suárez 2008).

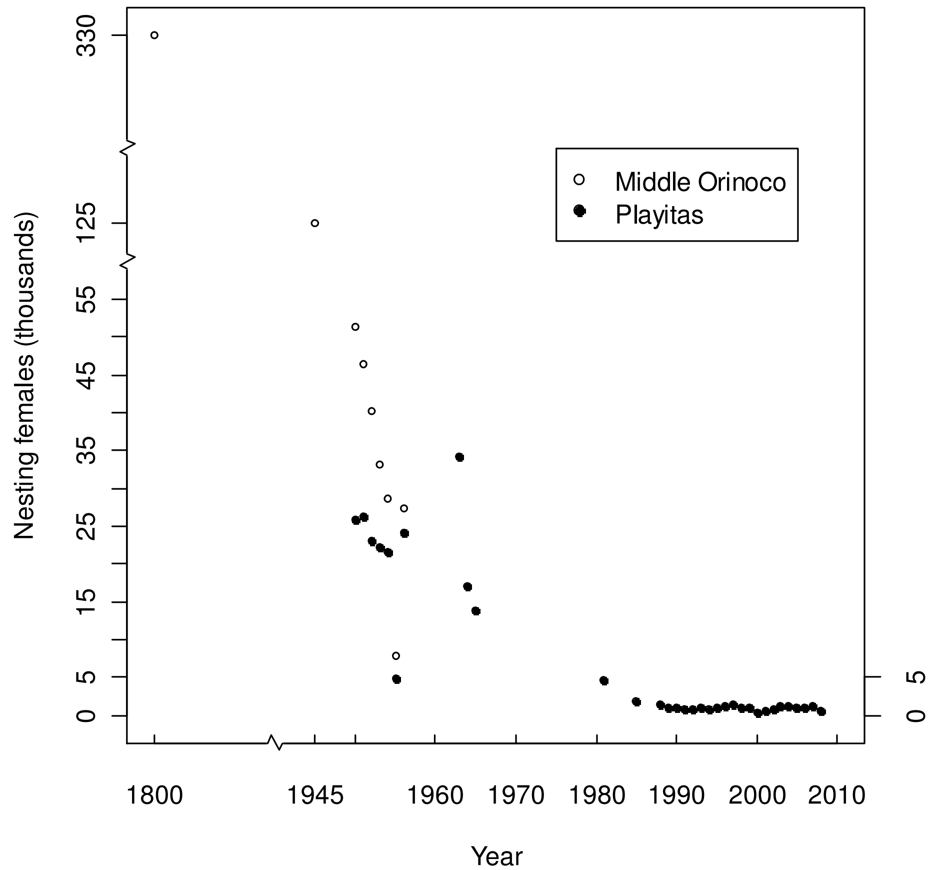

Figure 1: Nesting female population in the Middle Orinoco determined from direct observation or estimated from nest counts (one nest per female) or egg production. The Middle Orinoco included several nesting beaches from the cities of Puerto Páez to Caicara. Currently most nesting (~98%) occurs on Playitas, the main nesting beach within the Wildlife Refuge. Historically important nesting beaches now account for less than 2% of nesting (data compiled from Humboldt 1820; Licata & Elguezabal 1997; Marín 2010; MARNR 1999; MINAMB 2008; Mogollones et al. 2010; Mosqueira-Manso 1945; Ramírez 1956).

Because turtles are often long-lived and slow maturing, they are particularly susceptible to overharvesting (Congdon et al. 1993). Depending on its particular dynamics, a turtle population may be very sensitive to harvest of one life stage and not another, i.e., population growth is affected more by changes in certain life stages. In turtles with late maturity, like loggerhead sea turtles (*Caretta caretta*), high juvenile survival is essential for population growth. For turtles with earlier maturity, high adult survival is more important for population growth (Heppell 1998). With an estimated age at maturity of 17 and 11-28 years (Hernández & Espín 2006; Mogollones 2004), the arrau would be considered a late maturing species, while informal estimates suggest the terecay and galápago mature much sooner (Ramo 1982; Thorbjarnarson et al. 1993).

Even if we consider a particular stage of life, eggs for example, harvesting nests from a certain beach or location within a beach can have detrimental effects on the entire population by drastically skewing sex ratios and possibly eliminating the nests most likely to survive and produce vigorous hatchlings (Escalona & Fa 1998). Additionally, the influence of modern cultures has changed traditional harvest practices for more efficient and less selective methods in order to satisfy subsistence and commercial harvest demands (Escalona & Loiselle 2003; Perez A. et al. 1995; Thorbjarnarson et al. 2000; Thorbjarnarson et al. 1993). Historically, indigenous communities along the Orinoco and Amazon rivers kept juvenile and adult turtles in flooded enclosures and directed wild harvest towards eggs on the nesting beaches (Carvajal 1504-1584; Humboldt 1820). Changing these practices has caused the demise of turtle populations and displacement of traditional cultures as the main consumers of turtles (Thorbjarnarson et al. 2000).

The Arrau Turtle Wildlife Refuge (AWR) was created in 1989 to protect this species' main nesting-beaches in the Middle Orinoco, Venezuela (Licata & Elguezabal 1997). After over 20 years of protecting nesting females, eggs, and hatchlings, and 15 years of reintroducing headstarted yearlings (>350,000 yearlings), the population has stabilized, but is not recovering (Hernández & Espín 2003, 2006; Mogollones et al. 2010). In addition, arrau scarcity, increasing human populations, and an ongoing economic crisis (Rodríguez 2000) have led to increased harvest pressure on terecay and galápago (Escalona & Fa 1998; Thorbjarnarson et al. 1993).

In other South American countries, adequate protection and involvement of local communities have increased turtle abundance. In Bolivia, four years after the creation of a protected area that eliminated hunting pressure, the abundance of terecay and arrau turtles is higher in the protected area than in neighboring communities (Conway-Gómez 2008). In Ecuador, a Cofán Indian community-based conservation program, which protects nests, hatchlings, and adults, has resulted in a two to three-fold increase in turtle abundance in only 10 years (Townsend et al. 2005). In Venezuela, even though the AWR conservation program includes community outreach and environmental education programs, illegal commercial and subsistence harvest of the arrau, and unmonitored harvest of terecay and galápago still exist (Hernández & Espín 2003).

In order to make sound management decisions to ensure the ecological viability and sustained use of the arrau, terecay, and galápago turtles, we must fully understand current harvest pressure and link it to life history traits. In this study, we describe and quantify the harvest of arrau, terecay, and galápago turtles, and determine if there is selective harvest (by size or sex) when compared to in-water turtle surveys in the Middle Orinoco, Venezuela. We suggest management actions based on harvest and life history characteristics.

1.2 Methods

1.2.1 Study area

The study area comprises a 120 Km stretch of the Middle Orinoco River, Venezuela between the city of Puerto Páez, Apure (across from the Colombian border) and the town of La Urbana, Bolivar (Figure 2). This stretch includes the AWR and 29 riverine communities (ribereños) located both up- (south) and down-river (north) from the wildlife refuge. From 19 April to 12 June 2008, we visited each community by river to search for turtle remains in open dumps and tracts of land adjacent to these communities and we conducted in-water turtle surveys within and north of the AWR.

1.2.2 Harvest

We looked for turtle shells (carapaces and plastrons) discarded in the recent dry season (December 2007 – March 2008) distinguished by the presence of epidermal scutes and overall structural integrity (as opposed to shells from the previous dry season that generally had disjointed bony plates or were too fragile to handle) (Thorbjarnarson et al. 1993). We identified each shell to species level according to its shape (Pritchard & Trebbau 1984) and measured it to the nearest millimeter with a fiberglass tape measure (over-the-curve carapace length, CCL, and intergular to anal notch for plastrons, PL). We sexed plastrons by the shape of the anal notch or plastral length. Males have u-shaped anal notches while females and juveniles have v-shaped ones (Perez A. et al. 1995; Pritchard & Trebbau 1984; Thorbjarnarson et al. 1993). Plastrons with a u-shaped anal notch were considered males. Plastrons with a v-shaped anal notch were considered females if they were larger than the geometric mean size for male turtles caught in the area since 1998 (Hernández unpublished data; Hernández & Espín 2006; Mogollones et al. 2010, see Table 1); smaller plastrons were considered juveniles. We define the population sex ratio as the sex ratio of all sexed individuals rather than of only sexually mature individuals to reduce the overrepresentation of males inherent in our sexing method.

We defined harvest as the number of turtle remains found in each community. Total harvest ranges from the largest total of either carapaces or plastrons (minimum harvest) up to the addition of both carapaces and plastrons (maximum harvest) for a particular community. This allows us to account for carapaces and plastrons that may have come from the same turtle without having to discard information about sex ratios or harvest numbers from communities where mostly plastrons where found (turtle meat is sometimes cooked in the carapace on an open fire; this cooking method does not leave carapace remains). We defined per capita harvest as total harvest per person in each community divided by percentage of community-land surveyed. This method underestimates actual turtle harvest because it does not account for turtles transported to other communities for consumption or turtle remains discarded into the river by ribereños who know consumption of certain turtles is illegal. Community size was provided from surveys by C. Peñaloza (unpublished data).

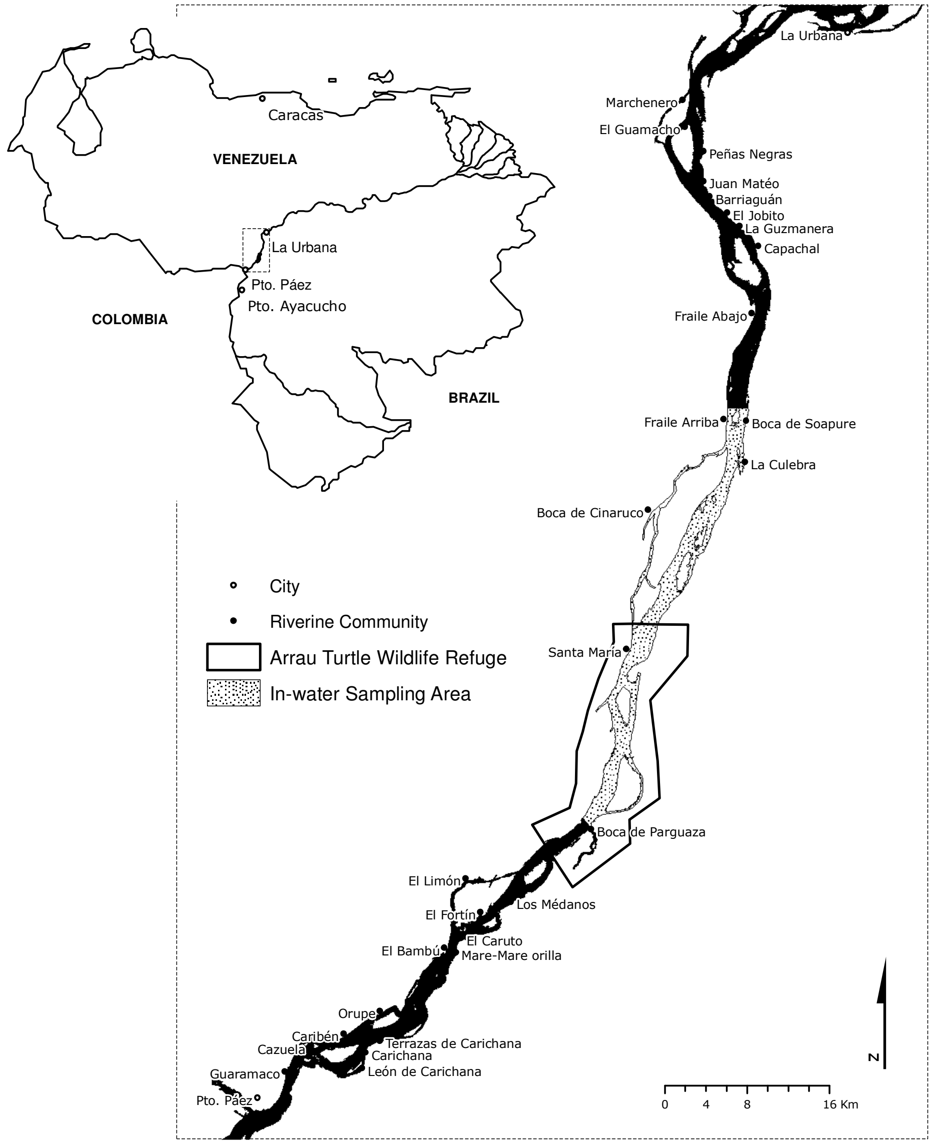

Figure 2. Map of study area displaying name and location of riverine communities, the Arrau Turtle Wildlife Refuge, and the in-water sampling area in the Middle Orinoco, Venezuela. The overlapping fishing area corresponds to in-water sampling area located outside of the refuge boundaries.

1.2.3 Capture

We conducted in-water turtle surveys inside and outside of the AWR along a 50 km stretch of the Orinoco River from the Parguaza River mouth to Fraile Arriba Island (Figure 2), with 5 cm mesh-size trawl nets. We surveyed turtles using the same fishing method used by ribereños, beach-seining, where the net is pulled between two boats or one boat and a person on land. Once landed, we identified turtles by species, measured CCL and PL, sexed male turtles by secondary sexual characteristics and individually marked turtles by shell notching before release. As with harvested turtles, we distinguished between females and juveniles by size using the geometric mean male size for the area (Table 1); all turtles with v-shaped anal notches larger than the male mean were considered females, whereas those smaller than the mean were considered juveniles.

Table 1. Shell size of male sideneck turtles caught in the Middle Orinoco from 1998-2008. Values are geometric mean (mm) and minimum-maximum. The appearance of secondary sexual characteristics (u-shaped anal notch and engrossed and elongated tail) allows external sex determination in males. We distinguished between females and juveniles by size using the geometric mean male size; we assume turtles larger than the mean with a v-shaped anal notch were females.

Species	Plastrons	Carapaces
Arrau (n = 51)	236 145-293	321 184-425
Terecay (n = 91)	199 156-251	279 225-360
Galápago (n = 4)	170 132-219	216 160-310

1.2.4 Harvest vs. Capture

We compared the species composition and size distribution of turtles harvested by locals (harvested) and those captured in our surveys (captured) during 2008 in an overlapping fishing area just north of the AWR. Ribereños consume turtles taken as bycatch while fishing with trawl nets (10 cm mesh-size) outside the AWR; they also harvest terecay and galápago on land while female turtles nest (C. Peñaloza unpublished data). We used a Chi-squared test for all proportion comparisons, i.e., population sex ratios, proportion of juveniles to adults, species distribution along the river, comparison of species composition between harvested and captured turtles, etc. We compared size distributions of harvested and captured turtles using normal (Gaussian) kernel density plots in R (Bowman & Azzalini 2007; R Development Core Team 2008). The test statistic is the integrated squared difference between the two density estimates. Under the null hypothesis, the distribution of this test statistic is calculated from datasets created by random permutation of group labels on the entire dataset. A reference band is used to illustrate the comparison between density curves; it is centered at the average of the two curves and is equal to the width of two standard errors at any given point (Bowman & Azzalini 1997).

1.3 Results

1.3.1 Harvest

Turtle consumption was widespread throughout the Middle Orinoco (Figure 3). We found turtle remains in 69% of the communities visited (20 out of 29 communities). Total turtle harvest in communities varied widely ($\bar{x} = 13 - 19,$ 0-101 shells), though this variation decreases once harvest was adjusted by community size. In most communities there was a per capita consumption rate of about 0.6 turtles per person for the 2007-2008 dry season, though two communities, Boca de Suapure II and La Culebra, had higher per capita consumption rates, 1.8 and 2.0 turtles per person per season, and one community had a rate of 3.6 turtles per capita for the season (Caribén). We did not find turtle remains in communities within the AWR, though we were informed that Ministry of the Environment officials had confiscated a 721 mm CCL arrau carapace from a member of the Santa María community earlier in the season. The size distribution of arrau turtle shells scaled to per capita harvest for each riverine community is shown in Figure 4.

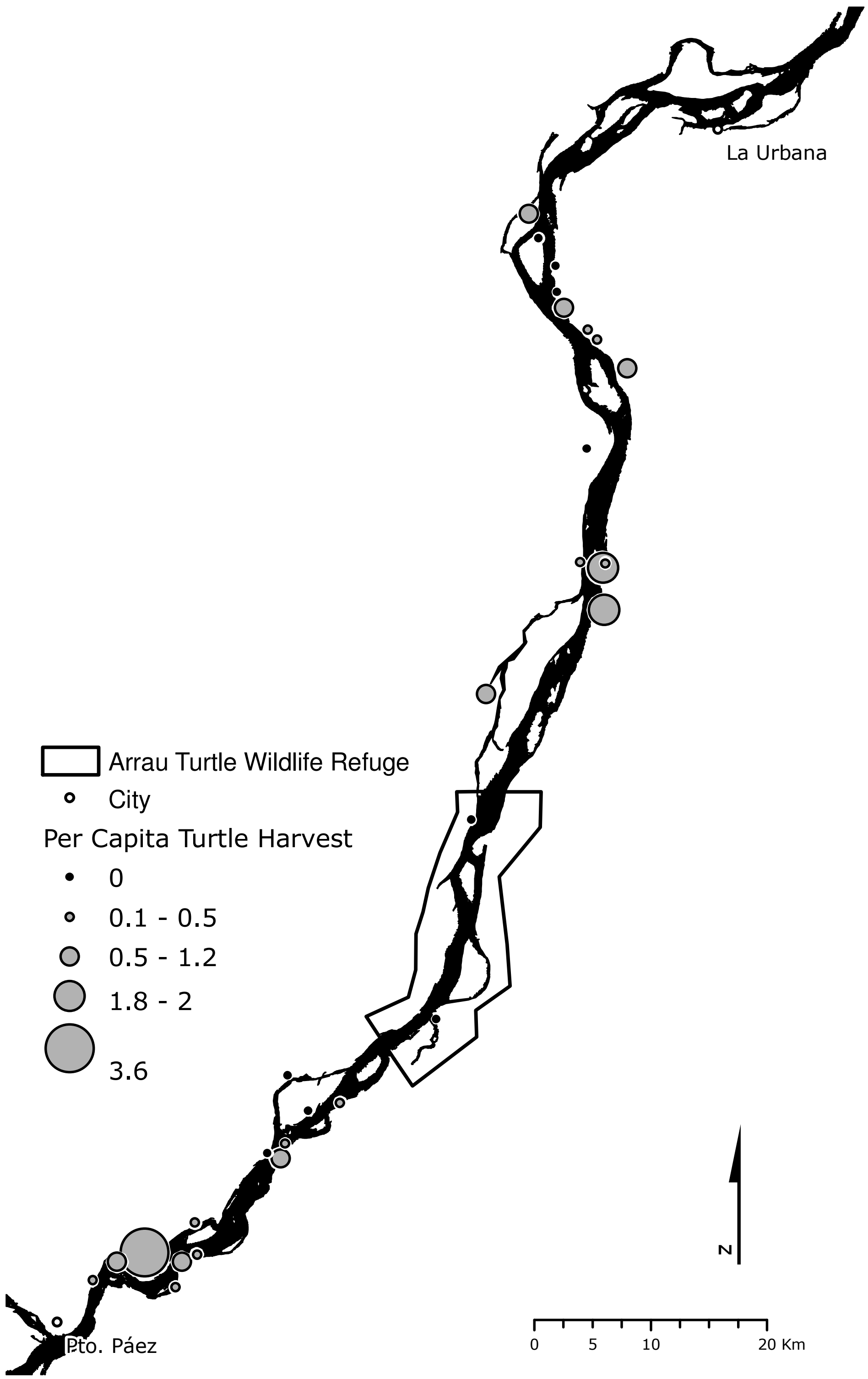

Figure 3. Per capita harvest of sideneck turtles in Middle Orinoco riverine communities.

