To my hubby, mami, papi, y hermanita
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The Amazon River dolphin (*Inia geoffrensis*), or boto, has shared the same aquatic resources and space with fishers for thousands of years. In the last decades, due to human population expansion, growing markets, and technological advancements, interactions between botos and fishers have increased substantially. Since the mid-1990’s, botos are being harvested to be used as bait to fish the catfish *Calophysus macropterus*. To meet growing demands for this food fish in Colombia and Brazil, the harvest has spread throughout the Amazon and poses a considerable threat to the species. The overall objective of my dissertation was to use an interdisciplinary approach to identify conservation strategies for the boto with a specific focus on determining if protected areas (PAs) could be an effective tool.

The Mamirauá Sustainable Development Reserve (MSDR), in the Brazilian Amazon, served as a focal area for my research. I first determined the effect of illegal harvest on boto survival. Then, I explored fisher attitudes and behaviors toward botos to determine the effect, if any, of the MSDR on fisher-boto interactions. Next, I...
investigated boto habitat use and movement patterns. Finally, I developed a model to determine the effect of the MSDR on boto abundance and to evaluate potential PA design improvements. Major findings included: 1) the current harvest level in the study area is likely unsustainable, 2) the MSDR has promoted positive attitudes toward the boto and, in some areas, may have limited the harvest by means of local enforcement, 3) based on boto movement patterns, and the presence of the MSDR initiatives, expanding the PA boundaries and programs could lead to boto population increase.

These findings support the conclusion that, under stringent circumstances, PAs could be an effective strategy to conserve botos. In the case of the MSDR, expanding the boundaries to include river habitat adjacent to the floodplain would provide a sanctuary for botos during the low water season. Moreover, community-based research, ecotourism, and enforcement programs would need to be expanded along with the boundaries. By meeting these criteria, the MSDR could prevent the decline of the local boto population.
CHAPTER 1
INTRODUCTION

The Amazon River dolphin, or boto (*Inia geoffrensis*), has coexisted with fishers in the Amazon basin for thousands of years. Low human population densities, primitive fishing gear, and the prevalence of subsistence economies throughout the river basin are factors that have likely contributed to the persistence of the boto. However, the Amazonian environment has been shifting quickly and growing economic forces are exerting pressure on terrestrial and aquatic resources in unprecedented ways. As Amazonian residents have become more integrated into market-based economies, wildlife has become a quick source of cash (Sierra et al., 1999). Many Amazonian wildlife species have become threatened by local hunting (Bodmer et al., 1997; Peres, 2000) and the boto is no exception (da Silva et al., 2011; Mintzer et al., 2013).

Illegal killing for use as bait has become the primary threat affecting botos. Since the mid-1990s, boto carcasses have been used to attract the catfish *Calophysus macropterus* commonly known as *piracatinga* in Brazil and *mota* in Colombia (da Silva et al., 2011; Gómez et al., 2008; Gómez-Salazár et al., 2012; Loch et al., 2009; Portocarrero Aya et al., 2010a; Shostell and Ruiz-Garcia, 2010; Trujillo et al., 2010b, 2010c). Demand for *mota* has grown in Colombia in the last decade because it is acting as a replacement for another catfish known as *capaz* (*Pimelodus grosskopfii*) that was overfished from Colombia’s Magdalena River. Consequently, an international market has emerged involving the catch of *mota* in Brazil (and recently Venezuela, Ecuador, and Peru) and the export of this food fish to Colombia and a few large Brazilian cities. Although little is known about the extent and intensity of the boto harvest, we know that
it occurs in at least twelve locations in four out of the five Amazonian countries with *mota* fisheries (Diniz, 2011).

Protected areas (PAs) are a key conservation tool in the Amazon (Peres, 2005). At present, however, there are no PAs aimed specifically at protecting botos, although populations do occur in PAs throughout their range (e.g., Santos Luzardo National Park in Venezuela, Pacaya-Samiria National Reserve in Peru, Noel Kempff Mercado National Park in Bolivia, Cuyabeno Wildlife Production Reserve and Yasuní National Park in Ecuador, and the Mamirauá Sustainable Development Reserve in Brazil; Aliaga-Rossel, 2002; da Silva and Martin, 2000; McGuire and Winemiller, 1998; Utreras et al., 2010). To address this apparent deficiency, the Whale and Dolphin Conservation Society is coordinating with aquatic mammal and conservation scientists in South America to establish the South American River Dolphin Protected Area Network (SARDPAN). The network includes over 30 protected areas, in six South American countries, that could, in theory, help protect botos from the illegal harvest (Portocarrero et al., 2010b; <http://sardpan.wordpress.com/protected-areas/>).

Currently, however, there is very limited information on if and how PAs can be a successful strategy for the conservation of botos. Moreover, the extent, impact, and drivers of the illegal harvest are poorly understood. Key questions that need to be addressed to carry out successful conservation initiatives include: What is the impact of the harvest on the boto? Is the harvest sustainable? Are PAs effective in reducing harvest rates within their boundaries? If so, how is this achieved? What are the drivers of the harvest? What aspects of river dolphin biology and ecology need to be taken into account when establishing PAs? Answers to these questions are most appropriately
pursued through an interdisciplinary perspective that considers social and ecological components (Gunderson and Holling, 2002; Oakerson, 1992; Ostrom, 2007; Ostrom et al., 2007). By considering various elements of the social-ecological system that surround the harvest and emphasizing the importance of both botos and fishers, I aim to answer these questions in a holistic manner.

My study takes place in the Mamirauá Lake System (MLS) located in the southern segment of the Mamirauá Sustainable Development Reserve (MSDR) and surrounding areas (Figure 2-1). The MSDR is an International Union for the Conservation of Nature (IUCN) Category VI protected area in the Brazilian Amazon. It is recognized by the Ramsar Convention and is considered a World Heritage site by the United Nations Educational, Scientific, and Cultural Organization. The MSDR consists of a focal area of about 260,000 hectares, where management efforts are in place, and a subsidiary area of approximately 864,000 hectares (Koziell and Inoue, 2006). It was established in 1996 with the aim of combining biodiversity conservation and sustainable resource use, with the active participation of local human populations (SCM, 1996). The MSDR consists mostly of floodplain habitat or várzea and is recognized as important habitat for a boto population that has been studied continuously since 1994 (da Silva and Martin, 2000; Martin and da Silva, 2004a, 2004b). Regardless of the PA status afforded by the MSDR, this boto population has been subject to illegal harvest for bait since approximately 2000 (da Silveira and Viana, 2003; Estupiñán et al., 2003).

In Chapter 2, I examine the effect of the harvest on survival of the boto population occurring in and near the MSDR. Using mark-recapture modeling, I compare survival probabilities of the pre-harvest and harvest periods to quantify the impact of the
harvest on the boto population. In Chapter 3, I explore the human dimensions of the harvest by assessing attitudes and behaviors of fishers toward the boto population. I investigate various aspects of fisher-boto interactions, including types and frequencies, and assess whether the MSDR is limiting the boto harvest. In Chapter 4, I evaluate boto movement patterns and home range sizes by using a combination of mark-recapture and spatial analyses tools. By determining linear home ranges, core use areas, and seasonal movement patterns, I am able to identify essential habitat for the population and define how botos use the MSDR. Finally, in Chapter 5, I develop a population model to determine the effectiveness of the MSDR in protecting botos and evaluate various PA scenarios to identify potential improvements. Together, the results of these studies will help inform conservation initiatives aimed at protecting Amazon River dolphins.
CHAPTER 2
EFFECT OF ILLEGAL HARVEST ON APPARENT SURVIVAL OF AMAZON RIVER
DOLPHINS (INIA GEOFFRENSIS)

Background

Interactions with fisheries, mostly through incidental capture in fishing gear but also through targeted harvesting are recognized as a key threat to aquatic mammal populations (Clapham and Van Waerebeek, 2007; Costello and Baker, 2011; Jefferson and Curry, 1994; Mangel et al. 2010; Northridge and Hofman, 1999; Perrin et al., 1994; Read, 2008; Read et al., 2006; Robards and Reeves, 2011; Vidal, 1993). Perhaps the least well quantified aspect of aquatic mammal–fisheries interactions is the harvesting of mammals for use as bait, a practice affecting at least 38 species of aquatic mammals worldwide (Diniz, 2011). Direct harvest of aquatic mammals for this purpose is considered an illegal activity in many nations where it takes place; hence, the prevalence of this illicit practice and subsequent impact has proved challenging to quantify. Most studies on the issue only provide information on where the illicit harvest occurred without related data on intensity, duration, or effects of the harvest (Diniz, 2011). However, in a limited number of cases where such ancillary data has been provided, findings suggest illegal harvests for bait may have considerable impacts on targeted populations (e.g., da Silva et al., 2011; Manzur and Canto, 1997; Sinha, 2002).

The Amazon River dolphin (*Inia geoffrensis* de Blainville, 1817), or boto, has been harvested for use as bait in the fisheries for the catfish known as *piracatinga,*
mota, simi, zamurito or mapurite (*Calophysus macropterus* Lichtenstein, 1819) (da Silva et al., 2011; Gómez et al., 2008; Gómez-Salazár et al., 2012; Loch et al., 2009; Portocarrero Aya et al., 2010a; Shostell and Ruiz-Garcia, 2010; Trujillo et al., 2010b, 2010c). During the last decade, demand for *C. macropterus* has grown in Colombia as other species of catfish once popularly consumed in the country have been overfished (Gómez et al., 2008; Petrere et al., 2004; Trujillo et al., 2010b). In fact, demand is such that an international market has emerged with Brazil, Venezuela, Peru, and Bolivia, all contributing to the export of this food fish to Colombia, where it is often sold under the name *capaz*, one of the depleted catfish species from the Magdalena River (Diniz, 2011; Gómez et al., 2008; Trujillo et al., 2007, 2010b). More recently, consumption of *C. macropterus* has also gained popularity in a few Brazilian cities where it is marketed as douradinha, a “new” species of food fish (da Silva et al., 2011; Trujillo et al., 2010b). Thus, although the boto is considered the least endangered of the river dolphins (Inioidea and Platanistidae; Leatherwood and Reeves, 1994; Smith and Smith, 1998), the demand for *C. macropterus* and related harvest of boto for bait raises substantial concern.

At present, harvest of botos for bait is known to occur in at least twelve locations in four of the five Amazonian countries with *C. macropterus* fisheries (Diniz, 2011), including in and around the Mamirauá Sustainable Development Reserve (MSDR) upriver of the Brazilian town of Tefé. Although the harvest in this region may have started as early as the mid-1990s, the first cases in MSDR were documented in 2000 (da Silveira and Viana, 2003; Estupiñán et al., 2003). Using *C. macropterus* landings data from Tefé, da Silva et al. (2011) estimated that roughly 1650 botos are killed in the
area per fishery season. Moreover, the same authors reported a 10% average annual
decline in boto abundance in one of the MSDR’s main channels beginning in 2001, a
trend coincident with the first documented occurrence of the illegal harvest. These
findings highlight the need to further explore the impact of harvesting for bait on the boto
population.

Herein, we provide estimates of apparent survival for the boto population
occurring in and around the Mamirauá Lake System (MLS) at the southern edge of the
MSDR. Using mark-recapture/resighting models, we explore changes in survival
between periods of varying harvest pressure. We expected that survival estimates prior
to the documented start of the harvest, i.e. 1994–2000, would be greater than estimates
for the more recent period for which data were available, i.e. 2000–2011. Additionally,
we compared survival between the sexes, with the expectation that survival of males
would be significantly lower than that of females, based on differences in morphology
and behavior. Males are larger (55% heavier and 16% longer than females), exhibit high
levels of intermale aggression (Martin and da Silva, 2006), and show preference for
river habitat outside the protected area boundary (Martin and da Silva, 2004b).

Methods

Study Area
All data were collected in and around the MLS located at the confluence of the Solimões
and Japurá rivers, 20 km upriver of Tefé in Amazonas State, Brazil (Figure 2-1). The
study area straddles the southern edge of the MSDR. Typical of whitewater floodplain or
várzea habitat, the MLS has numerous channels and lakes and a diverse fish fauna that
varies seasonally in response to water fluctuations. During May and June, water levels
rise 11–15 m and the MLS is completely flooded. Lowest water levels typically occur
between September and November. These water fluctuations determine what habitats are available for the boto population. While botos may be restricted to the deepest channels and lakes during the low water months, they may swim freely and enter submerged forest at high water. Previous estimates suggest approximately 260 botos occur in or near the 225 km² MLS year-round (Martin and da Silva, 2004a, 2004b). Half of these individuals exhibit strong site fidelity to the study area, while others are considered transient and visit for shorter periods (Martin and da Silva, 2004a).

**Capture and Recapture/Resight**

Our capture–recapture and resight data spans 17 years (January 1994 – November 2011). These data were collected through Projeto Boto, a river dolphin research program in the MSDR. Capture–recapture and marking of botos occurred approximately 3 weeks each year. With few exceptions, we captured botos with seine nets during low water at the entrance of the MLS. When captured, we freeze-branded botos with a unique code in areas allowing for maximum contrast and visibility (usually the dorsal fin and flank). When previously marked botos were captured, we recorded their code and rebranded the individual if necessary. Further description of capture procedures is available in da Silva and Martin (2000) and Martin et al. (2006). These data were collected with the approval of the Instituto Chico Mendes de Conservação da Biodiversidade (Sistema de Autorização e Informação em Biodiversidade #13462-1).

In addition to the capture–recapture events, we conducted year-round observational work to provide resightings between capture events. We conducted sighting surveys throughout the MLS and surrounding areas, including segments of the main rivers. Due to varying water levels, we did not evenly distribute effort across the entire study area. Most areas, however, were surveyed at least once per week by 2–3
observers from a 4 m skiff. We included additional sightings from other platforms, such as the Projeto Boto floating laboratory. When a marked boto was sighted, we recorded its unique code and our percent confidence in the identification (ranging from 50% to 100%, but normally 100%). Since 1999, an average of almost 1500 h of observational work has been conducted each year with an increasing trend over time (Figure 2-2).

Survival Model Selection and Data Analysis

We estimated apparent survival of the marked population with the Barker model (Barker, 1997, 1999) in Program MARK (White and Burnham, 1999). This model allows for physical capture–recapture during discrete primary periods, and continuous resighting data during secondary periods (the intervals between primary periods). We created capture histories for marked individuals captured between 1994 and 2011, using resightings made with 100% confidence. We coded for uneven time intervals by scaling 365 days to equal an interval of length 1. Program MARK estimates seven parameters for the Barker model (Table 2-1) (White and Burnham, 1999). As resightings did not occur over the entire geographic range of the study population, we estimated apparent survival ($\phi$), which includes the effects of emigration ($\phi = \text{true survival} \times (1 - \text{probability of emigration})$). We transformed real parameter values [0,1] to $\beta$-values [-$\infty$,+$\infty$] with the sin-link or logit-link function for numerical optimization. We used simulated annealing for optimization due to a prior simulation that identified problematic likelihood surfaces leading to convergence failures when using the Newton-Raphson method with the Barker model.

The Barker model is heavily parameterized; hence, we made a priori assumptions on how to treat $p$, $r$, and $R$ (Table 2-1). We fixed $r$ as a time-independent
(. parameter because we had few dead recoveries (only 12 marked carcasses were found during the study period) and therefore lacked sufficient data to inform time-dependent estimates. We defined R and R′ as time-dependent parameters to allow for changes in observation effort through time (Figure 2-2). Both of these parameters were allowed to vary between 3-year intervals (3y) to reduce the parameter count. Capture probability (p) was treated as a time-dependent parameter (t) because we expected p to vary according to the environmental conditions of each capture expedition. We created a series of models that allowed φ, F, and F′ (Table 2-1) to vary with time dependence (t) or independence (.). We also built models that allowed φ and F to vary according to sex (G). Additionally, because the illegal harvest of botos in the MSDR started approximately in 2000, we created models where φ was allowed to vary between two periods: 1994–2000 (i.e., pre-harvest) and 2000–2011 (i.e., harvest). The data were partitioned on November 20, 2000, the last day of the 2000 capture expedition.

We conducted a median ĉ goodness-of-fit test on the global model ϕ(G*t)p(G*t)r(G*t)R(G*t)R′(G*t)F(G*t)F′(G*t) to assess overdispersion (White and Burnham, 1999). We then applied the estimated ĉ (variance inflation factor) to the model set. Values that do not fall within \(1 \leq \hat{c} \leq 4\) indicate a structural lack of fit (Burnham and Anderson, 2002). We used Akaike’s Information Criterion (AIC) values to rank models (Akaike, 1973). Lower AIC values indicate models that better explain the variation in the data with maximum parsimony (Taper et al., 2008). Because we applied the estimated ĉ to our model set, we used the small-sample, ĉ -corrected version of AIC, QAICc, for model ranking. Models with QAICc values that differed by less than 2 were considered equal (Burnham and Anderson, 2002, 2004). We tested for a
significant difference between apparent survival estimates corresponding to different
time periods and sex by examining the 95% confidence intervals (CIs) of the φ β-values
representing the time or sex effect (if the 95% CIs of the β-value did not include 0.0, a
significant effect was determined at the α = 0.05 level).

Results

We uniquely branded 528 botos (256 females and 272 males). Excluding botos
first marked in 2011, we resighted 87.71% of females and 88.93% of males at least
once. We recaptured an average of 25.56 (±17.90 SD) branded individuals each year
(Figure 2-3). The median c goodness-of-fit test resulted in c = 1.162, well within the
acceptable range, and we adjusted all model results with this value. QAICc strongly
supported a model with fully time-dependent survival estimates (Table 2-2; Model 1).
This model estimated a significant difference in F by sex, with estimates of φ = 0.808
(SE = 0.051) for females and φ = 0.706 (SE = 0.064) for males (Table 2-2; Model 1).
Capture probability (p) varied considerably between years, with an average of p =
0.253. This model suggested declining apparent survival through time, with an average
annual apparent survival of 0.912 over the study’s duration (Figure 2-4). When
estimating apparent survival separately for the pre-harvest and harvest periods, we
found a significant difference (pre-harvest: φ = 0.968, SE = 0.009; harvest period: φ =
0.899, SE = 0.007) (Table 2-2; Model 5; Figure 2-5).

The model including sex as a group attribute of survival (Table 2-2; Model 8)
estimated a non-significant difference in annual apparent survival between females (φ =
0.919, SE = .008) and males (φ = 0.904, SE = 0.009). Moreover, no significant
difference was found between apparent survival of females and males for the pre-
harvest (females: $\phi = 0.973$, SE = 0.011; males: $\phi = 0.963$, SE = 0.014) or harvest period (females: $\phi = 0.906$, SE = 0.009; males: $\phi = 0.891$, SE = 0.010) (Table 2-2; Model 6).

Discussion

Model Performance

The Barker model fit the data well ($\hat{c} = 1.162$) and accounted for variable sighting effort with time-dependent estimates of the resighting parameter, $R$. Although botos are known to occasionally emigrate from the study area for several years, it is unlikely this temporary emigration induced a major negative bias in apparent survival estimates as the Barker model is robust to emigration due to its parameterizations (Barker, 1997; Horton and Letcher, 2008). Additionally, the $\hat{c}$ value near 1 suggested a lack of major model assumption violations.

Survival Estimates

Our results indicate that annual apparent survival significantly decreased by 0.069 after the documented start of the harvest. The apparent survival estimate of 0.968 for the pre-harvest period is consistent with boto life history, which is characterized by traits associated with high annual survival such as slow maturation and birth intervals of approximately 3 years (da Silva, 2008). This apparent survival estimate is comparable to survival estimates of non-harvested populations of *Tursiops truncatus* (Speakman et al., 2010), *Tursiops aduncus* (Mansur et al., 2012), and *Orcinus orca* (Matkin et al., 2012) which range from 0.951 to 0.990. However, annual apparent survival estimates for the full study duration ($\phi = 0.912$) and for the harvest period ($\phi = 0.899$; SE = 0.007)
are lower than most published survival estimates of other odontocetes, suggesting a negative effect of harvest on the population.

We did not expect equal apparent survival between the sexes. The species is sexually dimorphic, and males exhibit corresponding high levels of intermale aggression that may lead to life threatening injuries (Martin and da Silva, 2006). Furthermore, when a wide range of habitats is available during high water, females show preference for várzea habitats within the MLS, while males are found more frequently in the main rivers outside of the protected area boundary (Martin and da Silva, 2004b). Thus, in theory, males are at a higher risk of being harvested because they spend more time outside protected waters. For these two reasons, we expected lower apparent survival in males. It is possible the harvest is exerting selective pressure on females (if, for example, females are easier to catch), and increasing mortality of females to the extent that survival of females and males have equalized. However, our results did not show a significant difference between male and female apparent survival during the pre-harvest period, suggesting that similar survival probability between the sexes is a natural characteristic.

**Significance of the Harvest and Conservation Implications**

Assuming declines in apparent survival were due to lethal as opposed to sub-lethal effects (e.g., changes in behavior), the results indicate that mortality of the study population more than doubled between the two time periods. Dividing the harvest period apparent survival estimate by the pre-harvest period estimate, we calculate a reduction in survival corresponding to an annual harvest rate \( h \) of 0.071. The Potential Biological Removal (PBR) method, commonly applied to cetaceans, calculates the level of mortality that will inhibit a stock from reaching or maintaining its optimum sustainable
population (Wade, 1998). According to the PBR approach, the maximum allowable
harvest rate ($h_{\text{max}}$) is equal to $1/2R_{\text{max}}$ (Dillingham and Fletcher, 2008), where $R_{\text{max}}$ is
defined as the maximum annual recruitment rate (Wade, 1998). If we apply an $R_{\text{max}}$ of
0.04, the default value used for cetaceans (Wade, 1998), the $h_{\text{max}}$ would equal 0.02, a
value about three times smaller than our estimated $h$. If we apply a higher $R_{\text{max}}$ value of
0.06 (theoretically possible in odontocetes with high survival, Reilly and Barlow, 1986;
Wade, 1998), the estimated $h$ is still more than double the $h_{\text{max}}$ of 0.03 calculated by the
PBR rule. This comparison suggests the current harvest rates exceed conservation
limits commonly applied to cetaceans and could lead to depletion of the population
(Dillingham and Fletcher, 2008).

It is possible that factors other than illegal harvest could explain, in part, declines
in boto survival. Throughout its geographic range, dam construction, pollution,
entanglement in fishing gear, habitat degradation, boat traffic, and depleted prey
resources have been identified as important anthropogenic threats to the species (Best
and da Silva, 1989a; 1993; da Silva and Best, 1996; Gómez-Salazár et al., 2012;
Leatherwood and Reeves, 1994; Martin et al., 2004; McGuire and Aliaga-Rossel,
2010a; Portocarrero Aya et al., 2010a; Reeves and Leatherwood, 1994; Rosas and
Lehti, 1996; Smith and Smith, 1998; Trujillo et al., 2010b, 2010c; Utreras et al., 2010;
Vidal, 1993). However, due to the location of the study, we suggest that aside from
illegal harvest, only entanglement in fishing gear is likely to substantially affect mortality
of the study population.

Although incidental mortality in fishing gear has not been studied in most areas in
the Amazon, it is known that seine nets and gillnets pose a significant threat to botos
(e.g., da Silva and Best, 1996; Leatherwood and Reeves, 1994). In the central Amazon, the lampara seine is the most lethal type of net for botos and accounts for over 80% of deaths caused by entanglement (da Silva and Best, 1996). Many of the boto carcasses recovered by Projeto Boto during the study period showed evidence of entanglement (da Silva and Martin, 2010; Martin et al., 2004). Furthermore, observations suggest fishers kill botos intentionally because they regard them as competitors, and because botos cause damage to fishing nets (da Silva and Best, 1996; da Silva and Martin, 2010; Loch et al., 2009). The number of artisanal and commercial fleets in the study region has remained relatively stable in the last two decades after experiencing a period of fast growth in the 1970s and 1980s (Almeida et al., 2003; Barthem, 1995; Best and da Silva, 1989a). Thus, although fishery interactions other than boto harvest for bait are likely causes of additive mortality for our study population (Martin et al., 2004), there is no indication that such interactions have increased considerably since the onset of this study, and are therefore not likely to explain the decrease in apparent survival.

However, this threat should be carefully considered in conservation and management plans, as it was the primary cause of the functional extinction of the Yangtze River dolphin (Turvey et al., 2007) and changes in the size, gear, or techniques of Amazonian fishing fleets could lead to considerable increases in boto mortality.

