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Master of Science

Evaluation of Aerial Blimp and Visual Boat Surveys for Counting the Araguaian River Dolphin (*Inia araguaiaensis*) in the Cantão State Park, Brazil

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Abstract

A blimp (non-rigid airship system) mounted with a camera was used to compare an aerial survey method with a visual boat survey, counting the recently described Araguaian River dolphin (*Inia araguaiaensis).* The study was carried out in the low water season (August – November 2015) in the Cantão State Park (PEC), a seasonally flooded lake system in the transition zone of Amazonian forest and Savanna in the State of Tocantins, Brazil. I tested effects of survey methods on dolphin sighting, including factors that influenced dolphin abundance and sighting. Six sectors (4.27 km^2) were replicated, applying full counts in strip transects. A boat with three observers travelled mid-river and a second boat in which the pilot held the blimp, was navigated simultaneously. The camera recorded videos continuously. The aerial survey method detected significantly more river dolphins. The observers sighted 74.1% of the dolphins sighted by the blimp method. In wider sections, significantly larger group size was encountered by the blimp than by the visual survey method. More adult dolphins and calves were encountered by both survey methods in sections of larger area. Regarding habitat, the highest dolphin abundance was found in mouths of arms and lakes. A high dolphin density was found in the surveyed area (19.7/km^2). To enhance river dolphin conservation, robust abundance and distribution data are needed. With further development of blimps and also drones, aerial methods are promising for providing inexpensive and efficient surveys.

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1 Introduction

River dolphins of the genus *Inia* are exclusively freshwater cetaceans in South America. The Amazon river dolphin, *Inia geoffrensis,* is distributed throughout the Amazon and Orinoco river basins (Aliaga-Rossel et al., 2006). *Inia boliviensis,* which occurs in the Amazon tributaries in Eastern Bolivia, is considered a subspecies of *Inia geoffrensis* by the International Union for Conservation of Nature (IUCN) and The Society for Marine Mammalogy (IUCN, 2015, Committee on Taxonomy, 2015). But according to Hrbek et al. (2014), it is a distinct species. In the year 2014, Hrbek et al. (2014) described the Araguaian river dolphin, *Inia araguaiaensis*. It probably diverged from its sister taxon *Inia geoffrensis* about 2.08 million years ago when the Amazon basin separated from the Araguaia-Tocantins River basin, where the species is distributed. *Inia* river dolphins are about 1.5 to 2.7 meters long (males are larger than females) and their body is very flexible, due to unfused neck vertebrae, which allows them to enter flooded forests (Best & da Silva, 1993). Young dolphins are dark grey and adults often present pinkish skin color due to depigmentation and scars, especially males (e.g. Aliaga-Rossel, 2002). In contrast to marine dolphins, river dolphins emerge for a very short period of time and show very little of their body when surfacing (Reeves et al., 2000).

River dolphins are some of the most endangered vertebrates worldwide (Hrbek et al., 2014). Anthropogenic impacts can lead to a rapid decline of river dolphin populations as it happened with the Chinese Yangtze river dolphin (*Lipotes vexillifer*). This species became most likely extinct between 2004 and 2006 by human activities, mostly by by-catch in local fisheries, but also boat collisions and dam construction (Turvey et al., 2007). The Indian River dolphin Ganges (*Platanista gangetica*) is listed as endangered by the IUCN red list (IUCN, 2015). River dolphins are frequently killed for use as bait and to avoid competition for fish and damage to fishing gear (Loch et al., 2009). According to the International Whaling Commission, conservation of freshwater cetaceans is hindered by missing reliable abundance data (Williams et al., 2016). *Inia geoffrensis* is listed as “data deficient” by the IUCN and the status of *Inia boliviensis* and *Inia araguaiaensis* has not been yet established (IUCN, 2015). By obtaining knowledge of population size and define the conservation status of a species, more attention for conservation effort can by attracted. The status of Orinoco crocodiles, for example, has improved greatly due to increased action by protection programs (Crocodile Specialist Group, IUCN, 2015).

To conduct abundance surveys of river dolphins is a challenge as riverine habitats are very complex to survey and the species occur in countries with low budgets for conservation (Dawson et al., 2008). For wildlife monitoring in areas that are difficult to access and of species that are hard to detect aerial surveys by Unmanned Aircraft Systems (UASs) or drones have been implemented. Martin et al. (2012) used drones to estimate abundance and distribution of the Florida Manatee (*Trichechus manatus latirostris*), and Hodgson et al. (2013) surveyed dugongs (*Dugong dugon*). However, drones provide low flight endurance of maximum 25 minutes, except for those powered by fuel, which are large, heavy and noisier, and difficult to handle (Koh & Wich, 2012, Linchant et al., 2015). A relatively new alternative for inexpensive aerial surveys with low flight height, high qualitative permanent data and high flight endurance are blimps, non-rigid airship systems, mounted with a camera (Hodgson, 2007). Blimps can be tethered at a given location or maneuvered and are easily operated by one person (Murden & Risenhoover, 2000). Harris et al. 1996 used a blimp to document range vegetation, Murden & Risenhoover (2000) operated a blimp to video-record herbivore activity, and some studies used blimps to survey the behavior of marine mammals (e.g. Flamm et al., 2000, Nowacek et al., 2001, Hodgson, 2007).