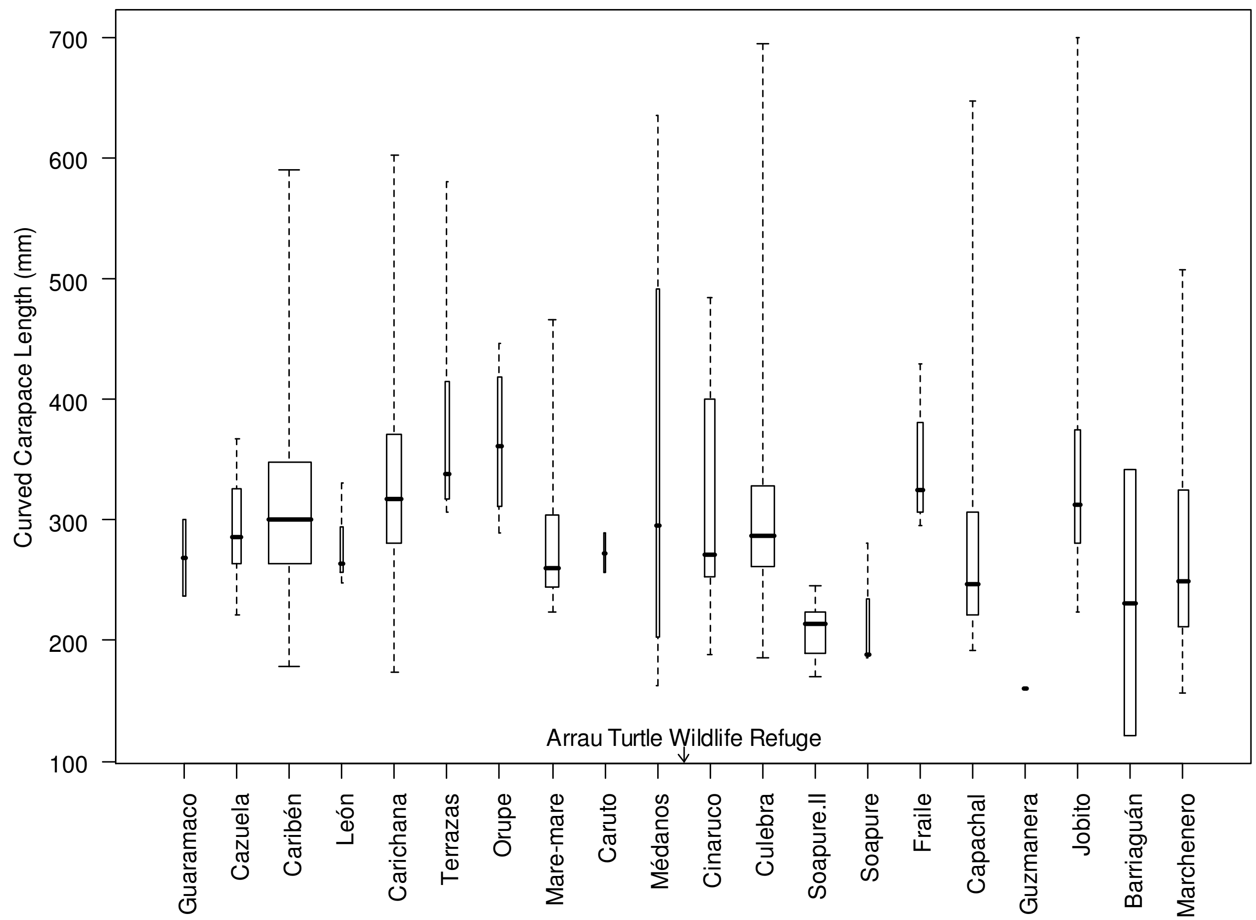

Figure 4. Size of harvested arrau turtles in each riverine community scaled to per capita harvest. Each box contains the lower data extreme, first quartile, median, third quartile and upper data extreme (outliers are included in whiskers). The width of the box equals per capita harvest for each community. Communities are listed in south to north, up-river to down-river, order with the Arrau Turtle Wildlife Refuge approximately in the middle.

The shells we found were from arrau, terecay, and galápago turtles. Most of the turtle remains found were of arrau (74% of carapaces and 78% of plastrons), followed by terecay (16% of carapaces and 13% of plastrons), and galápago (10% of carapaces and 10% of plastrons). We found three Mata-mata (*Chelus fimbriatus*) shells (carapaces and plastrons still connected), though we consider these as natural mortality because cooking requires removing the plastron to disembowel and carve the turtle. We found mostly arrau remains up-river of the AWR whereas down-river the proportion of terecay and galápago increased (χ^2, $p < 0.0001$) (Figure 5).

The total harvest per turtle species in the Middle Orinoco is shown in Table 2. Within each species, we found mostly carapaces (63-70%) and female plastrons (45-65%). The plastron sex ratio of harvested turtles was skewed towards females for arrau (3:1, χ^2, $p < 0.0001$) and galápago (13:1, χ^2, $p < 0.005$) and balanced for terecay (3:1, χ^2, $p > 0.05$). Assuming arrau females reach sexual maturity at the minimum nesting female size of 465 mm CCL (367 mm PL) and males do so at the geometric mean male size of 321 mm CCL (236 mm PL), 3-23% (female maturity size – male maturity size) of carapaces and 19% of plastrons were from adult turtles (18 males, 11 females). For terecay turtles, assuming sexual maturity at the geometric mean male size of 279 mm CCL (199 mm PL), 59% of carapaces and 68% of plastrons were from adult turtles (4 males, 13 females). If we assume galápago turtles reach maturity at the geometric mean male size of 216 mm CCL (170 mm PL), 71 % of carapaces and 65% of plastrons were from adult turtles (0 males, 13 females).

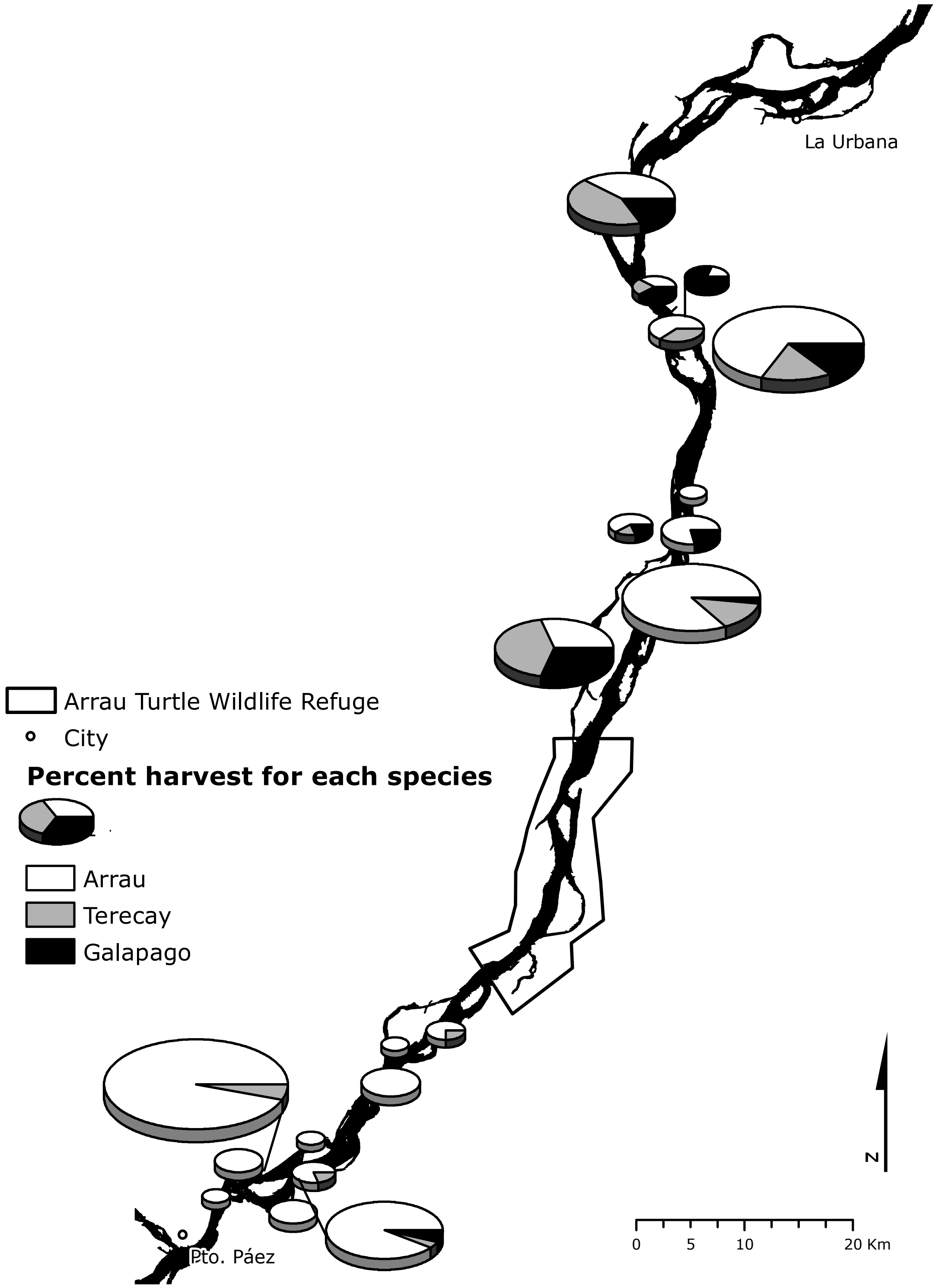

Figure 5. Percent harvest of arrau, terecay and galápago turtles scaled to total turtle harvest per community in the Middle Orinoco.

Table 2. Sideneck turtles harvested in the Middle Orinoco during the 2007-2008 dry season. Values correspond to geometric mean curved length (curved carapace length and curved plastral length -intergular scute to anal notch-), size range and sample size in parentheses. Sex ratio in females:males, star indicates significantly skewed ratio (χ^2, $p < 0.005$). Total harvest ranges from the largest total of either plastrons or carapaces to the addition of both in an effort to account for shells coming from the same turtle.

Species	Carapaces (mm)	Plastrons (mm)			Sex ratio	Total Harvest
		Juvenile	Female	Male		
Arrau	275 157-700 (261)	194 93-235 (62)	295 236-550 (70)	302 191-512 (23)	3 : 1*	n = 261-416
Terecay	302 190-438 (58)	148 100-173 (7)	261 212-313 (13)	251 190-325 (5)	3 : 1	n = 58-83
Galápago	246 173-342 (34)	162 155-170 (6)	205 177-247 (13)	165 na (1)	13 : 1*	n = 34-54

1.3.2 Capture

We captured arrau, terecay, and galápago turtles in the following proportions: 61% arrau, 37% terecay, and 2% galápago. Most of the arrau turtles were juveniles (96%) and most of the terecay and galápago were males (76% and 67%, respectively). Under the previous assumptions of size at sexual maturity, 4% of arrau were adults (3 males, 2 females), 76% of terecay were adults (63 males, 20 females), and 57% of galápago turtles were adults (2 males, 2 females). We did not capture juvenile galápago. Sex ratio was skewed towards females for arrau (6:1, χ^2, $p < 0.0005$), males for terecay (1:4, χ^2, $p < 0.0001$) and balanced for galápago (1:2, χ^2, $p > 0.5$). A description of capture per turtle species is shown in Table 3 and the size distribution of arrau turtles captured in the Middle Orinoco scaled to sampling effort is shown in Figure 6.

Table 3. Sideneck turtles captured in the Middle Orinoco during the 2008 dry season. Values correspond to geometric mean curved length (curved carapace length and curved plastral length -intergular scute to anal notch-), size range and sample size in parentheses. Sex ratio in females:males, star indicates significantly skewed ratio (χ^2, $p < 0.0005$). Carapaces and plastrons correspond to the same (live) turtle. Plastral length was not taken for all individuals, which accounts for sample size differences.

Species	*Carapaces (mm)*	*Plastrons (mm)*			*Sex ratio*
		Juvenile	*Female*	*Male*	
Arrau	211 101-617 (174)	141 75-231 (100)	299 240-502 (23)	230 176-255 (4)	6:1*
Terecay	301 98-474 (105)	97 75-190 (5)	331 209-384 (20)	210 149-260 (79)	1:4*
Galápago	222 160-296 (7)	na	227 210-245 (2)	165 132-194 (4)	1:2

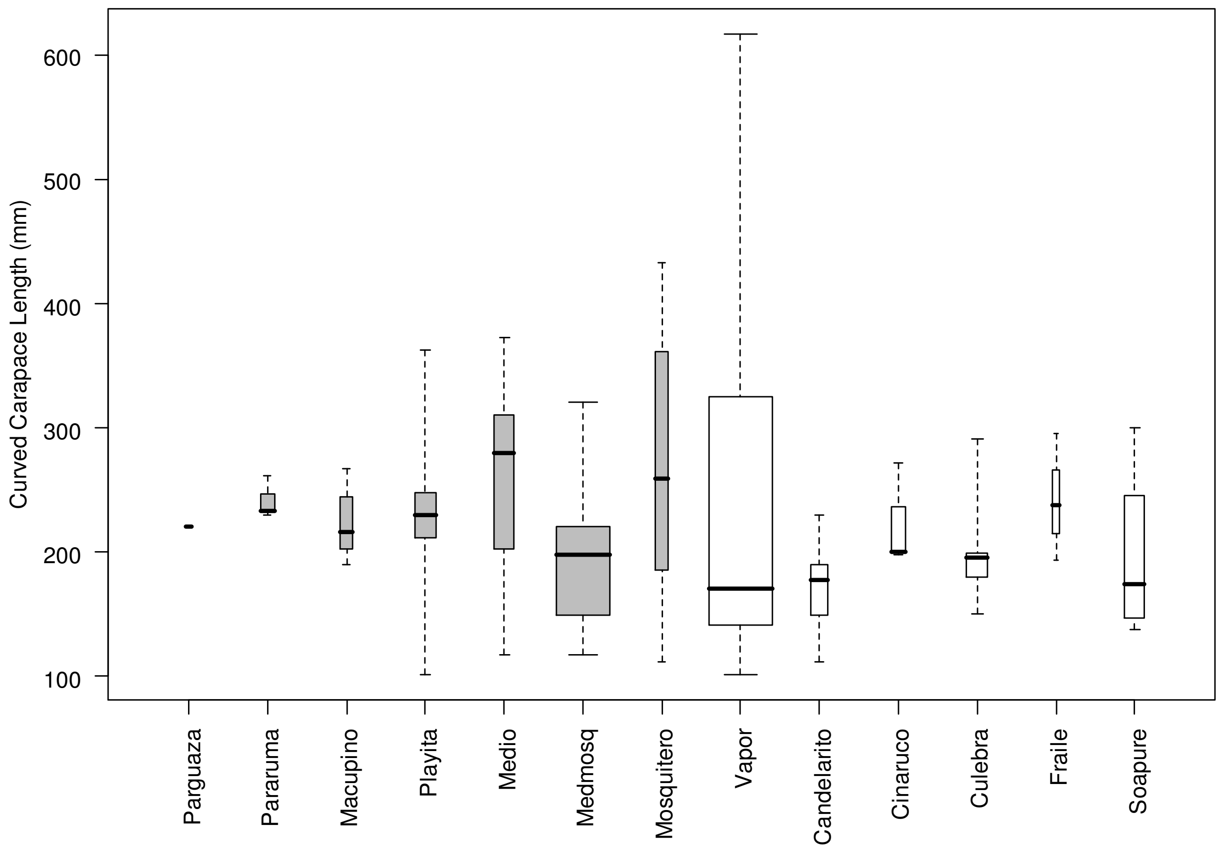

Figure 6. Size of captured arrau turtles inside and just north of the Arrau Turtle Wildlife Refuge. Each box contains the lower data extreme, first quartile, median, third quartile and upper data extreme (outliers are included in whiskers). The width of the box equals percent capture for each site corrected by sampling effort. Sites listed in south to north, up-river to down-river, order. Sites inside the wildlife refuge in grey.

1.3.3 Harvest vs. Capture

The proportion of arrau, terecay, and galápago was different between harvested and captured turtles (χ^2, $p < 0.0001$). In general, there were more harvested arrau and galápago and fewer harvested terecay than captured during in-water surveys (Table 4). The sex ratio of arrau turtles was female biased for harvested (3:1, χ^2, $p < 0.005$) and captured turtles (6:1, χ^2, $p < 0.005$), though these are not significantly different from each other (χ^2, $p > 0.1$). Male terecay and galápago were not harvested in the overlapping fishing area. Captured terecay were male biased (1:4, χ^2, $p < 0.0001$) and galápago sex ratio was balanced (1:2, χ^2, $p > 0.5$); sex ratios of harvested and captured terecay and galápago were significantly different (χ^2, $p < 0.0005$ and $p < 0.03$, respectively) (Table 5).

Table 4. Proportion of sideneck turtles harvested and captured in overlapping fishing area north of the Arrau Wildlife Refuge, Middle Orinoco (values in percentages).

Species	***Carapaces***		***Plastrons***	
	Harvest	***Capture***	***Harvest***	***Capture***
Arrau	61	61	80	61
Terecay	23	37	11	37
Galápago	16	2	9	2

Table 5. Sideneck turtles harvested and captured during 2007-2008 dry season from the overlapping fishing area north of the Arrau Turtle Wildlife Refuge. Values correspond to geometric mean curved length (curved carapace length and curved plastral length -intergular scute to anal notch), size range and sample size in parentheses. Sex ratio in females:males, star indicates significantly skewed ratio (χ^2, $p < 0.0005$). Carapaces and plastrons correspond to the same (live) turtle for captures; not all captured arrau plastrons were measured, accounting for sample size differences.

HARVEST					
Species	***Carapaces (mm)***	***Plastrons (mm)***			***Sex ratio***
		Juvenile	***Female***	***Male***	
Arrau	259 170-612 (57)	197 145-235 (27)	295 236-550 (26)	300 212-500 (8)	3:1*
Terecay	305 225-405 (22)	150 141-156 (3)	266 226-297 (5)	-	na
Galápago	229 173-299 (15)	160 155-166 (2)	222 201-245 (5)	-	na
CAPTURE					
Arrau	200 101-617 (94)	130 78-231 (64)	298 240-502 (18)	252 250-255 (3)	6:1*
Terecay	319 191-474 (56)	-	338 287-384 (12)	212 149-241 (44)	1:4*
Galápago	218 160-296 (3)	-	245 na (1)	152 132-175 (2)	1:2

The size distribution of harvested and captured turtles is shown in Figure 7. Harvested and captured arrau turtle carapaces, juvenile, and male plastrons differed in size distribution ($p = 0$, $p = 0$ and $p < 0.05$, respectively), whereas female plastrons were similar. Harvested and captured terecay shells and female plastrons had different size distributions ($p < 0.01$ and $p = 0$, respectively). The size distribution of galápago was similar for harvested and captured turtle carapaces. In the overlapping fishing area, we only captured one female galápago and we did not capture juvenile terecay or galápago. Male terecay and galápago were not harvested in this area. The combined size distributions of female and juvenile plastrons is shown in Figure 8. Harvested arrau turtles were larger than captured arrau; 15% of harvested arrau were adults (6 males, 3 females) whereas only 6% of captured arrau were adults (3 males, 2 females), though this difference was not significant (χ^2, $p > 0.1$). There was a bimodal harvest of terecay all together smaller than captured terecay; 59% of harvested terecay were adults (0 males, 5 females) while 88% of captured ones were (39 males, 12 females) (χ^2, $p < 0.02$). A wide size range of galápago turtles were harvested, only one female was captured (245 mm PL); 53% of harvested galápago were adults (0 males, 5 females) and 67% of captured ones were (1 male, 1 female) (χ^2, $p < 0.007$).

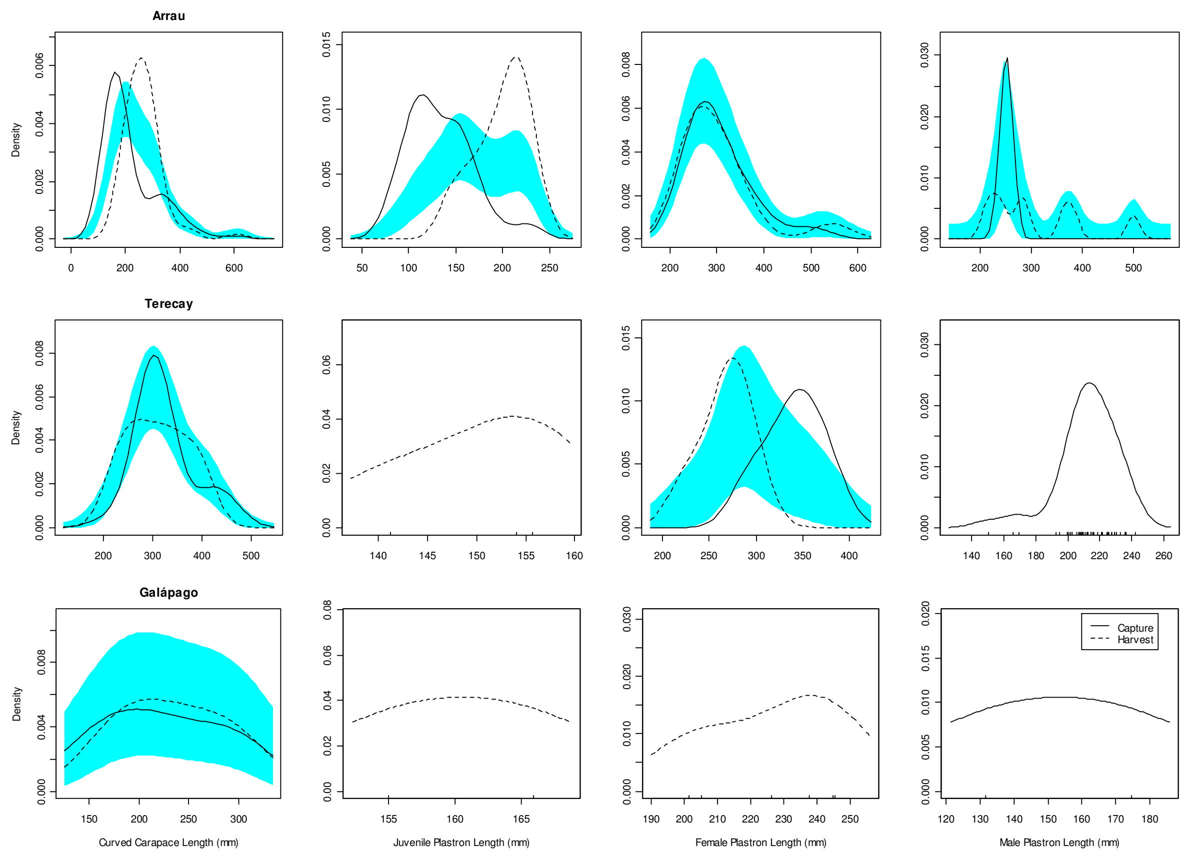

Figure 7. Size comparison with kernel density distributions of captured and harvested sideneck turtles from the overlapping fishing area. The reference bands display differences between curves (equal to two standard errors). Captured and harvested shell size distributions were different for arrau carapaces ($p = 0$), juvenile ($p = 0$) and male plastrons ($p < 0.05$) and terecay carapaces ($p < 0.01$) and female plastrons ($p = 0$). Size distribution of female arrau plastrons and galápago carapaces were not different. Male terecay and galápago were not harvested, whereas juvenile terecay and galápago were not captured. We captured only one female galápago (245 mm PL).