The significant decline in apparent survival estimated in this study suggests a need for conservation measures aimed at decreasing the boto harvest. Currently, two main tools are in place that should aid in the protection of the study population. First, the boto is protected by Brazilian federal laws, predominantly Law 7.643 (1987) that makes it illegal to kill or harass cetaceans in jurisdictional waters. However, enforcement of
The second major conservation mechanism is the partial spatial protection provided by the MSDR. Although the MSDR was not created with the specific purpose of protecting river dolphins, the reserve includes important river dolphin habitat. To our knowledge, the harvest does not occur in the section of our study area that falls within the MSDR (Figure 2-1). Our results indicate that both females ($F = 0.808; \text{SE} = 0.051$) and males ($F = 0.706; \text{SE} = 0.064$) exhibit high fidelity to our study area; therefore, the protected area should function by protecting the population at least part of the time (primarily during rising water when botos enter the várzea, Martin and da Silva, 2004b). If the MSDR did not exist, it is likely the mortality of our study population would have been higher in the harvest period. Nevertheless, our results imply that the spatial protection in our study area, with its current design and state, may not be sufficient in and of itself to protect this population.

Marine protected areas have been shown recently to be effective in increasing survival rates of small cetaceans by reducing fishery–dolphin interactions (Gormley et
al., 2012). These findings suggest that properly designed protected areas in the Amazon basin might translate into similar benefits for river dolphins. As proposed by the South American River Dolphin Protected Area Network (SARDPAN), protected areas created or improved explicitly for river dolphin conservation could have the potential to reduce the impact of fishery–river dolphin interactions, as well as help conserve vulnerable freshwater habitats largely underrepresented in South American protected areas (Portocarrero Aya et al., 2010b). Although much remains to be understood about river dolphin ecology, several studies have provided valuable information on boto habitat preference and movement that could prove useful in designing new protected areas or improving existing ones (e.g., Gómez-Salazár et al., 2012; Leatherwood et al., 2000; Martin and da Silva, 2004a, 2004b; Martin et al., 2004; McGuire and Henningsen, 2007; McGuire and Winemiller, 1998). In our study site, for example, extending spatial protection to adjacent areas where botos aggregate (e.g., mouths of channels that connect to the main rivers), could benefit the study population. The effectiveness of new or enhanced conservation measures can be monitored and evaluated using the baseline survival estimates provided in this study.

Although improvements made to enforcement and spatial protection could prove to be beneficial, numerous challenges will have to be overcome to decrease boto harvest. With administrative boundaries being crossed, the remoteness of the harvest sites, and high economic incentives, both local and international action and cooperation will be required. Broad scale initiatives like the SARDPAN could facilitate the necessary international collaboration and the implementation of new and improved conservation mechanisms. Moreover, it is imperative that all drivers of the harvest be considered
when formulating solutions, including the troubling status of the preferred food catfish species in Colombia, as well as the socio-economic conditions of fishers at the harvest sites. With this in mind, solutions of varying scope and scale should be simultaneously explored. For example, while a widespread public education campaign to halt the trade and consumption of *C. macropterus* may be the focus of conservation efforts in Colombia (Trujillo et al., 2010c), more localized initiatives that educate fishers on existing legislation and alternative activities may prove successful at harvest sites (da Silva and Martin, 2010; Trujillo et al. 2010a).

Interviews with local fishers have revealed the potential economic importance of the *C. macropterus* fishery for families in the central Brazilian Amazon (da Silva et al., 2011). A skilled fisher can expect to catch anywhere from USD 500 to 1000 worth of *C. macropterus* with just one boto carcass in one night (da Silva et al., 2011), a substantial profit considering the low average annual income of people in the region. The use of alternative baits (Gómez et al., 2008; Trujillo et al., 2010a, 2010b, 2010c) may be an economically viable solution and encourage a shift away from the practice of harvesting botos. In the Ganges River system, for example, fish oil is an efficient and inexpensive fish attractant substitute for river dolphin (*Platanista gangetica*) oil (Sinha 2002). Furthermore, the role of river dolphins in ecotourism is being increasingly recognized throughout the Amazon (Portocarrero Aya et al., 2010b; Trujillo et al., 2010c), and in some locales, carefully regulated tourism activities could form an important link between boto conservation and economic development (Trujillo et al., 2010a, 2010c). Regardless of the corrective actions pursued to decrease the harvest, providing viable economic
alternatives for fishers is essential to ensure a smooth and more permanent transition away from the practice of harvesting botos.

**Conclusion**

The significant decrease in apparent survival of the study population is a serious concern and warrants the attention of natural resource managers. The issue likely extends beyond the study area as harvest of botos is known to occur throughout the Amazon basin, and the decline in boto survival could be mirrored in other locales. In areas without designated protection status, harvest levels are likely to be higher and survival lower than estimated in this study. A timely and transdisciplinary approach is needed to address all components of the intricate socio-ecological system that surround this illegal harvest.
Table 2-1. Barker joint data model parameter definitions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_i$</td>
<td>The probability that an animal alive at $i$ is alive at $i + 1$</td>
</tr>
<tr>
<td>$p_i$</td>
<td>The probability an animal at risk of capture at $i$ is captured at $i$</td>
</tr>
<tr>
<td>$r_i$</td>
<td>The probability an animal that dies in $i$, $i + 1$ is found dead</td>
</tr>
<tr>
<td>$R_i$</td>
<td>The probability an animal that survives from $i$ to $i + 1$ is resighted alive some time between $i$ and $i + 1$</td>
</tr>
<tr>
<td>$R'_i$</td>
<td>The probability an animal that dies in $i$, $i + 1$ without being found dead is resighted alive in $i$, $i + 1$ before it died</td>
</tr>
<tr>
<td>$F_i$</td>
<td>The probability an animal at risk of capture at $i$ is at risk of capture at $i + 1$</td>
</tr>
<tr>
<td>$F'_i$</td>
<td>The probability an animal not at risk of capture at $i$ is at risk of capture at $i + 1$ (this definition, as applied in Program MARK (White and Burnham, 1999), differs from the one provided in Barker (1997) in order to enforce internal constraints)</td>
</tr>
</tbody>
</table>

Table 2-2. QAICc table from Barker survival model results

<table>
<thead>
<tr>
<th>Model</th>
<th>QAICc</th>
<th>$\triangle$QAICc</th>
<th>QAICc Weight</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $\phi(t)F(G)F'(t)$</td>
<td>6097.76</td>
<td>0.00</td>
<td>0.71</td>
<td>69</td>
</tr>
<tr>
<td>2. $\phi(t)F(.)F'(t)$</td>
<td>6099.87</td>
<td>2.11</td>
<td>0.25</td>
<td>68</td>
</tr>
<tr>
<td>3. $\phi(t)F(t)F'(t)$</td>
<td>6105.55</td>
<td>7.79</td>
<td>0.01</td>
<td>84</td>
</tr>
<tr>
<td>4. $\phi(t)F(t)F'(.)$</td>
<td>6105.57</td>
<td>7.80</td>
<td>0.01</td>
<td>69</td>
</tr>
<tr>
<td>5. $\phi(94-00)(00-11)F(G)F'(t)$</td>
<td>6106.82</td>
<td>9.06</td>
<td>0.01</td>
<td>52</td>
</tr>
<tr>
<td>6. $\phi(G^*(94-00)(00-11)F(G)F'(t)$</td>
<td>6109.41</td>
<td>11.65</td>
<td>0.00</td>
<td>54</td>
</tr>
<tr>
<td>7. $\phi(.)F(G)F'(t)$</td>
<td>6128.11</td>
<td>30.36</td>
<td>0.00</td>
<td>51</td>
</tr>
<tr>
<td>8. $\phi(G)F(G)F'(t)$</td>
<td>6128.53</td>
<td>30.78</td>
<td>0.00</td>
<td>52</td>
</tr>
</tbody>
</table>

The parameter of primary interest was apparent survival ($\phi$). Time-dependence ($t$) and sex effect ($G$) were represented with the associated symbols. Parameters $p$, $r$, $R$, and $R'$ were fixed through a priori assumptions. Number of estimated parameters (K) is listed for each model.
Figure 2-1. Map of study site, the Mamirauá Lake System and surrounding areas, located at the junction of the Japurá and Solimões rivers in the southern segment of the Mamirauá Sustainable Development Reserve in Amazonas State, Brazil (GIS layers: IUCN and UNEP 2010; DCW and GADM downloaded from <http://www.diva-gis.org>).

Figure 2-2. Hours of observation work conducted in and around the Mamirauá Lake System to provide resight data of *Inia geoffrensis* between primary capture events. Effort from 1999 to 2009 is displayed showing an increasing trend over time. These sighting surveys were typically conducted by 2-3 observers from a 4m aluminum skiff, powered by a 15HP outboard motor.
Figure 2-3. Capture, recapture, and resight counts from 1994 to 2011 of *Inia geoffrensis* occurring in and around the Mamirauá Lake System. Capture counts (solid lines) displayed by sex represent the cumulative number of individuals marked. Approximately three weeks each year were dedicated to the capture-recapture and marking of botos. Observational work was conducted between primary capture events to obtain resighting data.
Figure 2-4. Apparent survival estimates for 1994-2011 for *Inia geoffrensis* occurring in and around the Mamirauá Lake System. Apparent survival estimates displayed were the results of the Barker model where \( \phi \) was treated as a fully time-dependent parameter: \( \phi(t)p(t)r(.)R(3y)R'(3y)(F(G)F'(t)) \).
Figure 2-5. Apparent survival estimates for the pre-harvest (January 1994 - November 2000) and harvest period (November 2000 - November 2011) for *Inia geoffrensis* occurring in and around the Mamirauá Lake System. These estimates were the results of the model: \( \phi(94-00)(00-11)p(t)r(.)R(3y)R'(3y)(F(G)F'(t)) \). The difference in apparent survival probability between periods was found to be significant at the \( \alpha = 0.05 \) level.
CHAPTER 3
AN EVALUATION OF THE INTERACTIONS BETWEEN FISHERS AND AMAZON RIVER DOLPHINS (INIA GEOFFRENSIS) IN A BRAZILIAN PROTECTED AREA: A HUMAN DIMENSIONS PERSPECTIVE

Background

Interactions with fisheries are considered a primary threat to cetacean populations worldwide (Clapham and Van Waerebeek, 2007; Costello and Baker, 2011; Hall and Donovan, 2001; Mangel et al., 2010; Northridge and Hofman, 1999; Read et al., 2006; Read, 2008; Robards and Reeves, 2011; Smith and Smith, 1998; Vidal, 1993). Through depletion of fish stocks (DeMaster et al., 2001), incidental capture in fishing gear (Read et al., 2006), and targeted harvesting (Costello and Baker, 2011; Robards and Reeves, 2011), fishing activities may increase cetacean mortality. Interactions are also potentially detrimental to fishers, who may experience financial losses in the form of gear or catch damage and depletion of fish stocks (Hall and Donovan, 2001). Every species of cetacean is likely to experience conflicts with fishers to some extent but a lack of data prohibits an assessment of the type, degree and effects of these interactions on many populations and fisheries (Northridge, 1984).

Although interactions between fishers and Amazon River dolphins, or botos (Inia geoffrensis de Blainville, 1817), likely date back thousands of years, they have not been studied in most areas of the Amazon. However, sufficient information does exist to describe the most common types of interactions and their negative effects. From the perspective of maintaining a viable boto population, the primary interaction of concern is the direct harvest of botos that has developed in the last two decades. Since around the mid-1990s botos have been harvested to be used as bait in the fisheries for the catfish known as piracatinga, mota, simi, zamurito, or mapurite (Calophysus
Macropterus Lichtenstein, 1819) (Brum, 2011; da Silva et al., 2011; Gómez et al., 2008; Gómez-Salazár et al., 2012; Loch et al., 2009; Pinto de Sa Alves et al., 2012; Portocarrero Aya et al., 2010; Shostell and Ruiz-Garcia, 2010; Trujillo et al., 2010a, 2010b). Although killing botos is illegal in most Amazonian countries, the practice appears to be increasing to meet growing demands for this food fish in Colombia and Brazil. Recent evidence suggests the harvest may be unsustainable in and around the Mamirauá Sustainable Development Reserve in the Brazilian Amazon (da Silva et al., 2011; Mintzer et al., 2013), where the harvest began approximately in 2000 (da Silveira and Viana, 2003; Estupiñán et al., 2003).

Aside from the direct harvest, entanglement in fishing gear is another interaction of concern. Previous studies have shown that botos may become entangled in seine nets and gillnets and consequently drown (Best and da Silva, 1989b; Best and da Silva, 1993; Brum, 2011; da Silva and Best, 1996; Iriarte and Marmontel, 2013; Leatherwood and Reeves, 1994; Martin et al., 2004). In the Central Amazon, da Silva and Best (1996) determined that lampara seine is the most lethal type of net for botos accounting for over 80% of fishery-caused deaths. Seines are commonly used along beaches, where botos take advantage of the net and use it as a wall to corral fish. If botos are foraging close to the seine when it is closed, they may become trapped in the net or purse. Gillnets appear to be less of a threat because botos can take fish from them without causing considerable damage to the net. If they do become entangled, most adults can tear free from a gillnet (da Silva and Best, 1996).

From the perspective of the fisher, several forms of interactions with botos are unfavorable. Botos may disrupt fishing operations and cause financial losses by
frightening fish, taking fish from nets, and becoming entangled (Best and da Silva, 1989b; Best and da Silva, 1993; da Silva and Best, 1996; Leatherwood and Reeves, 1994; Loch et al., 2009; Martin et al., 2004; Pinto de Sa Alves et al., 2012). Recent reports from the Brazilian Amazon suggest local fishers have negative attitudes toward boto, believing that it is “bad-tempered,” a competitor, and a threat to fishing operations (Iriarte and Marmonte, 2011; Iriarte and Marmontel, 2013; Loch et al., 2009; Pinto de Sa Alves et al., 2012). As a result, some fishers kill boto intentionally even though they will not use the carcass for bait (da Silva and Best, 1996; Loch et al., 2009).

Most fishery-cetacean interaction studies, including those on the boto, have focused on describing and quantifying the physical characteristics (i.e., gear type, seasonality, location) and degree or impact of the interactions on the cetacean (i.e., catch numbers, changes in demographic parameters) (e.g., Brotons et al., 2008; Díaz López, 2006; Lauriano et al., 2009; Mangel et al., 2010; Mintzer et al., 2013), with limited or no focus extended to the fisher attitudes and behaviors that may fuel these interactions. However, as with other natural resource conservation issues, this human-wildlife conflict is a combination of social, economic, and environmental factors, and solutions with realistic potential need to be informed by both biophysical and human dimensions research (McShane et al., 2011; Ostrom, 2007; Ostrom, 2009). Identifying and evaluating the human dimensions components may be especially important in the case of Amazon fisheries where enforcement is challenging (Peres and Lake, 2003; Peres and Terborgh, 1995) and human livelihoods are at stake (Batista et al., 1998; Bayley and Petrere, 1989; Gram et al., 2001).
In this study, we aimed to better understand the nature of fishery-boto conflicts from a primarily human dimensions perspective. Specifically, our main objectives were to determine the type and frequency of fishery-boto interactions, investigate attitudes and behaviors of fishers toward botos, and identify the factors that affect these attitudes and behaviors. Moreover, through these objectives we evaluated if and how the Mamirauá Sustainable Development Reserve (MSDR), a sustainable use protected area (PA) in the Brazilian Amazon, and related programs, has been effective in promoting positive fisher attitudes toward botos and the effect, if any, of these changes in attitudes on behaviors. In light of the harvest for botos, a pressing need exists to develop conservation strategies that address conflicts between fishers and botos, and understanding fisher attitudes and behaviors toward botos will be essential in formulating successful conservation tactics and improving existing ones.

**Methods**

**Study Setting**

**The Mamirauá Sustainable Development Reserve**

We conducted this study in communities and towns located in or in close proximity (≤31km) to the southern segment of the MSDR. The MSDR is located at the intersection of the Solimões and Japurá rivers in the Brazilian state of Amazonas approximately 30 km upstream of Tefé (Figure 3-1). The MSDR is located within a floodplain, or várzea, with water levels typically ranging 10-15 meters seasonally. It is comprised of a focal area of about 260,000 hectares, where management efforts are in place, and a subsidiary area of approximately 864,000 hectares (Koziell and Inoue, 2006).
The MSDR was established in 1996 as the first Reserva de Desenvolvimento Sustentável (Sustainable Development Reserve, SDR) in Brazil, a category of PA with the objective of reconciling the conservation of nature and economic development (<http://www.mma.gov.br>). According to the SDR mandate, inhabitants of SDRs should actively participate in management decisions and in the monitoring of the SDR. Currently, there are nine administrative zones in the focal area of the MSDR, each of which has a local coordinator who is responsible for organizing regular meetings to discuss management issues. General meetings are held annually and are the vehicle through which decisions are voted on. This model of community participation was chosen by the MSDR residents (SCM, 1996).

The main institution responsible for the management of the MSDR is the Mamirauá Sustainable Development Institute (MSDI), an entity of the Brazilian Ministry of Science, Technology, and Innovation, that was established in 1999. The MSDI’s main goals are the protection of ecosystems, the conservation and sustainable use of natural resources, and the sustainable development of local populations. Specific programs facilitated by the MSDI include: Management of Agroecosystems, Community Management, Fishing Management, Community Forest Management, Quality of Life, and Community-based Tourism (visit <http://mamiraua.org.br> for program details).

Most current inhabitants of the MSDR are considered caboclos, a term used to describe the Brazilian Amazonian peasantry (Lima, 2009). As of 2011, the focal area of the reserve was inhabited by 1852 people, residing in over 20 communities. Additionally, 3,114 people classified as reserve users resided in communities neighboring the focal area (IDSM, 2012a). One of the principal economic benefits that
the MSDR offers its residents and users is the conservation of várzea fish, the most important source of income and protein in the region (Barthem, 1999; Viana, 2004). In general, fishing pressure in the MSDR is low largely due to access restrictions placed on nearby commercial fishers (Barthem, 1999; Batista et al., 2004; Crampton et al., 2004; Queiroz, 1999; Viana, 2004).

**Projeto Boto**

Projeto Boto, a not-for-profit research project supported by the MSDI and the Instituto Nacional de Pesquisas da Amazônia (INPA), has been active in the focal area of the MSDR since its inception. Projeto Boto focuses on collecting data related to the life history, behavior, ecology, and physiology of botos. The project is based in a floating field base located in the focal area of the MSDR. Because of the proximity of the base to the MSDR communities, Projeto Boto researchers interact with locals both formally and informally throughout the year. Observational work, when researchers are actively monitoring the area for botos, takes place year-round in and around the southern segment of the MSDR, primarily the Mamirauá Lake System (Figure 3-1).

Furthermore, approximately three weeks each year, since 1994, have been dedicated to the capture and marking of botos. During this event, about twenty local fishers are employed by Projeto Boto to assist with the capturing and handling of botos. Details on Projeto Boto protocols are available in da Silva and Martin (2000), Martin and da Silva (2004a, 2004b), Martin et al. (2004), and Mintzer et al. (2013).

**Interview Protocol and Questionnaire**

We conducted structured oral interviews in six rural communities and two towns located in or near the MSDR (Figure 3-1). The communities were selected because they were located within Projeto Boto’s study area and because the majority of
inhabitants rely on fishing as their main source of income (determined during preliminary interviews with community leaders). Interviews were carried out in October and November 2012. The interviewer (VJM) was accompanied by a local guide and a Brazilian assistant. Communities were visited between three and ten times throughout the data collection period. During the initial visit, we conducted preliminary interviews with the president of the community and/or another elected representative and sought permission to return. All community leaders granted permission to carry out the research. The interview protocol was approved in Brazil by the Comitê de Ética em Pesquisa com Seres Humanos do Instituto Nacional de Pesquisas da Amazônia and the Comissão Nacional de Ética em Pesquisa do Ministério da Saúde (processo Nº 292/2012, 16891) and in the United States by the University of Florida Institutional Review Board (protocol #2011-U-0834).

During subsequent visits, we invited all fishers that were present and accessible to participate in the study. Upon arrival at each community, we visited meeting areas and houses to recruit initial fishers. Using a snowball sampling approach (Goodman, 1961), after each interview, we asked for suggestions on other fishers to interview and we were usually guided and introduced to the next fisher, and so on, until no more fishers were present or available. Our intent was to interview as many diverse fishers as possible, not to target those actively engaged in killing boto. Interviews were conducted in the fisher's house, in a shaded location outside, or in a community structure (e.g., school). All interviews conducted within the two towns took place at the offices of the Colônia de Pescadores.
The questionnaire consisted of both closed and open-ended questions. In some cases, visual aids (e.g., maps, picture of marked boto) were used in conjunction with questions. The questionnaire was designed to gather information on the fisher’s 1) background and fishing techniques, 2) involvement in the MSDR and Projeto Boto activities, 3) perception of the boto population and illegal harvest, 4) frequency, type, location, and timing of interactions with botos, 5) mythological beliefs, 6) attitudes toward botos, and 7) behaviors exhibited toward botos. We analyzed the closed-ended responses using standard parametric and non-parametric statistical tests. For the open-ended questions, we used coding and categorizing, where we grouped and summarized responses according to their similarities and inclusion of key words or phrases.

Attitude Assessment

We defined attitude as beliefs about an object or situation that influence one’s response toward that object or situation (Rokeach, 1968). The fishers expressed their attitudes toward botos by replying to four close-ended questions (Table 3-1). Descriptions of the explanatory variables that we tested and rationale for their selection are provided below and summarized in Table 3-2, and relationships are expressed in a flow chart in Figure 3-2. We used Fisher’s Exact Test to determine which explanatory factors were significantly correlated with positive attitudes. Additionally, open-ended questions explored the reasons behind the answers provided for the attitude questions. Results of the quantitative analyses were used in conjunction with the responses to the open-ended questions to assess the factors underlying the attitudes expressed.
Socioeconomic and Demographic Variables

**Education Level.** Previous studies have shown that educated people may better understand the short and long-term benefits of conservation (Fiallo and Jacobson, 1995; Heinen, 1993; Infield, 1988; Lee and Zhang, 2008). For example, the level of acceptance of a PA among residents is positively correlated with their level of education (Fiallo and Jacobson, 1995; Heinen, 1993). Education is also an important factor in determining local attitudes toward wildlife (Akama et al., 1995; Selebatso et al., 2008). Consequently, we expected that more educated fishers would demonstrate more positive attitudes toward botos.

**Dependency on Fishing.** Fishers that rely on fishing as their main source of income are likely to spend more time on the water and consequently interact with botos on a regular basis. Their income will be affected more proportionally by these interactions. Conflict with wildlife has been determined as an important factor in determining negative attitudes toward wildlife (Campbell, 1992; De Boer and Baquete, 1998; Gillingham and Lee, 1999; Mehta and Kellert, 1998; Oli et al., 1994; Parry and Campbell, 1992). Therefore, we expected that participants who rely on fishing financially would have more negative attitudes toward botos.

**Fisher Age.** Several authors have reported that botos were protected for many generations due to local legends (described in mythology section; Cravalho, 1999; da Silva, 2008; da Silva and Best, 1996; da Silva et al., 2011). However, the popularity and effect of these stories is declining among the current generations (da Silva and Best, 1996; da Silva et al., 2011; Pinto de Sa Alves et al., 2012). Consequently, we expected a difference in attitudes between fishers of varying age.
Interaction Variables

**Frequency of depredation and entanglement.** Depredation refers to a predatory attack, and in this case describes the act of botos removing or biting fish from nets. Depredation may result in a decrease in the value of the catch and damage to fishing gear (Lauriano et al., 2004; Read, 2005; Rocklin et al., 2009). Similarly, boto entanglement in gear may interrupt fishing operations and cause net damage (Lauriano et al., 2004; Rocklin et al., 2009). Because conflict may determine attitudes toward wildlife, we expected that fishers who have experienced frequent depredation and entanglement would have more negative attitudes toward botos.

**Positive Interactions.** Although many interactions between dolphins and fishers are detrimental, accounts from various parts of the world suggest that positive interactions do occur (e.g., Neil, 2002; Pryor et al., 1990). In eastern Australia, for example, Aboriginals cooperate with bottlenose dolphins and orcas during fishing activities, and this collaboration has emotional and spiritual implications for the fishers (Neil, 2002). Based on these accounts, we expected that fishers that have experienced a positive interaction with botos would have a more positive attitude toward botos.