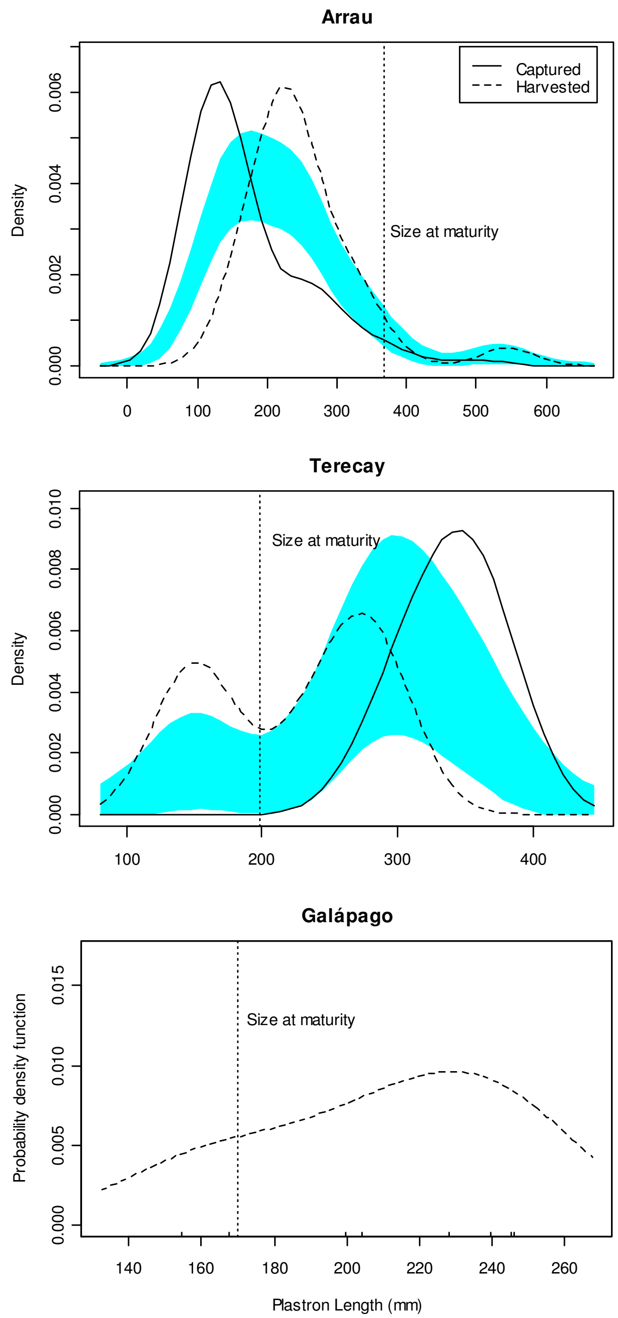

Figure 8. Size comparison with kernel density distributions of captured and harvested sideneck turtles from the overlapping fishing area; pooled juvenile and female plastron data. The reference bands display differences between curves (equal to two standard errors). Vertical dotted lines indicate minimum nesting female size for arrau and geometric mean male size for terecay and galápago. Because terecay and galápago are also harvested while they nest, we consider mean male size approximates size at maturity for females.

1.4 Discussion

1.4.1 Harvest

Despite their protection under Venezuelan and international environmental law, harvest of sideneck river turtles is still prevalent in the Middle Orinoco (as previously found by Hernández & Espín 2003). Harvest of the arrau has been illegal since 1962 and terecay and galápago have an unenforced quota of two turtles per person per year. The continued unregulated harvest of these species undermines arrau conservation efforts in the area carried out by the Venezuelan Ministry of the Environment.

In addition to subsistence harvest, unusually high per capita harvest in some communities suggests external turtle demands are being satisfied, i.e., commercial harvest is occurring. For example Caribén, with the highest per capita harvest of all riverine communities visited (3.6 turtles per person), may be an ideal site for a seasonal "turtle restaurant" because of its proximity to the city of Puerto Páez and the availability of several motor boats in the community. In the case of Boca de Suapure II, a seasonal camp of non-local fishers with the third highest per capita harvest rate (1.8 turtles per person) and among the smallest turtles harvested (Figure 4), larger turtles may have been sold along with the fish catch while small turtles provided sustenance for fishers. This was found for terecay on the Nichare-Tuwadu rivers, tributaries of the Orinoco to the east (Escalona & Fa 1998) and a comparison of our results with commercial harvest data from Hernández & Espín (2003) indicates larger turtles are channeled towards commerce (Figure 9).

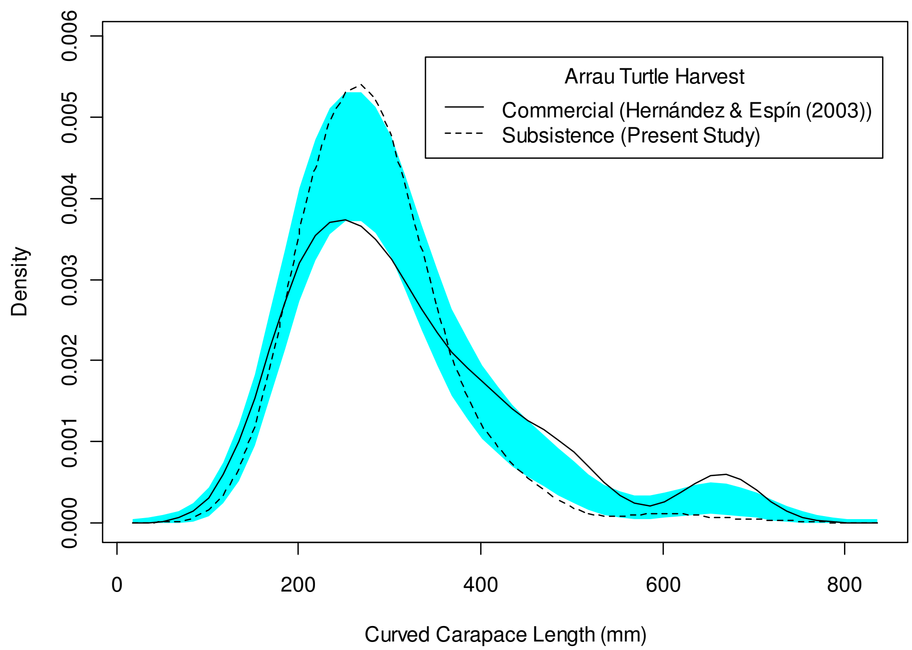

Figure 9. Comparison of commercial (Hernández & Espín 2003) and subsistence harvest (present study) of arrau turtles in the Middle Orinoco, Venezuela. Larger harvested turtles are channeled towards commerce (p = 0).

The difference in species composition up- and down-river of the AWR (Figure 5) may be due to selective harvest or differences in species distribution along the river. If we consider terecay and galápago turtles are generally associated with smaller rivers (Pritchard & Trebbau 1984), the presence of four Orinoco tributaries (Parguaza, Villacoa, Cinaruco, and Suapure rivers) within and down-river of the AWR, could explain an increase in relative abundance of these species. Spillover effect from AWR protection could also contribute to increased terecay and galápago abundance.

1.4.2 Capture

Most of the arrau turtles captured during in-water surveys were juveniles. Because this is a long-lived, late maturing species (17 years, Hernández & Espín 2006; 11-28 years, Mogollones 2004), we expect most of the population to be juvenile. In addition, it is possible nesting beach protection and the reintroduction of captive-bred yearlings has increased the proportion of juvenile turtles; headstarted hatchlings account for 45% of captured turtles from 1998-2008 (Hernández & Espín 2006; present study). Similarly, the predominance of adult turtles in terecay and galápago captures is expected for these species, which are thought to mature sooner than arrau (Ramo 1982; Thorbjarnarson et al. 1993).

Out of captured turtles, only galápago had a balanced sex ratio, arrau were skewed towards females and terecay towards males. Even though Smith (1979) states that turtle sex ratio depends on capture method and reproductive status of the population, we believe the ratios we obtained reflect actual population sex ratios for these species. During the reproductive season for sidenecks (dry season), baited trot lines produced equal sex ratios for terecay in two studies (Smith 1979; Thorbjarnarson et al. 1993) whereas the same method produced a 2:1 female biased sex ratio in another study (Perez A. et al. 1995). Similarly, trawl and trammel nets have produced both female and male biased sex ratios during the reproductive season for sideneck turtles (present study; Balensiefer & Vogt 2006; Hernández & Espín 2006). In the case of the arrau, historical commercial harvest may have left a relatively young nesting female population, with smaller females who build shallower and therefore hotter nests, which in turn produce a larger proportion of female hatchlings (Valenzuela 2001). Preliminary studies of hatchling sex ratio confirm a strong female bias for this population (96%

female, C. Peñaloza, unpublished data) and genetic studies show the population has low indices of multiple paternity for this species (Pearse et al. 2006; Valenzuela 2000). Concerning the terecay, current harvest pressure may have affected sex ratios (see below). For both species, turtles may distribute along the river according to their sex and specifically for females, by nesting preference. Female arrau would be near island nesting beaches in the main river whereas female terecay would be close to river banks in the main river and in smaller tributaries of the Orinoco. However, because most of the arrau we captured are not sexually mature, this may not be the case.

1.4.3 Harvest vs. Capture

We used the same fishing method as ribereños with a smaller net mesh-size (10 vs. 5 cm). However, barring selective harvest, we expect similar species composition and size distribution between harvested and captured turtles in the overlapping fishing area. Balensiefer and Vogt (2006) found sideneck turtles comparable in size to our captured arrau using 10 and 20 cm mesh-size nets (108 – 162 mm compared to 98 -161 mm for the present study), suggesting that in our study, ribereños are selecting for arrau larger than 190 mm during harvest. Because ribereños also harvest nesting female terecay and galápago, differences between harvest and captured turtles may be caused by harvest method. In a reanalysis of Hernández and Espín (2003), using kernel density distributions to compare between harvested and captured turtles, we also found selective harvest of larger arrau turtles (Figure 10); in fact, ribereños consistently harvest turtles in a certain size range (Figure 11).

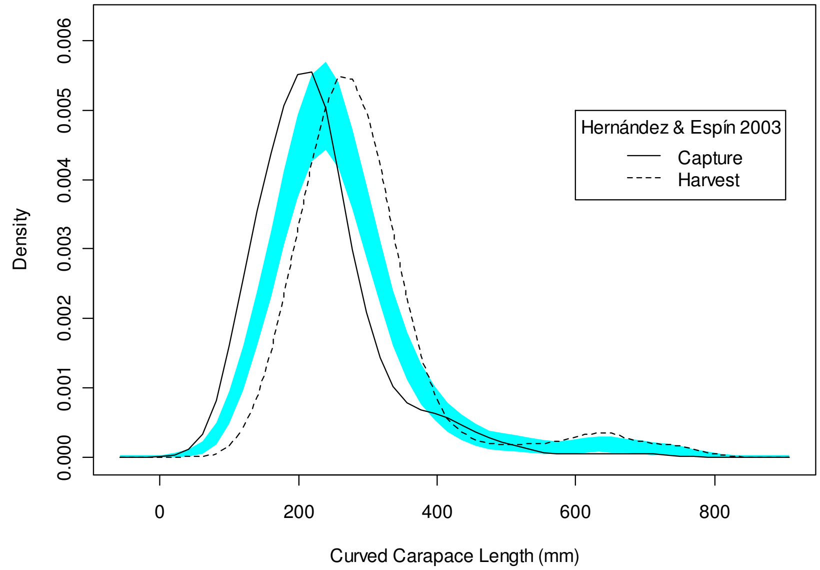

Figure 10. Reanalysis of captured and harvested arrau turtles from Hernández and Espín (2003) using kernel density plots. Larger arrau are selected during harvest (p = 0).

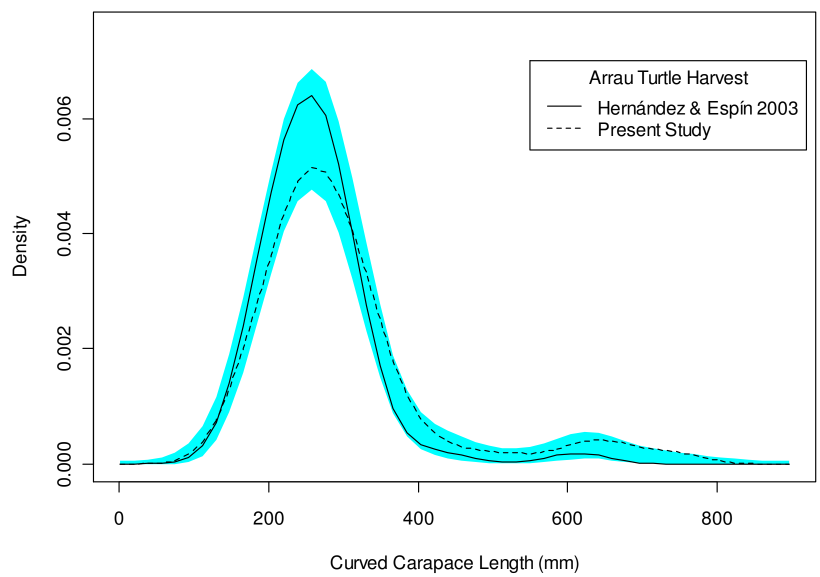

Figure 11. Comparison of harvested arrau between Hernández and Espín (2003) and the present study using kernel density plots. Ribereños are consistent in size selection of harvested arrau (p = 0.09).

The difference between species composition of harvested and captured turtles suggests that ribereños from the Middle Orinoco prefer to consume the arrau turtle over terecay and galápago turtles. This result supports findings by Hernández and Espín (2003). Even though only arrau plastrons are harvested in a larger proportion than they were captured (Table 4), the proportion of carapaces is probably underestimated due to their destruction in meal preparation (roasted over an open fire).

Ribereños selectively harvested larger arrau juveniles and males and, although the size of harvested and captured arrau females is not significantly different, slightly more adult females were harvested than were found in the wild. Being a long-lived, late maturing species, we expect juvenile reproductive value in arrau to increase with size until maturity is reached (Heppell 1998). If so, selective harvest of large juveniles will have a greater negative effect on population growth than, for example, harvesting arrau according to availability in the wild. In fact, preferential harvest of large juveniles may affect population growth more than harvesting any other life stage as was found for the loggerhead sea turtle, another long-lived species (Crouse et al. 1987; Crowder et al. 1994; Heppell 1998). Current levels of exploitation may affect recovery by hindering growth of the breeding population making it necessary to control or eliminate harvest for some time. Reinstating traditional harvest of eggs, a life stage with less influence on population growth, while eliminating harvest of wild juvenile and adult turtles, may be a long-term solution for population persistence.

There is no relationship between the size of harvested or captured turtles and the location along the Middle Orinoco (Figures 4 and 6), which discredits the assumption that the AWR will protect nesting females because they will remain close to nesting beaches inside the refuge. This fact also substantiates the need for decentralized protection of sideneck turtles along the river. On the other hand, the AWR plays an instrumental role in protecting nests. The second most important breeding area for arrau in Venezuela, Brazo Casiquiare, is unprotected and 100% of nests there are poached (Hernández et al. 2007; Narbaiza et al. 1999). Because of the continued widespread harvest of this species there is a need to strengthen the conservation program to ensure its survival.

Terecay and galápago harvest were selective both in proportion and in type of turtle harvested. Fewer terecay were harvested than found in the wild whereas more galápago than available were harvested. This may result from ribereños harvesting the nesting females of these species. There may be more terecay available in the water, but those were not taken because of the harvest method. Few galápago were available in the Orinoco because they prefer smaller rivers and lagoons, making harvest seem selective towards galápago. In addition to differences in species proportion, small female terecay and galápago were selectively harvested. This is consistent with nesting female harvest method; whether or not smaller individuals indicate an earlier size at maturity than previously expected, requires more study. The absence of larger harvested terecay females suggests emigration of larger females to the main river, far away from riverine communities or, less likely, a self-imposed prohibition by ribereños against harvesting large females. Overall, differences in harvest and capture method confound comparisons for terecay and galápago.

Sex ratio differences between harvested and captured terecay turtles are disturbing. Harvested terecay were significantly biased towards females, while captured terecay were so towards males. Selective harvest of females could be affecting population sex ratios both by decreasing the number of females in the population and by increasing the proportion of older larger females who build deeper cooler nests, which in turn produce a higher proportion of male hatchlings (Valenzuela 2001). The absence of smaller females among captured terecay may indicate intensive harvest of these individuals or size dependent distribution between the Orinoco and its tributaries. The persistence of this population may depend on determining and addressing the cause of these differences.

Both terecay and galápago undergo selective harvest of nesting females, which may negatively affect population growth largely depending on the particular population dynamics for each species. Some authors hypothesize these species have an earlier age at maturity than arrau, from 3 to 9 years (Ramo 1982; Thorbjarnarson et al. 1993). If so, selective harvest of adult females has the greatest negative effect on population growth (Heppell 1998). Reduced adult harvest, localized captive breeding for consumption, and protection of eggs and hatchlings by ribereños, could assist in population recovery. In Ecuador, a two to three fold increase in population size was recorded after 5 years of egg and 10 years of adult protection (Townsend et al. 2005).

1.5 Conclusions

After 21 years of protecting turtles in and around the AWR, it is obvious that strict enforcement of the existing regulation may not be the most effective way to achieve conservation. The consumption of arrau, terecay, and galápago, are deeply rooted in the lifestyle and economic reality of the ribereño. Locating, quantifying, and eliminating commercial harvest could be much more productive at this point. To decrease subsistence harvest of wild arrau, terecay, and galápago turtles until populations have recovered, reinstating long-forgotten traditional use practices, i.e.: localized captive breeding of sideneck turtles, especially the smaller and faster-maturing galápago, should be promoted. This species is known to be prolific in artificial floodplain lagoons with minimal or no intervention (Ramo 1982; Thorbjarnarson et al. 1993). Ideally, we should work towards a future that resembles the past, where "there is hardly a village containing fewer than a hundred corralled turtles and thus [ribereños] are ignorant of hunger" (Acuña 1641).

Regardless of the program chosen for recovery, and due to scarce funds for conservation law enforcement and the wide distribution and dependence of ribereños on the turtle resource, reestablishing the rights and responsibilities of ribereños in the stewardship and preservation of sideneck turtles is fundamental for the persistence of these species.

2. SIDENECK TURTLE CONSERVATION; THE *RIBEREÑO'S* PERSPECTIVE.

2.1 Introduction

Traditional western resource management has emphasized the creation of protected areas and centralized management for endangered species conservation. Following "command and control", the central government would create (top-down) rules and regulations governing the use, or non-use, of resources in protected areas and said rules would be enforced by traditional law enforcement agencies. With competent bureaucracy (Barrett et al. 2001) and sufficient funding (Dietz et al. 2003), "command and control" can effectively protect natural resources. However, exclusionary conservation (Agrawal & Ostrom 2006; Alcorn 1993; Berkes 2004; Fiallo & Jacobson 1995; Ghimire & Pimbert 1997; Heinen 1996; Newmark et al. 1993; Robinson & Redford 1991) and resource management under the sole authority of central governments have often resulted in catastrophic failure (Agrawal & Gibson 1999; Dietz et al. 2003; Ludwig 2001; Ludwig et al. 1993).

Community-based conservation has emerged as a response to the failure of exclusionary conservation (Ghimire & Pimbert 1997; Robinson & Redford 1991) just as it has for ill-managed government resources (Ludwig et al. 1993). However, these purported solutions have not been successful either (Berkes 2004; Dietz et al. 2003). Among the problems with community-based programs are:

1. had were, a focus on conservation rather than participation (Campbell & Vainio-Mattila 2003);
2. not returning authority to locals;
3. lack of rules of access and lack of use and enforcement of these rules (Berkes 2004; Gibson et al. 2005);

4. unresolved conflicts between locals and protected area managers (Fiallo & Jacobson 1995; Newmark et al. 1993); and
5. trying to implement these programs amidst weak social and governmental institutions (Agrawal & Gibson 1999; Agrawal & Ostrom 2006; Barrett et al. 2001).

Not surprisingly, creating well defined rules with consistent enforcement (Dietz et al. 2003; Gibson et al. 2005), building trust between stakeholders (local people, environmental non-governmental organizations, government officials, etc.) (de Castro & McGrath 2003; Ludwig 2001), working to return authority to locals (Berkes 2004), understanding the relationship between people and their resources (Agrawal et al. 2008; Berkes 2004) and strengthening institutions at all scales (Agrawal & Ostrom 2006; Barrett et al. 2001) are suggested as solutions to these problems.