Effect of Protected Area

**Participation in MSDR and Projeto Boto Activities.** Involvement of local communities is recognized as an essential component of successful conservation initiatives (Bawa, 2006; Kainer et al., 2009; Vermeulen and Sheil, 2006;). Positive attitudes toward PAs and conservation are highly influenced by the level of involvement in management or research programs (Fiallo and Jacobson, 1995; Kideghesho et al., 2007; Mehta and Heinen, 2001). Active participation can lead to feelings of “ownership” of the environment, increase knowledge about wildlife, and promote understanding of
natural resource management issues (Campbell and Vainio-Mattila, 2003; Evans et al., 2008). Programs that provide economic benefits can also encourage attitudes and behaviors that better align with conservation goals (Archabald and Naughton-Treves, 2001; Gadd, 2005; Gillingham and Lee, 1999; Holmes, 2003; Infield, 1988; Lewis et al., 1990).

As expected from the SDR model, some of the interviewees have been involved in activities coordinated by the MSDR and Projeto Boto, including management meetings, conservation lectures, ecotourism, research, and monitoring. We considered three levels of participation: “no participation”, meaning the fisher had never participated in the MSDR or Projeto Boto activities, “meeting or project participation”, meaning the fisher had attended management or conservation meetings or had participated in a specific project, and “employment”, referring to fishers who had worked in ecotourism, research, monitoring, or enforcement. Employment related to wildlife has been associated with more positive attitudes toward wildlife and conservation (Parry and Campbell, 1992); therefore, we expected that “employment” fishers would show the most positive attitudes toward botos. Due to their lack of involvement, we expected fishers in the “no participation” category to have the least positive attitudes.

**Community Type.** The fishers interviewed in this study reside in communities belonging to one of the following categories: focal area, reserve-user, and non-reserve. The focal area is where the MSDR outreach, research and conservation efforts have been focused (SCM, 1996). The reserve-user communities are located outside the MSDR but have access to the MSDR resources and may participate in meetings and management decisions. Non-reserve communities are located outside the MSDR with
no access to the MSDR resources. We expected that fishers from focal area communities would have the most positive attitudes toward botos because of the heavy exposure they have had to the MSDR activities (SCM, 1996). Moreover, focal area and reserve-user communities have received concrete benefits from the MSDR, like participation in ecotourism, so we expected fishers from these communities to have more positive attitudes than fishers from non-reserve communities.

**Mythology-Belief in the Legend of the Encantado**

The mythology surrounding botos speak to sources of misfortune, the afterlife, and the relationship between men and women (Slater, 1994). According to one common legend, botos can shape-shift into a handsome young man, the *encantado*, who seduces women (Cravalho, 1999). Prior to the *piracatinga* fishery there was no widespread hunt directed at botos, and several authors have suggested that due to the legends and the supernatural powers attributed to these animals, botos were respected and feared and consequently protected for many generations (e.g., Brum, 2011; Cravalho, 1999; da Silva, 2008; da Silva and Best, 1996; da Silva et al., 2011). In Peru, for example, botos are regarded with “superstitious dread” and fishers do not want to handle a dead boto because of possible consequences to their families (Leatherwood and Reeves, 1994). In Indonesia, where mythological beliefs surround dolphins, research suggests that positive attitudes toward dolphins are linked with the belief that dolphins have human origins (Kreb and Budiono, 2005). Whether belief in the *encantado* legends should have a positive or negative effect on attitudes is not clear. Fishers may fear botos and consequently dislike it (Pinto de Sa Alves et al., 2012), while others may respect botos and favor their protection.
**Behavior Assessment**

According to the Theory of Planned Behavior, behavior is closely guided by behavioral intention, which is a result of three components; attitudes toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991). Although previous research has made connections between conservation attitudes and resource use (Abbot et al., 2001; Adams and Infield, 2001; Holmes, 2003), the exact circumstances or motivators that lead to behavioral changes related to resource use are unclear (Holmes, 2003). Nevertheless, these studies have suggested that improved attitudes as a result of outreach initiatives and economic benefits may, in turn, lead to more conservation-friendly behaviors (Abbot et al., 2001; Adams and Infield, 2001; Holmes, 2003).

Herein, we assessed if positive attitudes toward botos were manifested as positive behaviors. We quantified one specific behavior (releasing/rescuing a living, entangled boto from a net) and used Fisher’s Exact Test to examine if the attitude variables (Table 3-1) correlated with this behavior. We expected that if positive attitudes toward botos affect behavior toward botos, fishers that expressed positive attitudes should release/help botos.

Through open-ended questions, we also investigated the impacts of behavioral controls (i.e., enforcement) on two behaviors: refraining from killing botos and releasing/rescuing an entangled boto. We directly asked fishers if they have ever killed a boto and the reasons behind their action. To examine the potential influence of the MSDR on this behavior, we also asked the fishers “Would you kill (more) botos if you were not fishing in (or near) the MSDR?” and “Do you think other people in your community would kill (more) botos if they were not fishing in (or near) the MSDR?”. We
asked him/her to explain the reason(s) for the expected change. If a fisher stated that he/she had disentangled a boto, we asked them to explain their reason for helping the boto.

Finally, we explored the role of subjective norms primarily by asking fishers if their families’ and other people in their community like, dislike, or feel neutral toward bots. We then tested for correlations between these opinions and fishers’ behavior. Furthermore, we tested for a relationship between a fisher’s behavior and the behaviors of others in their community (i.e., do others in the community refrain from killing bots and help/release bots).

Results

Fisher Demographics

We conducted a total of 57 structured interviews. The average age of the participants was 42 (s = 12.15) ranging from 18 to 74. They have lived in their current community or town an average of 23 years (s=16.60) and have fished in the area surrounding their community or town an average of 20 years (s=14.17). Fifty-six participants were male. We targeted fishermen because preliminary interviews suggested that boto interactions occur more frequently with the types and size of nets used by men (women typically use weaker nets), and because women do not kill bots intentionally because of the physical strength and danger associated with this activity. One woman was included because she replaces her husband as the primary fisher in the family when her husband works in a nearby town.

The fishers had used over ten different types of fishing gear in the last year (Figure 3-3). The most common type of fishing gear used was the *malhadeira*, or gillnet. Fishers made the distinction between two general types of gillnet. The *tramalha*
was described as a relatively new type of gillnet used primarily for the capture of small fish, commonly bait fish, in shallow areas. The term *malhadeira* alone was frequently used to describe a stronger gillnet used in the capture of larger fishes such as the *tambaqui*. Brum (2011) recorded the same distinction made by fishers in the region.

**Perception of Boto Population Trend**

We asked fishers if they think the boto population in the area is declining, increasing, or stable. Forty-five fishers (79%) replied that the number is increasing, three (5%) replied that it is decreasing, and seven (12%) believe the number is stable. When we asked why they think the numbers are increasing, 49% (*n*=22) replied that they now see a lot or more botos when they are fishing. Others explained that less botos are being killed in recent years (24%, *n*=11). Some fishers specifically mentioned enforcement (4%, *n*=2), the presence of the MSDR (4%, *n*=2), and research (7%, *n*=3) as the main factors responsible for the population increase. The fishers who claimed that the boto population is decreasing attributed the decline to botos being killed in nearby areas and to botos moving away.

**Fishery-Boto Interactions**

Ninety-three percent of fishers (*n*=53) had observed depredation behavior by botos. Of these fishers, 30% (*n*=16) indicated that botos depredate every time they go fishing. Fifteen percent (*n*=8) stated that depredation occurred every time only when they fish in a particular location, primarily river or bay habitat. Forty percent (*n*=23) had found at least one boto accidentally entangled in their nets. Interactions with botos can occur with any type of fishing gear used (Figure 3-3); however, 74% (*n*=17) of fishers were using a *malhadeira* when a boto became entangled.
When we asked fishers if their interactions with botos have increased, decreased, or stayed the same since they began to fish in the area near their community, 56% (n=32) of fishers stated they have increased, 18%(n=10) indicated a decrease, and 14%(n=8) claimed they have been stable. Of the fishers that indicated an increase, half (n = 16) attributed this change to an increase in botos. A couple of fishers (n=2) noted that they were forced to change fishing location when the MSDR was established (from lakes to river habitat) and interact more with botos now because there are more botos in the river. Of the fishers who claimed that interactions with botos have decreased, 40% (n=4) explained that botos have become afraid of the nets and try to avoid them (a behavioral change attributed to the Projeto Boto capture expedition).

When asked if they have ever experienced a positive interaction with a boto, 46% (n=26) of fishers replied affirmatively. The most common positive interaction mentioned by fishers (n=11) was that botos helped them to find fish (“Where there are botos, there are fish”). Other incidents described included a boto pushing fish to nearby land or to a net (n=4), a boto biting off a fish’s tail and then leaving the fish for the fisher (n=4), and a boto bringing a fish to the fisher (n=4).

When we asked interviewees if they have heard of botos being killed to be used as bait to catch *piracatinga*, 98% (n=56) replied affirmatively. Although no one we interviewed stated that they have killed a boto for this purpose, 17 participants (30%) acknowledged that they were aware of botos having being killed in their community and seven confirmed that the botos were used for bait. Most fishers (67%, n=38) identified at least one community (their own or elsewhere) where killings were occurring for bait.
From this information, we gathered that fishers from at least three communities and the two towns, out of eight settlements visited, were killing botos to be used as bait at the time of the interviews. Additionally, the fishers identified nine other communities and towns where they believe the harvest for botos was occurring and, in some cases, increasing. These settlements are primarily located in the Solimões River, north west of our study area, where management, research, and enforcement presence is limited.

When we asked fishers if they thought more, less or the same number of botos were killed in the mid-2000s compared to 2011, over 80% (n=28) of fishers that could identify a trend stated that more botos were killed during the mid-2000s. Some interviewees explained that enforcement agents from the MSDR or the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA, Brazilian Institute of Environment and Renewable Natural Resources) visited communities with active harvests and the killings decreased subsequently. In one community, the harvest decreased after community members asked the poachers to stop because they were severely affecting the water quality of the channel in front of the community (due to the excess blood). One fisher attributed the decrease to a visit by Projeto Boto’s researchers.

When we asked each fisher if it would be easy for them to kill a boto to use it for bait, over 77% (n=44) stated that it would not be easy. Fishers explained that botos are “smart” and “unfriendly” and can evade capture. Others noted that they do not have the appropriate materials or expertise, and that it is a dirty and dangerous job. When we asked if killing a boto for use as bait would be a profitable activity for them, 86% (n=49) replied “No.” Most fishers explained a boto carcass would be no good to them because
they do not fish *piracatinga*. Most fishers who stated that the boto harvest was occurring in their community identified only a few community residents as the poachers, typically those living in floating houses close to the entrance of channels, who fish primarily *piracatinga*. It appears that the activity requires time, courage, and most likely an initial monetary investment (for the purchase of a large harpoon).

**Fisher Attitudes Toward Botos**

When we asked fishers their opinion of the boto, twenty-one fishers replied that they liked botos (37%) and fourteen (25%) replied that they disliked (Table 3-1). The only variables that were significantly correlated with opinion were “Community Type” (Fisher’s Exact Test, p-value=.001) and “Participation in MSDR or Projeto Boto activities” (Fisher’s Exact Test, p-value=.008) (Figure 3-4, 3-5). As expected, fishers that have actively been involved in activities related to conservation, ecotourism, management, and research have a more positive opinion of botos compared to those unexposed to such activities (Figure 3-4).

Almost 60% (n=33) of fishers stated that their opinion about botos has not changed with time, while 26% (n=15) of fishers claimed their opinions have changed. Eleven of the latter (73%) claim to have developed a more positive opinion and five of them attributed this difference to their exposure to research and ecotourism. Over 70% (n=8) of fishers with altered opinions reside in the community located within the MSDR boundaries, in closest proximity to the Projeto Boto field base. Four of these eight fishers attributed their changes in opinion to their exposure to the research, claiming the research has taught them about the importance of the species and that they now “understand the boto better”. However, two fishers that stated that their opinions have changed negatively explained that interactions with botos have increased since the
research started because botos have become more accustomed to humans and are less afraid of nets.

We asked fishers if they consider botos to be an important animal in the Amazon. Forty-eight fishers (84%) replied affirmatively and provided fifteen different reasons for their answer (Table 3-3). Additionally, we asked fishers if botos should be protected from being killed; 89% (n=51) of fishers replied favorably and provided 20 reasons for their affirmation (Table 3-4). Because such a high rate of fishers responded affirmatively to these questions, we refrained from conducting a statistical test with the explanatory variables.

When we asked fishers if they believe the Amazon would change if botos were to become extinct, 32 fishers replied affirmatively (56%), while ten (18%) did not believe it would change. Some fishers would consider it a good change because there would be more fish available to them. Others noted it would be more difficult to fish because botos help fish and are good for the environment. Because the explanations varied greatly, and some can be interpretative as counterintuitive of positive attitudes, we did not conduct statistical tests with the explanatory variables.

We asked fishers if they were familiar with the legend of the boto or encantado and asked them to describe the legend. Ninety-eight percent of fishers (n=56) replied that they knew the legend and over 60% (n=36) described the legend in varying levels of details. Of these fishers, over 80% (n=29) stated that according to the legend botos are shapeshifters. Some fishers elaborated by saying botos attend parties in their human form (n=3), seduce or impregnate women when in human form (n=5), and wear white when human (n=7).
Almost 30% (n=16) of the fishers interviewed stated that they believe in the legend(s). As expected, we found that the average age of fishers that believe in the legend (46.56 ±15.61 yrs) was greater than those that do not believe in the legend (40.71 ± 11.06 yrs); however, this difference was not statistically significant (two-sample t(23)= 1.714, p-value = 0.097). Five fishers (9%) described personal encounters with the encantado or shapeshifter boto. Additionally, another seven (12%) told a story where a close relative had an encounter. The setting of the stories varied (e.g., beach, lake, floating house) and involved anywhere from one to three male botos.

**Self-reported Fisher Behaviors Toward Botos**

We did not find any statistically significant correlation between the attitude variables and the behavior of releasing/rescuing an entangled boto. Whether a fisher expressed like or dislike toward botos was not correlated with this behavior (Fisher’s Exact Test, p-value = 0.413). Unexpectedly, almost half of fishers that have disentangled a boto from their net (46%, n=6) claim to dislike botos. Reasons provided for releasing a boto included: it is a life (n=4), it is not valuable dead (n=3), it is a crime to kill a boto (n=2), it will rot and smell if it dies (n=1), “I was in a conservation area” (n=1), and “I have worked with Projeto Boto and understand the research and botos” (n=1).

Six fishers (10%) stated that they would (n=4) or might (n=2) kill botos if they were not fishing in or near MSDR. Fishers mentioned research, lectures, ecotourism, and enforcement as reasons for not killing botos. One fisher admitted to having killed a boto before moving to the area and stated that he would “never kill a boto now.” Thirty percent (n=17) of fishers believed people (or more people) in their community would kill botos if they were not fishing in or near the MSDR. The fishers explained that the
MSDR provides enforcement and researcher presence that discourages people from killing. We refrained from conducting a statistical analysis between fisher behavior and community type (theoretically focal area communities have more enforcement presence so we would expect fishers in focal area communities to exhibit more positive behaviors) because enforcement agents have specifically targeted some of the study communities outside the focal area and therefore results would be biased.

Primarily, botos are killed to be used as a bait, but they are also killed because they disturb fishing operations. Two fishers admitted to having deliberately killed a boto. One of these fishers killed a boto because it had become badly entangled in his net and he did not want to make the effort to save it. Another older fisher stated that he killed roughly ten botos because they were “messing with him” while he fished.

We found no significant correlation between the behavior of releasing/helping a boto and positive family opinions (Fisher’s Exact Test, p-value = 0.2862) or positive community opinions of botos (Fisher’s Exact Test, p-value = 0.5301). However, our sample size for these tests was greatly reduced because many fishers explained that they do not know others’ opinions of botos. We also did not find a significant correlation between fishers that have released/helped a boto and whether their community refrains from killing botos (Fisher’s Exact Test, p-value = 0.193).

Of fishers that believe in the legend(s), eight (50%) affirmed that these beliefs affect their behaviors toward botos. Over half of these fishers explained that they do not trust botos or are afraid of them, and therefore try to avoid them. Two fishers, on the other hand, claimed that they feel a sense of respect toward botos because of the
stories. Four fishers mentioned that their wives are afraid of botos due to the legend and one explained that his wife does not canoe alone due to this fear.

**Discussion**

**Interactions**

Almost all fishers reported that they have experienced depredation by a boto and almost half have had a boto become entangled in their net. Most entanglement incidents occurred with *malhadeiras*, an important finding considering that previous work has suggested that gillnets do not pose a considerable threat to botos (da Silva and Best, 1996). Our results suggest that while gillnets made of weaker materials (i.e., *tramalhas*) do not appear to pose a threat to botos, stronger gillnets do. However, interactions such as depredation are common with *tramalhas* (Brum, 2011), so their importance should not be ignored. The difference in findings regarding gillnets between da Silva and Best (1996) and the more recent studies is likely explained by the changes in gillnet popularity/availability, material, and size in the last two decades.

Fish depredation by botos in our study is higher than that reported in other artisanal fishery-boto studies within the Amazon. In Manacupuru, for example, only 63% of fishers reported depredation (Pinto de Sa Alves et al., 2012). However, considering that many of the habitats with high fish densities in our study area (i.e., beaches, bays) are frequented both by fishers and botos (Martin et al., 2004), the levels of depredation reported herein are not surprising. Particularly during the dry season, the decrease in the overall amount of aquatic habitat physically forces fishers and botos to be in close proximity to each other.

It is possible that fishers are overestimating the frequency of their interactions. In other similar studies, fishers have overestimated interactions because they perceive
potential benefits from exaggerating their problems. For example, Bearzi et al. (2011) reported that fishers perceived interviews as an opportunity to influence decision-making related to monetary compensation. To ameliorate this concern, the objectives of our study were made clear to the fishers before the start of each interview and we explicitly stated that we did not have connections to decision-making or enforcement agencies. Nevertheless, it is likely some fishers exaggerated the frequency of depredation to justify their negative actions.

Almost half of the fishers stated that they have experienced a positive interaction with a boto. Numerous studies have described similar or more elaborate types of cooperation between fishers and other species of dolphins (e.g., Neil, 2002; Pryor et al., 1990; Zappes et al., 2011); however, this is the first time positive interactions have been reported to occur with botos. This is noteworthy given the numerous negative anecdotes and stigma that surround botos as competitors and pests (e.g., Iriarte and Marmontel, 2011; Iriarte and Marmontel, 2013; Loch et al., 2009, Pinto de Sa Alves et al., 2012).

Although several authors have noted that fishers “hate” botos because of negative interactions (Loch et al., 2009; Pinto de Sa Alves et al., 2012), our results suggest that there is not a clear relationship between frequency of depredation and entanglement, and negative attitudes toward botos. Some fishers explained that although botos are annoying, they understand that they need to eat and do not “blame” them for their behaviors. Moreover, while botos’ behaviors disrupt fishing operations, this may not be as costly to the fishers as previously suspected, although quantitative data are lacking on the economic loss resulting from such interactions.
Perception of the Boto Population and Harvest

Almost half of interviewees stated that the boto population has increased since they first began to fish in or near the MSDR. This perception is inconsistent with recently reported data that suggest boto abundance has been decreasing (da Silva et al., 2011). This incongruity could be a result of several factors. First, many of the fishers attributed this increase to a decrease in the harvest in recent years, since they believe more botos were killed in the mid-2000s. This result is consistent with boto survival probabilities that were estimated to be lowest for 2003-2006 (Mintzer et al., 2013). Thus, it is possible that fishers replied affirmatively to this question based only on a perceived relative increase in the boto population in recent years. Second, many fishers believe the boto population is increasing because they see more botos when they are fishing, a result consistent with the majority perception that interactions have increased. However, interactions may have increased due to changes in fishing locations or because botos have learned to depredate effectively without getting entangled (explanations provided by fishers). Moreover, changes in boto habitat preference or movement could be responsible for the perception of population increase. Finally, it is possible that fishers are exaggerating an increase in the boto population to appease what they perceive as a concern for the researchers.

Regardless of the sensitivity of the subject, most interviewees were forthcoming with information about the illegal harvest. According to fishers’ perceptions, the harvest for botos is widespread, occurring in five out of the eight communities we visited. However, it appears that only a few fishers in each community engage in the killing of botos, an activity that, in most cases, is not supported by the communities as a whole. In addition to the study communities, fishers identified nine other communities where
they believe the harvest has been occurring. One of the communities most commonly mentioned was an indigenous community. The indigenous status of the community may pose a challenge to conservation efforts, because it limits researcher and enforcement presence. Overall, it appears that the harvest has been migrating upstream on the Solimões, away from the focal areas targeted by the MSDR and Projeto Boto, and may be more intense in communities rarely visited by researchers and enforcement agents. These areas now require special attention by natural resource managers.

Several interviewees who denied that botos were being harvested for bait in their communities stated that only caimans (*Melanosuchus niger*) are used for this purpose. Previous studies have noted that caiman are used as bait in *piracatinga* fisheries (Brum et al. 2011; da Silveira and Viana 2003). Among residents of these communities, there appears to be a general consensus that it is “acceptable” to kill caiman because they are dangerous while the boto is harmless and should be protected.

**Positive Attitudes and Effect of the MSDR**

Based on the frequency of negative interactions between fishers and botos, we did not expect that most participants would be in favor of protecting botos. The reasons provided for the importance and protection of botos suggest that the existence value of botos, and the fact that they are not perceived as a dangerous animal, trump the annoyances caused by the animals. Additionally, as discussed below, the MSDR has encouraged positive attitudes toward botos. Although we recognize that biases could exist if fishers did not tell the truth, the major patterns that speak to favorable attitudes and the effect of the MSDR appear to be consistent and robust.
Our findings suggest that the MSDR and Projeto Boto have had a significant effect in promoting positive attitudes toward botos. Primarily through involvement in ecotourism and research, fishers have learned to appreciate botos as an important animal in the Amazon ecosystem and recognize it as an animal that others value (i.e., researchers). In a study conducted in the Manacapuru region in the Amazon, the majority of the respondents stated that it is not important to protect botos (Pinto de Sa Alves et al., 2012). The difference in attitudes toward botos between these two studies is likely a reflection of the overall effect of the MSDR and Projeto Boto on fishers.

**Fisher Behaviors Toward Botos**

Most fishers included in this study stated that they have refrained from killing botos and many that have had a boto become entangled in their net have helped/released the boto before the animal drowned. Although the reasons behind these positive behaviors toward botos remain unclear, fisher responses suggest that these behaviors are likely a result of a combination of factors, including attitudes and behavioral controls.

More research is needed to determine if positive attitudes toward botos generally translate to more positive behaviors. Two fishers, one who resides within the MSDR and one who resides in a reserve-user community, claim to have stopped killing botos. One of these fishers, who has worked in the MSDR ecotourism lodge, distinctly attributes his change in behavior to the current importance he sees in botos as an ecotourism attraction. Moreover, some fishers stated that they would kill botos if they were not fishing in or near the MSDR because they would not have learned the importance of botos. These explanations imply that, in at least some cases, changes in attitudes encouraged by the MSDR may lead to more positive behaviors toward botos.
Fisher explanations also suggest that behavioral controls play a role in determining their behaviors. Some fishers released botos because they recognize that it is illegal to kill a boto and because they are in a PA. Moreover, a third of fishers believe that people in their community would kill more botos if they were not in or near the MSDR because the MSDR provides enforcement and researcher presence. Enforcement was also a common explanation as to why they believe the harvest has decreased.

Harming a boto, according to Brazilian Law, is punishable by up to five years in jail (Brazilian law 7.643, 1987; Lodi and Barreto, 1998). However, enforcement of natural resource protection laws in the Amazon is challenging and efforts are often compromised as a consequence of budget constraints, understaffing, and other institutional deficiencies (McGuire and Aliaga-Rossel, 2010a; Peres and Terborgh, 1995; Trujillo et al., 2010b; Utreras et al., 2010). In our study region, only four federal officials have been available to enforce natural resource protection laws in an area greater than 251,000 km² (Peres and Lake, 2003). Although two fishers in our study mentioned federal enforcement as a reason for the perceived decrease in the harvest, other fishers referred to enforcement coordinated by the MSDR.