In Venezuela, the giant side-neck river turtle, or arrau (*Podocnemis expansa*), experienced precipitous decline to near population extinction under centralized regional government management (Figure 12) (Licata & Elguezabal 1997; Ojasti 1967; Ramírez 1956; Thorbjarnarson et al. 2000). This prompted the creation of a wildlife refuge to protect the species' main nesting beaches in the Middle Orinoco (Decreto N° 271, 7 June 1989).

Over 20 years later, nesting female numbers have not increased (Licata & Elguezabal 1997; MARNR 1999; Mogollones 2004) and there is still widespread illegal harvest (Hernández & Espín 2003). Additionally, reduced arrau abundance has put congeneric species, the yellow-headed sideneck or terecay (*P. unifilis*) and the savannah sideneck or galapago (*P. vogli*), under increased harvest pressure (Escalona & Loiselle 2003; Pritchard & Trebbau 1984; Thorbjarnarson et al. 1997). Despite meager conservation success, the Venezuelan Ministry of the Environment, the government agency charged with arrau management, does not acknowledge the lack of recovery of nesting female abundance, illegal commercial and subsistence harvest and views of local people (*ribereños*), while focusing its effort, publicity, and budget on the captive rearing and reintroduction program (Flores 2005, Tortoza Z. 2009).

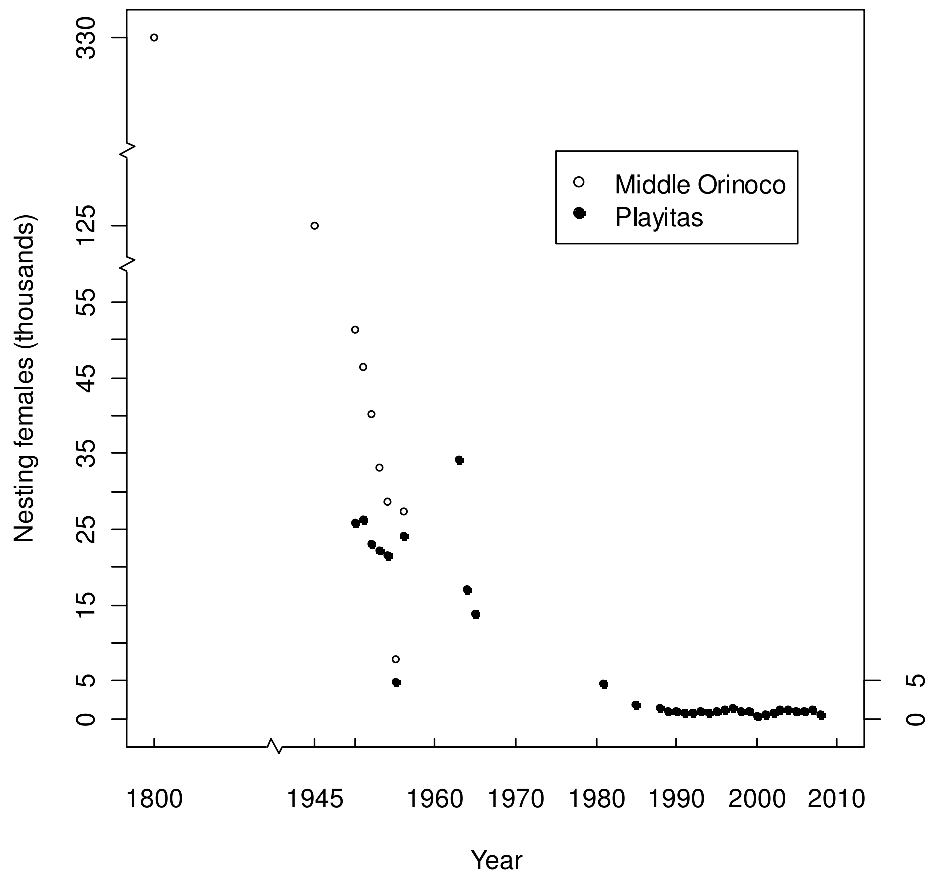

Figure 12. Nesting female population in the Middle Orinoco determined from direct observation or estimated from nest counts (one nest per female) or egg production. The Middle Orinoco included several nesting beaches from the cities of Puerto Páez to Caicara. Currently most nesting (~98%) occurs on Playitas, the main nesting beach within the Wildlife Refuge. Historically important nesting beaches, now account for less than 2% of nesting (data compiled from Humboldt 1820; Licata & Elguezabal 1997; Marín 2010; MARNR 1999; MINAMB 2008; Mogollones 2004; Mosqueira-Manso 1945; Ramirez 1956).

In the study reported here, we studied ribereño ("river-bank people") perception of sideneck turtle conservation in the Middle Orinoco. Using semi-structured interviews, we determined ribereño demographics, economic activities, current institutional structure of ribereño communities, turtle consumption, perceived turtle abundance, and attitudes towards conservation efforts and actors. We determined the current level of ribereño participation in conservation activities and analyzed strengths and weaknesses of the conservation program. In the final section of this paper, we recommend ways to improve participation, management, and ultimately, conservation outcomes.

2.2 Methods

2.2.1 Study area and interview participants

The study area comprises a 120 Km stretch of the Middle Orinoco River, Venezuela, between the city of Puerto Páez, Apure (across from the Colombian border) to the town of La Urbana, Bolivar (Figure 13). This stretch includes the Arrau Turtle Wildlife Refuge and 29 riverine communities located both up- (south) and down-river (north) from the wildlife refuge. The wildlife refuge spans 25 km of the Orinoco River, from La Cazuela to the southern tip of Santa Isabel Island, and a 50 m buffer zone on either bank (17,431 ha). Eleven families, from two communities (Boca de Parguaza and Santa María), are inside refuge boundaries. There is a National Guard post and a Ministry of the Environment Research Station (N 06° 36' 04", W 67° 07' 38.9") in Santa María. Officers from these two governmental agencies form joint commissions to patrol the wildlife refuge and manage egg transplanting on the turtle-nesting beach. Hatchling arrau turtles are also reared in captivity for one year at the research station (and in off-site facilities).

From 8 May to 12 June 2008, we visited each community by river to conduct interviews. We contracted two boat captains, one from Puerto Páez and another from Capachal, to take us to each community and introduce us to community leaders and members. We carried out semi-structured interviews with leaders and all willing heads of family from each community; up to 100% of community members were interviewed, no less than 10% were interviewed for large communities (>50 families).

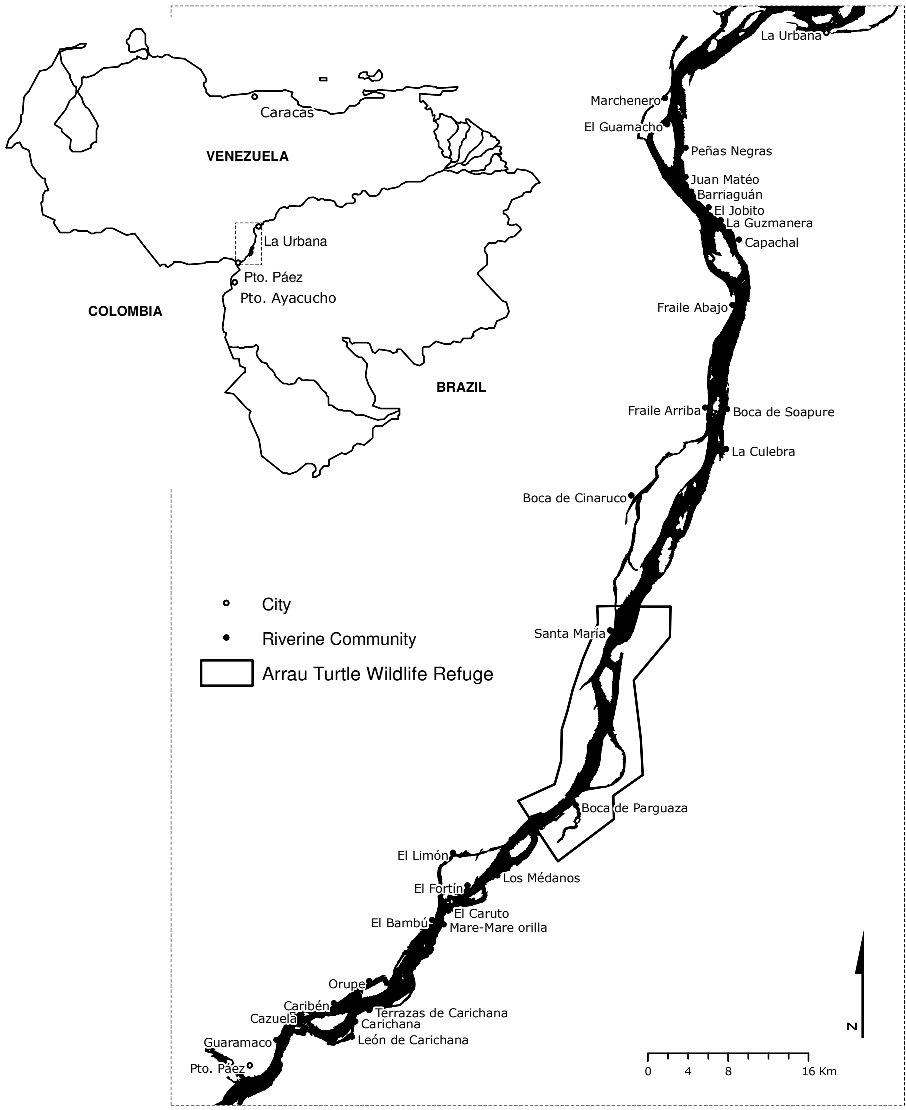

Figure 13. Map of study area displaying name and location of riverine communities visited and the Arrau Turtle Wildlife Refuge in the Middle Orinoco, Venezuela.

2.2.2 Interview design and analysis

The interview questionnaire had 35 open-ended questions focusing on community size and political structure, local livelihoods and needs, and turtle consumption and conservation (Appendix A). During each interview we took written notes and made an audio recording. We fully transcribed to text ten randomly chosen interviews from different communities spanning the entire sampling area. These interviews were thoroughly examined and coded (using Nvivo 2.0) according to questions asked and themes that emerged in the ribereños' responses. The resulting coding scheme was then used to classify ribereño responses while listening to the remaining interviews. Additional answers and new themes were added to the classification scheme if they arose in these remaining interviews. Resulting classified responses were used in tables and figures to describe how ribereños live and how they perceive sideneck turtles and their conservation.

2.2.2.1 Summary of interview responses

The number of ribereños (n, sample size) that answered each question varied. We calculated the percent contribution to each question depending on the sample size for that question and whether or not it allowed single or multiple responses. Percentages for single response questions add up to 100, whereas for multiple response questions they exceed 100 because each ribereño can give several answers to these questions. Total sample size is given for themes spontaneously introduced by ribereños, i.e., number of ribereños that mentioned each theme.

2.2.2.2 Classification and Regression Tree Models

We used classification and regression tree (CART) models to study the relationship between turtle consumption, perception of turtle conservation, opinion of Ministry and National Guard personnel, and the characteristics of ribereños in the Middle Orinoco. CART models are widely used for exploratory data analysis and model building;

they are particularly well suited for data mining tasks where there is little a priori knowledge or no theories or predictions as to how variables are interrelated (De'ath and Fabricius 2000; Moisen 2008; StatSoft 2010). CART recursively partitions data to yield models known as tree-models (Breiman et al. 1984), which are easier to interpret than linear models, are non-parametric, non-linear, and capture non-additive behavior (De'ath and Fabricius 2000). These models, now widely used in ecology, have also been applied to social science interview data similar to ours (Karanth et al. 2008). We used the package “rpart” (Therneau and Atkinson 1997, 2002) in R (R Development Core Team 2008) to build our CART models, determine optimal tree size through cross-validation, and assess model performance by misclassification rate. Trees are allowed to grow to a size beyond which additional splits would not improve the model. Cross-validation errors are obtained for each tree in "rpart" and we selected the tree size for which cross-validation error is minimized. The misclassification error, which is the proportion of responses misclassified by the fitted model, is reported by R using the percentage improvement over the “root misclassification error”. Said error is based on a null model where every case has the same probability of a certain outcome. The model “improvement” is the improvement over the root misclassification error.

2.3 Results

2.3.1 Ribereños and their communities

We completed a total of 65, 20-min to 2-h long interviews. Six ribereños did not want to be interviewed (92% response rate) and two refused to be recorded. Ribereños referred to Ministry of the Environment employees as “*Ambiente*” and members of the

National Guard as "*La Guardia*". Arrau turtles were called *"tortuga"*, terecay turtles, "*terecay de río*" and galápagos either "*terecay sabanero"* or "*galápago sabanero*".

Table 6 shows the demographic characteristics of interview participants. The ribereños we interviewed were permanent inhabitants of the Orinoco River banks; most had local roots (53%) and had lived on the river bank for over 20 years (73%). Heads of household were mostly male (92%), had children (98%) and made a living, directly or indirectly, in fishing, agriculture and/or livestock (80%). Most ribereño farmers used seasonal river islands (depositional features) as communal agricultural land, whereas the mainland was used for grazing livestock by ribereños who had an easement or own land and by non-local landowners. In some cases where livestock grazing conflicted with agricultural land-use, uncertain land tenure forced ribereños to abandon agriculture for fishing (22%). Land-use and yearly flooding, conflict with agricultural practices making agriculture a predominantly dry-season activity (97%).

Table 6. Demographic characteristics of interview participants (n=65).

Characteristic			Percentage (%)
Gender	Male Female		92 8
Average age			53 years (range 30 – 86)
Origin	Local (<25Km) Same State Other State/Country		54 39 7
Permanence	0-10 years 11-20 years > 20 years		11 16 73
Children	None 1-4 5-7 ≥8		2 30 33 35
Livelihood	Fishing/Agriculture/Livestock (direct or indirect)		80
	Exclusive	Fishing Agriculture Livestock Fish Resale	20 16 3 8
	Combination		33
	Salary job / pension Commerce Wage labor		8 7 5
Land Tenure	Self Communal Easement Other's		30 49 9 12
Land use	Seasonal agricultural land (river islands, depositional features)		97
	Main-land livestock grazing precludes use for agriculture		22

Most riverine communities lack well defined social institutions, internally chosen community leadership, access to law enforcement institutions, and mechanisms for conflict resolution (Table 7). Ribereños complain about insecurity (38%), corruption in government institutions (i.e.: National Guard, 34%), lack of employment opportunities (other than fishing and growing cotton for the "company"), and difficulty in obtaining government assistance (62%).

Table 7. Social institutions found in riverine communities along the Middle Orinoco.

Type of institution	Characteristic	Percentage (%)
Community leader	Founder	20
	Elected	22
	Designated	33
	Founder & Elected/Designated	9
	None	16
Communal councils / Cooperatives	Efficient & just	27
	Elitist & corrupt	24
	We need help getting organized	11
	None	38
Legal institutions for conflict resolution	Easy access	21
	Difficult/costly access	29
	None	38
	No conflicts	13

2.3.2 Turtles

2.3.2.1 Consumption

Most ribereños in the Middle Orinoco consume sideneck turtles: arrau, 70% of ribereños (n=62), terecay, 50% of ribereños (n = 36) and galápago, 69% of ribereños (n=36). The reported frequency of arrau turtle consumption has decreased in the past 20 years (Figure 14) because "[*tortugas*] are hard to find" (n=22), "we are helping Ambiente" (n=39), "I don't want to get in trouble with Ambiente or la Guardia" (n=15). Ribereños would prefer to consume arrau turtles about 10 times more frequently than at present, if the turtles were abundant and they were allowed to consume them (Figure 14).

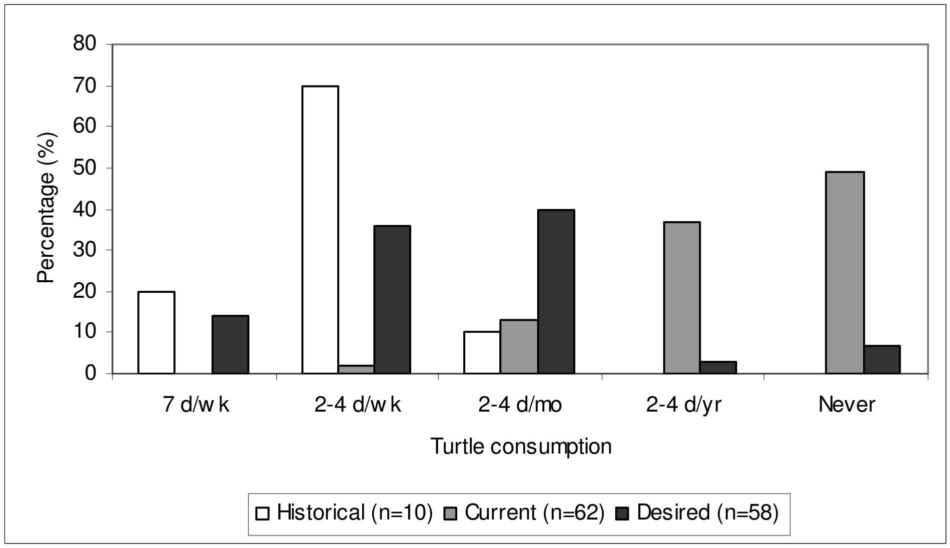

Figure 14. Frequency of arrau turtle consumption by ribereños in the Middle Orinoco. Historical, consumption of arrau turtles > 20 years ago, before they were banned and the wildlife refuge was created; Current, turtle consumption this dry season; Desired, turtle consumption if turtles were abundant and ribereños were allowed to consume them.

2.3.2.2 Abundance

In the past 20 or more years, ribereños mention a steep decline in arrau turtle abundance (Figure 15). “When I was about 18 years old there were lots of tortuga. I worked on the nesting beach, there were so many you could hardly walk.” (SI01, 44 years old). “Sometimes they took too long to nest and we needed extra help to throw them back in the water, ten thousand of them, before the sun cooked them on the beach” (CA02, 65 years old). “Several thousand tortuga would nest each night, now barely a thousand nest in the entire season” (EF04, 66 years old). In the last 5 years, most ribereños say adult arrau abundance is still decreasing although they are divided on the perceived abundance change in juveniles (Figure 16). Ribereños blame commercial exploitation for the historical demise and unsuccessful recovery of arrau turtles (Table 8). Some ribereños (36%) also see the harvest ban as a barrier to recovery because of its multiplying effect on turtle selling price making illegal turtle extraction a very lucrative business (a medium sized turtle, ~5 kg and 35 cm curved carapace length, will sell for two weeks worth of minimum-wage salary, USD $186.00).

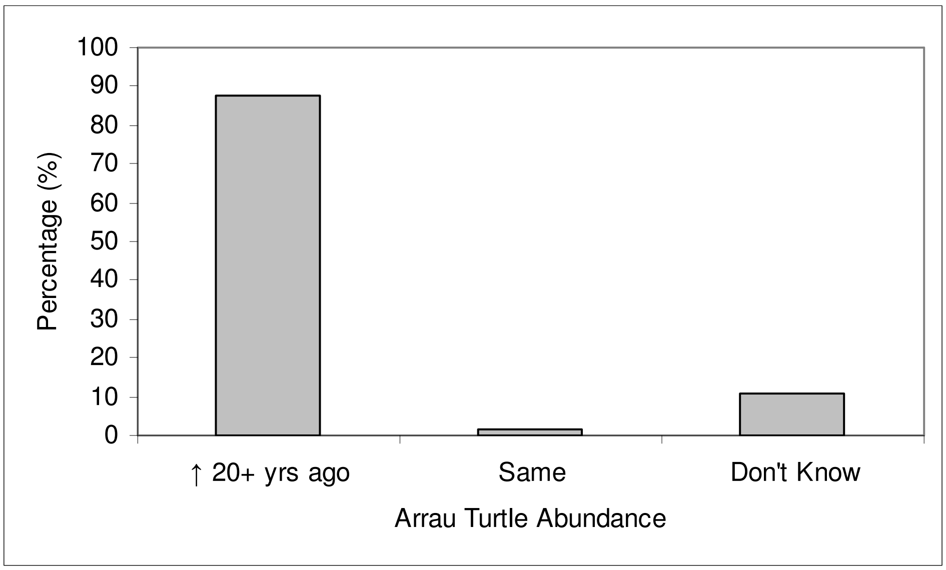

Figure 15. Comparison between current and historical abundance of arrau turtles as perceived by ribereños (n=64).

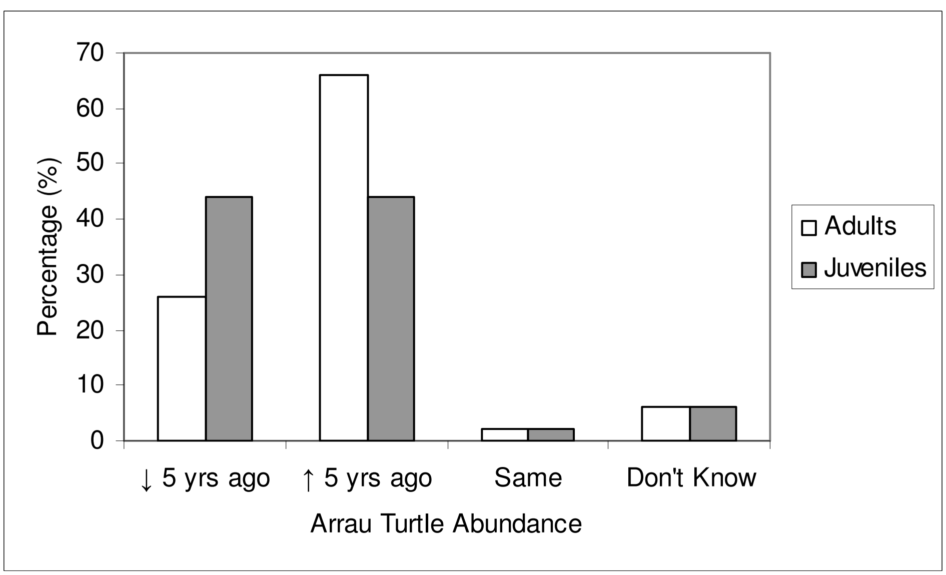

Figure 16. Change in arrau turtle abundance in the past five years as perceived by ribereños (n=50).