The MSDR and IBAMA have facilitated an enforcement agent program in which community residents are trained to become enforcement agents (Koziell and Inoue, 2006; Queiroz and Crampton, 1999). These agents are responsible for reporting infractions in their sectors. Although this program has been criticized based on the notion that residents are not going to report their own families and friends, anecdotes provided by the fishers in our study suggest otherwise. Perhaps because the killing of
botos appears to be a specialized activity, that is not supported by most members of these communities, reprehensions by these enforcement agents may be effective.

Effect of the Legends

Most fishers were able to describe details associated with boto legends and almost a third of fishers believe in the stories. Unlike previous studies that suggest that these legends no longer provide protection for botos (e.g., Brum, 2011; Pinto de Sa Alves et al., 2012), our results suggest otherwise since half of the fishers that believe in the legend claimed to avoid harming botos because of the superstitions. Furthermore, although other studies claim that present generations no longer believe in these legends (e.g., Brum, 2011, Pinto de Sa Alves et al., 2012), our study shows that a considerable number of younger fishers do believe in the legends.

Conclusion

Although botos are embedded deeply in Amazonian culture through rich mythology, negative interactions between botos and local Amazonian fishers have increased substantially in the last decades. Interactions such as depredation and entanglement are common, and the harvest of botos for bait was reported in the majority of the communities visited. Although boto survival estimates (Mintzer et al., 2013) and fisher perception suggest the harvest may be decreasing in the study area, the harvest appears to be increasing in neighboring areas where there is less PA management presence. The current scale of influence of the PA initiatives is insufficient to prevent boto population decline (da Silva et al., 2011; Mintzer et al., 2013). Based on the results of our study that suggest that the MSDR programs are having a positive effect on fisher attitudes toward botos, we recommend that the management model and community-based initiatives that have been developed in the
study area (a relatively small geographical area) be expanded to neighboring areas. Furthermore, increasing community-based enforcement coordinated by the MSDI may be a good strategy to limit or decrease the harvest. Programs focused on community-based management, involvement of communities in wildlife research, continuous education and outreach initiatives, and training of community enforcement agents, could be replicated in other SDRs where the same basic management schemes are already in place. Expanding the MSDR model both at the local and regional level could have a positive impact in decreasing or limiting the harvest which is becoming increasingly prevalent throughout the Amazon basin.
Table 3-1. Questions and responses included in questionnaire to determine fisher attitudes toward botos.

<table>
<thead>
<tr>
<th>Question</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you like or dislike botos?</td>
<td>Like</td>
</tr>
<tr>
<td></td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
</tr>
<tr>
<td></td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td>Dislike</td>
</tr>
<tr>
<td></td>
<td>25%</td>
</tr>
<tr>
<td>Do you think botos are an important animal in the Amazon?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>84%</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td>Don’t know</td>
</tr>
<tr>
<td>Do you think botos should be protected from being killed?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>89%</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Will the Amazon change if botos become extinct?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>16%</td>
</tr>
</tbody>
</table>

Table 3-2. Explanatory variables included in the attitude assessment.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Type</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-economic variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisher age group</td>
<td>Ordinal categorical</td>
<td>&lt;=29, 30-39, 40-49, &gt;=50</td>
</tr>
<tr>
<td>Education level</td>
<td>Ordinal categorical</td>
<td>None, 1-5 yrs, 6-9 yrs, 9&lt;</td>
</tr>
<tr>
<td>Dependency on fishing</td>
<td>Categorical</td>
<td>Main source of income, shared, not main source</td>
</tr>
<tr>
<td>Interactions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of boto entanglement</td>
<td>Ordinal categorical</td>
<td>Never, 1, 2+</td>
</tr>
<tr>
<td>Frequency of boto depredation</td>
<td>Ordinal categorical</td>
<td>Never, sometimes, always</td>
</tr>
<tr>
<td>Positive Interaction</td>
<td>Binary</td>
<td>Experienced positive interaction, has not experienced positive interaction</td>
</tr>
<tr>
<td>Effect of Protected Area</td>
<td>Categorical</td>
<td>No participation, meetings/projects, employed</td>
</tr>
<tr>
<td>Participation in MSDR activities</td>
<td>Categorical</td>
<td>Focal, reserve-user, non-reserve</td>
</tr>
<tr>
<td>Community Type/Location Mythology</td>
<td>Categorical</td>
<td></td>
</tr>
<tr>
<td>Belief in Legend</td>
<td>Categorical</td>
<td>Believer, unsure, non-believer</td>
</tr>
</tbody>
</table>
Table 3-3. Reasons reported by fishers for why they believe botos are an important animal in the Amazon.

<table>
<thead>
<tr>
<th>Reason</th>
<th>% of Fishers (n=44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It is not dangerous/harmful</td>
<td>27%</td>
</tr>
<tr>
<td>2. It serves a purpose in nature</td>
<td>20%</td>
</tr>
<tr>
<td>3. It is alive/It exists</td>
<td>14%</td>
</tr>
<tr>
<td>4. It is important to researchers</td>
<td>11%</td>
</tr>
<tr>
<td>5. It is God's creature</td>
<td>7%</td>
</tr>
<tr>
<td>6. It is a companion</td>
<td>7%</td>
</tr>
<tr>
<td>7. It is a pretty animal</td>
<td>7%</td>
</tr>
<tr>
<td>8. It protects fish</td>
<td>5%</td>
</tr>
<tr>
<td>9. It helps with fishing</td>
<td>5%</td>
</tr>
<tr>
<td>10. It is unique to the Amazon</td>
<td>2%</td>
</tr>
<tr>
<td>11. It is important for people that fish piracatinga</td>
<td>2%</td>
</tr>
<tr>
<td>12. It is important for tourism</td>
<td>2%</td>
</tr>
<tr>
<td>13. It is intelligent</td>
<td>2%</td>
</tr>
<tr>
<td>14. It is useful in children’s therapy</td>
<td>2%</td>
</tr>
<tr>
<td>15. Everything is important</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 3-4. Reasons reported by more than one fisher for why they believe it is important to protect botos from being killed.

<table>
<thead>
<tr>
<th>Reason</th>
<th>% of Fishers (n=45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It is not dangerous/harmful</td>
<td>27%</td>
</tr>
<tr>
<td>3. It needs protection/More people would kill</td>
<td>16%</td>
</tr>
<tr>
<td>2. No good reason to kill a boto (“We don’t eat it, so why kill it?”)</td>
<td>13%</td>
</tr>
<tr>
<td>4. It deserves to live</td>
<td>9%</td>
</tr>
<tr>
<td>6. It is a pretty animal</td>
<td>7%</td>
</tr>
<tr>
<td>7. Everything should be protected</td>
<td>7%</td>
</tr>
<tr>
<td>8. For the research</td>
<td>4%</td>
</tr>
<tr>
<td>9. It is part of Nature</td>
<td>4%</td>
</tr>
</tbody>
</table>
Figure 3-1. Map of the study area, the southern segment of the Mamirauá Sustainable Development Reserve and surrounding areas in Amazonas State, Brazil (GIS layers: IUCN and UNEP 2010; DCW and GADM downloaded from <http://www.diva-gis.org>).
Figure 3-2. Flow chart of independent/explanatory variables (blue) and dependent variables (red) included in attitude/behavior assessment. The mechanisms by which the MSDR is expected to positively affect fisher attitudes and behaviors are also displayed (black).

Figure 3-3. Most common types of fishing gear used by participating fishers.
Figure 3-4. Fisher opinion of botos grouped by the level of participation of the fisher in MSDR and Projeto Boto activities.

Figure 3-5. Fisher opinion of botos grouped by community type in which the fisher resides.
CHAPTER 4
HOME RANGE AND SEASONAL MOVEMENTS OF RIVER DOLPHINS (INIA GEOFFRENSIS) IN A PROTECTED AMAZONIAN FLOODPLAIN

Background

The Amazon River dolphin, or boto (Inia geoffrensis), is the only obligate river dolphins species still considered relatively abundant throughout its range (Leatherwood and Reeves, 1994; Martin and da Silva, 2004a; Smith and Smith, 1998). However, in the last few decades, anthropogenic pressures, particularly the direct harvest of botos for use as bait in the fishery for the catfish Calophysus macropterus, are posing a considerable threat to the species. With illegal harvesting becoming more widespread throughout the Amazon region, timely conservation action is needed to conserve threatened populations (da Silva et al., 2011; Mintzer et al., 2013). Establishing and improving freshwater protected areas has been suggested as a possible course of action (Trujillo et al., 2010a). However, river dolphin ecology is poorly understood (Martin and da Silva, 2004a) and more information is needed regarding boto habitat use, home ranges, and movement patterns to assure that these spatial protection initiatives meet their intended purpose.

Botos occupy most of the Amazon and Orinoco basins and occur in diverse habitats, though they show preference for whitewater floodplain systems or várzeas (Martin and da Silva, 2004b). These systems are common throughout the upper and middle Amazon basin, encompassing more than 300,000km² in Brazil alone (Junk, 1997). The ecology of the várzea is largely defined by seasonal water level fluctuations (range of < 20m) dependent on local and regional precipitation patterns and the Andes’ snowmelt (Junk, 1997; McGuire and Aliaga-Rossell, 2010b).
Although individual botos exhibit site fidelity to várzeas, the extreme water level fluctuations lead to “forced” exodus from shallow habitats (Martin and da Silva, 2004b). During the driest periods, botos are limited to the deepest rivers and channels within the river basin. High water levels, on the other hand, provide a much larger expanse of habitat for the species, including the várzea and its flooded forests and lakes. Prey availability, determined by reproduction cycles and migration patterns of fishes, is also dependent on water fluctuations (Martin and da Silva, 2004b; McGuire and Aliaga-Rossell, 2010b). Seasonal fluctuations in habitat and prey availability appear to be reflected in many aspects of river dolphin biology, including reproduction, mortality, distribution, morphology, and movement patterns (Martin and da Silva, 2004b; McGuire and Aliaga-Rossell, 2010b).

Previous studies of boto home ranges and individual movement have been spatially or temporally constrained (McGuire and Henningsen, 2007), but nevertheless have identified water fluctuations as an important driver of both. The most detailed information on boto movement to date has been provided by Martin and da Silva (2004b) who analyzed radio telemetry data for 24 botos in a várzea. Based on this sample, they estimated that 80-90% of the local population occupy várzea habitat during rising water (~3 months). While for approximately six months, from high water to low water, the várzea was occupied only by 50% of less of the local population. Moreover, at one or two weeks at both extremes of the seasonal hydroperiod, only a very small proportion of the boto population was observed within the várzea. During low water, botos entered the rivers to avoid getting trapped in the channels and lakes of the várzea. These telemetry results were corroborated with seasonal estimates of boto
density in the várzea and river (Martin and da Silva, 2004b). Similar patterns of movement were observed in the Bolivian and Ecuadorian Amazon (Aliaga-Rossel, 2002; Denkinger, 2010).

Boto habitat use patterns appear to be dependent on both sex and age. Martin and da Silva (2004b), for example, reported strong sexual segregation by botos. Throughout the year, except for the low water months, rivers were occupied mostly by males, while the most remote areas of várzea were occupied almost exclusively by females. Moreover, males spent most of their time in bays, at the interface between the várzea and main river channel. Martin and da Silva (2004b) hypothesized that females spent more time within the várzea primarily for the benefit of their calves. In a separate study in Venezuela, McGuire and Winemiller (1998) suggested that habitat use by botos may also be a function of age; juveniles were most often found in lakes and rarely in channels regardless of season. Juveniles may have frequented lakes to avoid boat traffic and to take advantage of high fish availability (McGuire and Winemiller, 1998).

Linear home range estimates for botos, based on previous studies, range from 10km to over 200km (Aliaga-Rossel, 2002; Denkinger, 2010; Martin and da Silva, 2004a; McGuire and Henningsen, 2007; McGuire and Winemiller, 1998). In the Brazilian Amazon, tracked botos generally exhibited daily movements of 20km or less and some individuals remained in the same lakes (~1km²) for weeks, although maximum movements of 100km were recorded (Martin and da Silva, 2004b; McGuire and Henningsen, 2007). McGuire and Henningsen (2007) estimated a maximum linear home range of 220km and a mean of 61km for botos in Peru. Individuals frequently traveled 40 to 60 km in a 24hr period, though some individuals stayed in the same area
for several days (McGuire and Henningsen, 2007). Maximum linear home ranges of 60km and 10km were reported for botos in Bolivia and Venezuela, respectively (Aliaga-Rossel, 2002; McGuire and Winemiller, 1998). A recent study conducted in Ecuador reported maximum boto linear home ranges of over 200km that extended to different rivers, although most identified botos had linear home ranges of 0-50km or 100-150km (Denkinger, 2010).

In light of the increasing anthropogenic threats to botos, it is essential to expand our knowledge of boto home ranges and movement patterns. Such information is necessary to guide management actions aimed at the conservation of river dolphins (e.g., design and implementation of protected areas). Thus, the main goal of this study was to use long-term mark-recapture/resight data to estimate boto linear home ranges, core use areas, and quantify seasonal movements in and out of the Mamirauá Sustainable Development Reserve (MSDR), a protected várzea, in the Brazilian Amazon. Specific objectives were to determine how the timing of movement in and out of the MSDR differed between sex and age class, and between years with varying water level fluctuations.

Methods

Study Area

This study was conducted in and around the Mamirauá Lake System (MLS), the southern portion of the MSDR, located at the confluence of the Solimões and Japurá rivers, 30km upriver of the town of Tefé in Amazonas State, Brazil (Figure 4-1). The MLS consists of whitewater floodplain or várzea habitat, with diverse fauna that varies seasonally in response to extreme water fluctuations. Although the timing of peak high and low water levels varies annually, typically the highest water mark is reached in
June, and lowest water levels occur between September and November. From 1994 to 2011, the annual water level fluctuation averaged 10.23 meters, with a maximum range of 12.35 meters in 2011, and a minimum range of 8.95 in 1996 (Ramalho, 2009; IDSM, 2012b). Based on the local water levels, four main hydro-climatic seasons are recognized in the study area: rising water (RW), high water (HW), falling water (FW), and low water (LW).

**Capture and Recapture/Resight Protocol**

The data for this study were collected through Projeto Boto, a river dolphin research program in the MLS that has been active since 1994. Capture-recapture and marking of botos occurred approximately three weeks each year. With few exceptions, botos were captured with seine nets during low water at the entrance of the MLS (Figure 4-1). During the capture, botos were freeze-branded with a unique code in areas of the body allowing for maximum visibility. In addition to the physical capture-recapture events, observational work was conducted year-round. Sighting surveys were carried out within the MLS and surrounding areas, including segments of the main rivers (Figure 4-1). Effort was not evenly distributed across the entire study area due to the varying water levels; however, most areas were surveyed at least once per week. When a marked boto was sighted, its identification code and location were recorded. Further description of capture and observation procedures is available in da Silva and Martin (2000), Martin and da Silva (2004a, 2004b), Martin et al. (2006), and Mintzer et al. (2013).

**Linear Home Range**

Home range is the “area traversed by the individual in its normal activities of food gathering, mating, and caring for young” (Burt 1943, p. 351). In cases when species
have home ranges that conform to relative linear features, home ranges are often described in terms of length or the linear distance between the two most extreme sighting locations. Although the home ranges are not truly linear, the second dimension of variation in space use is small compared to the first (Rayment et al., 2009). The linear approach has been used to describe home ranges of cetaceans inhabiting rivers and coastal waters (e.g., Bräger et al. 2002; Defran et al. 1999; Gubbins, 2002; Flores and Bazzalo, 2004; McGuire and Henningsen, 2007; Rayment et al., 2009).

In this study, we estimated the observed complex linear range (OCLR) of botos with 50 sightings or more between January 1994 and March 2012. The complex linear range has been previously defined as the minimum-length centerline-based tree that spans all sighting locations of the individual (Ouellette and Cardille, 2011). Herein, the OCLR is the minimum linear range that includes the network of all channels connected by confluences where an individual was observed. Following this definition, we estimated OCLR for an individual boto by plotting all its sightings in ArcMap 10 (ESRI, 2011) and drawing a center-line based structure that connected all sighting points (Figure 4-2). The total length of the tree, measured with the ArcMap 10 “measure” tool, was considered the OCLR for the individual. The maximum possible OCLR for an individual was delimited by the area surveyed, i.e., 160km.

To determine the minimum number of sightings necessary to estimate OCLR independent of sample size, we plotted sighting number vs. OCLR. By including only those animals 150 or more times, we eliminated any positive trend between number of sightings and OCLR (Figure 4-3). After obtaining the OCLR estimates for all botos with 150 sightings or more, we conducted a Mann-Whitney U test to determine if there was a
significant difference in OCLR between adult males and females. We expected that males would have larger home ranges than females, based on previous research that showed that males were found frequently in the main rivers, away from the MLS, while females were found primarily within the MLS (Martin and da Silva, 2000a, 2004b). Additionally, we calculated the length and percentage of each OCLR that overlapped with the MSDR boundary. Calves were excluded from these analyses, as their OCLR was expected to be dependent on the OCLR of their mothers.

**Core Use Area Estimation**

In contrast to the OCLR approach, Kernel methods assign a level of use to any given point in the habitat based on the entire set of observations during the study period (Vokoun, 2003; Worton, 1987). To estimate boto core use areas, we calculated the fifty percent kernel density estimates ($K_{50}$) of home ranges for botos observed at least 15 times during surveys conducted between November 30, 2010 to January 23, 2012 (e.g., Flores and Bazzalo, 2004, Rayment et al., 2009; Worton, 1989). A minimum of 15 sightings has been used to obtain accurate kernel estimates for other cetaceans (Rayment et al., 2009). To minimize the effects of autocorrelation, we used only the first sighting per day for each individual (Rayment et al. 2009). We used the command “kde” in the Geospatial Modelling Environment (GME) platform, which utilizes both Program (RCT, 2013) and ArcMap 10 (ESRI, 2011), to conduct the kernel analyses (Beyer, 2012).

For 71 days between November 30, 2010 and January 23, 2012, botos were observed using the protocol described above. Additionally, observers recorded locations visited where botos were not observed. Based on these records, we were able to assign each sighting a weight according to the probability of obtaining that
sighting (Fieberg, 2007; Horne et al., 2007). We used the “weightfield” option in the GME “kde” tool to add a field with weights. The weight for each location \( (W_i) \) was calculated as follows:

\[
W_i = \frac{1}{\sum_{i=1}^{T} V_i}
\]

(4-1)

Where, \( V_i \) is the number of visits to each location during the sampling period, and \( T \) is the total number of locations surveyed. Using GME, the kernel based on each point was weighted by \( W_i \), and the density estimates were then standardized by dividing by the sum of all weight values.

The choice of bandwidth or smoothing parameter is of critical importance in density estimation. Because there can be large differences among the different bandwidth estimators, the application and evaluation of various bandwidths is recommended (Beyer, 2012). Therefore, we applied the following algorithms to the data: plug-in estimator (PLUGIN), smoothed cross validation (SCV), biased cross-validation (BCV), and a second biased cross-validation (BCV2). We did not use least squares cross validation (LSCV) because this algorithm is sensitive to points with identical coordinates, which occurred in our data (Beyer, 2012). After assessing the performance of each algorithm, we deemed SCV to be the best performing and most biologically relevant.

Once the \( K_{50} \) estimates were obtained for all individuals with 15 sightings or more, we used the “overlay-intersect” analysis tool in ArcMAP 10 (ESRI, 2011) to determine what segments of the core use areas for the individuals overlapped. Finally, using the same tool, we determined what segment of the overlapping core use area straddled the MSDR.
Seasonal Movement

To quantify seasonal movement patterns, we used multi-state recapture only models in Program Mark (White and Burnham, 1999) to estimate transition probabilities of individuals moving between the MLS and adjacent areas during a 24 month period, January 2009 to December 2011. This time period allowed for comparisons of transition probabilities between years with pronounced differences in water level extremes and hydroperiods (Figure 4-4). With an average of 33.28 m.a.s.l., 2009 had the highest average water level of any year in the last decade, along with the highest monthly recorded water level of 38.24 m.a.s.l. In contrast, 2010 had the second lowest average water level of the last decade (30.68 m.a.s.l.), and was unique in having three continuous months with water levels at lower than 26 m.a.s.l. (Rimalho et al., 2009; IDSM, 2012b) (Figure 4-4).

As applied in other cetacean mark-recapture studies (e.g., Cantor et al. 2012; Wilson et al. 1999), we used visual sightings of uniquely identified individuals as encounter events. Encounter histories were created for 305 botos sighted between 2009 and 2010, based on monthly time intervals, and using only sightings made with 100% confidence. We included a total of 6331 observations.

For multi-state models, encounter histories represent both the encounter (or sighting) and the state (or location) of the encounter. In our modeling, we defined three states (Figure 4-1). The first two states form part of the MSDR: the MLS channels and lakes (M), and bays or ressacas at the entrance of the MLS (R). A distinction between these two states was made for two reasons: first, the bay system is assumed to be an area of high use, especially by males (Figure 4-2; Figure 4-5; Martin and da Silva, 2004b), and unlike many areas inside the MLS, the bays are deeper and may contain
water at low water levels. The third state was outside the MSDR (A) and consisted mostly of river habitat (Figure 4-1). If an animal was seen within the MLS channels or lakes during a month, it was assigned a M for that month. If it was sighted in the bay system, it was given a R for the month. If it was sighted outside the MSDR (outside M or R) during a month, it was assigned an A. For instance, an encounter history of M0RA describes an individual that was sighted in the MLS in period 1, not detected in period 2, seen in the bay system in period 3, and detected outside the MSDR in period 4. A boto identified in more than one state during the same month was assigned to the location with the most sightings. Using this approach, ties occurred on less than 5% of occasions. In these cases, we assigned the boto to the state that minimized movement related information (Bechet et al. 2003). For example, a boto sighted in M at t-1 and t+1, and in both states M and A at period t, was assigned to state A for period t because we know the boto moved from M to A to M.

Program Mark estimates the following three parameters for multi-state recaptures only models: $S_t^r$ = the probability that a boto in location $r$ at time $t$ survives until time $t+1$, $P_t^r$ = the probability that a boto is sighted at time $t$ in location $r$, given that the boto is alive and in the study area at time $t$, $\Psi_t^{rs}$ = the probability that a boto in location $r$ at time $t$ is in location $s$ at time $t+1$, given that the boto survived from time $t$ to $t+1$. As resightings did not occur over the entire geographic range of the study population, we refer to $S$ as apparent survival ($\phi$), which confounds the probability of dying and permanent emigration. We made a priori assumptions on how to treat $\phi$, $p$, and $\Psi$. We differentiated between apparent survival inside and outside the MSDR: $\phi^M$ and $\phi^R$ were fixed at .968, and $\phi^A$ was fixed at .899 (these values were based on estimates from
Mintzer et al., 2013). We defined $p$ as fully time-dependent ($t$) and state dependent ($L$) to allow for changes in observation effort through time and space. To estimate $\Psi$ for the four main seasons (RW, HW, FW, LW) we allowed estimates to vary according to four time periods. Because water fluctuations vary annually, we used the water level measurements of the specific year (Figure 4-4) to determine what months, and corresponding encounter occasions, would comprise what period. Then, we built models that allowed estimation of transition probabilities for each season of each year and some that restricted estimation of transition probabilities per season across all years.

Additionally, we built models that allowed $\Psi$ to vary according to sex and age group (G). Each individual boto was categorized as being in one of four groups: adult males (AM), adult females (AF), mother/calf pairs (MCP), and immature individuals (IMM). Immature botos were those that have not yet reached reproductive age (6-7 years of age) but are no longer dependent on their mother (i.e., encounter history differs from the encounter history of their mother). We built models in which transition probabilities were allowed to vary with the four groups (AM, AF, MCP, and IMM), three groups (adults, MCP, and IMM), or two groups (adults and MCP, where MCP and IMM were combined into one group).

We transformed real parameter values $[0,1]$ to $\beta$-values $[-\infty,\infty]$ with the sin-link or logit-link function for numerical optimization. We used simulated annealing for optimization, as recommended for multi-state models where parameter estimates are expected to be close to the 1 boundary. We tested for a significant difference between transition probabilities by examining the 95% confidence intervals (CIs) of the $\Psi \beta$ -
values representing the season or group effect (a significant effect was determined at the $\alpha = 0.05$ level if the 95% CIs of the $\beta$ -values did not include 0.0). We used the Akaike’s Information Criterion (AIC) approach for model ranking (Akaike, 1973). Models with AICc values that differed by less than 2 were considered equal (Burnham and Anderson, 2002, 2004).