Table 8. Causes of arrau turtle demise and unsuccessful recovery as perceived by ribereños.

Ribereño perception	Percentage of total answers (%)
Causes of Demise (n=56):	
Commercial exploitation (historical, legal)	86
Turtle migration (gone to the Meta River in Colombia)	29
Human population growth	21
Consumption (non-commercial)	21
Barriers to recovery (n=55):	
Commercial exploitation (current, illegal)	80
Seine nets	44
Price increase due to restriction	36
Corrupt National Guards aiding commerce	36
Fishing boats scare turtles away	24
Impunity, law-breakers go unpunished	18
Fish eat reintroduced turtles	5
Ministry	4

2.3.2.3 Conservation

Most ribereños defined conservation from a utilitarian perspective, “protect in order to use”. Some had a biocentric view, “protect so [turtles] exist”. Others mentioned both view points as being important, and a few ribereños did not recognize the word “conservation” (Table 9). Ribereños felt primarily responsible for protecting riverine wildlife, with the Ministry playing a secondary or partnership role to ribereños. Without being asked, a few ribereños (n=9) mentioned that turtles, and other riverine wildlife belongs to ribereños and that they must coordinate efforts for protection; "The Ministry protects the turtles, but they have no claim to them and cannot and will not take them away; turtle protection ultimately benefits ribereños" (e.g., SM01). A larger number of ribereños mentioned that future generations have a right to “get to know the turtles”, and that is an important reason to protect them (Table 9).

In general, ribereños say the Ministry's turtle conservation program is positive (n=61, 87%). Some believe without the Ministry's protection, there would be no turtles left (21%). However, many point out negative aspects to the conservation program, for example, the National Guard are perceived as corrupt (28%) and some management work is thought to be detrimental to turtles (boats/lights/noise scare the turtles, egg transplant, captive rearing) (20%). A few ribereños were not familiar with the conservation program (7%). Even though many ribereños have had negative interactions with Ministry employees (n=52, 17%), some like interacting with the Ministry (21%) and most want more interaction (62%) in the form of participatory conservation.

Table 9. How Ribereños perceive conservation: definition, responsibility and personal incentives for wildlife protection.

Conservation Attitudes of Ribereños	Percentage or number
What does conservation mean to you? (n=58)	
Utilitarian	81%
Biocentric	7%
Both	5%
What is that?	7%
Who is responsible? Who should conserve wildlife? (n=62)	
Us, ribereños	66%
Government	18%
Both	16%
The ministry protects turtles for our benefit not for their own; those turtles belong to the ribereños and we need to help	9
We need to protect turtles so our children and grandchildren can know them, maybe even eat them	25

Most ribereños offered many recommendations for improving the conservation program, the most salient being increasing local participation in conservation (70%). Many ribereños feel antagonized, bullied, and disrespected by Ministry of the Environment officials and National Guards (39%) and some express their discontent through turtle extraction: “nowadays people eat *tortuga* to get back at *Ambiente* for the things they do to us” (LM01, 36 years old). Nevertheless, ribereños are willing to help with arrau conservation in many ways, among them are giving bycaught turtles to the Ministry (40%) and not consuming turtles until the population recovers (38%) (Table 10).

Table 10. Recommendations from ribereños for improving arrau conservation program and how they can contribute.

Ribereño contribution	Percentage of total answers (%)
Recommendations for improving turtle conservation (n=56)	
Participatory conservation	70
Authority for ribereños	54
Alternative livelihood (no fishing or cotton)	43
Build respect and trust between ribereños & Ministry	39
- Graduated sanctions	25
- Don’t hinder livelihood	21
- Don’t instill fear	27
More vigilance	39
Eliminate corrupt National Guards	34
Protection for collaborating ribereños	14
Allow to fish “turtle predators” inside reserve	11
Ribereños choose authority/responsible figures	11
Anonymous reports	7
Conserve other species	7
Eliminate all wildlife commerce, including fish	4
None	23
How do ribereños want to participate in conservation? (n=53)	
Hand-in bycatch turtles	40
Stop consuming turtles	38
Vigilance	28
Report illegal commerce	21
Captive rearing	17
Beach work	6
Community organizer	4

2.3.3 CART Models

Turtle consumption was related to ribereño characteristics. Ribereños living close (<20 Km) to the wildlife refuge report not consuming turtles. Ribereños living further from the refuge (>20 to <38.5 Km) report consuming turtles 1-3 times a year. Farmers, grazers and ribereños with other forms of livelihood who live far (≥38.5 Km) from the wildlife refuge report eating turtles 1-3 times a month, while in the same area young fishers (<47 years old) report eating turtle 1-3 times a year and older fishers (≥47 years old) report not eating turtles at all (Figure 17).

What explains turtle consumption?

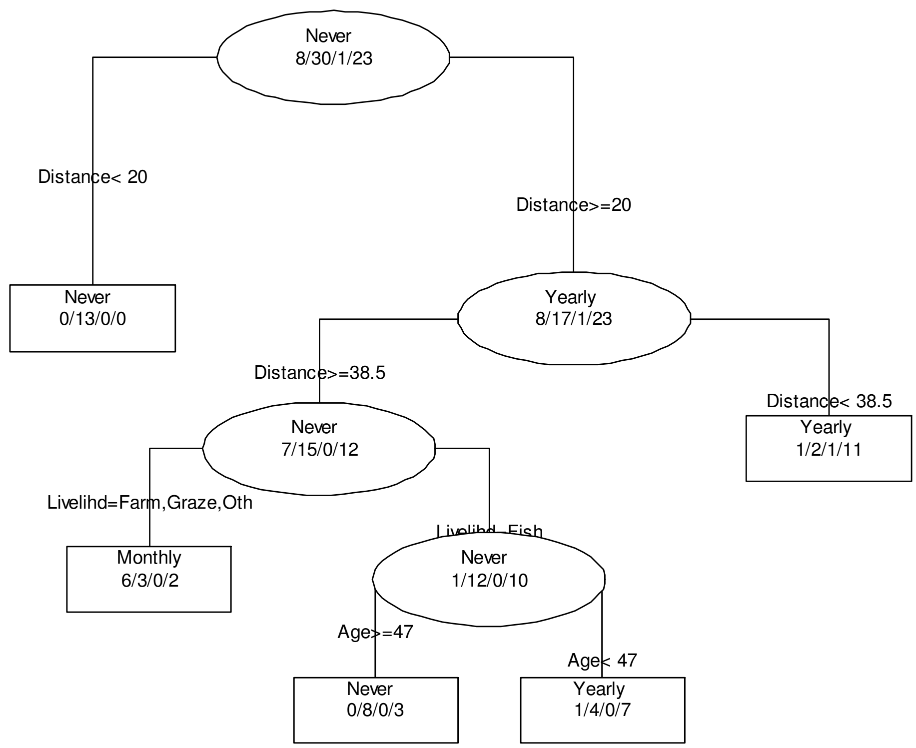

Figure 17. Ribereños living close to the wildlife refuge report not consuming turtles. Ribereños living further from the refuge report consuming turtles 1-3 d/yr. Farmers, grazers and ribereños with other livelihoods who live far from the wildlife refuge report eating turtles 1-3 d/mo, while in the same area young fishers report eating turtle 1-3 d/yr and older fishers report not eating turtles (model improvement = 0.52). Branch length represents proportion of variance explained.

Ribereños were divided in their perception of juvenile abundance (see Figure 16) and several groups emerged depending on their location. Older ribereños (≥58.5 years old) living up river from the wildlife refuge report juvenile turtles are more abundant than 5 years ago. Ribereños living down river and far (≥42 Km) from the wildlife refuge report fewer juveniles than 5 years ago, whereas ribereños living closer to the refuge (<42 Km) consider juvenile abundance has increased in the past 5 years (Figure 18).

Who thinks conservation is working?
(perceived change in juvenile abundance)

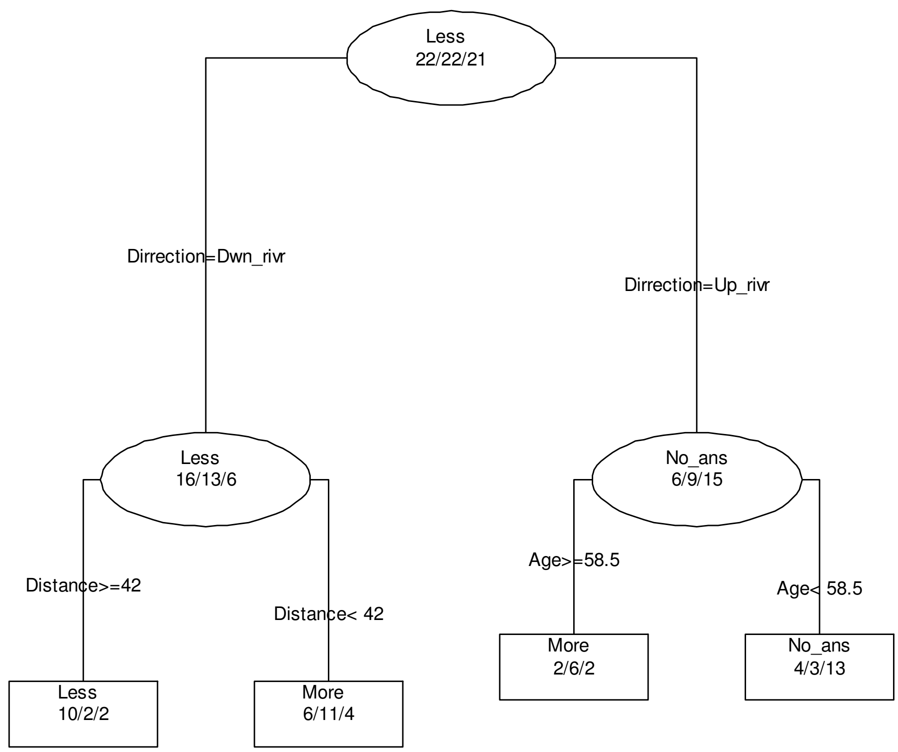

Figure 18. How groups of ribereños perceive changes in juvenile abundance. Older ribereños living up river from the wildlife refuge report juvenile turtles are more abundant than 5 years ago. Ribereños living down river and far from the wildlife refuge report fewer juveniles than 5 years ago, whereas ribereños living closer to the refuge consider juvenile abundance has increased in the past 5 years (model improvement = 0.66). Branch length represents proportion of variance explained.

Many ribereños mentioned they would "eat a turtle if it got caught in their net" (n=34), though this was not related to the two groups that emerged according to their perception of whether or not eating and selling turtles is illegal. Ribereños living close to the wildlife refuge (<44 Km) report eating or selling turtles is illegal whereas ribereños living far (≥44 Km) from the refuge only report selling turtles as illegal (model improvement= 0.46). Some ribereños complain about their interaction with the Ministry of the Environment and the National Guard. Ribereños from communities close to (<44 Km) the wildlife refuge report having problems with Ministry employees (model improvement= 0.49). Young ribereños (<42.5 years old) who live close to the wildlife refuge (<50.5 Km) perceive National Guards as being corrupt. Older ribereños (>42.5 to <54 years old) living in Bolivar State, close to the wildlife refuge (<50.5 Km) also perceive National Guards as corrupt (Figure 19).

Are National Guards corrupt?

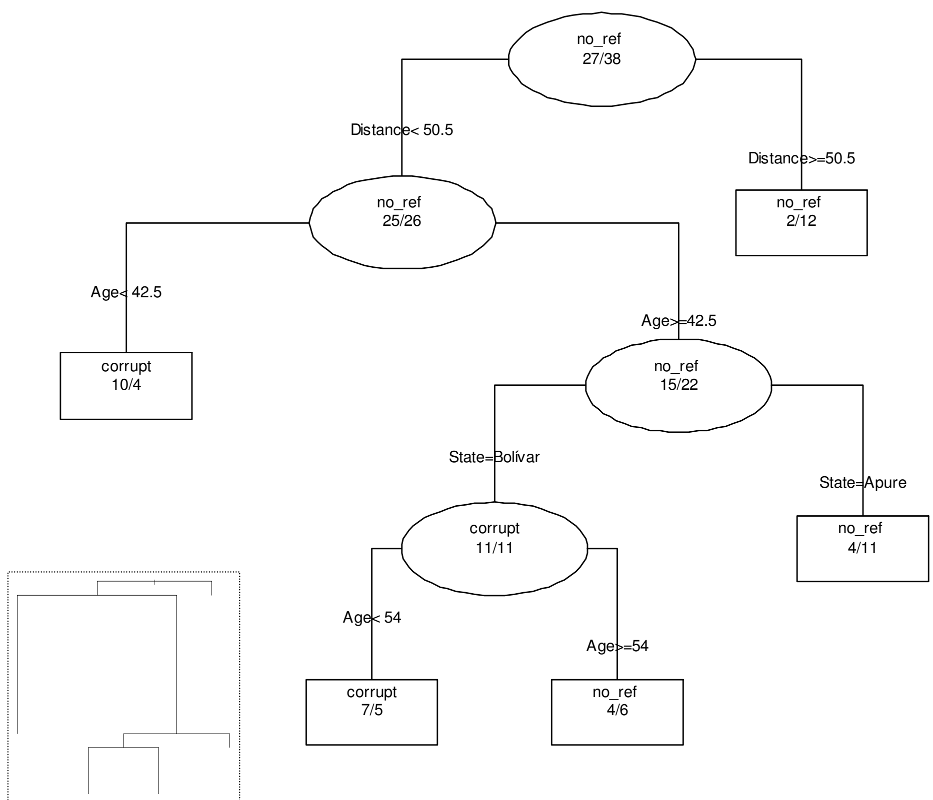

Figure 19. Groups of ribereños who perceive National Guards as being corrupt. Young ribereños who live close to the wildlife refuge perceive National Guards as being corrupt. Older ribereños living in Bolivar, close to the wildlife refuge also perceive National Guards as corrupt (model improvement = 0.42). Branch length of inset represents variance explained in each split.

2.4 Discussion

More than 20 years ago, the Arrau Turtle Wildlife Refuge was created to recover the Middle Orinoco population of this species. Though nesting female numbers of arrau show no indication of recovery, the conservation program has affected turtle and human populations in the area.

Ribereños living close to the refuge consider both selling and eating arrau is illegal and report decreased turtle consumption. They also report having problems with the Ministry of the Environment and consider National Guards to be corrupt, suggesting methods to ensure compliance may not be ideal, as is often the case for protected areas (Fiallo & Jacobson 1995; Newmark et al. 1993). The difference in perception of what is illegal between ribereños close and far from the refuge indicates government ideals (preservationism) are either being accepted by nearby ribereños, they have learned to say what the government wants to hear to stay out of trouble or they truly are ignorant of the arrau turtle harvest ban. In the latter case, the use of hypocrisy does not undermine successful establishment of community-management. Hypocrisy can facilitate emergence of collective action and, with increased monitoring and rule enforcement, give way to full compliance (Heckathorn 1989).

Local perception has proven useful in determining relative wildlife abundance in several studies (Evans & Guariguata 2008; Stronza & Durham 2008; van Rijsoort & Jinfeng 2005). However, the effectiveness of hatchling rearing and reintroduction in aiding population recovery of arrau, is uncertain as perceived by ribereños. Those living closer to the refuge believe it has increased juvenile abundance, but many others do not. It is possible turtle populations have increased inside the refuge (source) but not enough to produce a noticeable spillover effect outside of the refuge (sink). The Cofán Indian terecay conservation program in Ecuador, which includes headstarting and reintroduction of terecay, direct turtle monitoring inside the Cofán reserve by Indians and interviewing villagers outside of the reserve did not find recovery outside of the reserve, even though it was obvious inside the reserve (Townsend et al. 2005).

Most ribereños believe illegal commercial harvest by outsiders, at times aided by National Guards, is the main obstacle to turtle recovery. Similar cases have been reported elsewhere (Alcorn 1993; Rebelo & Lugli 1996) and emphasize the need to apply key principles of successful common-pool resource management, i.e., rules of use and exclusion and transparent, accountable enforcement officials (Agrawal & Ostrom 2006; Gibson et al. 2005; Ostrom 1990). Regardless of who controls turtle conservation in the Middle Orinoco, illegal commercial harvest must be dealt with and enforcement officials need to be trustworthy and just. Reducing harvest has increased terecay abundance in Bolivia (Conway-Gómez 2007), the same could happen for arrau if commercial harvest is stopped.

Out of the three species of sideneck turtles found in the Middle Orinoco, ribereños prefer the arrau. Ribereño interviews and the level of subsistence harvest determined for these species support this (Peñaloza et al. *In prep.-a*). Whether preference is due to differences in abundance, ease of capture, impunity or flavor, is unknown. Given that terecay and galápago reach maturity faster than arrau (Hernández & Espín 2006; Mogollones 2004; Ramo 1982; Thorbjarnarson et al. 1993), encouraging captive breeding and consumption of the smaller species instead of arrau could help recovery efforts.

2.5 Conclusions

In the Middle Orinoco, there is a mismatch between government conservation objectives and those of ribereños. The first is exclusionary and preservationist and the latter wants to participate in conservation while still using the turtle resource. This sort of incongruence in goals and the ensuing failure of conservation programs is well-documented (Agrawal & Ostrom 2006; Berkes 2004; Fiallo & Jacobson 1995; Lindsey 1989; Price 1994). If we add the lack of enforcement (Novoa 1982) and the dwindling environmental budget in Venezuela (Rodríguez 2000), it is obvious changes to the Arrau Conservation Program are essential for success (Dietz et al. 2003; Gibson et al. 2005).

Ribereños have a widespread desire to participate in wildlife conservation activities, to have the authority to exclude outsiders and manage, use, and conserve river resources. If we were to place the Middle Orinoco ribereño communities on Arnstein's (1969) "Participation Ladder", given current interaction between the Ministry of the Environment and ribereños, at best they would fall between "therapy" (non-participation) and "informing" (tokenism) (Table 11). There are no set channels for communication or interaction between the Ministry and ribereños, and all decisions are unilateral. We recommend initiating communication by instating regular meetings (once every month or two) between Ministry officials and all interested community members. Meetings should take place in the communities, should not interfere with daily labor, should offer transportation for community members if necessary, and have an open discussion format to foster interaction. Eventually, both parties should express their expectations of the conservation process and ultimately act upon a mutually binding agreement.

Table 11. Arnstein's ladder of citizen participation. Modified from Arnstein (1969) and Sokolova (2005).

Citizen participation	Citizen Control	"Have-not" citizens obtain the majority of decision making seats, or full managerial power. Traditional power holders "give away" decision making, resources and control.	Voice & Power
	Delegated Power		
	Partnership	Enables citizens to negotiate and engage in trade-offs with power holders. Partnership in decision making starts; joint actions or common objectives.	
Tokenism	Placation	Two-way communication. "Have-nots" advise but decision rights remain with power holders.	Voice, No Power
	Consultation	Face-to-face contact. Citizen input heard but not necessarily headed.	
	Informing	One-way communication. Citizens are informed about decisions already made.	
Nonparticipation	Therapy	Enables power holders to "educate" or "cure" participants.	No voice, No power
	Manipulation		

Given the weak or absent social institutions ribereño communities have in the Middle Orinoco, an essential step towards participation would be to strengthen these institutions (Agrawal & Gibson 1999; Agrawal & Ostrom 2006; Barrett et al. 2001; Ostrom 1990). Ribereños can practice community management by working on other wildlife use problems, such as fisheries (Novoa 1982) for example, by creating rules of use and exclusion which are essential to successful resource management (Dietz et al. 2003; Gibson et al. 2005; Ostrom 1990), and sharing monitoring responsibility with the government. In Brazil, floodplain fisheries management has transitioned from government to community to co-management, taking advantage of the strengths of both actors, e.g., a grounded knowledge of the resource and the behavior of stakeholders on the community's side and the ability to enforce rules of use among disparate stakeholder groups on the government's side (de Castro & McGrath 2003). In Ecuador, a terecay and arrau conservation program was started by an environmental non-governmental organization (ENGO) with the consent of the indigenous community (Cofán) managing the area. At first, the ENGO offered modest economic incentives for hatchling conservation and a few turtle monitoring jobs to the community. In time, terecay populations started to grow, turtle monitors were trusted with managing the conservation program and the proportion of community members supporting and involved in the program continued to increase (Caputo et al. 2005; Townsend et al. 2005).