We defined our movement predictions within the framework of multi-state models, with a focus on the expected exodus of botos from the várzea prior to water reaching its lowest levels. We expected that transition probabilities depicting movement away from the MSDR (M to R, R to A, M to A) would be highest during FW and LW and movement probabilities representing movement into the MSDR (A to M, R to M, A to R) would be highest during RW. Moreover, we expected that transition probabilities depicting movement away from the MSDR would be higher in 2010 than in 2009. While the extreme low water levels of 2010 (Figure 4-4) should have forced all botos to leave M, water levels in 2009 may have allowed botos to remain in some areas of M. Although a boto transitioning from R to M or M to R has technically not left or entered the MSDR, because R is located at the MSDR boundary, a transition from R to M was considered to be movement in the direction of the MSDR, and a transition from M to R was considered movement away from the MSDR.

In terms of group differences, we expected that MCP would exhibit higher transition probabilities into the MSDR during RW compared to all other groups. This expectation was based on previous work that has shown that females spend more time in the MLS, presumably to increase survival of their dependent calves (Martin and da Silva, 2004b). Furthermore, based on previous work that has shown that juveniles
prefer lakes to river habitat (McGuire and Winemiller, 1998), we also expected that IMM would have higher transition probabilities than adults into the MSDR at RW.

**Results**

**Observed Linear Home Range**

The average OCLR for the 70 botos with 150 or more sightings (Table 4-1) was 62.63km (SD=18.78, min=32.08, max=106.95). The median OCLR for the adult females and males was 52.37 and 69.59, respectively; the two groups differed significantly (Mann–Whitney $U = 149$, $n_f = 27$, $n_m = 18$, $P < 0.05$). The average length of the OCLR located within the MSDR boundaries was estimated to be 42.28km (SD=8.68). An average of 81% of adult female OCLRs and 66% of adult male OCLRs overlapped with the MSDR.

**Core Use Areas**

We calculated the $K_{50}$, or core use area, for six botos that had 15 sightings or more between November 30, 2010 and January 23, 2012. Core use area size ranged from 1.49km$^2$ to 7.73km$^2$ (Table 4-2). A total of only 0.43 km$^2$ of core area overlapped for all six individuals. However, by excluding the individual with the smallest core use area (Boto ID#184), the total overlapping area increased to 2.56 km$^2$. This overlapping core use area was comprised mostly of the bays and main channel located at the entrance of the MLS, and also includes a segment of the Japurá River located adjacent to the bay system (Figure 4-5). Over half of this core use area, or 1.60km$^2$, fell within the MSDR boundary. Due in part to the minimum sighting requirement, these findings are likely only a representation of the core use area of individuals that show high site fidelity to the study area (those more likely to be observed an adequate number of times).
Seasonal Movement

AICc strongly supported the model with fully season-dependent transition probabilities, and with two groups, adults (AM and AF) and MCI (MCP and IMM) (Table 4-3; Model 1). Encounter probabilities (p) varied considerably between seasons and years, with the following average estimates from this model (Table 4-3; Model 1): MLS (M), p=0.677; Bays (R), p=0.870; Outside (A), p=0.320. This model showed no significant difference in transition probability estimates for the FW periods in 2009 and 2010 in which botos were expected to move away from the MSDR. In fact, this was true for both groups in all three transitions (Table 4-3; Model 1, Figure 4-6). However, Model 1 (Table 4-3) did estimate one significantly different transition probability between 2009 and 2010 in the direction away from the MSDR: \( \psi_{MCI, LW}^{MR, 2009} = 0.154 \) (SE=0.085) and \( \psi_{MCI, LW}^{MR, 2010} = 0.621 \) (SE=0.182) (Figure 4-6). The largest significantly different transition probabilities in the direction toward the MSDR were R to M at LW (\( \psi_{MCI, LW}^{RM, 2009} = 0.631 \) (SE=0.065) and \( \psi_{MCI, LW}^{RM, 2010} = 0.213 \) (SE=0.067). Collectively, these estimates suggested that movement varied more at LW than at FW between years of varying water level fluctuations, and that this disparity was more pronounced in the MCI group.

As predicted, transition probabilities representing movement away from the MSDR (M to A, M to R, and R to A) were usually highest during FW for all models and groups (Figure 4-6, Figure 4-7). The highest three transition probabilities from Model 5 (Table 4-3), where transition probabilities were estimated across both years for the two groups (adults and MCI), corresponded to \( \psi_{MCI, FW}^{MR} = 0.701 \) (SE=0.086), \( \psi_{Adults, FW}^{RA} = 0.659 \) (SE=0.069), and \( \psi_{Adults, FW}^{MA} = 0.474 \) (SE=0.102) (Figure 4-7). The
highest transition probabilities in the direction of entering the MDSR (A to R, R to M, and A to M) did not always occur during RW as expected, although the highest R to M probability did occur at RW ($\Psi_{MCI, RW}^{RM} = 0.462$; SE=0.075) (Figure 4-7, Table 4-3; Model 5).

AICc favored a model where individuals were separated into two groups, adults (AM and AF), and MCI (MCP and IMM) (Table 4-3; Model 1). This model outperformed the equivalent models where individuals were divided into four groups, AF, AM, MCP, and IMM, and three groups: adults, MCP, and IMM (Table 4-3; Model 2 and Model 3). This suggested that adult females and adult males exhibited similar movement patterns, and that mother/calf pairs and immature individuals displayed analogous patterns. A comparison of seasonal $\Psi$ estimates between AF, AM, MCP, and IMM individuals from the models with four groups yielded a similar inference.

Estimates from the model with two groups and condensed seasonal transition probabilities (Table 4-3; Model 5) showed significantly higher transition probabilities for the MCI from M to R during the FW season ($\Psi_{MCI, FW}^{MR} = 0.701$; SE=0.057), compared to adults ($\Psi_{Adults, FW}^{MR} = 0.357$; SE=0.064) (Figure 4-7). The adult group showed significantly higher transition probabilities from R to A and M to A during the same time period. The largest difference in transition probabilities between groups estimated by Model 5 (Table 4-3) corresponded to the R to A transition probabilities during FW:

$\Psi_{MCI, FW}^{RA} = 0.174$ (SE=0.038) and $\Psi_{Adults, FW}^{RA} = 0.658$ (SE=0.046) (Figure 4-7). These results suggest that during FW many MCP and IMM move from M to R, and many appear to remain in R, or spend a long time in R, before transitioning back into M during LW and RW ($\Psi_{MCI, LW}^{RM} = 0.427$; SE=0.071, $\Psi_{MCI, RW}^{RM} = 0.462$; SE=0.075, Figure 4-7).
Transition probabilities from R to A for this group remained consistently low (between 0.100 and 0.150) throughout the year. Although estimates from M to A are even lower, there was a small peak during FW, where estimates rose to

\[ \psi_{MA}^{FW} = 0.140; \ SE=0.069, \] suggesting that a number of MCP and IMM do transition directly or quickly from M to A (Figure 4-7). Although estimates for the adult group were also highest leaving the MSDR during FW (M to R, R to A, M to A), the relatively high estimates of R to A (\(\psi_{RA}^{Adults, FW} = 0.658; \ SE=0.069\)) and M to A (\(\psi_{MA}^{Adults, FW} = 0.474; \ SE=0.102\)) (Figure 4-7), suggest that most adults, unlike the MCP and IMM, may not stay in R for very long during FW, but transition quickly all the way outside of the MSDR to A.

**Discussion**

**Home Range**

Boto OCLR estimates were consistent with results from earlier studies, falling within previously published linear ranges (Aliaga-Rossel, 2002; Denkinger, 2010; Martin and da Silva, 2004b; McGuire and Henningsen, 2007). The OCLR results suggested that females have smaller home ranges than males, and spend more time within the MSDR boundaries. This finding is consistent with an earlier study in the MSDR that suggested that females spend more time in várzea habitat while males are found more frequently in river habitat (Martin and da Silva, 2004b).

Our home range results are limited by the size of the study area, and one major constraint was the lack of sampling within flooded forest habitat. Moreover, the home ranges of transient botos that may extend hundreds of miles (Martin and da Silva 2004a) are likely to have been considerably underestimated. However, most of the
OCLRs were less than half of the total area surveyed (averaged 39% of the 160km surveyed and ranged from 20% to 67%), suggesting that the study area was large enough to encompass the OCLR of many of the individuals (likely those that exhibit strong site fidelity to the várzea). The finding that male and female OCLRs were significantly different also suggested that the study area is large relative to most OCLRs, and in many instances, sufficient to capture individual differences in OCLR.

**Movement Patterns**

We expected more variation in transition probabilities between the two years at FW and LW due to the varying water level, but our results suggest that boto movement is mostly predictable independent of the range of water fluctuations. Because water fluctuations are unpredictable and quick (falling as much as a 30cm in a single day, Ramalho et al., 2009; IDSM, 2012b), botos may leave M as a precaution regardless of the water level. However, our estimates suggest that if water levels remain high at LW (as in 2009), many MCP and IMM stay in R and move back into M at LW, without waiting for the water to start rising. Overall, it seems that MCP and IMM are more responsive to variations in the water level fluctuations than solitary adults.

The model results suggested that movement patterns did not differ between male and female adults, but did differ between female adults and females with calves. This finding is consistent with the hypothesis that female botos spend more time in the MLS to increase the survival probability of their calves (Martin and da Silva, 2004b). The MLS likely provides three benefits for MCP: high prey densities (that benefit the calf and lactating mother), physical protection from aggressive male adults, and reprieve from riverine currents (Martin and da Silva, 2004b). Martin and da Silva (2004b) also suggested that males may not need to frequent the várzea if ovulating females also
exhibited preference for main rivers. This appears to be the case, as sexually mature females and males exhibited similar movement patterns.

Our findings also suggest that immature individuals follow the same movement patterns they followed when dependent on their mothers and prefer the waters of the MLS and bays, a behavior likely based on the benefits the várzea offers. Similar habitat use patterns have been described for immature boto in Venezuela where juveniles are most often found in lagoons (McGuire and Winemiller, 1998). These results provide further support for the importance of floodplain habitats for boto in vulnerable life stages.

By structuring the models to estimate transition probabilities for the four main seasons, and using monthly time intervals to build our capture histories, we may have limited our ability to detect finer scale movement patterns. Because we were interested primarily in quantifying the exodus prior to the lowest water level, this structure was pertinent; however, some potential weaker patterns were not evident from the transition probability results. For example, Martin and Da Silva (2004b) found that some boto leave the várzea at high water and re-enter when water first begins to fall. Developing a similar multi-state model with weekly time-intervals would be complex but could reveal such patterns.

Bay Core Use Area

The results of our core use area estimation and transition probability models highlight the importance of the bay system at the entrance of the MLS. This area appears to be important boto habitat, especially for MCP and IMM. Bays are productive areas with high fish abundance, have lower currents than river channels (Martin and da Silva 2004b; Martin et al., 2004), and may retain water during the low water months.
While Martin and da Silva (2004b) found that more males use these bays than females, our results suggest that these areas are important for both sexes, and while immature individuals use the bays for extended periods, adults tend to transition more quickly out of these bays and into the main rivers. When várzea habitat is unavailable at low water, these bay systems appear to act as an important refuge for young botos.

**A Note on Capture Probabilities**

The substantial difference in capture probability estimates between states has important implications for future studies. The average capture probabilities resulting from the top performing model varied highly between locations, with the highest average $p$ corresponding to the bay system, and the lowest to the outside area. While the outside state consists mostly of river habitat, with large surface areas and the presence of waves, the bay system and MLS locations have much smaller surface areas and calmer waters allowing for easier observation of botos and their brands. These differences in capture probabilities between habitat types should be carefully accounted for in river dolphin studies aimed at estimating demographic parameters.

**Implications for Conservation**

Deliberate killing for use as bait has become the primary threat affecting botos. Boto carcasses are being used to attract the catfish commonly known as *piracatinga* in Brazil and *mota* in Colombia (*Calophysus macropterus*) (Brum, 2011; da Silva et al., 2011; Gómez et al., 2008; Gómez-Salazár et al., 2012; Loch et al., 2009; Pinto de Sa Alves et al., 2012; Portocarrero Aya et al., 2010a; Shostell and Ruiz-Garcia, 2010; Trujillo et al., 2010a, 2010b). Demand for *mota* has increased in Colombia in the last decade because it is acting as a replacement for another catfish known as *capaz* (*Pimelodus grosskopfii*) that was overfished in Colombia (Gómez et al., 2008; Petrere et
al., 2004; Trujillo et al., 2010b). Consequently, an international market has emerged involving the catch of *mota* in Brazil (and recently other nations), and the export of this food fish to Colombia (Diniz, 2011; Gómez et al., 2008; Trujillo et al., 2010b, 2007). As of 2013, the boto harvest is taking place in at least twelve locations throughout the Amazon (Diniz, 2012), and in and near the MSDR the harvest level is likely unsustainable (Mintzer et al., 2013).

Spatial protection, through the establishment and management of protected areas (PAs), is recognized as a tool for the conservation of cetaceans (Gormley et al., 2012; Hooker and Gerber, 2004; Hooker et al., 1999; Hoyt, 2005; Kreb and Budiono, 2005). At present, however, no PAs have been developed with the specific aim of protecting the boto, although populations do occur in PAs throughout the Amazon (e.g., Santos Luzardo National Park in Venezuela, Pacaya-Samiria National Reserve in Peru, Noel Kempff Mercado National Park in Bolivia, Cuyabeno Wildlife Production Reserve and Yasuní National Park in Ecuador, and the Mamirauá Sustainable Development Reserve in Brazil; Aliaga-Rossel, 2002; da Silva and Martin, 2000; McGuire and Winemiller, 1998; Utreras et al., 2010). These PAs, along with new complementary ones, may be a successful strategy to mitigate the effects of the boto harvest. With this in mind, the Whale and Dolphin Conservation Society is coordinating with conservation scientists in South America to establish the South American River Dolphin Protected Area Network (SARDPAN) (Portocarrero et al., 2010b; <http://sardpan.wordpress.com/protected-areas/>), an initiative that includes over 30 protected areas in six South American countries. However, for this initiative to be successful, it is critical that the findings of this study and other studies of boto habitat...
use, home range, and distribution be taken into account in the improvement and establishment of these PAs.

Based on the findings of this study we emphasize four main conclusions that should be considered when developing and implementing boto spatial protection initiatives for the study population and elsewhere. First, várzea habitat appears to play a key role as a refuge for MCP and IMM of both sexes. Second, bay systems at the transition between várzea habitat and the main river appear to be essential habitat for botos, acting as a refuge during low water when várzea habitat is unavailable. Third, most MCP and IMM transition out and back into the MSDR várzea quickly and, in our study area, should be protected within the MSDR for all but approximately one or two months of the year (when water level is at its lowest). Perhaps an increase in enforcement directly outside the MSDR (i.e., expanding PA boundaries temporarily) at the lowest water month could play an important role in protecting the population. Finally, the core use area and linear home ranges for the study population did not fall entirely within the PA boundary. Although the protected várzea channels and bay system are used heavily by botos during most of the year, individuals frequently travel to unprotected areas on the main river. Creating a protected area buffer zone that encompasses the main river waters adjacent to the várzea and bay system could aid in the protection of the study population.
Table 4-1. Resighting records and observed complex linear range (OCLR) of *Inia geoffrensis* captured and resighted in the Mamirauá Lake System and surrounding areas between January 1994 and March 2012.

<table>
<thead>
<tr>
<th>Boto ID</th>
<th>Sex</th>
<th># of Sightings</th>
<th>Span of Sightings (yrs)</th>
<th>OCLR(km)</th>
<th>OCLR(km) in MSDR</th>
<th>%OCLR in MSDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>158</td>
<td>14.69</td>
<td>65.55</td>
<td>51.59</td>
<td>79%</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>727</td>
<td>18.08</td>
<td>52.37</td>
<td>40.53</td>
<td>77%</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>249</td>
<td>13.63</td>
<td>72.53</td>
<td>53.36</td>
<td>74%</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>221</td>
<td>18.04</td>
<td>49.55</td>
<td>41.33</td>
<td>83%</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>706</td>
<td>17.42</td>
<td>51.50</td>
<td>39.52</td>
<td>77%</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>365</td>
<td>17.23</td>
<td>50.03</td>
<td>39.59</td>
<td>79%</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>326</td>
<td>17.29</td>
<td>69.53</td>
<td>47.99</td>
<td>68%</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>351</td>
<td>9.80</td>
<td>41.72</td>
<td>33.50</td>
<td>80%</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>246</td>
<td>10.58</td>
<td>69.65</td>
<td>50.35</td>
<td>72%</td>
</tr>
<tr>
<td>21</td>
<td>M</td>
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<td>17.32</td>
<td>104.46</td>
<td>37.20</td>
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</tr>
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<td>39.80</td>
<td>38.52</td>
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</tr>
<tr>
<td>25</td>
<td>M</td>
<td>344</td>
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<td>71.35</td>
<td>46.95</td>
<td>66%</td>
</tr>
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<td>30</td>
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<td>72.94</td>
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</tr>
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</tr>
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<td>95%</td>
</tr>
<tr>
<td>38</td>
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</tr>
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<td>56.54</td>
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<td>54.40</td>
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</tr>
<tr>
<td>48</td>
<td>M</td>
<td>603</td>
<td>16.32</td>
<td>82.48</td>
<td>51.97</td>
<td>63%</td>
</tr>
<tr>
<td>49</td>
<td>M</td>
<td>226</td>
<td>15.73</td>
<td>84.35</td>
<td>47.92</td>
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<td>F</td>
<td>243</td>
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<td>97.46</td>
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<td>F</td>
<td>236</td>
<td>16.34</td>
<td>96.85</td>
<td>54.15</td>
<td>56%</td>
</tr>
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<td>M</td>
<td>159</td>
<td>8.90</td>
<td>39.99</td>
<td>32.12</td>
<td>80%</td>
</tr>
<tr>
<td>73</td>
<td>M</td>
<td>176</td>
<td>15.17</td>
<td>65.77</td>
<td>55.44</td>
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</tr>
<tr>
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<td>F</td>
<td>543</td>
<td>14.26</td>
<td>45.10</td>
<td>38.51</td>
<td>85%</td>
</tr>
<tr>
<td>106</td>
<td>M</td>
<td>343</td>
<td>14.29</td>
<td>75.19</td>
<td>46.99</td>
<td>62%</td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
<td>119</td>
<td>M</td>
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</tr>
<tr>
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<td>131</td>
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<td>178</td>
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</tr>
<tr>
<td>133</td>
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</tr>
<tr>
<td>136</td>
<td>F</td>
<td>463</td>
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<td>45.63</td>
<td>40.07</td>
<td>88%</td>
</tr>
<tr>
<td>140</td>
<td>F</td>
<td>373</td>
<td>10.85</td>
<td>60.21</td>
<td>41.41</td>
<td>69%</td>
</tr>
<tr>
<td>Boto ID</td>
<td>Sex</td>
<td># of Sightings</td>
<td>Span of Sightings (yrs)</td>
<td>OCLR (km)</td>
<td>OCLR (km) in MSDR</td>
<td>%OCLR in MSDR</td>
</tr>
<tr>
<td>--------</td>
<td>-----</td>
<td>----------------</td>
<td>-------------------------</td>
<td>-----------</td>
<td>-------------------</td>
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</tr>
<tr>
<td>149</td>
<td>F</td>
<td>356</td>
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</tr>
<tr>
<td>150</td>
<td>F</td>
<td>152</td>
<td>5.74</td>
<td>51.16</td>
<td>44.80</td>
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</tr>
<tr>
<td>168</td>
<td>F</td>
<td>346</td>
<td>12.24</td>
<td>37.74</td>
<td>37.74</td>
<td>100%</td>
</tr>
<tr>
<td>169</td>
<td>M</td>
<td>602</td>
<td>12.30</td>
<td>92.41</td>
<td>51.19</td>
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</tr>
<tr>
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<td>809</td>
<td>11.89</td>
<td>64.70</td>
<td>53.48</td>
<td>83%</td>
</tr>
<tr>
<td>172</td>
<td>M</td>
<td>218</td>
<td>5.17</td>
<td>64.44</td>
<td>45.97</td>
<td>71%</td>
</tr>
<tr>
<td>173</td>
<td>M</td>
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<td>171</td>
<td>9.36</td>
<td>95.69</td>
<td>50.11</td>
<td>52%</td>
</tr>
<tr>
<td>181</td>
<td>F</td>
<td>335</td>
<td>11.25</td>
<td>59.09</td>
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<td>62%</td>
</tr>
<tr>
<td>183</td>
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<td>81.03</td>
<td>30.86</td>
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</tr>
<tr>
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<td>53%</td>
</tr>
<tr>
<td>201</td>
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</tr>
<tr>
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<td>46.77</td>
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</tr>
<tr>
<td>205</td>
<td>F</td>
<td>209</td>
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<td>34.43</td>
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<tr>
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<td>54.70</td>
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</tr>
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<td>63.64</td>
<td>42.73</td>
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<tr>
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<td>F</td>
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<td>40.77</td>
<td>40.77</td>
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<td>47.93</td>
<td>39.30</td>
<td>82%</td>
</tr>
<tr>
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<td>61.46</td>
<td>23.97</td>
<td>39%</td>
</tr>
<tr>
<td>236</td>
<td>M</td>
<td>389</td>
<td>9.88</td>
<td>71.83</td>
<td>43.97</td>
<td>61%</td>
</tr>
<tr>
<td>264</td>
<td>M</td>
<td>217</td>
<td>10.59</td>
<td>76.66</td>
<td>54.39</td>
<td>71%</td>
</tr>
<tr>
<td>280</td>
<td>M</td>
<td>190</td>
<td>9.30</td>
<td>106.95</td>
<td>41.02</td>
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</tr>
<tr>
<td>307</td>
<td>M</td>
<td>311</td>
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<td>74.87</td>
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<tr>
<td>311</td>
<td>M</td>
<td>198</td>
<td>8.32</td>
<td>57.24</td>
<td>25.22</td>
<td>44%</td>
</tr>
<tr>
<td>326</td>
<td>M</td>
<td>235</td>
<td>8.35</td>
<td>72.16</td>
<td>57.97</td>
<td>80%</td>
</tr>
<tr>
<td>330</td>
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<td>156</td>
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<td>32.08</td>
<td>32.08</td>
<td>100%</td>
</tr>
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<td>77%</td>
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<td>268</td>
<td>7.24</td>
<td>35.52</td>
<td>33.97</td>
<td>96%</td>
</tr>
<tr>
<td>378</td>
<td>F</td>
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<td>43.11</td>
<td>36.53</td>
<td>85%</td>
</tr>
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<td>44.45</td>
<td>37.72</td>
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</tr>
<tr>
<td>405</td>
<td>M</td>
<td>210</td>
<td>5.34</td>
<td>52.18</td>
<td>30.78</td>
<td>59%</td>
</tr>
<tr>
<td>421</td>
<td>M</td>
<td>187</td>
<td>5.25</td>
<td>54.96</td>
<td>34.90</td>
<td>64%</td>
</tr>
<tr>
<td>451</td>
<td>M</td>
<td>184</td>
<td>3.81</td>
<td>37.99</td>
<td>30.33</td>
<td>80%</td>
</tr>
</tbody>
</table>
Table 4-2. Core use area (CUA) of six *Inia geoffrensis* individuals as determined by kernel density estimation.

<table>
<thead>
<tr>
<th>Boto ID</th>
<th>Sex</th>
<th># of polygons comprising CUA</th>
<th>Total size of CUA (km²)</th>
<th>CUA (km²) in MSDR</th>
<th>%CUA in MSDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>F</td>
<td>4</td>
<td>5.26</td>
<td>3.35</td>
<td>64%</td>
</tr>
<tr>
<td>184</td>
<td>M</td>
<td>2</td>
<td>1.49</td>
<td>0.18</td>
<td>12%</td>
</tr>
<tr>
<td>218</td>
<td>F</td>
<td>2</td>
<td>7.73</td>
<td>5.83</td>
<td>75%</td>
</tr>
<tr>
<td>437</td>
<td>M</td>
<td>2</td>
<td>3.80</td>
<td>2.67</td>
<td>70%</td>
</tr>
<tr>
<td>490</td>
<td>M</td>
<td>3</td>
<td>7.36</td>
<td>5.37</td>
<td>73%</td>
</tr>
<tr>
<td>492</td>
<td>F</td>
<td>2</td>
<td>5.29</td>
<td>3.97</td>
<td>75%</td>
</tr>
</tbody>
</table>

Table 4-3. AICc table from multi-state model results

<table>
<thead>
<tr>
<th>Model</th>
<th>AICc</th>
<th>ΔAICc</th>
<th>AICc Weight</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ψ (SeasonLG2)</td>
<td>8884.21</td>
<td>0.00</td>
<td>0.998</td>
<td>177</td>
</tr>
<tr>
<td>2. Ψ (CSeasonLG4)</td>
<td>8897.03</td>
<td>12.92</td>
<td>0.002</td>
<td>165</td>
</tr>
<tr>
<td>3. Ψ (SeasonLG4)</td>
<td>8922.80</td>
<td>38.69</td>
<td>0.000</td>
<td>285</td>
</tr>
<tr>
<td>4. Ψ (CSeasonLG3)</td>
<td>8932.41</td>
<td>48.30</td>
<td>0.000</td>
<td>141</td>
</tr>
<tr>
<td>5. Ψ (CSeasonLG2)</td>
<td>8949.24</td>
<td>65.13</td>
<td>0.000</td>
<td>117</td>
</tr>
</tbody>
</table>

The parameter of primary interest was transition probability (Ψ). Season-dependence (Season), state/location-dependence (L), and group effect (G) were represented with the associated symbols. Condensed season-dependence (CSeason) corresponds to models where estimation of transition probabilities was restricted per season across all years. Different group combinations were considered: adult males, adult females, mother/calf pairs, and immature in separate groups (G4); adults, mother/calf pairs, and immature individuals in separate groups (G3); adults, and then mother/calf pairs and immature individuals combined in one group (G2). Parameters Φ and p were fixed through *a priori* assumptions. The number of estimated parameters (K) is listed for each model.
Figure 4-1. Map of study site, the Mamirauá Lake System (MLS) and surrounding areas, located at the junction of the Japurá and Solimões rivers in the southern segment of the Mamirauá Sustainable Development Reserve (MSDR) in Amazonas State, Brazil. Map displays the three states/locations used in the multi-state models. The first two states/locations form part of the MSDR: the MLS channels and lakes (M), and ressacas or bays at the entrance of the MLS (R). The third state/location is outside the MSDR (A) and is comprised mostly of river habitat.
Figure 4-2. Map showing the Observed Complex Linear Range (OCLR) of *Inia geoffrensis* ID 6. The individual was observed 221 times between 2/4/1994 and 2/15/2012 in the Mamirauá Lake System and surrounding areas. OCLR = 49.55km (red line).
Figure 4-3. Observed Complex Linear Ranges (OCLR) of *Inia geoffrensis* individuals sighted at least 150 times in the Mamirauá Lake System and surrounding areas between January 1994 and March 2012.

Figure 4-4. Water level (m.a.s.l.) in the Mamirauá Sustainable Development Reserve from January 2009 to December 2010. The average monthly water level for ten years (2002-2011) is also displayed.
Figure 4-5. Map of the overlapping core use areas of five *Inia geoffrensis* as determined from kernel density estimation. Individuals were observed at least 15 times between November 30, 2010, and January 23, 2012 in the study area.
Figure 4-6. Seasonal transition probability estimates for 2009 and 2010, for adults, and mother/calf pairs and immature boto (MCI), from the top performing model: $\Phi(0.968,0.899)p(Lt)\Psi(SeasonLG2)$. Transition probabilities in the direction leaving the MSDR (M to A, M to R, R to A; top panel) and in the direction entering the MSDR (A to M, R to M, A to R; bottom panel) are displayed.
Figure 4-7. Condensed seasonal transition probability estimates for 2009 and 2010, for adults, and mother/calf pairs and immature botos (MCI), resulting from the model: \( \Phi(=0.968, 0.899)p(Lt)\Psi(\text{CSeasonLG2}) \). Transition probabilities in the direction leaving the MSDR (M to A, M to R, R to A; top panel) and in the direction entering the MSDR (A to M, R to M, A to R; bottom panel) are shown.
CHAPTER 5
PROTECTED AREA EVALUATION FOR THE CONSERVATION OF HARVESTED
AMAZON RIVER DOLPHINS (INIA GEOFFRENSIS)

Background

Protected Areas (PAs) are recognized as a valuable tool for the conservation of cetaceans (Gormley et al., 2012; Hooker and Gerber, 2004; Hooker et al., 1999; Hoyt, 2005; Kreb and Budino, 2005; Reeves and Reijnders, 2002). Potential benefits of PAs for cetaceans include the protection of feeding, nursery, and rest areas (Hoyt, 2005; Notarbartolo-Di-Sciara et al., 2008), as well as protection of target populations from direct anthropogenic threats (Hooker and Gerber, 2004). Currently, some of these threats include habitat deterioration (Harwood, 2001), reduced prey resources (DeMaster et al., 2001), incidental mortality in fisheries (Read, 2008), and deliberate killing (Costello and Baker, 2011; Robards and Reeves, 2011).

Although numerous PAs have been established throughout the world with the purpose of protecting marine mammals (Hoyt, 2005), few assessments have been conducted to determine the effectiveness of these PAs in protecting the target species against the above mentioned threats. To our knowledge, only one set of studies has systematically quantified the effectiveness of a PA in decreasing mortality of a cetacean population. Using population viability analysis, Slooten et al. (2006) concluded that the Banks Peninsula Marine Mammal Sanctuary was insufficiently large to effectively protect the local population of Hector’s dolphins threatened by incidental entanglement in gillnets. Subsequently, Slooten (2007) compared four possible PA scenarios for Hector’s dolphins and identified two potential PA scenarios that could significantly reduce population decline. Later, Gormley et al. (2012) estimated survival rates of Hector dolphin’s for pre-sanctuary and post-sanctuary periods, and concluded that
survival rates had improved significantly since inception of the sanctuary, although not enough to allow population recovery. This last study provided the first empirical evidence that PAs can be effective in decreasing cetacean mortality.

With the growing popularity of establishing PAs for cetaceans, it is important to continue to develop and improve PA evaluation methods like those developed for the Hector dolphin population. The functional extinction of the Baiji or Yangtze River Dolphin (*Lipotes vexillifer*) in 2006 (Turvey et al., 2007) and the critical status of the vaquita (*Phocoena sinus*) (Aragon-Noriega et al., 2010) emphasize the importance of developing quantitative evaluation methods. PAs set up for the purpose of protecting these two species have failed (Turvey et al., 2007, Aragon-Noriega et al., 2010), but it has not been determined whether the PAs were unsuccessful due to a lack of enforcement, incorrect design, or simply because they were implemented too late. An urgent need exists to evaluate the effectiveness of PAs in conserving cetaceans to ensure PA initiatives meet their potential and are not creating false impressions of conservation.

In South America, deliberate killing for use as bait has become the primary anthropogenic threat affecting the Amazon River dolphin or boto (*Inia geoffrensis*). Since the mid-1990s, boto carcasses have been used to attract the catfish *Calophysus macropterus* commonly known as *piracatinga* in Brazil and *mota* in Colombia (da Silva et al., 2011; Gómez et al., 2008; Gómez-Salazár et al., 2012; Loch et al., 2009; Portocarrero Aya et al., 2010a; Shostell and Ruiz-Garcia, 2010; Trujillo et al., 2010b, 2010c). Demand for this food fish has increased in the last decade because it is acting as a replacement for another catfish known as *capaz* (*Pimelodus grosskopfii*) that was
overfished from Colombia’s Magdalena River (Gómez et al., 2008; Petrere et al., 2004; Trujillo et al., 2010b). Consequently, an international market has developed involving the catch of piracatinga in Brazil (and recently other nations), and the export of this food fish to Colombia and a few Brazilian cities (da Silva et al., 2011; Trujillo et al., 2010b). As of 2013, the harvest of boto was occurring in at least twelve locations in four out of the five Amazonian countries with piracatinga fisheries (Diniz, 2011), and in at least one of these locales, the harvest level may lead to depletion of the population (da Silva et al., 2011; Mintzer et al., 2013).

Currently, there are no PAs aimed specifically at protecting boto. However, populations occur in PAs throughout their range (e.g., Santos Luzardo National Park in Venezuela, Pacaya-Samiria National Reserve in Peru, Noel Kempff Mercado National Park in Bolivia, Cuyabeno Wildlife Production Reserve and Yasuní National Park in Ecuador, and the Mamirauá Sustainable Development Reserve in Brazil; Aliaga-Rossel, 2002; da Silva and Martin, 2000; McGuire and Winemiller, 1998; Utreras et al., 2010). Currently, the Whale and Dolphin Conservation Society is partnering with researchers in South America to establish the South American River Dolphin Protected Area Network (SARDPAN). The initiative includes over 30 protected areas, in six South American countries, that should assist in the protection of boto (Portocarrero et al., 2010b; <http://sardpan.wordpress.com/protected-areas/>). However, there is very limited information on the effectiveness of PAs for the conservation of river dolphins. Such information is critical to inform initiatives like SARDPAN.

Herein, we develop a model to assess the effectiveness of a PA in protecting boto. Using a case study approach, we determined the effectiveness of an existing PA
and evaluated various PA scenarios to identify potential improvements. We describe the steps conducted to develop the evaluation model, present the model predictions and parameter estimates, and discuss potential improvements in PA design for the conservation of Amazon River dolphins.

**Methods**

**Case Study**

This study took place in and around the southern segment of the Mamirauá Sustainable Development Reserve (MSDR) located at the confluence of the Solimões and Japurá rivers, approximately 30km upriver of the town of Tefé in Amazonas State, Brazil (Figure 2-1). The MSDR consists of a focal area of about 260,000 hectares and a subsidiary area of approximately 864,000 hectares. It was established in 1996 with the aim of combining biodiversity conservation and sustainable resource use, with the active participation of local human populations (SCM, 1996).

The MSDR is a whitewater floodplain or várzea, with aquatic fauna that varies seasonally with extreme water fluctuations. As the water level rises, the lowland forest floods, channels widen, and lakes form. Although the exact timing of peak high and low water levels vary annually, typically the highest water mark is reached in June, and lowest water levels occur between September and November (Ramalho et al., 2009; IDSM, 2012b; Figure 4-4). Based on the water fluctuations, four main seasons are recognized in the study area: rising water (RW), high water (HW), falling water (FW), and low water (LW).

The data utilized in this study were collected through Projeto Boto, a not-for-profit river dolphin research program that has been active since 1994 in the southern segment of the MSDR, the Mamirauá Lake System (MLS) and adjacent waterways (Figure 2-1).
Three methodologies implemented by Projeto Boto were utilized in this study: physical capture and marking of botos, year-round observational surveys, and standardized monthly count surveys. Physical capture-recapture and marking of botos occurred approximately three weeks each year during low water. During capture, botos were freeze-branded with a unique code to allow for subsequent individual identification. In addition to the physical capture-recapture events, year-round observational work was conducted throughout the MLS and surrounding areas, including segments of the main rivers. When a boto or group of botos was sighted, the unique codes of any marked individuals were recorded, along with the location. In addition, standardized count surveys were carried out once per month along a 30km route from the entrance of the MLS, to the Mamirauá Lake (Figure 4-1). The objective of these surveys was to enumerate botos, not to identify marked individuals. Further descriptions of Projeto Boto procedures are available in da Silva and Martin (2000), Martin and da Silva (2004a, 2004b), Martin et al. (2006), and Mintzer et al. (2013).

As expected from the temporal dynamics of the floodplain, Projeto Boto has shown that dolphin distribution in MSDR is highly dependent on seasonal variation in water levels (Martin and da Silva, 2000b). During the dry season, botos are concentrated in the main rivers and channels, whereas during the flooded season they enter the MLS (da Silva, 2008; Martin and da Silva, 2000b). Furthermore, Projeto Boto has identified a “resident” population of botos in the study area; individuals that are observed in the area for at least seven of 12 months of the year (Martin and da Silva, 2004a). Because of the water fluctuations, no boto spends its entire life within the MLS; however, some individuals stay in close proximity to the floodplain system until the
water rises enough to allow them back into the MLS (Chapter 4; Martin and da Silva, 2004b).

It is important to emphasize that the MSDR was not created with the specific goal of protecting botos, but instead “for the preservation of fragile habitats with the sustainable development of local resident communities” (SCM, 1996. Pg.11). A PA should not be evaluated for goals it was not created to achieve; hence, we want to stress that our objective herein was not to evaluate the success or failure of the MSDR in protecting river dolphins, but instead, to use the MSDR as a model to build our evaluative framework. We considered the MSDR to be a good candidate for our evaluation because it consists of várzea, considered essential habitat for the species (Chapter 4; Martin and da Silva, 2004b; Utreras et al., 2010), and it is home to a resident population of botos (Martin and da Siva, 2004a).

**Model Structure**

We built the evaluative model in a spreadsheet to represent 50 years of the study population’s abundance. The model predicted population changes from one year to the next for seven age classes. Age classes 1-3 included calves, or botos still dependent on their mother. Botos in age classes 4-6 were considered to be immature, or individuals no longer dependent on their mother but not yet sexually mature. The final age class 7 consisted of both females and males of reproductive age. These age classes were based on previous work suggesting that botos reach sexual maturity at 6-7 years of age (da Silva, 2008) and that most calves stay with their mothers 3-4 years (Projeto Boto, unpublished data).

Because of the importance of water level fluctuations on boto movement and reproduction (Chapter 4; Martin and da Silva, 2004a, 2004b; McGuire and Aliaga-
Rossel, 2010), we incorporated the four water-level based seasons in the model: FW, LW, RW, and HW. Although the exact timing and duration of these seasons varies from year to year, we assigned a total length, in months, to each season, based on water level records from the MSDR during the last decade (Ramalho et al., 2009; IDSM, 2012b; Figure 4-4). Births were represented only once a year, at high water, since most births occur during this time period (Best and da Silva, 1989a; Best and da Silva, 1993; da Silva, 2008).

We considered the beginning of the year to be the start of the FW, because we wanted to begin by modeling population changes shortly after the calving season. The following equations were utilized in the model to estimate changes in abundance from the HW to the FW season (from one year to the next) inside the MSDR:

\[ n_{1,t+1} = (Bpn_{7,t})*(\phi^M(1/12))^L_HW \]  (5-1)

\[ n_{2,t+1} = (n_{1,t}^M*(1-\Psi_{MA_{MCL,HW}})+n_{1,t}^A*\Psi_{AM_{MCL,HW}})^*(\phi^M(1/12))^L_HW \]  (5-2)

\[ n_{3,t+1} = (n_{2,t}^M*(1-\Psi_{MA_{MCL,HW}})+n_{2,t}^A*\Psi_{AM_{MCL,HW}})^*(\phi^M(1/12))^L_HW \]  (5-3)

\[ n_{4,t+1} = (n_{3,t}^M*(1-\Psi_{MA_{MCL,HW}})+n_{3,t}^A*\Psi_{AM_{MCL,HW}})^*(\phi^M(1/12))^L_HW \]  (5-4)

\[ n_{5,t+1} = (n_{4,t}^M*(1-\Psi_{MA_{MCL,HW}})+n_{4,t}^A*\Psi_{AM_{MCL,HW}})^*(\phi^M(1/12))^L_HW \]  (5-5)

\[ n_{6,t+1} = (n_{5,t}^M*(1-\Psi_{MA_{MCL,HW}})+n_{5,t}^A*\Psi_{AM_{MCL,HW}})^*(\phi^M(1/12))^L_HW \]  (5-6)

\[ n_{7,t+1} = ((n_{7,t}^M*n_{6,t}^M)^*(1-\Psi_{MA_{Adults,HW}})+(n_{7,t}^A*n_{6,t}^A)^*\Psi_{AM_{Adults,HW}})^*(\phi^M(1/12))^L_HW \]  (5-7)

where, \( B \) = annual fecundity, \( p \) = proportion of adult females, \( \phi^M \) = annual apparent survival in the MSDR, \( \phi^A \) = annual apparent survival outside the MSDR, \( L_{HW} \) = number of months in HW season, \( \Psi_{G,HW} \) = group (G) dependent seasonal transition probability.
from inside(M) to outside(A) the MSDR, $\Psi_{G,HW}^{AM}$ group (G) dependent seasonal transition probability from outside(A) to inside(M) the MSDR.

We made slight modifications to these equations to represent changes from FW to LW, LW to RW, and RW to HW. Moreover, we used analogous equations to calculate changes in abundances outside of the MSDR. The transition probabilities synchronized abundance inside the MSDR (M) with abundance outside the MSDR (A). Figure 5-1 depicts a flow chart representation of the model and Table 5-1 shows the model's five year output.

**Parameter Estimation**

*Apparent Survival ($\phi$)*

Apparent survival ($\phi = \text{true survival} \times (1 - \text{probability of permanent emigration})$) estimates of the study population were determined using mark recapture/resight modeling described in detail by Mintzer et al. (2013). In this previous analysis, apparent survival estimates for the pre-harvest and harvest period were estimated to be 0.968 and 0.899, respectively. Because no harvest occurs inside the MSDR section included in this study (Chapter 3), we assigned 0.968, the pre-harvest survival estimate, as the MSDR apparent survival probability ($\phi^M$). We assigned 0.830 as the outside the MSDR apparent survival probability ($\phi^A$), to make the average of the two probabilities 0.899, which equals the estimated harvest period (or current) apparent survival probability for the population (Mintzer et al., 2013).

*Annual Fecundity ($B$)*

Fecundity rate is defined as the mean number of live births a female produces over an interval of age (Caughley, 1977). We estimated fecundity by first determining
the first year a female boto was captured or sighted with a calf (to establish sexual maturity), and then dividing the number of times the female was seen with a new calf by the number of subsequent years the female was sighted (Thayer, 2012). We only included adult females sighted for 10 or more consecutive years, and with unambiguous calf histories. The average annual fecundity of the 15 females included in this calculation was 0.298 (SD=0.083).

*Initial Abundance (N₀) per Age Class and Proportion of Females (p)*

The initial abundance was considered to be 528, which corresponds to the boto population included in the apparent survival analysis in Mintzer et al. (2013). The initial proportion of botos in each class was determined based on the proportion of botos in each age class sighted in the year 2009. Proportion of females in the study population was 0.485 (Mintzer et al., 2013).

*Transition Probabilities (Ψ)*

We used multi-state mark-recapture models in Program MARK (White and Burnham, 1999) to estimate transition probabilities of botos moving from inside to outside the MSDR (Ψ⁺⁻), and from outside to inside the MSDR (Ψ⁻⁺). We created encounter histories for 305 botos sighted between January 2009 and December 2010, using visual sightings of uniquely identified individuals. The encounter histories were based on monthly time intervals and included only sightings made with 100% confidence.

For multi-state models, encounter histories represent both the encounter (or sighting) and the state (or location) of the encounter. In our modeling, we defined two states/locations: inside the MSDR (M) and outside the MSDR (A). If an animal was
seen within the MSDR during a month, it was assigned an M for that month. If it was sighted outside the MSDR during a month, it was assigned an A. For instance, an encounter history of M0A describes an individual that was sighted in the MSDR in period 1, not detected in period 2, and seen outside the MSDR in period 3.

We calculated transition probability estimates across these states/locations ($\Psi^{MA}$ and $\Psi^{AM}$) for each of the four seasons (HW, FW, LW, RW). Program Mark estimates the following three parameters for multi-state recaptures only models: $S_t' = \text{the probability that a boto in location } r \text{ at time } t \text{ survives until time } t+1$, $P_t' = \text{the probability that a boto is sighted at time } t \text{ in location } r$, given that the boto is alive and in the study area at time $t$, $\Psi_t^{rs} = \text{the probability that a boto in location } r \text{ at time } t \text{ is in location } s \text{ at time } t+1$, given that the boto survived from time $t$ to $t+1$. We considered $S$ to be apparent survival ($\phi$) (defined in the section on apparent survival). We treated $\phi$, $p$, and $\Psi$ based on a priori assumptions. We fixed $\phi^M$ and $\phi^A$ at 0.968, and 0.830 respectively (refer to section on apparent survival). To allow for changes in observation effort through time and space, we defined $p$ as fully time-dependent (t) and state/location dependent (L). We built models that allowed estimation of transition probabilities ($\Psi$) for each season of each year, and some that restricted estimation of transition probabilities per season across all years. Additionally, we built models that allowed $\Psi$ to vary according to sex and age group (G). Four groups were considered: adult males (AM), adult females (AF), mother/calf pairs (MCP), and immature individuals (IMM). Transition probabilities were allowed to vary with the four groups (AM, AF, MCP, and IMM), three groups (adults, MCP, and IMM), or two groups (adults and MCI, where MCP and IMM were combined). Please refer to Chapter 4 for additional information.
regarding the building of the encounter histories, and definition and treatment of the seasons and groups.

We used the sin-link function to transform real parameter values \([0,1]\) to \(\beta\)-values \([-\infty,\infty]\) for numerical optimization. We used simulated annealing, which is recommended for multi-state models where parameter estimates may be close to the 1 boundary. We conducted a median \(\hat{c}\) goodness-of-fit test on the global model to assess overdispersion (White and Burnham, 1999) and subsequently applied the estimated \(c\) (variance inflation factor) to the model set. We used the Akaike’s Information Criterion (AIC) for model ranking (Akaike, 1973); however, because we applied the estimated \(c\) to our model set, we used the small-sample, \(c\) corrected version of AIC, QAICc, to determine model rank.

**Scenario Building**

We built the original model to present the current PA scenario, with the above parameter estimates, and checked model performance by comparing the resulting abundance trend to an abundance trend representing an annual decrease in the population of 4.926%. We estimated this average annual decrease from the 1995 to 2011 minimum count monthly standardized surveys conducted in one channel in the MSDR.

To simulate the various PA scenarios, we adjusted the transition probabilities that were inputted into the evaluative model. For these adjustments, we manipulated the input files used in the multi-state models in Program MARK. For example, an original encounter history of AM0A0AAA describes an individual that was most often seen outside the MSDR boundaries (in A). If we were considering a scenario where the
MSDR boundaries were expanded, we would examine the sightings that occurred in A, and change them to M if they occurred in an area considered newly protected for the scenario. The adjusted encounter history could result in MM0A0MMM. With each scenario, all capture histories were altered in this manner to represent the areas considered to be newly protected under the scenario being explored. We built a new transition probability model for each set of altered capture histories, with the structure of the top performing model as determined by QAICc ranking (i.e., the most parsimonious model built with the Scenario 1 input file).

We considered five different PA scenarios: the current MSDR boundary (Scenario 1), three scenarios with expanded boundaries (Scenarios 2-4), and one scenario with no PA (Scenario 5) (Figure 5-2). Scenarios 2-4 represented an expansion in the boundaries that included segments of the main river, the Japurá, at the entrance of the MSDR. In Scenario 2, an area of 4.968km² directly adjacent to the entrance of the MLS was included as protected (Figure 5-2). Scenario 3 included the same area in Scenario 2 plus the area of the Japurá that meets the Solimões River, totaling 7.024km² of additional protected water (Figure 5-2). Scenario 4 included a total additional area of 16.633km², consisting of the area protected in Scenario 3 plus an additional large segment upriver on the Japurá (Figure 5-2). Finally, to simulate a scenario with no reserve (Scenario 5), we set survival both inside and outside the MSDR equal to 0.830.

We expected that protecting sections of the Japurá would benefit the population because during low water, when boto are forced out of the MSDR, many individuals stay in close proximity to the MSDR entrance (Chapter 4; Martin and da Silva, 2004b). If boto do indeed utilize this area of the Japurá River extensively, we would expect
transition probabilities going from inside to outside the MSDR to decrease considerably in scenarios where the PA boundary is expanded to include this area. Subsequently, we would expect abundance estimates to be greater in scenarios including the Japurá River sections as PA. With a decrease in transition probabilities leaving the MSDR, botoș would be subject to a lower mortality probability for longer periods of time.

Results

Model Performance

The trend in abundance predicted by the evaluative model closely followed the trend expected with an annual 4.926% decline (Figure 5-3); thus, we did not adjust any of the original parameter estimates in the model. As expected, based on Chapter 4 and Martin and da Silva (2004a, 2004b), the abundance numbers fluctuated in accordance with the season. The lowest number of botoș within the MSDR boundaries occurred during low water (Figure 5-4).