There is no tried and true formula to ensure sustainable use of community-based or co-managed resources or how to transition to them from an exclusionary and non-participatory conservation model (Barrett et al. 2001; Berkes 2004; Dietz et al. 2003; Ludwig 2001; Ostrom 1990), but management diversification has been successful (Agrawal et al. 2008; Gibson et al. 2005, Ostrom 2009). Some combination of community or co-management should be attempted (Berkes 2004; de Castro & McGrath 2003; Ludwig 2001; Robinson & Redford 1991). In any case, participatory conservation is key (Alcorn 1993; Berkes 2004; de Castro & McGrath 2003; Dietz et al. 2003; Evans & Guariguata 2008; Fiallo & Jacobson 1995; Ludwig 2001; Price 1995; van Rijsoort & Jinfeng 2005) to accomplish the ultimate goals of recovery and sustained use of sideneck river turtles in the Middle Orinoco.

3. MODELING GIANT SIDENECK TURTLE POPULATION RECOVERY AND SUSTAINABLE HARVEST

3.1 Introduction

Many authors have warned against harvesting long-lived species like turtles (Congdon et al. 1993; Cunnington & Brooks 1996; Thorbjarnarson et al. 2000) assuring that life-history traits of turtles preclude against any sort of chronic disturbance much less allow for sustainable harvest of these species. However, the socio-economic reality of humans who are in contact with turtles demands their use as food (Thorbjarnarson et al. 2000). Population models allow us to study life-history traits and determine best management practices for recovery and harvest of species of interest (Akcakaya et al. 1999; Caswell 2001; Crouse et al. 1987; Heppell et al. 2000).

The giant sideneck river turtle or arrau (*Podocnemis expansa*) in the Middle Orinoco was all but driven to extinction by government-run commercial harvest in the 20th century (Ojasti 1967, 1971). After 48 years of banned harvests and 21 years of *in situ* protection, the nesting female population has yet to show signs of recovery (Mogollones et al. 2010).

The arrau is the largest freshwater turtle in the Neotropics, with a record 89 cm curved carapace length (CCL) and 73 kg (Pritchard & Trebbau 1984). It has delayed maturity (17 and 11-28 years, Hernández & Espín 2006; Mogollones et al. 2010), like many other freshwater species (Shine & Iverson 1995). However, it nests in aggregations similar to olive ridely sea turtle, *Lepidochelys olivacea*, arribadas (Lutz et al. 1997), and has unusually high fecundity for a freshwater turtle (77.8 female eggs/female, Mogollones et al. 2010) comparable to sea turtle fecundity (76.5 female eggs/female, Crowder et al. 1994).

In Venezuela, conservation efforts for this species include nesting beach protection, hatchling rearing (for 1 year) and reintroduction into the wild. Over 300,000-tagged yearlings have been reintroduced into the Middle Orinoco since 1994. Despite protection and being banned from extraction, the arrau is commonly taken in the area for subsistence and commercial harvest (Peñaloza et al. *In prep.-a;* Peñaloza et al. *In prep.-b*). In spite of illegal harvest, the population has been stable since 1989 (Mogollones et al. 2010), however, at less than 1% of its historical abundance (Humboldt 1810, Mosqueira-Manso 1945).

Recent recovery of similarly long-lived, late-maturing, and high fecundity Kemp's ridley sea turtles (*Lepidochelys kempii*) in Rancho Nuevo, Mexico (Heppell et al. 2005) and green sea turtles (*Chelonia mydas*) in Hawaii and Costa Rica (Balazs & Chaloupka 2004, Troëng & Rankin 2005) is encouraging. Despite decades of nesting beach and egg protection, these populations had not shown recovery until mortality decreased in key life-stages. By-catch reduction of the Kemp's ridley when Turtle Excluder Devices (TED) were implemented in shrimp fisheries and green turtle harvest bans in Hawaii (1970's) and the Caribbean (1960's in Costa Rica, Nicaragua and Panama) are thought to have increased juvenile, subadult and adult survival (Balazs & Chaloupka 2004, Heppell et al. 2005, Troëng & Rankin 2005). Protection of eggs and hatchlings further boosted population recovery. Decreasing mortality in stages with naturally high survival and the most influence on population growth (i.e.: have high survival elasticity) is essential to population recovery (Crowder et al. 1994; Heppell & Crowder 1998; Heppell et al. 1996). Continued protection of eggs and hatchlings can shorten recovery time to target abundance and thereafter provide a surplus of individuals, from eggs to adults, for sustainable harvest.

We estimated demographic parameters for the Middle Orinoco arrau turtle population from nesting beach surveys, in-water surveys, and mark-recapture data for incorporation into population models that we designed to determine the recovery potential and impacts of harvest on this population. By using transition matrix population models (Caswell 2001) and accounting for parameter uncertainty, we estimated the relative contribution of each life-stage to the asymptotic population growth rate, the increase in survival required to recover nesting females to 10,000 nesters, and a level of sustainable harvest that would satisfy ribereño demand while maintaining ~1-10% yearly growth in the arrau population. We will use a deterministic, female-only post-breeding census model. In this model, we assume a closed population (supported by genetic studies, Pearse et al. 2006), stable age structure (Mogollones 2004), size-dependent survival between stages, constant survival within stages, size-dependent fertility, and a primary sex ratio equal to adult sex ratio. The arrau population in the Middle Orinoco has not increased in the past 21 years, we assume illegal subsistence and commercial harvest are responsible and that these harvests are sustainable at their current level. However, because the current population is less than 1% of its historical abundance, we believe 10,000 nesting females (Endangered Species Act delisting criteria for Kemp's ridley, Heppell et al. 2005) should be set at the recovery target for this population.

3.2 Methods

To build our population models, we used two sources of data: nesting-beach data from the Venezuelan Ministry of the Environment (MINAMB), the agency in charge of arrau turtle conservation, and in-water turtle survey data from the Foundation for the Development of Mathematical, Physical and Natural Sciences (FUDECI), a non-governmental organization involved in arrau turtle conservation. MINAMB data includes clutch size, hatching success, and nesting female size and abundance since the beginning of the Middle Orinoco arrau conservation program in 1989. FUDECI data includes hatchling survival from hatching to reintroduction as yearlings, mark-recapture data on reintroduced turtles and in-water turtle surveys from 1994-2008.

With these data, we estimated demographic parameters for the Middle Orinoco arrau turtle population and built a stage-based population growth model to determine which stages have the most influence on population growth. Additionally, we used the growth model to study the result of various management scenarios and ultimately propose a sustainable level of harvest for this species.

3.2.1 Demographic Parameters

3.2.1.1 Egg and Hatchling Survival

Egg survival or hatching success, corresponds to the proportion of live hatchlings out of the total number of eggs in each nest. Since 1989, MINAMB has collected data on nest numbers, clutch size and live hatchlings per nest for the main arrau nesting beaches in the Middle Orinoco, Venezuela. We calculated hatching success for 1990-1992 and used estimates from MINAMB for 1995-1996 and 1998-1999 (MARNR 1999). We used a weighted average of these combined estimates as the population hatching success.

Since 1992, about half the production of hatchlings from the Middle Orinoco (7-26% of total births from 1992-1999 and an average of 50% since then) have been reared in captivity for one year and then reintroduced to their natal beach area (16% were reintroduced to Orinoco tributaries). During this time, FUDECI reared over 80% of the headstarted hatchlings. We calculated the survival of headstarted hatchlings to 1 year of age by determining the proportion of turtles that survived until reintroduction with respect to the total sent to captivity for 1994-2007 cohorts of arrau turtles headstarted by FUDECI (O. Hernández, unpublished data; Hernandéz 2009). We then determined the proportion of yearling headstarted turtles in the wild from mark-recapture data and used this proportion, the headstarted hatchling survival, the proportion of wild hatchlings a natural hatchling survival of 5-20% (Diniz & Santos 1997; Roze 1964), and hatching success to determine overall first year survival using the following expression:

$$\sigma_{eggs/hatchlings} = \left(\left(\frac{Headstarted_{hatchlings}}{Total_{hatchlings}} . \sigma_{heastarted} \right) + \left(\frac{Wild_{hatchlings}}{Total_{hatchlings}} . \sigma_{wild} \right) \right) . \sigma_{eggs}$$

where sigma, σ , denotes survival of designated stages.

3.2.1.2 Juvenile, Subadult, and Adult Survival

We used mark-recapture data from reintroduced arrau turtles to calculate juvenile, subadult, and adult survival. Over 280,000 hatchlings reared by FUDECI, tagged by toe clipping to indicate birth cohort, have been returned to the wild. To monitor the outcome of the reintroduction program, in 1998, 2000, 2001, 2004, 2005 and 2008 FUDECI carried out in-water turtle surveys in and nearby the AWR; we worked with FUDECI in 2005. To capture turtles, we used beach seining techniques recommended by local fishers where a trammel net is held between two boats or a boat and a person on land and swept along the riverbed for a certain distance. We landed captured turtles, checked them for the headstarting cohort tag, measured (curved carapace length, CCL), weighed, sexed, and marked them individually by shell notching. We then created capture histories for individual headstarted turtles to determine survival in program

MARK (White & Burnham 1999). Due to very low male recapture rate (3 out of 581), we only determined survival for females. We did not determine adult survival separately because there were too few recaptures of individuals large enough to be considered adults (minimum nesting female size is 465 mm CCL in the Middle Orinoco, (MARNR 1999)). However, we consider juveniles, subadults and adults experience similar mortality rates because their distribution along the river is not size or age dependent (Penaloza et al. *In prep.-a*) and they are known to migrate together (Vogt et al. 2010). In MARK, we used the Cormack-Jolly-Seber model for live recaptures in which we assume equal catchability, equal survival for marked animals, no tag-loss, and instantaneous sampling. We consider our data meet these assumptions. Almost all our captures are initial captures of reintroduced turtles, it is the first time these individuals have been sampled in the water, i.e., they cannot have changed their behavior due to sampling. Turtles of all sizes are distributed uniformly along the river (Penaloza et al. *In prep.-a*). Tagging should not affect survival because toe clipping is minimally invasive and hatchlings are tagged at least one month before being reintroduced, having time to heal. Tags can only be lost in the event of a forelimb amputation. Minimum time between sampling bouts is 1 year, the longest sampling bout was 26 days, and we processed individual catches in less than one hour. No turtles died during processing. We fit a constant survival model to our mark-recapture data; sparse data precluded fitting more complex models (Doherty 2010). The model accounted for differences in sampling effort among years, absence of sampling in some years, and cohort strength.

3.2.1.3 Fecundity

In a female only post-breeding census model, like in the present study, fecundity is the combination of fertility, adult female survival, and the proportion of females in the population. Fertility is the number of offspring, in this case clutch size (number of eggs), produced by an individual in a breeding season. Because the population is counted right after breeding (post-breeding census), the eggs in a given season are produced by the females from the previous season that survived to lay eggs.

Clutch size corresponds to the total number of eggs in each nest. We calculated average clutch size for 1990-1992 and used clutch size averages reported by MINAMB for 1995-1996 and 1998-1999, a total of 1134 arrau turtle nests. We used the weighted average of these combined estimates as the population clutch size and obtained clutch size range from complete data tables reported in 1990-1992 (MARNR 1999).

The proportion of females in the population corresponds to the population sex ratio. Using data from in-water turtle surveys, we sexed turtles by secondary sexual characteristics and size. Males have engrossed and elongate tails and u-shaped anal notches while females and juveniles have smaller tails and v-shaped anal notches (Perez A. et al. 1995; Pritchard & Trebbau 1984; Thorbjarnarson et al. 1993). Turtles with a v-shaped anal notch were considered females (subadults and adults) if they were larger than the geometric mean size for all male arrau caught during in-water surveys (321 mm CCL); smaller turtles were considered juveniles. We define the population sex ratio as the sex ratio of all sexed individuals rather than of only sexually mature individuals to reduce the overrepresentation of males inherent in our sexing method. For the population growth model, we defined the minimum and maximum proportion of females in the population as the proportion of subadult females to males and all females to males to avoid overrepresenting females because of their wider size range.

Adult fecundity increases with adult size in arrau turtles (Alho & Pádua 1982; Valenzuela 2001) and, in our model, we assume fecundity increases as adult turtles age. Average fecundity is assigned to the median adult age and decreased (increased) in a stepwise manner for younger (older) ages until reaching the minimum (maximum) fecundity registered for the population. We assigned minimum fecundity to maturing subadults.

3.2.1.4 Age at maturity

We determined age at maturity by comparing the size of the smallest nesting females to the size and age of mark-recaptured turtles.

3.2.2 Population Model

We built a stochastic staggered-entry stage-structured model for the Middle Orinoco arrau turtle population. Stage duration is determined by the minimum and maximum number of years it takes a turtle to reach a certain size, which corresponds to each life stage. Growth of turtles between these stages is delayed until turtles reach the minimum stage duration and is progressive thereafter, i.e., until turtles reach the maximum stage duration. Therefore, in each size-based stage there are different aged turtles to account for growth plasticity in this species. The resulting matrix is square; stages are divided into yearly time steps and each row and column corresponds to one year of a turtle's life. The subdiagonal has within stage survival probabilities and non-diagonal elements have growth probabilities between stages. Because this is a post-breeding census model, the first row of the matrix has fecundity values for adults and subadults that will survive and become reproductive adults before the next census.

Figure 20 shows an example of the staggered-entry matrix model construction. There are three stages in this example, eggs/hatchlings, juveniles, and adults. The eggs/hatchlings stage lasts one year (EH), the juvenile stage three to six years (J_{1-6}), and the adults have no terminal age (small adults, A_S, medium adults, A_M, and large adults, A_L). *P*, represents survival and *F* represents fecundity. Subscripts indicate the initial and final stage involved in the transition, i.e., P_{J_2,J_3} , is the probability stage 2 juveniles have of transitioning (surviving) to become stage 3 juveniles in the next time step. Subdiagonal elements have within stage survival probabilities and non-diagonal elements have between stage survival (growth) probabilities, e.g., P_{J_4,A_S} , is the probability a stage 4 juvenile will survive and transition (grow) to become a small adult in the next time step. Because it is a post-breeding census model, fecundity is also applied to juveniles that will survive and grow to become small adults in the next time step. In this example, growing turtles must remain in the juvenile stage a minimum of two years after which they will either grow to become small adults or remain as juveniles in the next time step. Individuals in this model reach maturity between the ages of 3- 7-years-old. Adult fecundity varies with age (size).

$$
\begin{bmatrix}
0 & 0 & 0 & F_{J_3,A_S} & F_{J_4,A_S} & F_{J_5,A_S} & F_{J_6,A_S} & F_{A_{S,M}} & F_{A_{M,L}} & F_{A_{L,L}} \\
P_{EH,J_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & P_{J_1,J_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & P_{J_2,J_3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & P_{J_3,J_4} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & P_{J_4,J_5} & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & P_{J_5,J_6} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & P_{J_3,A_S} & P_{J_4,A_S} & P_{J_5,A_S} & P_{J_6,A_S} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & P_{A_{S,M}} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & P_{A_{M,L}} & P_{A_{L,L}}
\end{bmatrix}
$$

Figure 20. Staggered-entry stage-based matrix model. *P* denotes survival and *F* denotes fecundity (pre-breeding census model). Subscripts designate initial and final stages involved in the transition. EH, egg/hatchling stage, $J_{1\text{-}6}$ juvenile stages, $A_{S,M\text{ or }L}$ small, medium or large adult stages. Adults have no terminal age.

We divided our model into the following four life stages: eggs/hatchlings, juveniles, subadults and adults to account for size-related variation in survival. The egg/hatchling stage corresponds to the first year of life from the moment females lay their eggs until the hatchlings from these eggs become 1-year-old turtles or yearlings. Juvenile and subadult stage duration is derived from mark-recapture data, we use the minimum and maximum number of years it takes a turtle to reach a certain size; ~100 - 321 mm CCL for juveniles and 322 - 545 mm CCL for subadults. We consider turtles larger than 545 mm CCL are adults. Subadults mature, i.e., transition to the adult stage, between 11 and 28 years of age. Adults do not have a maximum lifespan.

We randomly generated model parameters from average fecundity (normal distribution) and minimum and maximum survival estimates to obtain averages and confidence intervals for our model results (population growth, stable age distribution, reproductive value, parameter elasticities and population size) using a Monte Carlo simulation in Poptools (1000 iterations).

We built a model representing density-independent maximal population growth with initial survival estimates from Program MARK. We then matched model growth (λ) to current nesting-female population growth by iteratively decreasing juvenile, subadult, and adult survival. This decrease in survival would represent both estimated and unknown, commercial and subsistence harvest.

To determine current population growth, we estimated the intrinsic rate of increase for the nesting-female population $(r = \ln(\lambda))$ in R (R Development Core Team 2008) by applying a linear regression to the natural logarithm of the number of nesting-females (equivalent to applying an exponential regression to the number of nesting-females) from 1989-2009. We plotted the exponential curve by taking the exponents of the predicted values and confidence intervals. We used the current-growth model as the base model for management scenarios.

3.2.3 Management Simulations

3.2.3.1 Population recovery

The goal of protecting the arrau turtle in the Middle Orinoco is to increase the abundance of its population. However, the Venezuelan Ministry of the Environment, the governmental agency charged with this task, has not defined target abundance or a timeframe for recovery. We chose 10,000 nesting females as our target because riverine communities (*ribereños*) expressed a desire to consume 11 times as many turtles as they do now (Peñaloza et al. *In prep.-b*). Given that the turtle population has been stable for the past 20 years, and assuming neither turtle harvest nor human population have fluctuated much in this time nor will in the near future, the desired consumption level may be sustainable with 10,000 nesters, ~12 times current nesting females ($\bar{x} = 841$). To boost population growth, we propose eliminating commercial, and if necessary subsistence harvest, during the time required to reach 10,000 nesting females (starting at 1000 nesters).

According to Penaloza et al. (*In prep.-a*), maximum subsistence harvest in the area is close to 500 turtles a year. Regarding commercial harvest, if we assume the three communities with the highest per capita harvest are engaging in commercial extraction and they have similar extraction levels, which are not apparent because turtles are sold and consumed elsewhere, commercial extraction is also close to 500 turtles a year in the Middle Orinoco. Within subsistence and commercial extraction, 77 and 63% are juvenile, 21 and 31% are subadults, and 2 and 6% are adults, respectively. In total, this would correspond to an average of less than 10% of juvenile, subadult, and adult arrau turtles from the current population (given 1000 nesters) (1.41% juvenile, 3.22% subadults, 4% adults). We modeled an increase in survival equal to total harvest for each life stage with a Monte Carlo simulation (1000 iterations) and determine the average amount of time required to reach 10,000 nesting females.

We assumed harvest determined by Penaloza et al. (*In prep.-a*) underestimated actual harvest and modeled growth for the population after eliminating estimated and unknown commercial harvest, i.e. maximal-growth survival was only decreased by subsistence harvest. In this case, we decreased survival by double the amount of current subsistence harvest to match consumption levels reported by ribereños (Penaloza et al. *In prep-b*). We then projected population growth into the future (independent growth rate between years) with a Monte Carlo simulation (1000 iterations) to determine the average amount of time it would take to reach a nesting female population of 10,000.

3.2.3.2 Sustainable Harvest

Once the population had increased to 10,000 nesting females, we modeled the extraction of 10,000 juvenile, subadult, and adult turtles in the same proportion they are taken by subsistence harvest (77% juveniles, 21% subadults and 2% adults) (Penaloza et al. *In prep.-a*). We determined an extraction schedule that corresponds to current harvest behavior according to turtle size (age). We then projected population growth into the future and used a Monte Carlo simulation (1000 iterations) to determine average adult population size.

3.3 Results

3.3.1 Demographic Parameters

3.3.1.1 Egg and Hatchling Survival

Hatching success, or egg survival, for the Middle Orinoco arrau turtle population is shown in Table 1 (n = 1134 nests). Headstarted turtle survival (hatchling to age 1 or time of reintroduction) averaged 0.8585 (0.3949 – 0.9885) from 1994-2007. The proportion of headstarted turtles recaptured after reintroduction was 0.8331 (0.7362 – 0.9781) for the same period. After assigning 0.05 – 0.2 as survival for wild hatchlings, overall hatchling survival averaged 0.6178 (0.3680 – 0.8986) (Table 12).

Table 12. Demographic parameters for female arrau turtles from the Middle Orinoco, Venezuela.

Stage	Age (yrs)	Size (CCL mm)	Survival	Fecundity (female eggs/female)
Eggs	0	na	0.7214 0.4768 – 0.8883	
Hatchlings			0.6178 0.3680 – 0.8986	
Juveniles	1 - (5-9)	~ 100	0.8641 0.8188 – 0.8995	
Subadults	(6-11) - (11-28)	321		
Adults	(11-28) - 60	545		49.05 12.69-105.96

3.3.1.2 Juvenile, Subadult, and Adult Survival

During in-water turtle surveys conducted from 1998-2008, we recaptured 581 headstarted turtles (only 3 males). Turtle ages ranged from 1-14-years-old and sizes ranged from 107-590 mm CCL. Table 12 contains average survival and 95% confidence intervals for juveniles, subadults, and adults for the density independent maximal-growth stochastic population model.

3.3.1.3 Fecundity

Table 12 shows average, minimum, and maximum fertility of adult female arrau turtles for the Middle Orinoco. The proportion of females in the population varies from 0.7478-0.8246, which corresponds to sex ratios of 3:1 subadult females to males and 5:1 all females to males. After multiplying fecundity by the proportion of females in the population and by adult survival or maturing subadult survival, fecundity varied from 12.73-117.23 for the stochastic population model.

3.3.1.4 Age at maturity

The minimum size for a nesting female in this population is 465 mm CCL (MARNR 1999) (~ 7-year-old turtles), however, most of the small nesting females are ~ 550 mm CCL (~ 10-year-old turtles) (Figure 21), which is why we chose 545 mm CCL as the minimum size for adults. The current maximum nesting female size is 755 mm CCL, assuming a 545 mm CCL at maturity would correspond to the average ratio between maximum size and size at maturity found by Shine and Iverson (1995) for turtles. This size also corresponds to an initial age at maturity of 10 years, similar to what Mogollones et al. (2010) found for this population.

The mark-recapture data we have does not extend into adult sizes, therefore, to account for growth plasticity, i.e., not all turtles mature at the same age; we chose a maximum age at maturity of 28 years following Mogollones (2004). This estimate is plausible given that some turtles take up to 10 years to reach subadult size and growth rates decrease with increasing size (C. Peñaloza, unpublished data, e.g. Chaloupka & Limpus 1997).

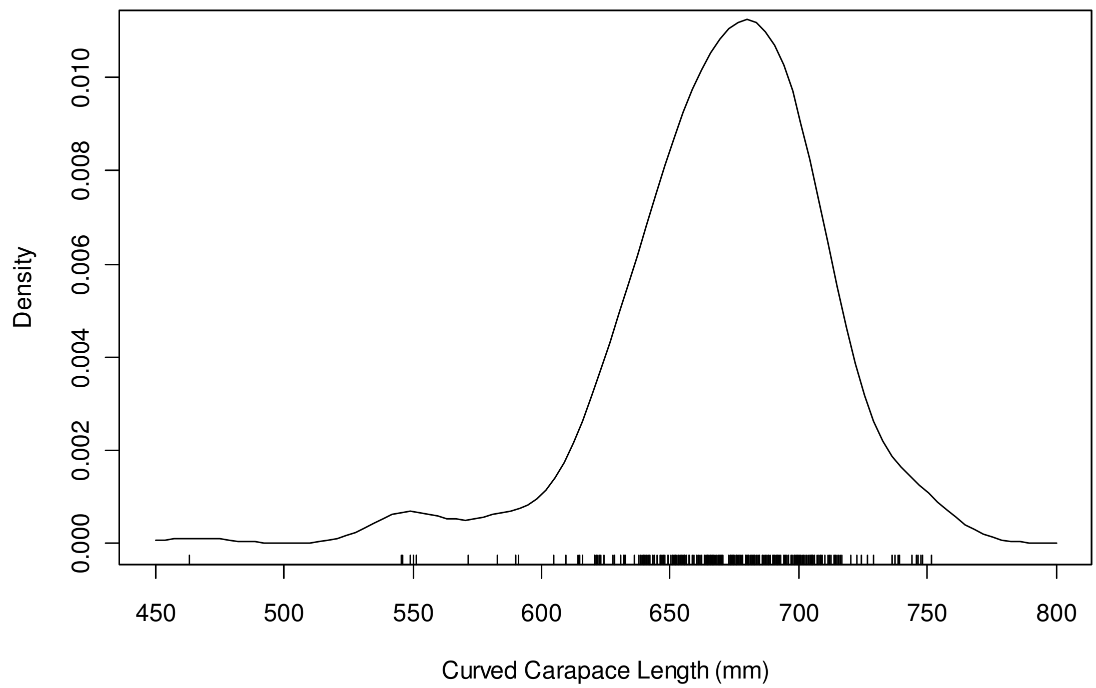

Figure 21. Kernel density distribution of Middle Orinoco arrau turtle nesting-female size (n = 264, 1990-1998).

3.3.2 Population Model

The exponential regression fit to nesting-female numbers yielded an intrinsic growth rate, r = 0.00005711, which corresponds to a finite rate of increase (lambda) of $\lambda = 1.0005711$ with a variance of 0.0001 and 95% confidence limits of 0.9802-1.0200, for the arrau nesting-female population in the Middle Orinoco (Figure 22). We iteratively decreased juvenile, subadult and adult survival from the maximal-growth model (Table 12) to match this growth rate.

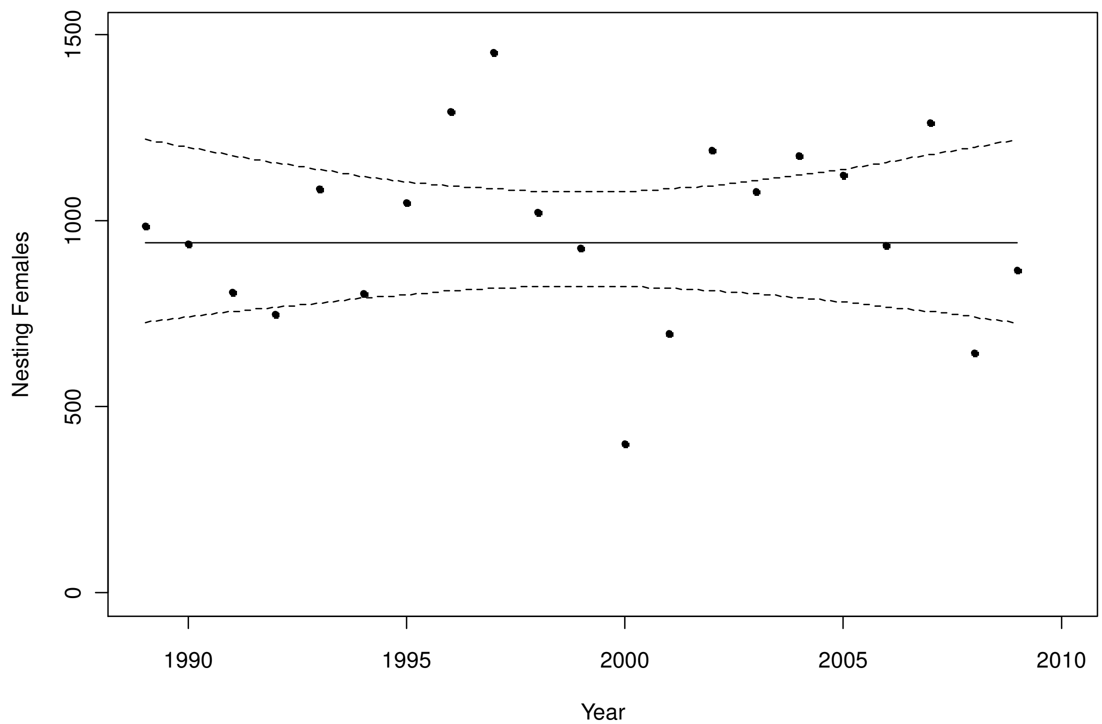

Figure 22. Intrinsic growth rate for the Middle Orinoco arrau turtle population derived from exponential regression applied to number of nesting females. Dotted lines represent 95% confidence intervals for the regression $y = 841.32e^{0.00005711.x}$ **(r^2_{adj} = -0.05263).**

The finite rate of increase for the population model based on mark-recapture data from Middle Orinoco arrau turtles was $\lambda = 1.0006$ with a variance of 0.0005 and 95% confidence limits of 0.9582 – 1.0402. Figure 23 shows projected population growth into the future under current management. Table 14 and Figure 24 show the matrix results for the Monte Carlo simulation; stable age distribution, reproductive values, survival and growth elasticities and population size.

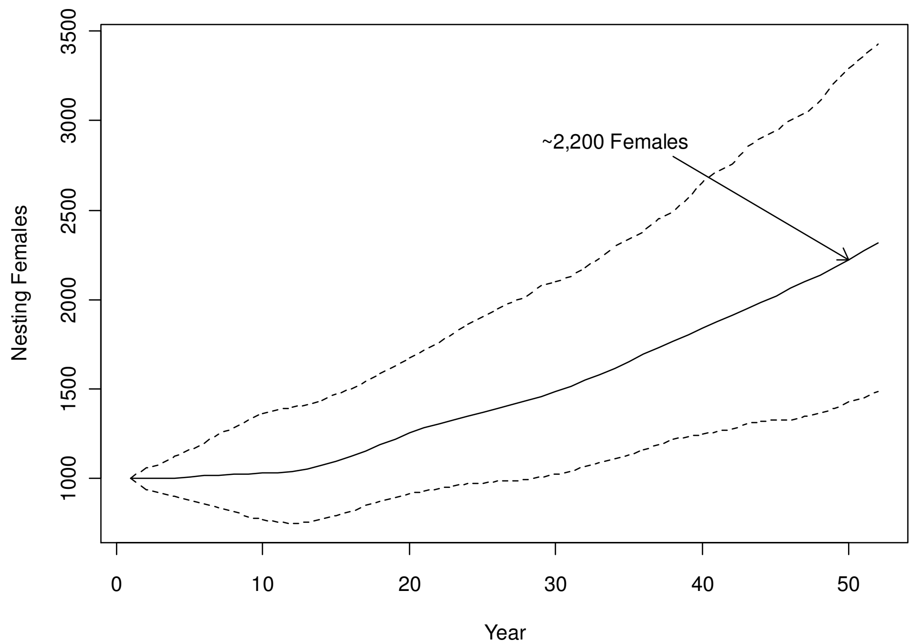

Figure 23. Projected growth of nesting female arrau turtles in the Middle Orinoco under current management (equivalent to decreasing maximal growth model survival of juveniles and subadults by 17% and adults by 13%). Solid line represents the average and dotted lines represent confidence intervals of population growth for 1000 iterations. The population increases in 83% of the simulations. In 50 years, there are an average of 2,224 nesters.

Table 13. Matrix results for Monte Carlo simulation of Middle Orinoco arrau turtle stochastic population model. Values correspond to average and 95% confidence limits.

Stage	Stable age distribution	Reproductive value (geometric mean, relative to Eggs)	Elasticities (survival and growth)	Population size (given 1000 adults)
Eggs	0.4019 0.2892 - 0.5356	1	0.0454 0.0393 - 0.0507	57701 49995 - 66355
Juveniles	0.5183 0.3920 - 0.6263	7.00 4.07 – 11.66	0.2658 0.2299 - 0.2973	76974 45024-116454
Subadults	0.0728 0.0582 - 0.0872	92.52 60.42 – 139.97	0.3287 0.2828 - 0.3691	10674 7255 - 14887
Adults	0.0070 0.0053 - 0.0090	611.69 426.54 – 880.17	0.3146 0.2340 - 0.4044	1000

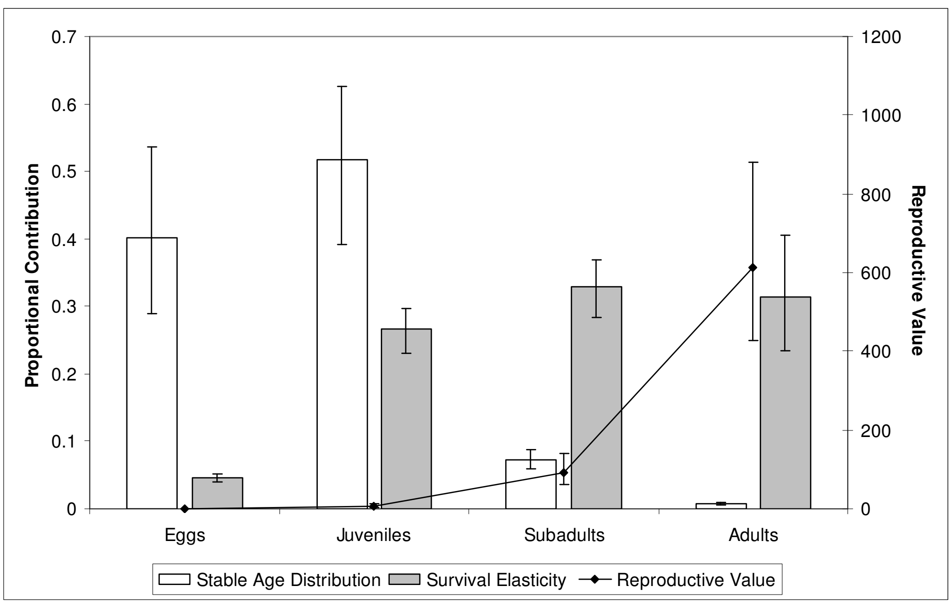

Figure 24. Matrix results for arrau turtle population model. Stable age distribution and elasticities are proportions (i.e.: scaled to sum 1). Reproductive value is relative to eggs. Whiskers represent 95% confidence intervals produced by the Monte Carlo simulation (1000 iterations).

3.3.3 Management Simulations

3.3.3.1 Population Recovery

The projected growth of arrau turtles after eliminating harvest is shown in Figure 25. On average, decreasing harvest-related mortality increases nesting female population size to 10,000 turtles after 39 years. In this scenario, 95% of the populations grow.

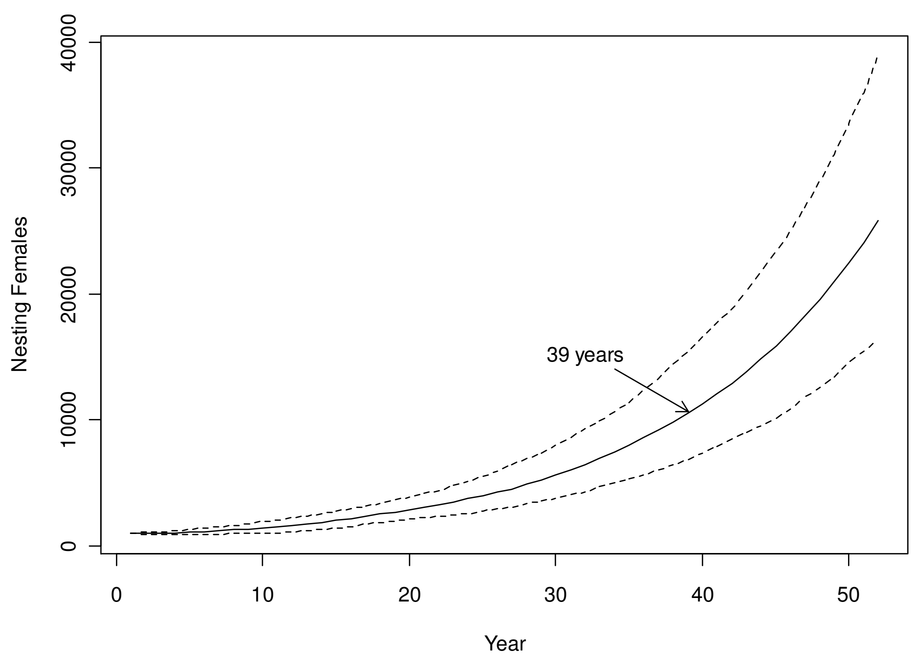

Figure 25. Projected growth of nesting female arrau turtles in the Middle Orinoco after eliminating estimated commercial and subsistence harvest (equivalent to a 7% increase in juvenile and subadult survival in current growth model). Solid line represents the average and dotted lines represent confidence intervals of population growth for 1000 iterations. In 39 years there are an average of 10,000 nesters. The population grows in 95% of the simulations.

Figure 26 shows population growth projected into the future for the "no commercial harvest" simulation. The population increases in 97% of the simulations and reaches the target 10,000 nesters in 25 years.

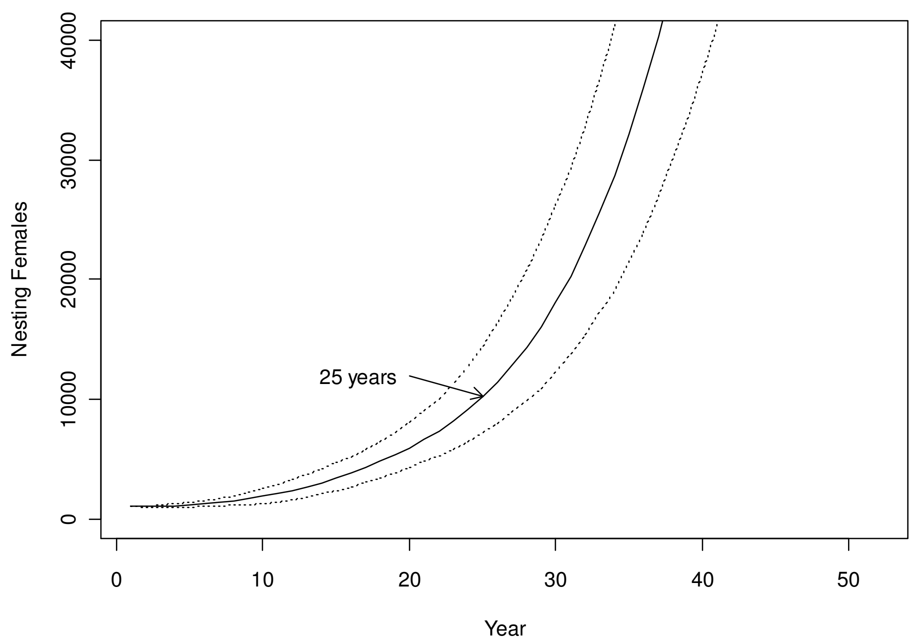

Figure 26. Projected growth of nesting female arrau turtles in the Middle Orinoco under double the current subsistence and no commercial harvest (equivalent to a 11% increase in juvenile and subadult survival in current growth model). Solid line represents the average and dotted lines represent confidence intervals of population growth for 1000 iterations. The population increases in 97% of the simulations. In 25 years, there are 10,000 nesters on average.

3.3.3.2 Sustainable Harvest

Figure 27 shows the projected population growth after the population reached the target 10,000 nesting females and we simulated a yearly harvest of 10,000 juveniles, subadults and adults. On average the population continues to grow reaching over 64,000 females in 15 years; 7% of iterations produce decreasing populations.

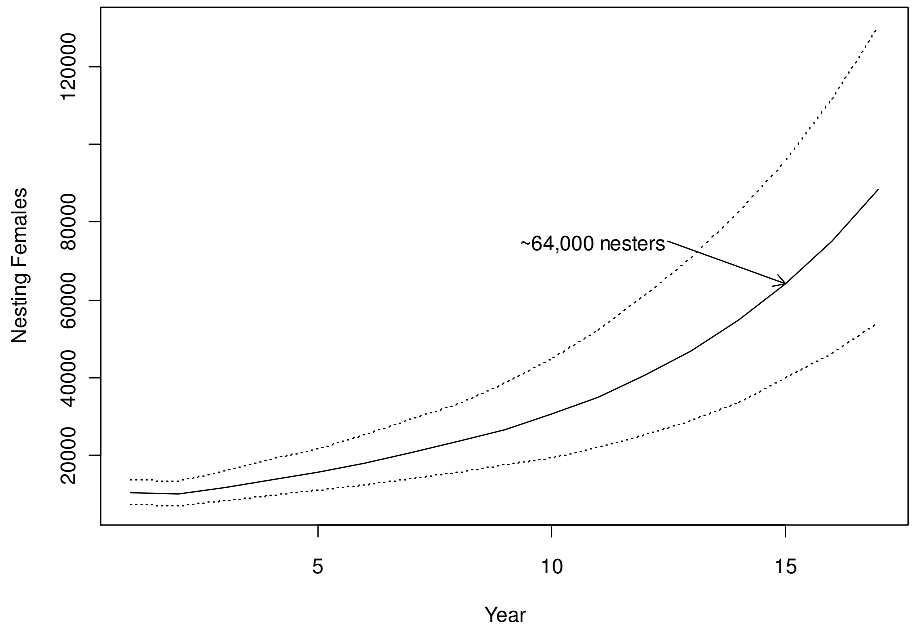

Figure 27. Projected growth of Middle Orinoco arrau turtle population with yearly harvest of 10,000 juvenile, subadult and adult turtles according to current harvest behavior. Solid line represents the average and dotted lines represent the confidence intervals of population growth for 1000 iterations. On average, the population continues to grow despite harvest, surpassing 60,000 nesting females in 15 years, less than 7% decrease in abundance.

3.4 Discussion

3.4.1 Demographic Parameters

The average demographic parameters we determined for the Middle Orinoco arrau turtle population are comparable to those of previous studies in the same area and for other turtle species. We found lower egg/hatchling survival (0.4455 vs. 0.584), higher juvenile/subadult survival (0.8641 vs. 0.44), and lower adult survival (0.8641 vs. 0.91-0.93) than Mogollones et al. (2010), respectively. We used the same dataset with additional years to calculate egg/hatchling survival. We determined juvenile and subadult survival from mark-recapture data, whereas Mogollones et al. adjusted juvenile growth to match population growth given survival estimates for the remaining stages. We could not determine how Mogollones et al. (2010) calculated adult survival. Estimates of age to maturity are based on the same data with additional years added for the present study.