Transition Probabilities

The median $\hat{c}$ goodness-of-fit test resulted in $\hat{c} = 2.223$, well within an acceptable range of $1 \leq c \leq 4$ (Burnham and Anderson, 2002), and we adjusted all multi-state model results with this value. QAICc supported a model with condensed season-dependent transition probabilities, and with two groups, adults (AM and AF), and MCI (MCP and IMM) (Model 1; Table 5-2). Thus, we used this model structure to build the additional multi-state models to estimate transition probabilities for the various scenarios. The difference in transition probabilities between adults and MCI was expected based on previous work (Chapter 4).

The transition probabilities in the direction away from the MSDR ($\Psi^{MA}$) varied considerably with the adjustments made to the input files. As expected, these estimates
decreased as the MSDR boundary was expanded to the Japurá River in the various scenarios, particularly for the FW season (Figure 5-5). The largest estimated difference was between the transition probabilities of the adult group in the direction leaving the MSDR between Scenario 1 \( (\Psi_{\text{Adults, LW}}^{\text{MA}} = 0.602; \ SE=0.057) \) and Scenario 4 \( (\Psi_{\text{Adults, LW}}^{\text{MA}} = 0.326; \ SE=0.043) \) (Figure 5-5).

**Scenario Predictions**

The abundance estimates corresponding to the current scenario (Scenario 1; Figure 5-2) predicted a decline in the study population in the decades to come, with only 50 botos remaining in 50 years (Figure 5-6). The estimates for Scenario 5, a scenario representing no PA status, predicted that in 30 years the population would decline to 10 individuals (Figure 5-6). In Scenarios 2 and 3 (Figure 5-2), where the PA boundaries were expanded to include small segments of the Japurá River adjacent to the entrance of the MLS, the model predicted gradual declines in abundance in the population in the next 50 years (Figure 5-6). In Scenario 4, where the PA was expanded considerably to include a larger portion of the Japurá River (Figure 5-2), the model predicted an increase in abundance in the next 50 years (Figure 5-6). The most note-worthy difference between Scenarios 2 and 3, and Scenario 4, was the inclusion of a lengthy beach, Praia Clarindo, within the PA boundary in Scenario 5 (Figure 5-2).

**Discussion**

**Abundance Trend**

Mintzer et al. (2013) and da Silva et al. (2011) suggested that the harvest of botos is having a detrimental effect on the study population, so it was unsurprising that the model predicted a declining trend in the study population under the current scenario.
If no management interventions take place and the harvest continues at the annual average rate of approximately 7% (Mintzer et al., 2013), the study population will be nearly depleted in 50 years. Importantly, our results suggested that expanding the MSDR boundaries to protect a larger portion of the study population’s range could have a positive effect on abundance and effectively limit the population decline.

**Model Limitations**

The increasing abundance trend predicted in Scenario 4 is likely an overestimation due to two model limitations. First, the model does not incorporate density dependent effects. Population parameters such as mortality and sexual maturity appear to be density dependent in marine mammals, although there is ongoing debate on the subject (Crespo and Hall, 2002). Nevertheless, reduction in the density of harvested whale species has been linked to changes in pregnancy rates and age of sexual maturation (Lockyer, 1984). With the considerable climb in abundance numbers represented in Scenario 4, it is likely that density dependence effects would come into play and limit the 50 year steep population growth through a decrease in fecundity rate or an increase in age at sexual maturity. To accurately predict 50-year abundance estimates for Scenario 4, a more complex model that incorporates density dependence would be required.

Second, the evaluative model assumed that the inside and outside states were homogenous in survival probability. In other words, botos found outside the PA were subject to one mortality rate, regardless of their exact location. The same held true for botos found within the MSDR. Because previous work has found that no boto harvest occurs within the segment of the MSDR included in this study (Chapter 3), this assumption holds true for the inside state. On the other hand, previous work has shown
that harvest activity is not evenly distributed outside of the MSDR (Chapter 3). Because we did not directly account for this heterogeneity in the model, the increasing trend in abundance in Scenarios 4 could be an overestimation, as the survival probability could already be high in some areas outside the MSDR. However, the PA in Scenario 4 straddles the entrance of a channel where boto harvest has been known to occur (per Chapter 3), so we did expect an increase in survival probability in that area once protected.

**Protected Areas for Amazon River Dolphins**

The results of this study suggest that spatial protection could be a successful tool for the conservation of boto populations that exhibit site fidelity to floodplains in the Amazon. However, at current harvest levels in the study area, protection of solely the floodplain in and in itself is insufficient to maintain the study population, as individuals are subject to high levels of mortality when leaving the floodplain. Given that the movement patterns of most individuals are predictable based on the water level, and that many individuals stay close to the várzea during low water, protecting areas of main rivers adjacent to várzea habitat, especially during the low water season, is essential. As shown in this study, these river PAs need not be large relative to the floodplain PA (Scenario 4’s PA expansion is equivalent to only 6% of the MLS), but need to include hotspots of boto activity such as beaches and confluences, to assure that botos spend a considerable portion of their time within the PA.

This study focused on a boto population that exhibits high site fidelity, with at least half the individuals considered residents (Martin and da Silva, 2004b). Not all botos exhibit site fidelity and PAs may do little to protect transient individuals who may travel hundreds of kilometers between river systems (Martin and Da Silva, 2004b).
However, site fidelity to várzeas or lakes has also been observed in botos in the River Negro, Tocantins rivers, Samiria River, and Orinoco basin (Best and da Silva, 1989b; Mcguire and Henningsen, 2007; Schnapp and Howroyd, 1992), so spatial protection may be an important strategy to protect specific boto populations throughout the species’ range.

Simply denoting an additional area as protected will not be enough to decrease the harvest of botos. Harvest of botos occurs within the MSDR boundaries (Estupiñán et al., 2003; Chapter 3), north west of our study area, where enforcement and management efforts are not carried out to the same degree as in our study area (the southernmost portion of the MSDR, or the MLS and adjacent waterways) (SCM,1996). The harvest has been limited in the MLS likely due to a combination of Projeto Boto researcher presence, education resulting from Projeto Boto and the MSDR community-based programs, and the MSDR enforcement agent surveillance (Chapter 3).

Throughout the Amazon, federal enforcement is challenging due to institutional deficiencies (McGuire and Aliaga-Rossel, 2010a; Peres and Terbough, 1995; Trujillo et al., 2010c; Utreras et al., 2010); thus, PAs will likely not be successful in limiting the boto harvest without strong local efforts.

**Protected Area Evaluation**

Because most PAs are monitored only after establishment, one of the main challenges in PA evaluation is a lack of pre-protected area data that would allow for pre- and post-PA comparisons. Evaluations are further complicated in cases were insufficient ecological data on populations exist to make comparisons between populations occurring inside PAs and outside PAs. In this study, regardless of the presence of these two challenges, a fairly simple population model was used to
evaluate the effectiveness of a PA in protecting a species, in a complex aquatic system, and test for improvements. The mark-recapture data set used here allowed for key parameter estimates to inform the model, particularly survival probability estimates that represented protected vs. unprotected areas and transition probabilities that measured animal movements between these areas. If a data set is available to estimate these demographic parameters, our framework could be utilized to evaluate PAs in various systems and for numerous species.
### Table 5-1. Five year output for the evaluative model.

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<td>HW(May-Jun)</td>
<td>2</td>
<td>26</td>
<td>32</td>
<td>34</td>
<td>35</td>
<td>28</td>
<td>17</td>
<td>136</td>
<td>308</td>
<td>11</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>112</td>
<td>163</td>
<td>470</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>FW(Jul-Sep)</td>
<td>3</td>
<td>20</td>
<td>27</td>
<td>32</td>
<td>34</td>
<td>35</td>
<td>28</td>
<td>155</td>
<td>332</td>
<td>16</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>109</td>
<td>167</td>
<td>499</td>
<td>478</td>
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<tr>
<td></td>
<td>LW(Oct-Nov)</td>
<td>2</td>
<td>18</td>
<td>24</td>
<td>28</td>
<td>29</td>
<td>30</td>
<td>24</td>
<td>80</td>
<td>232</td>
<td>17</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>10</td>
<td>175</td>
<td>253</td>
<td>486</td>
<td></td>
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<tr>
<td></td>
<td>RW(Dec-Apr)</td>
<td>5</td>
<td>20</td>
<td>26</td>
<td>28</td>
<td>29</td>
<td>30</td>
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<td>13</td>
<td>9</td>
<td>147</td>
<td>217</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>HW(May-Jun)</td>
<td>2</td>
<td>23</td>
<td>29</td>
<td>30</td>
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<td>32</td>
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<td>9</td>
<td>7</td>
<td>7</td>
<td>101</td>
<td>153</td>
<td>449</td>
<td></td>
</tr>
</tbody>
</table>
Table 5-2. QAICc table from multi-state model results

<table>
<thead>
<tr>
<th>Model</th>
<th>QAICc</th>
<th>ΔQAICc</th>
<th>QAICc Weight</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( \Psi ) (CSeasonLG2)</td>
<td>3360.98</td>
<td>0.00</td>
<td>0.69</td>
<td>62</td>
</tr>
<tr>
<td>2. ( \Psi ) (SeasonLG2)</td>
<td>3362.62</td>
<td>1.63</td>
<td>0.31</td>
<td>82</td>
</tr>
<tr>
<td>3. ( \Psi ) (CSeasonLG3)</td>
<td>3371.69</td>
<td>10.71</td>
<td>0.00</td>
<td>70</td>
</tr>
<tr>
<td>4. ( \Psi ) (CSeasonLG4)</td>
<td>3383.79</td>
<td>22.80</td>
<td>0.00</td>
<td>78</td>
</tr>
<tr>
<td>5. ( \Psi ) (SeasonLG3)</td>
<td>3390.88</td>
<td>29.89</td>
<td>0.00</td>
<td>100</td>
</tr>
</tbody>
</table>

The parameter of primary interest was transition probability (\( \Psi \)). Season-dependence (Season), state/location-dependence (L), and group effect (G) were represented with the associated symbols. Condensed season-dependence (CSeason) corresponds to models where estimation of transition probabilities was restricted per season across all years. Different group combinations were considered: adult males, adult females, mother/calf pairs, and immature individuals (G4); adults, mother/calf pairs, and immature individuals (G3); adults, and then mother/calf pairs and immature individuals combined (G2). Parameters \( \Phi \) and \( p \) were fixed through \textit{a priori} assumptions. Number of estimated parameters (k) is listed for each model.
Figure 5-1. A schematic representation of the evaluative model showing demographic parameters of botos within the MSDR (top panel) and outside the MSDR (bottom panel) for seven age classes. Apparent survival inside (M) and outside (A) the MSDR is denoted by $\phi^M$ and $\phi^A$ respectively. Movement in and out of the MSDR is represented by transition probabilities $\psi^{AM}$ and $\psi^{MA}$. Fecundity is indicated by $F$. This conceptual model does not display movement throughout all seasons, only at falling and rising water.
Figure 5-2. Protected area boundary scenarios applied in the evaluative model. Scenario 1 represents the true or existing protected area boundary of the Mamirauá Sustainable Development Reserve. Scenarios 2-4 convey situations where the protected area boundary is expanded.
Figure 5-3. Estimated abundance (N) for the captured boto population in the Mamirauá Sustainable Development Reserve (MSDR). The model abundance trend represents predictions from the scenario representing the current MSDR boundaries (Scenario 1). The “survey” line represents a 4.926% average annual decline in the population estimated from monthly standardized observation surveys conducted in a channel in the MSDR from 1994 to 2012.

Figure 5-4. Five year abundance estimates for *Inia geoffrensis* inside the Mamirauá Sustainable Development Reserve (MSDR) and outside the MSDR according to season (FW=falling water, LW=low water, RW=rising water, HW=high water).
Figure 5-5. Seasonal transition probability estimates for adults, and mother/calf pairs and immature botos (MCI), in the direction leaving the MSDR (M to A; top panel), and in the direction entering the MSDR (A to M; bottom panel), from the top performing model: $\Phi(0.968, 0.830)p(L_t)\Psi(C_{\text{SeasonLG2}})$. 
Figure 5-6. Fifty year abundance (N) trends of *Inia geoffrensis* estimated from five scenarios simulated in the evaluative population model. Scenario 1 represents the true or existing protected area boundary of the Mamirauá Sustainable Development Reserve. Scenarios 2-4 convey situations where the protected area boundary was expanded. Scenario 5 represents the circumstances under no protected area.
CHAPTER 6
CONCLUDING REMARKS AND RECOMMENDATIONS FOR CONSERVATION

This research focused on determining the effect of harvest on the boto population occurring in and near the Mamirauá Sustainable Development Reserve (MSDR), and the evaluation of protected areas (PAs) as a tool for boto conservation. In Chapter 2, I determined the effect of the harvest by using mark-recapture modeling to determine survival probabilities for the study population. The results suggested that the harvest level of approximately 7% is likely unsustainable. In Chapter 3, I evaluated fisher perceptions, attitudes and behaviors toward botos to explore the types and frequency of fisher-boto interactions, and to determine the effect, if any, of the MSDR on fisher attitudes and behaviors. Results suggested that the MSDR community-based initiatives have had a positive effect on fisher attitudes toward botos and their conservation. Although more research is needed to determine if these positive attitudes translate into positive behaviors, the findings suggest that the MSDR has likely limited boto mortality through behavioral controls. In Chapter 4, I investigated boto habitat use and seasonal movement patterns. Although botos are forced to leave the MSDR during the low water season, many stay close to the MSDR and transition back to the MSDR quickly. Moreover, bays appear to be of critical importance to botos in vulnerable life stages. Finally, in Chapter 5, I developed a population model that estimated the current effect of the MSDR on boto abundance and evaluated various PA scenarios. The results suggested that with the current scenario the boto population could be nearly depleted in 50 years; however, expanding the MSDR boundaries to include areas of the major river could lead to increases in population abundance and prevent extinction.
Together these findings support the conclusion that, under specific circumstances, PAs could be an effective strategy to conserve boto populations that exhibit site fidelity to várzeas. However, the protection of floodplain habitats alone is insufficient due to the water level dynamics that force botos out of shallow areas. In the case of the MSDR, expanding the boundaries to include river habitat adjacent to the floodplain system, particularly segments that include beaches and confluences, could provide the necessary sanctuary for botos during the low water season. Moreover, due to the difficulties of enforcing natural resource regulations in the Amazon, simply expanding the MSDR boundary would be insufficient to protect botos. Local community-based conservation programs involving research, ecotourism, and enforcement would need to be expanded along with the boundaries. Together these initiatives could promote positive attitudes toward botos and may limit boto mortality through behavioral controls imposed by community members. By meeting both design and management improvements, the MSDR could prevent the decline of the local boto population.

Based on the MSDR case study, I conclude that the success of PAs in conserving botos will likely be very dependent on local programs and large-scale initiatives like SARDPAN will need to encourage such efforts in order to ensure success. Accordingly, I have two major recommendations for the SARDPAN project and similar initiatives. At a minimum, PAs for boto conservation would need to account for the effects of water level fluctuations and protect multiple habitat types. Localized research may be necessary to determine key habitats for target boto populations. In most cases, however, PAs will likely need to include segments of major rivers that are
commonly key transportation routes and consequently almost always excluded from Amazonian PAs. Secondly, enforcement efforts would need to be established at the local level. In sustainable use or “people-inclusive” PAs, these efforts could be in the form of community-based enforcement programs, where locals are trained and compensated for enforcing boto and PA regulations. However, these programs would likely only be successful in areas where attitudes toward botos are generally favorable, as was the case in the Mamirauá Lake System. In order to promote such attitudes, outreach, tourism, and/or research initiatives with active community education and participation would need to be established. A timely and transdisciplinary approach with a focus on local boto population dynamics and human communities is needed to address the illegal harvest.

In addition to providing recommendations for the conservation of the boto, another goal of this work was to develop a modeling framework that would contribute to the demand and need for PA evaluation tools. Gerber et al. (2003) argued that while there are numerous existing examples of strategic models (aimed at answering broad-type questions) relating to PAs, more tactical models are needed to further develop reserve design theory. Tactical models are typically more complex and are used to address specific situations, like the design of a specific reserve or the management of a specific species (Gerber et al., 2003). Of the tactical models that have been developed pertaining to PA evaluation, few include explicit information on movement and demography (Gerber et al., 2003), belittling the credibility of the assessments.

In Chapter 5, I developed a tactical model that incorporated movement and demography to evaluate the effect of a PA on population abundance. After using a
combination of mark-recapture modeling tools to estimate demographic and movement parameters, I developed a model that could link these parameter estimates in a framework conducive to evaluating various PA scenarios. This modeling framework is applicable to other systems and species for which mark-recapture data exist.

Along with the information on demography and movement of the boto population gathered from Chapters 2 and 4, the modeling framework was built based on material in Chapter 3, where the focus was on human dimensions and not boto ecology. From the fisher attitude and behavior assessment, we learned that it is unlikely that the harvest occurs within the Mamirauá Lake System (MLS), probably due to a combination of researcher and enforcement presence, as well as education from involvement in community-based activities (key points mentioned in the recommendations above). From these results, I was able to establish the treatment of the survival parameters in the model (assumed no harvest in the MLS and harvest outside), and more importantly, make the assumption that expanding the boundaries could have a positive effect. The favorable abundance trend estimated in Chapter 5 would mean little without the human dimensions work that indicated that the MSDR is working to some extent. Chapter 3 provided a perspective on the issue that went past numbers and modeling, one that exposed mechanisms and drivers that could not only tell us if the PA was working, but the how. Beyond boto conservation recommendations and modeling frameworks, the final contribution of this work is to stress the importance of the interdisciplinary approach and the value that it can provide to the evaluation of conservation strategies.
APPENDIX A
FISHER SURVEY - ENGLISH

Date:  Day_____/Month_____/Year_____
Time:  ____:_____

Community Name:____________________________________________________________

Community Type (circle one):  Focal  Subsidiary
Reserve-User  Non-Reserve

Community location (circle all that apply):
River_____ Channel_____ Confluence_____ Beach_____ Bank_____ Bay_____ Lake_____

GPS Coordinates:  Latitude:_____________ Longitude:_____________

(1) Would you like to participate in the survey?
1 No_____  2 Yes_____  If No, thank the fisher and end survey.

(2) What year were you born?______  If participant is not 18 years old, please thank the fisher and end survey.

(3) Where you born in this community?
1 No_____  2 Yes_____  If No  →  3b,  If yes →  3d

(3b) Where were you born?_____________

(3c) How long have you lived in this community?_____________

(3d) Have you lived in this community your entire life?_____________
1 No_____  2 Yes_____  If No  →

(3e) Where else have you lived in the past?________________________

(4) Does your family live in this community?

(4b) How many people live with you?_____________
(5) Have you studied at a school in ___________ *(use response to Question 3)*?
1 No_____ 2 Yes_____  It Yes →

(5b) How long did you study (in each location)? __________________________

(6) How long have you fished in the area near this community?______________
If before 1996 →

(6b) Do you think fishing has changed since inception of Mamirauá in 1996?
1 No_____ 2 Yes____  If Yes →

(6c) How has fishing changed since inception of Mamirauá?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(7) Have you attended and/or participated in any meetings and/or workshops
coordinated by the Mamirauá Institute?
1 No_____ 2 Yes_____  If Yes →

(7b) Which meetings and/or workshops did you attend and when?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(8) How many times have researchers or other staff from the Mamirauá Institute
visited this community in the last month and in the last year?
___________________/ month and ________________/year If they visited →

(8b) How many times did you speak with researchers or other staff of the
Mamirauá Institute in the last month and in the last year?
___________________/ month and ________________/year

(9) What type(s) of fishing gear did use in the last year?
1 lampara seine_______ 2 drift gill net_______ 3 fixed gill net_______
4 Trawl_______ 5 Outro_________________ 6 Outro_________________
7 Outro_________________ If net →
(9b) What size mesh do you use? ________________________________

(9c) How long is your net(s)? ________________________________

(10) How many other fishermen in this community use the same type of fishing gear you use?
1 lampara seine_______ 2 drift gill net_______ 3 fixed gill net_______
4 Trawl_______ 5 Other____________________ 6 Other____________________
7 Other____________________

(11) What type of vessel do you use to fish
1 Canoe_______ 2 Canoe with motor _______ 3 Boat with motor_______
4 Other____________________

(12) What percentage or part of your catch did you sell in the last year?__________

(12b) Where did you sell your fish in the last year?__________________________

(12c) Where did you sell with more frequency?______________________________

(13) In what location(s) did you fish at during the last month and the last year? (Ask participant to point out location on the attached map if possible. Write the location names in the answers for question 15)

(14) Can you order the locations according to where you fished with more frequency? (Rank the locations in Question 15 according to frequency, with 1 being the most frequent.

(15) What habitat type(s) do you find at your fishing location(s)? (If more than one habitat, rank them according to their prominence, 1 being the most prominent.)

Location 1________________________ Rank__________
1 River____ 2 Channel____ 3 Confluence____ 4 Beach____ 5 Bank____
6 Bay____ 7 Lake____ 8 Other____ 9 Other____ 10 Other_____________________ Location 2________________________ Rank__________
1 River____ 2 Channel____ 3 Confluence____ 4 Beach____ 5 Bank____
6 Bay____ 7 Lake____ 8 Other____ 9 Other____ 10 Other____________________
### Location 3

|------|----------|------------|---------------|---------|--------|-------|--------|---------|---------|----------|

### Location 4

|------|----------|------------|---------------|---------|--------|-------|--------|---------|---------|----------|

### Location 5

|------|----------|------------|---------------|---------|--------|-------|--------|---------|---------|----------|

16) In which months did you fish at in the last year?

<table>
<thead>
<tr>
<th>Month</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td></td>
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<tr>
<td>March</td>
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<td>April</td>
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<td>May</td>
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<td>June</td>
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<td>July</td>
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<td>August</td>
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<td>September</td>
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<tr>
<td>October</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td></td>
</tr>
</tbody>
</table>

17) How many times do you fish in the last week and month?

<table>
<thead>
<tr>
<th>Week</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18) In the days that you fished in the last month, how many times per day did you fish?

(18b) At what time did you go fishing?

19) What species of fish did you target each month that you fished in the last year?

<table>
<thead>
<tr>
<th>Month</th>
<th>Targeted Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
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</tr>
<tr>
<td>February</td>
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<td>March</td>
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<td>April</td>
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<td>May</td>
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<td>June</td>
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<td>July</td>
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<tr>
<td>September</td>
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<tr>
<td>October</td>
<td></td>
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<tr>
<td>November</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td></td>
</tr>
</tbody>
</table>

20) Do you have another job other than fishing?

1. No  
2. Yes

(20b) What other job do you have?
(20c) With which job do you make more money?______________________________

(21) Have you ever seen a boto take or try to take a fish from your fishing net?
1 No_____ 2 Yes_____ If Yes ——>

(21b) How many times did you see botos take or try to take fish from your fishing net in the last week, month, or year?
________/week  __________/month  ________/year

(21c) In what fishing locations did botos try to take fish from your fishing net?  
(Circle the answers in Question 15 with red)

(21d) Did this occur more frequently in a particular location?
1 No_____ 2 Yes_____ If Yes ——>

(21e) In which location?  (Circle the answers in Question 14 with blue)

(21f) During what season do botos take or try to take a fish from your fishing net in the last year?
1 Low water ____ 2 Rising water ____ 3 High water ____ 4 Falling water ____

(21g) Did this occur more during a particular season?
1 No_____ 2 Yes_____ If Yes ——>

(21h) During which season?
1 Low water ____ 2 Rising water ____ 3 High water ____
2 4 Falling water ____

(21i) Why do you think it occurred more during this season?
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

(21j) Which botos took or tried to take fish from your fishing net?
1 Calf_____ 2 Juvenile_____ 3 Adult______
(21k) What type of net were you using when botos took or tried to take fish from your fishing net? *(Skip if only indicated one type of net in Question 9)*

- 1 lampara seine
- 2 drift gill net
- 3 fixed gill net
- 4 Trawl
- 5 Outro
- 6 Outro
- 7 Outro

(21l) What did you do the last time you saw a boto take or try to take a fish from your fishing net?

- 1 Nothing
- 2 Tried to scare it away
- 3 Killed it
- 4 Other

If 3 → 21m, if 1, 2, 4 → 21o

(21m) What did you do with the dead boto?