Egg/hatchling survival for this population is high compared to other freshwater turtles and similar to that of sea turtles. Survival estimates for freshwater turtles averaged 0.229 ± 0.182 (n = 15, nests) and for sea turtles 0.562 ± 0.286 (n = 14, nests) and 0.585 ± 0.007 (n = 2, eggs/hatchlings to age 1). Increased egg/hatchling survival is probably due to nest protection and headstarting program. Juvenile survival is higher than that reported for freshwater turtles (0.672 ± 0.179, n = 5) and sea turtles (0.820 ± 0.170, n = 2). Subadult and adult survival are also higher than reported for other freshwater turtles (0.837 ± 0.084, n = 4) and sea turtles (0.709 ± 0.144, n = 2) (Iverson 1991b). Several freshwater turtle species reach maturity at ages similar to the arrau; e.g., snapping turtle, *Chelydra serpentina*, 13 and 19 years (Congdon et al. 1994; Cunnington & Brooks 1996), yellow mud turtle, *Kinosternon flavescens*, 11 years (Iverson 1991a), blanding's turtle, *Emydoidea blangdingii*, 14 years (Congdon et al. 1993). However, arrau fecundity is only comparable to sea turtle fecundity, e.g., loggerhead, *Caretta caretta*, 76.5 female eggs/female (Crowder et al. 1994), Kemp's ridley (*Lepidochelys kempii*), 68.75 females eggs/female (Heppell et al. 2005).

3.4.2 Population Model

Elasticity patterns found for arrau turtle are similar to those found by Heppell (1998) for painted turtles (*Chrysemys picta*) (Tinkle et al. 1981), where subadult survival elasticity has the largest effect on population growth, followed closely by adult and then juvenile survival elasticities. This pattern indicates that changes in subadult and adult survival have the largest effect on population growth, i.e.: management focused on increasing subadult and adult survival would have the largest positive effect on population growth. For instance, eliminating commercial harvest would increase population growth more than eliminating subsistence harvest because large subadults and adults are the ones targeted in commercial harvest (Peñaloza et al. *In prep.-a*). Despite uncertainty and large variability in parameter estimates, elasticities within life stages do not vary much, making conclusions drawn from them more robust (Heppell 1998).

The reproductive value of adults is highly variable probably due to the use of size-dependent fecundity. The estimated population size, specifically the number of eggs and hatchlings, is comparable to the amount currently found on the main nesting beach (Marín 2010).

3.4.3 Management Simulations

3.4.3.1 Population Recovery

At the level of harvest found by Penaloza et al. (*In prep.-a*), eliminating harvest does not assure a rapid recovery of the Middle Orinoco arrau population. Assuming this population is able to grow under natural conditions and unless there is a significant unknown source of mortality, it is possible harvest was greatly underestimated. Once harvest decreases, turtle populations tend to increase rapidly. After reducing harvest of terecay (*Podocnemis unifilis*) in Ecuador, populations grew three- to four-fold in 10 years (Townsend et al. 2005). With the implementation of Turtle Excluder Devices (TED's), Kemp's ridleys are recovering at about 10-15% a year and are expected to reach 10,000 nesting females (delisting criteria) by 2020 (Heppell et al. 2005). Leatherbacks in Florida have been increasing at up to 16% a year possibly because of the collapse of commercial fisheries in which they were taken incidentally (Stewart et al. 2010). Considering these examples of rapid turtle population recovery with reduced harvest, we believe harvest of arrau in the Middle Orinoco was underestimated, therefore simulating the elimination of estimated harvest alone underestimates the potential reduction in mortality and concomitant increase in population growth.

The arrau population recovers rapidly when we eliminate commercial harvest (equivalent to a 12% increase in survival). Depending on the true level of commercial harvest, this 12% reduction in arrau mortality may be feasible, and with continued egg and hatchling protection, the population could increase 10-fold in about 25 years. Given a relatively small and stable human population in the area (Peñaloza et al. *In prep.-b*), a 10-fold increase in turtle abundance would allow continued subsistence harvest. While arrau populations recover, we propose galápago and terecay turtle farms as an alternative source of turtle protein for ribereños. Under natural conditions, the galapago has high adult survival, maximum age at maturity of 10 years and is prolific in semi-captive conditions (Ramo 1982). Terecay populations can grow rapidly if managed properly (Caputo et al. 2005; Townsend et al. 2005). Elasticity patterns for turtles similar to the galapago and terecay, earlier age at maturity and lower fecundity than the arrau, in which adults have the highest survival elasticity, suggest juveniles should be harvested while adults are protected (Heppell et al. 2005). The construction of artificial lagoons in each community and remote household for farming and ranching (closed loop vs. eggs from the wild) these turtles, could provide the incentive for ribereños to decrease consumption of arrau while they build stock.

3.4.3.2 Sustainable Harvest

Once the nesting female population has reached 10,000 nesters, controlled subsistence harvest of 10,000 turtles annually seems feasible. Nesting beach, egg, and hatchling protection would need to continue to ensure rapid growth, as found for Kemp's ridley and leatherback sea turtles (Heppell et al. 2005; Stewart et al. 2010). Successful sustainable harvest would require close management; detecting trends (abundance, size distribution) in nests, in-water juveniles and subadults, and nesting females is essential to avoid sudden population collapses from time-lag effects common to long-lived species (Congdon et al. 1993).

3.5 Conclusions

As Polisar (1994) found for the hickatee (*Dermatemys mawii*) in Belize, local communities were adverse to commercial extraction, especially by outsiders, but they did not support banning subsistence harvest. After almost 50 years of arrau harvest ban (commercial and subsistence) and 21 years of *in situ* protection in the Middle Orinoco, there is almost universal non-compliance and many local communities harbor negative sentiments towards environmental officials (Peñaloza et al. *In prep.-b*). In such a context, conservation efforts to increase arrau populations end up supporting turtle poachers and feeding ribereños. Because of the wide distribution of arrau along the Middle Orinoco, enforcing commercial harvest bans would benefit from a large network of, if necessary anonymous, observers charged with watching over designated portions of the river. If the Venezuelan government were amiable to co-management of the arrau turtle resource, ribereños would be ideal observers.

Although harvest is probably underestimated we do not recommend further efforts to determine actual harvest. If our immediate objective were to create better more realistic models, we would recommend collecting more data on arrau turtle life history. However, better models will not decrease harvest-related mortality. To recover the ecological and subsistence-food resource value of the arrau turtle in the Middle Orinoco, measures to reduce harvest must be implemented. Under natural conditions, and even more so with increased egg/hatchling survival, many turtle species are prolific and populations recover rapidly once key life stages are protected (Caputo et al. 2005; Heppell et al. 2005; Stewart et al. 2010; Townsend et al. 2005). We suggest future conservation efforts should establish home- or community-based turtle farms with faster maturing species to meet consumption needs while wild populations rebuild their stock. Once turtle populations have recovered, harvest of arrau turtles can resume without their impending demise.

4. CONCLUSIONS

Throughout our study of sideneck river turtles in the Orinoco, we have learned about the human socio-economic environment surrounding them, the conservation actions taken to recover their populations, and the outcome, realized and projected, of these actions. Our results indicate a need to update and adapt the conservation program for populations to recover.

In the Orinoco, sideneck river turtles are a widely distributed resource of great importance as a source of protein for riverine communities; additionally turtles may be of economic importance to some ribereños. The arrau, long sought after for its oil and meat, declined precipitously in the 20th century due to revenue-driven overexploitation by centralized governments. This decline led the central Venezuelan government to protect the last remaining nesting beaches by creating the Arrau Turtle Wildlife Refuge (AWR) in 1989. In the past 21 years, the population has stabilized, but is now at less than 1% historical abundance, our work indicates the population is not growing primarily because approximately 500 turtles are taken by the ribereños and another 1700 are taken for commercial harvest.

Although there is still widespread consumption of sideneck turtles along the 120 km stretch of the Orinoco River surveyed in this study, the creation of the AWR seems to have altered the turtle consumption behavior of ribereño communities. Ribereño communities closer to or inside the wildlife refuge have more complete knowledge of Venezuelan environmental law, have less or no indication of having consumed turtles (based on surveys of turtle remains), report less or no turtle consumption, and have more interaction, for better or for worse, with Ministry of the Environment and National Guard enforcement officials. Communities downriver and close to the wildlife refuge also report perceiving an increase in juvenile turtle population as a result of the headstarting and reintroduction program. There is no doubt the AWR has affected arrau turtles and Middle Orinoco ribereño communities, but arrau nesting female abundance has stabilized at a very low level and recovery-based objectives for increases since the creation of the AWR, suggest further conservation actions are required.

Ribereños would like to participate in conservation activities and have more and better quality interactions with officials from the Ministry of the Environment and National Guard. Presently, most of the ribereños who interact with the Ministry and National Guard feel marginalized and demeaned by officials from these institutions. In fact, some ribereños state they “steal turtles to get back at the Ministry for what they do to us”. With a dwindling AWR monitoring budget (Marin 2010), a continued Venezuelan economic crisis (Salmerón 2010) coupled to increasing wildlife extraction (Rodríguez 2000), and the wide distribution of sideneck turtles in the Orinoco, strengthening government enforcement of harvest-ban laws is unlikely to be a feasible path towards recovery.

In Northeastern Bolivia, the creation of a protected area and subsequent relocation of a village once inside this protected area, are thought to have caused a 10-fold increase in terecay abundance inside the protected area as compared to outside of it in just 4 years. The closest village is 40 km away from the protected area and fisher’s rarely travel more than 10 km on daily fishing trips (Conway-Gómez 2007). It is likely that the remoteness of this protected area, in addition to a shorter age to maturity in terecay than arrau, contributed significantly to terecay recovery in this case.

In Ecuador, a community-managed terecay recovery and sustainable egg-harvest program has seen turtle abundance increase 3-fold in 5 years. The Cofán Indian community in Zábalo, Ecuador banned adult turtle harvest in the 1970’s in the 1980’s they joined a collaborative turtle management effort with local Non-Governmental

Organizations (NGO's), and in 1990 the Cofán formed a research alliance with an Ecuadorian University (La Católica). In addition to the ban on adult harvest, a reduction in egg harvest was stimulated by monetary incentives to produce hatchlings for the head-starting program. In 1998, the Cofán formed a partnership with The Field Museum of Chicago who provided technical guidance to develop a turtle monitoring method. Cofán Indians, trained in data collection, kept detailed nesting records on all community-controlled beaches, which allowed for close monitoring of the resource and its distribution among community members. In 1999, a visual turtle census carried out by five Cofán monitors recorded turtle sightings to evaluate the effect of the headstarting program. Cofán participation and interest in turtle monitoring and conservation activities has increased every year since the 1970's. Currently they collect monitoring data for turtles and nests, perform data entry, and present results to other community members for decisions affecting turtle harvest (Townsend et al. 2005).

The success of these two very different programs seems to lie in certain characteristics of the systems where they were developed. In the Bolivian case, the remoteness of the area (after village relocation) seems to act as a barrier to terecay harvest. In Ecuador, the Cofán Indians have a well organized community. Most community members are interested and participate in turtle monitoring and conservation, and the entire community participates when deciding harvest quotas. The Cofán also have complete control and authority over the stretch of river they monitor. These characteristics along with their shared interest in rebuilding the terecay populations contribute to decreased harvest. Terecay turtles also mature sooner than arrau, requiring less time for population trends to change, which probably also contributes to the success of these programs.

The arrau in the Middle Orinoco, Venezuela, shares few characteristics with either of these programs. The wildlife refuge is only 25 km long, and the river is used intensely for transportation from cites down-river of the AWR to cities up-river from it. There are communities inside the refuge as well as close to the refuge boundaries. The ribereño "community" is not a distinct people with shared cultural values, community structure, and common authority. The approximately 1000 people living within the surveyed 120 Km stretch of the Orinoco, live in 29 different communities with anywhere from 1-50 families. However, they share the same livelihoods, many of the same problems, and they all seem to share the desire to recover the turtles to ensure future extraction.

The current organizational capacity of ribereños varies a great deal between communities. Some have well established community councils and, through these councils, have been able to appropriate funds from the Venezuelan government for home stabilization, fishing equipment, community transportation, among other projects. Other communities scarcely have a community leader. Organized communities would probably be the first to participate in changes to river resource management. In fact, the willingness to diversify turtle management on behalf of the Ministry of the Environment, will surely depend on the level of organization, interaction, and proactive turtle conservation behavior demonstrated by ribereño communities. Building trust between ribereños and the government officials will be essential if we are to move towards participatory conservation and sideneck turtle resource co-management.

To improve management of sideneck turtles in the Middle Orinoco, we must take steps towards consolidating ribereño life, livelihood, and sense of community. We recommend the following measures:

1) Foster interaction and organization between ribereño communities, and ribereño communities and officials from the Ministry of the Environment.

2) Consolidate communities by rebuilding houses with durable materials.

3) Formalize occupancy-based land rights on year-round and seasonal land, taking into account the dynamic character of river islands in the Orinoco (i.e.: distributing seasonal islands fairly and providing mechanisms for redistribution as new islands emerge and old ones change or disappear).

4) Promote flood-plain agriculture (food crops), with economic incentives (grants), cooperative training between ribereños, and distribution of tasks (land preparation, planting, harvest, and transportation and sale) among community members, as the primary source of income for the region.

5) Build lagoons for turtle ranching (and eventually, farming) in each community and remotely located household (dug out earth can be used to build and raise homes).

6) Assist ribereño communities in the development of rules, restrictions (gear, location, temporal), and access rights to Orinoco fisheries.

7) Encourage the creation of a special volunteer division within the National Guard dedicated to training operatives in wildlife management and protection.

8) Develop a region-wide volunteer sentinel program (anonymous phone-based, like community watch) where ribereños report to government

enforcement official illegal access of (newly) restricted fishing grounds by non-resident fishers.

9) Develop a spatial plan to define ribereño use restrictions and monitoring responsibilities along the Middle Orinoco.

10) Decrease river traffic (i.e.: use of river for long-distance transportation) by developing/rebuilding nearby terrestrial highways (like Caricara-Puerto Ayacucho) and increase public transportation on these highways.

11) Amend Venezuelan Endangered Species List to allow subsistence harvest of two juvenile arrau turtles per ribereño per season.

We believe following these recommendations will help consolidate Middle Orinoco communities and set forth a favorable environment for sustainable harvest of arrau, terecay, and galápago turtles.

Appendix A

GUIÓN DE ENTREVISTAS

Nombre del entrevistado: _______ Fecha: ____________
Edad: ___ Sexo: ______ Lugar: ____________
Foto número: Digital: Película: Código I: Código II:

CONSENTIMIENTO

Mi nombre es Claudia Peñaloza, soy estudiante y estoy haciendo mi pasantía. Quiero investigar que piensa la gente del Orinoco sobre las tortugas y la finalidad de mi trabajo es saber que se tiene que hacer para que la gente de por aquí siempre tenga tortugas. Le preguntaré sobre su comunidad, su familia, como se gana la vida, cuanta tortuga come, cuanta tortuga hay ahorita y que piensa sobre su conservación. La entrevista dura más o menos media hora y no esta bajo ninguna obligación de hacerla. Además, no tiene que contestar todas las preguntas y puede parar la entrevista cuando quiera. Si me da permiso, quisiera grabar la entrevista para luego pasar en limpio sus respuestas y que no se me olvide nada. Solo yo escucharé las grabaciones y las borraré en cuanto las pase en limpio. Al terminar la entrevista puede cambiar cualquier respuesta que quiera y puede decidir si quiere o no darme permiso de utilizar su entrevista en mi investigación. Quiero aclararle que sus respuestas son confidenciales y su nombre no se guardará junto con sus respuestas.

¿Quiere hacerme preguntas sobre mi investigación?

Si tiene alguna otra pregunta, puede llamar a mi tutor en Caracas, Guillermo Barreto. El podrá ayudarle con cualquier otra inquietud que usted tenga sobre mi investigación. Además, si me quiere hacer mas preguntas, me puede encontrar en Las Viviendas en

Puerto Páez (al lado de Don Luis Tovar), hasta medidos de Junio. Tome mi tarjeta que tiene mi número de teléfono y el de mi tutor.

¿Tiene alguna pregunta sobre la entrevista?

¿Quiere participar en mi investigación?

¿Puedo grabar la entrevista?

Voy a empezar a grabar. Le volveré a preguntar algunas cosas para que queden grabadas y luego comenzaré la entrevista. Mientras estemos grabando, por favor no diga su nombre. Recuerde que puede dejar de contestar cualquier pregunta y puede parar la entrevista cuando quiera. ¿Está listo?

Comienzo a grabar

¿Tiene alguna pregunta sobre la investigación que estoy haciendo?

¿Quiere participar?

¿Puedo utilizar sus respuestas en mi trabajo?

Comienza la entrevista

Código I: _____

I. Estructura comunitaria:

1. ¿A cuál comunidad pertenece usted?
2. ¿Quién mas pertenece a esta comunidad? (¿Cuánta gente? ¿Dónde están?)
3. ¿Existen Cooperativas o Consejos en esta comunidad? ¿Usted es parte de ellos?
4. ¿Hay un líder comunitario?
5. Cuando hay conflictos dentro de la comunidad, ¿cómo los resuelven? (ejemplos: ganado robado, le perro del vecino se comió sus gallinas, se soltaron los cochinos del vecino en su vega).

II. Modo de Vida:

1. ¿Dónde nació? ¿Hace cuanto tiempo vive aquí?
2. ¿Porque vino a vivir aquí? ¿Tiene más familia aquí?
3. ¿Está casado? ¿Tiene hijos? ¿Cuántos?
4. ¿Quién vive en su casa?
5. ¿Cómo se gana la vida?
6. ¿Donde pesca/caza/cosecha? ¿Qué? ¿Cuándo? ¿Lo vende?
7. ¿Su familia gana suficiente dinero?
8. ¿Le gusta como vive?
9. ¿Qué le hace falta para mejorar su vida? ¿Para vivir más cómodo?

Código II: _____

III. Costumbres alimentarias y consumo de tortugas:

1. ¿Cuál presa le gusta más?
2. ¿De donde la saca?
3. ¿Con que frecuencia come presa? ¿Es suficiente? Si no, ¿porqué no?
4. ¿Su familia come tortuga? ¿Qué tanto? ¿La ha vendido alguna vez? ¿La ha comprado?
5. ¿Por qué no come más tortuga?
6. ¿Cuánta tortuga comería usted si hubiese mucho? ¿Y el resto de la gente?
7. ¿Cómo le gusta cocinada la tortuga?
8. ¿Sabe si en esta comunidad hay gente que vende tortuga? ¿A quien se la vende?
9. ¿Por aquí se encuentra Terecay?

IV. Abundancia de Tortugas:

1. ¿Cómo ha cambiado la cantidad de tortugas… hace 5, 10, 25, 50, >50 años?
2. ¿Por qué ha cambiado?

V. Programa de Conservación:

1. ¿Qué significa la conservación para usted?
2. ¿Quién cree usted que debe cuidar la fauna?
3. ¿Usted conoce las Leyes Ambientales de Venezuela? ¿Cómo las afectan a usted?
4. ¿Usted conoce el programa de conservación de Ambiente aquí en Sta. María?
5. ¿Qué opina sobre este programa de conservación?
6. ¿Usted recomendaría algún cambio? ¿Cuál?

7. ¿Se siente involucrado en este programa?
8. ¿Le gustaría ayudar con la conservación de la tortuga? ¿Cómo?
9. ¿Cree que puede haber un programa de conservación de tortugas en su comunidad? ¿Cómo sería? ¿Quién participaría?

Después de finalizar la entrevista, pero antes de apagar la grabadora

¿Quiere cambiar alguna respuesta que me dio?
¿Aún puedo utilizar sus respuestas en mi trabajo?
Si me da permiso, quisiera tomarle una foto para guardar junto a su nombre en mis archivos. La foto no será ligada de ninguna manera a las respuestas que me dio durante la entrevista. Si me da permiso, utilizaré la foto para hacer presentaciones en la Universidad sobre mi investigación y quizá para buscar mas fondos para seguir mi pasantía. Si quiere, cuando regrese a (nombre del pueblo) le daré una copia de la foto para que usted se la quede.
¿Puedo tomarle una foto para mis archivos?
¿Puedo utilizar su foto en mis presentaciones?
¿Quiere que le dé una copia de su foto?

Apago la grabadora

¿Hay alguna respuesta de su entrevista que no quiere que utilice?
Muchísimas gracias por ayudarme en mi investigación.

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BIOGRAPHY

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SELECTED PUBLICATIONS

Peñaloza, C. *In press*. Recovering the giant South American river turtle (*Podocnemis expansa*): What will work? Turtle and Tortoise Newsletter.

Martínez, E. O., O. E. Hernández, E. O. Boede, C. Peñaloza, and A. Rodríguez. 2007. Inverntario de la tortuga arrau, *Podocnemis expansa* (Schweigger, 1812) en zoológicos de Venezuela. Valores referenciales del hemograma y la bioquímica sérica. Revista Científica **XVII**:433-440.

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GRANTS AND AWARDS
2008, 2007 - Center for Marine Conservation, Dissertation Research Grant, $3,650.
2008, 2003, 2000 - Idea Wild, Conservation Project Equipment Grant, ~$3,220.
2008, 2007 - Oak Foundation, Dissertation Research Grant, $3,650.
2007 - Chelonian Research Foundation, Linnaeus Fund Research Award, $2,000.
2005 - Pittsburgh Zoo & PPG Aquarium Conservation Fund, Research Grant, $2,500.
2003 - 2005 Honors: Fulbright-OAS Scholarship, Ecology, ~$80,000
2003 - Lincoln Park Zoo Field Conservation Fund, Research Grant, $4,000.
2003 - Centro Internacional de Ecología Tropical, Conservation Project Award, $690.
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1999 - EcoNatura, Conservation Project Grant, $500.

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