- 1 Leave it in the water
- 2 Use it to fish for *piracatinga*
- 3 Other

If 1 →

(21n) Why did you kill the boto?

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

(21o) In the last year, have you always ______ *(insert answer from 21l)* when a boto tries to take a fish from your fishing net?

- 1 No
- 2 Yes

If No →

(21p) What else have you done?

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

(21q) How many botos did you kill in the last month or year because they took or tried to take a fish from your fishing net? ________/month or ________/year.

(22) Has a boto ever become entangled in your fishing net?

- 1 No
- 2 Yes

If Yes →
(22b) How many times did a boto become entangled in your fishing net in the week, month, and year? ________/week _______/month _______/year

(22c) In what fishing locations have botos become entangled in your fishing net in the last year? (Circle in blue the locations in Question 15)

(22d) Did this occur more frequently in one location?
1 No_____ 2 Yes_____ If Yes

(22e) In which location? (Circle the location again in Question 15)

(22f) During what season(s) did botos become entangled in your fishing net in the last year?
1 Low water ____ 2 Rising water ____ 3 High water ____ 4 Falling water ____

(22g) Did it occur more frequently during one season?
1 No_____ 2 Yes_____ If Yes

(22h) Which season?
1 Low water ____ 2 Rising water ____ 3 High water ____ 4 Falling water ____

(22i) Why do you think occurred more during this season?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(22j) Which botos became entangled in your fishing net in the last year?
1 Calf____ 2 Juvenile____ 3 Adult_____

(22k) What type of net were you using when a boto became entangled in your fishing net in the last year? (Skip if only indicated one type of net in Question 9)
1 lampara seine_______ 2 drift gill net_______ 3 fixed gill net_______ 4 Trawl_______ 5 Outro________________ 6 Outro________________ 7 Outro________________

(22l) What did you do the last time a boto became entangled in your fishing net?
1 Released it before it drowned_____ 2 Disentangled it after it drowned_____ 3 Killed it _____ 4 Other__________________________ If 1, go to 22m
(22m) Why did you release the boto? 
_____________________________________________________

If 2 or 3, go to 22n ——>

(22n) What did you do with the dead boto? 
1 Leave it in the water____ 2 Use it to fish for piracatinga____
3 Other__________________ If 1 ——>

(22o) Why did you kill the boto? 
_____________________________________________________
_____________________________________________________
_____________________________________________________

(22p) Have you always ______(insert answer from 21l) when a boto has become entangled in your fishing net? 
1 No_____ 2 Yes____ If No ——>

(22q) What else have you done when a boto became entangled in your fishing net?______________________________
_____________________________________________________
_____________________________________________________
_____________________________________________________

(22r) If fisher has never disentangled boto ——> Do you think you could disentangle a boto successfully from your net if you tried? 
1 No_____ 2 Yes____

(22s) How many botos drowned accidentally in your fishing net in the last month and in the last year? 
_____/month and _____/year

(22t) How many botos that were entangled in your fishing net did you kill in the last month and in the last year? 
_____/month and _____/year

(22u) Do you use any techniques to try to prevent botos from stealing fish or getting caught in your nets? 
1 No_____ 2 Yes____ If Yes ——>
(22v) What techniques do you use?__________________________________________
__________________________________________
__________________________________________

(22w) Do you have any ideas to prevent botos from stealing fish or getting caught in your nets that you haven’t tried?
1 No_____ 2 Yes____  If Yes →

(22x) What ideas do you have?__________________________________________
__________________________________________
__________________________________________

(23) Have you ever killed a boto deliberately to use it to catch piracatinga?
1 No_____ 2 Yes____  If Yes →  23b,  If No →  23e

(23b) How many botos have you killed for this purpose in the last month or year?
_____________________/month  ___________________/year

(23c) Which botos did you kill to use to catch piracatinga?
1  Calves____  2 Juveniles____  3 Adults______

(23d) What would it take for you to stop killing botos for use as bait?____________
______________________________________________

(23e) Would it be easy for you to kill a boto to use as bait?
1 No_____ 2 Yes____

(23f) Would it be profitable for you to kill a boto to use as bait?
1 No_____ 2 Yes______

(24) Have you ever seen a dead boto with a mark on its body? (Show picture of branded dolphin)
1 No_____ 2 Yes______  If Yes →
(24b) How did the boto(s) die?
1 Entangled in fishing net____  2 Killed to use to fish piracatinga______
3 Other_______________________  4 Do not know______

(24c) Do you remember what the mark looked like?____________________
1 No_____  2 Yes______  If Yes ..................

(24d) Please draw the mark (provide a blank sheet of paper).

(25) Do you know about the legend of the Encantado?
1 No_____  2 Yes______  If Yes ..............

(25b) What is the legend?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

(25c) Does the legend affect the way you behave towards the boto?
1 No_____  2 Yes_____  If Yes ..............

(25d) How does it affect your behavior towards botos?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

(26) In your opinion, is the boto an important animal in the Amazon?
1 No_____  2 Yes_____  If Yes ..............

(26b) Why do you think the boto is important?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

(27) Do you think the boto population in this area is declining, staying the same, or increasing?
1 Declining______  2 Stable______  3 Increasing______  If 1, 3 ....

141
(27b) Why do you think the boto population is declining/increasing?

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(28) Do you like or dislike the boto?
1  Like _____  2 Dislike _____  3 Neutral________

(28b) Have your ideas about the boto changed since you first began to fish in this area?
No_____  2 Yes____  If Yes

(28c) How have your ideas changed?

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(28d) When did your ideas changed?

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(29) Do other people in your community like or dislike the boto?
1  Like _____  2 Dislike _____  3 Neutral________

(29b) Have other people’s ideas about botos changed since you first began to fish in this area?
1 No_____  2 Yes____  If Yes

(29c) How have other people’s ideas and interactions changed?

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(29d) When did their ideas change?
(30) Have your interactions with botos increased, decreased, or stayed the same since you first began to fish in this area?

1 Decreased_____  2 Stayed the Same______  3 Increased_______ If 1 or 3 

(30b) Why do you think your interactions with the boto have increased/decreased?

(30c) When did your interactions with the boto start to increase/decrease?

(31) Have other people in this community killed botos?

1 No_____  2 Yes______ If Yes 

(31b) How many botos do you know have been killed in this community in the last month or year?

_________________/month ____________________/year

(31c) Why were they killed?

(31d) Do you think more, less, or the same number of botos were killed in the years 2003-2008?

1 More_____  2 Same____  3 Less_____

(32) Would you kill (more) botos if you were not living in Mamirauá (near Mamirauá)?
1 No_____ 2 Yes____ If Yes →

(32b) Why?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(33) Do you think more people in this community would kill botos if the community was not located in (or near) Mamirauá?
1 No_____ 2 Yes____ If Yes →

(33b) Why?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(34) Do you think botos should be protected from being killed?
1 No_____ 2 Yes____ →

(34b) Why?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(35) Have you had any positive interactions with botos?
1 No_____ 2 Yes____ If Yes →

(35b) Can you describe the interaction(s)?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(36) Do you think the Amazon would change if the boto becomes extinct?
1 No _____ 2 Yes ______
(37) Is killing botos illegal in the Brazilian Amazon?
   1 No _____  2 Yes _______

(38) Does the Mamirauá Institute encourage you to protect botos?
   1 No _____  2 Yes _______

(39) Do the majority of people that are important to you like or dislike botos?
   1 No _____  2 Yes _______

(40) Is there anything else you would like to tell me about your interactions with botos?

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
APPENDIX B
FISHER SURVEY - PORTUGUESE

Data: Dia_____/Mês_____/Ano______  Hora: ____ : ____

Nome da comunidade:______________________________________________

Tipo de comunidade (*escolha um*): Focal  Subsidiária
Usuário da reserva  Fora da reserva

Localidade da Comunidade (*circule todos os habitats que aplicam, e classifique-los de acordo a sua proeminência 1-7, sendo 1 o mais proeminente)*:
Rio ___  Canal____  Confluência____  Praia____  Banco____
Ressaca____  Lago____

Coordenadas geográficas:  Latitude:___________  Longitude:____________

(1) Gostaria de participar neste estudo?
  1 Não_____  2 Sim______  *Se não, agradece o pescador e encerra o questionário.*

(2) Em que ano você nasceu?______
  Se não tem 18 anos de idade, agradece o pescador e encerra o questionário.

(3) Você nasceu nesta comunidade?
  1 Não _____  2 Sim _____  Se não →   3b,  Se sim →   3d

  (3b) Onde você nasceu?____________________________________________

  (3c) Desde que ano você mora nesta comunidade?_____________________

  (3d) Você tem morado nesta comunidade toda a sua vida?
  1 Não _____  2 Sim ____  Se não →

  (3e) Você onde mais morou no passado?_____________________________

(4) Sua família mora nesta comunidade?
  1 Não _____  2 Sim ____  Se sim →
(4b) Quantas pessoas moram com você?_______

(5) Você estudou numa(s) escola(s) em ______________? (utilizar respostas da Pergunta 3)
1 Não ____  2 Sim ____  Se sim →

(5b) Quanto tempo você estudou (em cada lugar)?__________________

(6) Há quanto tempo que você pesca na área em torno desta comunidade?
________________________________________ Se antes de 1996 →

(6b) Você acha que a pesca tem mudado desde a criação da Reserva Mamirauá, no ano 1996?
1 Não ____  2 Sim ____  Se sim →

(6c) Como a pesca tem mudado desde a criação da Reserva Mamirauá?
________________________________________________________________
________________________________________________________________
________________________________________________________________

(7) Você tem participado em reuniões e/ou oficinas coordenados pelo Instituto Mamirauá?
1 Não ____  2 Sim ____  Se sim →

(7b) Quais reuniões e/ou oficinas você assistiu e quando ocorreram?__________
________________________________________________________________
________________________________________________________________
________________________________________________________________

(8) Quantas vezes os pesquisadores ou outro pessoal do Instituto Mamirauá visitou esta comunidade no último mês e no último ano?
__________________/ mês e ________________/ano  Se visitaram →

(8b) Quantas vezes você conversou com os pesquisadores ou com outro pessoal do Instituto Mamirauá no último mês e no último ano?
__________________/ mês e ________________/ano
(9) Quais tipos de apetrechos você usou para pescar no último ano?
  1 Rede de cerco_____  2 Tramalha_____  3 Malhadeira_____
  4 Rede Arrastão____  5 Outro_________________  6 Outro__________
  7 Outro____________  Se rede →

(9b) Que tamanho de malha você usou?______________________________

(9c) Qual é o comprimento das redes?______________________________

(10) Quantos outros pescadores nesta comunidade usam o mesmo tipo de
  apetrechos de pesca que você?
  1 Rede de cerco____  2 Tramalha____  3 Malhadeira____
  4 Rede Arrastão_____  5 Outro______________  6 Outro__________
  7 Outro____________  

(11) Quais tipos de barco você usou para pescar no último ano?
  1 Canoa a remo ___  2 Canoa a motor ____  3 Voadeira a motor ____
  4 Outro____________

(12) Qual a porcentagem ou parte da sua captura que você vendeu no último ano?
  ____________________________________________________________

(12b) Onde você vendeu o seu peixe no último ano?__________________

(12c) Onde você vendeu com mais freqüência?______________________

(13) Em quais localidades você pescou no último mês e no último ano? (Pede o
  participante indicar a(s) localidade(s) no mapa se é possível. Escreva o
  nome da(s) localidade(s) na Pergunta 15.)

(14) Você pode classificar as localidades de acordo com onde você pescou com
  mais frequência? (Classifica as localidades na Pergunta 15 de acordo a
  frequência, sendo 1 a localidade mais frequentada).
(15) Quais tipos de habitat existem nestas localidades de pesca? *(Se mais de um habitat, classificá-los de acordo com sua importância, sendo 1 a mais proeminente.)*

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(16) Em que meses você pescou no último ano?

Janeiro__________ Fevereiro__________
Março____________ Abril__________
Maio_____________ Junho__________
Julho_____________ Agosto__________
Setembro_________ Outubro__________
Novembro_________ Dezembro__________

(17) Quantos dias você pescou na última semana e no último mês?

_______/semana e ______/mês
(18) Nos dias em que você pescou no último mês, quantas vezes por dia você saiu para pescar?_________________

(18b) A que horas você saiu para pescar?______________________________

(19) Quais tipos de peixes você quis pegar cada mês que você pescou no último ano?

Janeiro______________    Fevereiro______________
Março______________    Abril______________
Maio______________    Junho______________
Julho______________    Agosto______________
Setembro______________    Outubro______________
Novembro______________    Dezembro______________

(20) Você tem outro trabalho, além da pesca?
1 Não _____   2 Sim ____
Se sim →

(20b) Que outro trabalho você tem?_______________________________

(20c) Com que trabalho você ganha mais dinheiro?_______________________

(21) Você já viu um bote roubando ou tentando roubar um peixe da sua rede?
1 Não _____   2 Sim ____
Se sim →

(22b) Quantas vezes os botes roubaram ou tentaram roubar peixes da sua rede na última semana, no último mês, e no último ano?
______/semana    ______/mês    ______/ano

(21c) Em quais localidades os botes roubaram ou tentaram roubar peixes da sua rede? *(Circule as respostas da Pergunta 15 com vermelho)*

(21d) Isso aconteceu mais numa localidade?
1 Não _____   2 Sim ____
Se sim →

(21e) Qual localidade? *(Circule na resposta da Pergunta 14 com azul)*

(21f) Durante que estação os botes roubaram ou tentaram roubar peixes da sua rede no último ano?
1 Seca (água baixa) __ 2 Enchente (água em elevação) __ 3 Cheia (água alta) __ 4 Vazante (água em recuo) ______

(21g) Isso aconteceu mais numa estação?
1 Não ____ 2 Sim ____  Se sim →

(21h) Qual estação?
1 Seca _____ 2 Enchente _____ 3 Cheia _____ 4 Vazante _____

(21i) Por que você acha que isso ocorreu mais nesta estação?
_____________________________________________________________________________________________________
_____________________________________________________________________________________________________

(21j) Quais bots roubaram ou tentaram roubar peixes da sua rede?
1 Adultos____ 2 Juvenis____ 3 Filhotes ______

(21k) Que tipo de atrepecho você estava usando quando os bots roubaram ou tentaram roubar peixes? *(Ignorar pergunta se apenas indicou um tipo de atrepecho em Pergunta 9)*
1 Rede de cerco____ 2 Tramalha____ 3 Malhadeira____
4 Rede Arrastão____ 5 Outro____________
6 Outro____________  7 Outro____________

(21l) O que você fez da última vez que você viu um boto roubar ou tentar roubar um peixe da sua rede?

1  Nada____ 2 Espantei ____ 3 Matei ____  
4 Outro____________  Se 3 →  21m  Se 1,2,4, → 21o

(21m) O que você fez com o boto morto?
1 Deixeii na água____ 2 Usei como isca para piracatinga____
3 Outro__________  Se 1 →

(21n) Porquê você matou o boto?______________________________
_____________________________________________________________________________________________________
_____________________________________________________________________________________________________

(21o) No último ano, você sempre________ (utilizar resposta de Pergunta 21) os bots quando roubaram ou tentaram roubar um peixe de sua rede?
1 Não _____  2 Sim _____  Se Não  ➔

(21p) O que mais você fez?____________________________________________________________
____________________________________________________________

(21q) Quantos botos você matou no último mês e no ultimo ano por que estavam roubando ou tentando roubar peixes da sua rede?
 _____/mês   _____/ano

(22) Algum boto já se enredou na sua rede?
  1 Não _____  2 Sim _____  Se sim  ➔

(22b) Quantas vezes um boto se enredou na sua rede na última semana, no último mês, e no último ano?
 _____/semana   _____/mês   _____/ano

(22c) Em quais localidades um boto se enredou na sua rede no último ano?
(Circule com cor azul as localidades nas respostas da Pergunta 15)

(22d) Isso aconteceu mais numa localidade?
  1 Não _____  2 Sim _____  Se sim  ➔

(22e) Qual localidade? (Circule a localidade novamente na resposta da Pergunta 15)

(22f) Durante que estação um boto se enredou na sua rede no último ano?
  1 Seca _____  2 Enchente _____  3 Cheia ____  4 Vazante _____

(22g) Isso aconteceu mais numa estação?
  1 Não _____  2 Sim _____  Se sim  ➔

(22h) Qual estação?
  1 Seca _____  2 Enchente _____  3 Cheia ____  4 Vazante _____

(22i) Por que você acha que isso ocorreu mais nesta estação?
_____________________________________________________
_____________________________________________________
_____________________________________________________
(22j) Quais botos se enredaram na sua rede no último ano?
   1 Adultos____  2 Juvenis____  3 Filhotes _____

(22k) Que tipo de apetrecho você estava usando quando um boto se enredou na sua rede no último ano? *(Ignorar pergunta se apenas indicou um tipo de apetrecho em Pergunta 9)*
   1 Rede de cerco_____  2 Tramalha_____  3 Malhadeira____
   4 Rede Arrastão____  5 Outro______________
   6 Outro______________  7 Outro______________

(22l) O que você fez a última vez que um boto se enredou na sua rede?
   1 Liberei antes de morrer afogado____
   2 Liberei depois de morrer afogado____
   3 Matei _____  4 Outro_________________________

Se 1 → 22m, Se 2 ou 3 → 22n

   (22m) Porque você liberou o boto?
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

   (22n) O que você fez com o boto morto?
   1 O deixei na água____  2 Usei como isca para pescar piracatinga____
   3 Outro _____  Se 1 →

   (22o) Porque você matou o boto?
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

   (22p) Você sempre_______ *(utilizar resposta de Pergunta 23l)* os botos quando se enredaram na sua rede?
   1 Não _____  2 Sim ____ Se Não →

   (22q) O que mais você fez?______________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
(22r) Se o pescador nunca liberou um boto—→ Você acha que poderia liberar um boto da sua rede se você tentasse?
1 Não _____  2 Sim _____

22s) Quantos botos morreram afogados no último mês e no último ano por que estavam enredados na sua rede?
_____________________/mês  ___________________/ano

22t) Quantos botos você matou no último mês e no último ano por que estavam enredados na sua rede?
_____________________/mês  ___________________/ano

22u) Você utiliza alguma técnica para tentar impedir que os botos roubem peixes ou que fiquem enredados na sua rede?
1 Não _____  2 Sim _____  Se sim —→
22v) Que técnica(s) usa?
____________________________________________________
____________________________________________________
____________________________________________________

22w) Você tem algumas ideias para impedir que os botos roubem peixes ou que fiquem enredados na sua rede que você ainda não tenha tentado?
1 Não _____  2 Sim _____  Se sim —→
22x) Que ideias tem?
____________________________________________________
____________________________________________________
____________________________________________________

(23) Você já matou um boto para usá-lo como isca para pescar piracatinga?
1 Não _____  2 Sim _____  Se sim —→ 23b, Se Não —→ 23e

(23b) Quantos botos você matou no último mês e no último ano para usá-los como isca?
_____________________/mês  ___________________/ano

(23c) Quais botos você matou para usá-los como isca para pescar piracatinga no último ano?
1  1 Adultos_____  2 Juvenis_____  3 Filhotes_____
(23d) O que você precisaria para parar de matar botos para usá-los como isca?
__________________________________________________________
__________________________________________________________
__________________________________________________________

(23e) Seria fácil para você matar um boto para usá-lo como isca?
1 Não _____ 2 Sim ______

(23f) Seria lucrativo para você matar um boto para usá-lo como isca?
1 Não _____ 2 Sim ______

(24) Você já viu um boto morto com uma marca de ferro? *(Mostrar a foto de um boto marcado.)*
1 Não _____ 2 Sim ___ —> Se sim

(24b) Como o boto morreu?
1 Se enredou em uma rede de pesca_______
2 Foi morto para ser usado como isca para pescar piracatinga_____ 
3 Outro_________________________  4 Não sei_____________________

(24c) Você lembra a forma da marca de ferro?
1 Não _____ 2 Sim ____ —> Se sim

(24d) Por favor, desenha a marca. *(Fornecer uma folha de papel.)*

(25) Você conhece a lenda do Encantado?
1 Não _____ 2 Sim _____ —> Se sim

(25b) O que essa lenda conta?
__________________________________________________________
__________________________________________________________
__________________________________________________________

(25c) A lenda influencia seu comportamento com os botos?
1 Não _____ 2 Sim ____ —> Se sim

(25d) Como influencia seu comportamento com os botos?
(26) Em sua opinião, você considera o boto um animal importante na Amazônia?
1 Não _____  2 Sim _____  Se sim →
(26b) Porque você acha o boto importante?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(27) Você acha que a população de boto nesta área está em declínio, está
estável, ou está aumentando?
1 Declínio _____  2 Estável _____  3 Aumentando _____
Se 1, 3 →
(27b) Porque você acha que a população está em declínio/está aumentando?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

(28) Você gosta ou não gosta do boto?
1 Gosta _____  2 Não gosta _____  3 Neutro_______ →
(28b) Suas ideias sobre os botos já mudaram desde que você começou a
pescar nesta área?
1 Não _____  2 Sim _____  Se sim
(28c) Como mudaram suas ideias?________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
(28d) Quando mudaram suas ideias?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
(29) Outras pessoas da comunidade gostam ou não gostam do boto?
1 Não _____   2 Sim ___   3Neutro_______

(29b) As idéias das outras pessoas da comunidade sobre os botos já mudaram desde que você começou a pescar nesta área?
       1 Não _____   2 Sim _____    Se sim →

(29c) Como as idéias dos outros mudaram?
_________________________________________________________
_________________________________________________________
_________________________________________________________

(29d) Quando mudaram as idéias dos outros?
_________________________________________________________
_________________________________________________________
_________________________________________________________

(30) Suas interações com botos têm aumentado, diminuído, ou têm mantido estável desde que você começou a pescar nesta área?
       1 diminuído _____  2 estável ______  3 aumentado _______
       Se 1 ou 3 →

(30b) Porque você acha que suas interações com os botos têm aumentado/diminuído?
_________________________________________________________
_________________________________________________________
_________________________________________________________

(30c) Quando suas interações com os botos começaram aumentar/diminuir?
_________________________________________________________
_________________________________________________________
_________________________________________________________

(31) Há outras pessoas nesta comunidade que tem matado botos?
   1 Não _____   2 Sim _____    Se sim →

(31b) Do seu conhecimento, quantos botos foram mortos no último mês e no último ano nesta comunidade?
_________________________/mês    ________________/ano
(31c) Porque foram mortos?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

(31d) Você acha que mais, menos, ou o mesmo número de botos foram mortos nos anos 2002-2008?

1 Menos_____   2 Mesmo____   3 Mais_____  

(32) Será que você mataria (mais) botos se você não estivesse pescando na Reserva Mamirauá (perto da Reserva Mamirauá)?

1 Não _____   2 Sim _____   Se sim →

(32b) Por quê?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

(33) Será que mais pessoas nesta comunidade matariam (mais) botos se eles não estivessem pescando na Reserva Mamirauá (perto da Reserva Mamirauá)?

1 Não _____   2 Sim _____   Se sim →

(33b) Por quê?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

(34) Você acha que os botos devem ser protegidos para não ser mortos?

1 Não _____   2 Sim _____   Se sim →

(34b) Por quê?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
(35) Você já teve alguma interação positiva com um boto?
1 Não _____  2 Sim _____  Se sim →

(35b) Você pode descrever a interação ou as interações?
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

(36) Você acha que a Amazônia vai mudar se o boto se extinguir?
1 Não _____  2 Sim ______

(37) Matar botos é ilegal na Amazônia brasileira?
1 Não _____  2 Sim ______

(38) O Instituto Mamirauá te encoraja a proteger os botos?
1 Não _____  2 Sim ______

(39) A maioria das pessoas que são importantes para você gostam ou não gostam do boto?
1 Não _____  2 Sim ______

(40) Tem algo mais que você gostaria de me contar sobre suas interações com os botos?
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BIOGRAPHICAL SKETCH

Vanessa J. Mintzer received a Bachelor of Science in Environmental Science from the School of Natural Resources and Environment at the University of Florida in August 2004. She received a Master in Environmental Management from the Nicholas School of the Environment at Duke University in 2006. After three years of employment at the Galveston Bay Foundation in Webster, TX, Vanessa returned to Gainesville to begin a Doctor in Philosophy in interdisciplinary ecology at the School of Natural Resources and Environment. She completed her doctorate in December 2013.