Aerial surveys by means of blimps may be a good option for counting river dolphins, since their movement and emergence can be accompanied well from aerial view (Hodgson, 2007).

The types of methods that are mostly used to assess abundance of river dolphins are mark – recapture and sighting surveys, in which the animals are counted in line-, zig-zag- or strip transects. Gómez-Salazar et al. (2011) for example, used photo-identification to study *Inia geoffrensis* in the Colombian Amazon. Da Silva & Martin (2000) and Martin & da Silva (2004a) implemented capture-mark techniques in the Brazilian Amazon by artificial marking and deploying VHF radio transmitters. The capture program allows valuable data of dolphin movement but is costly and may be stressful for the dolphins (Da Silva & Martin, 2000). Martin et al. (2004) and Martin & da Silva (2004b) conducted line - transect surveys of *Inia geoffrensis* with distance sampling, which requires the estimation of the perpendicular distance from the survey track line to each sighting. Vidal et al. (1997) combined line and strip transects in the Amazon River. Problems with most visual sighting surveys are that due to the erratic and brief surfacing behavior of river dolphins, many individuals could be missed or double-counted (Vidal et al., 1997).

An important question for the development of aerial survey methods is whether aerial surveys are more effective than traditional survey methods (Linchant et al., 2015). The objective of the present study is to test the efficiency of an aerial survey method using a blimp mounted with a camera to count *Inia araguaiaensis* in the Cantão State Park, which is an important protected habitat for the species. As to a probably low level of genetic diversity, the very restricted distribution area and threats by human activity, the Araguaian river dolphin merits attention and high conservation efforts (Hrbek et al., 2014). The present study compares the aerial survey with visual boat survey using strip transects and tests the effects of survey methods and confounding factors on dolphin abundance, number of groups, group size and number of calves. The study predicts more accurate counting of dolphins by means of the aerial method compared to the visual method. A recently developed methodology is presented that can potentially be applicable to further river dolphin surveys. Furthermore, the study provides aspects of the ecology of the Araguaian river dolphin, including habitat preferences.

2 Material and Methods

2.1 Study Site

The study was carried out in the Cantão State Park (PEC), in the municipality Caseara, State of Tocantins in Central Brazil. PEC, created in 1998, covers 89.000 ha and corresponds to the IUCN category II. The park is located between 9°10`S and 50° 10`W in the delta of the river Javaés and bordered by the rivers Araguaia in the West, Javaés in the south and Rio do Côco in the East. PEC consists of Amazonian forest and adjoins directly the biome Cerrado, the Brazilian savanna, at the East side of the park. Being in the transition area of these two very rich biomes, PEC has a very high biodiversity (Parque Estadual do Cantão, 2000). Up to 20% of the forest in PEC is seasonal semidecidual forest, which is rarely flooded and 80% of the forest is known as “Igapó”, which is seasonally flooded by nutrient-poor blackwater coming from the river Rio Javaés (NGO Instituto Araguaia, personal communication). However, the water in PEC is also considered to be clearwater like in the Araguaia River. The pH varies between 5.2 to 7.9. PEC holds up to 840 oxbow lakes and approximately 150 km of meanders and channels (Ferreira et al., 2011).

Almost all of the annual precipitation of 2000 mm falls between October to April. In May, the water level starts to sink 6-10 m and during the dry season (June-October/November) large sand banks and sand beaches build a mosaic of different sized and different shaped lakes, some of them connected by channels and some isolated. The water temperature varies between 29 and 33 degrees Celsius along the year and the annual mean temperature is 28 degrees Celsius (Pinheiro & Dornas, 2009).

298 fish species were identified in PEC (NGO Instituto Araguaia, personal communication). The high fish diversity and the diverse habitat in PEC attract many piscivorous predators, including several bird species, caimans, the giant otter, the pirarucu (*Arapaima gigas*, one of the world`s largest freshwater fish), and the Araguaian river dolphin. From October, with the rising waters, many fish and also river dolphins migrate from the Araguaia River into PEC. The fish reproduction takes place in the interior lakes of the park (Parque Estadual do Cantão, 2000).

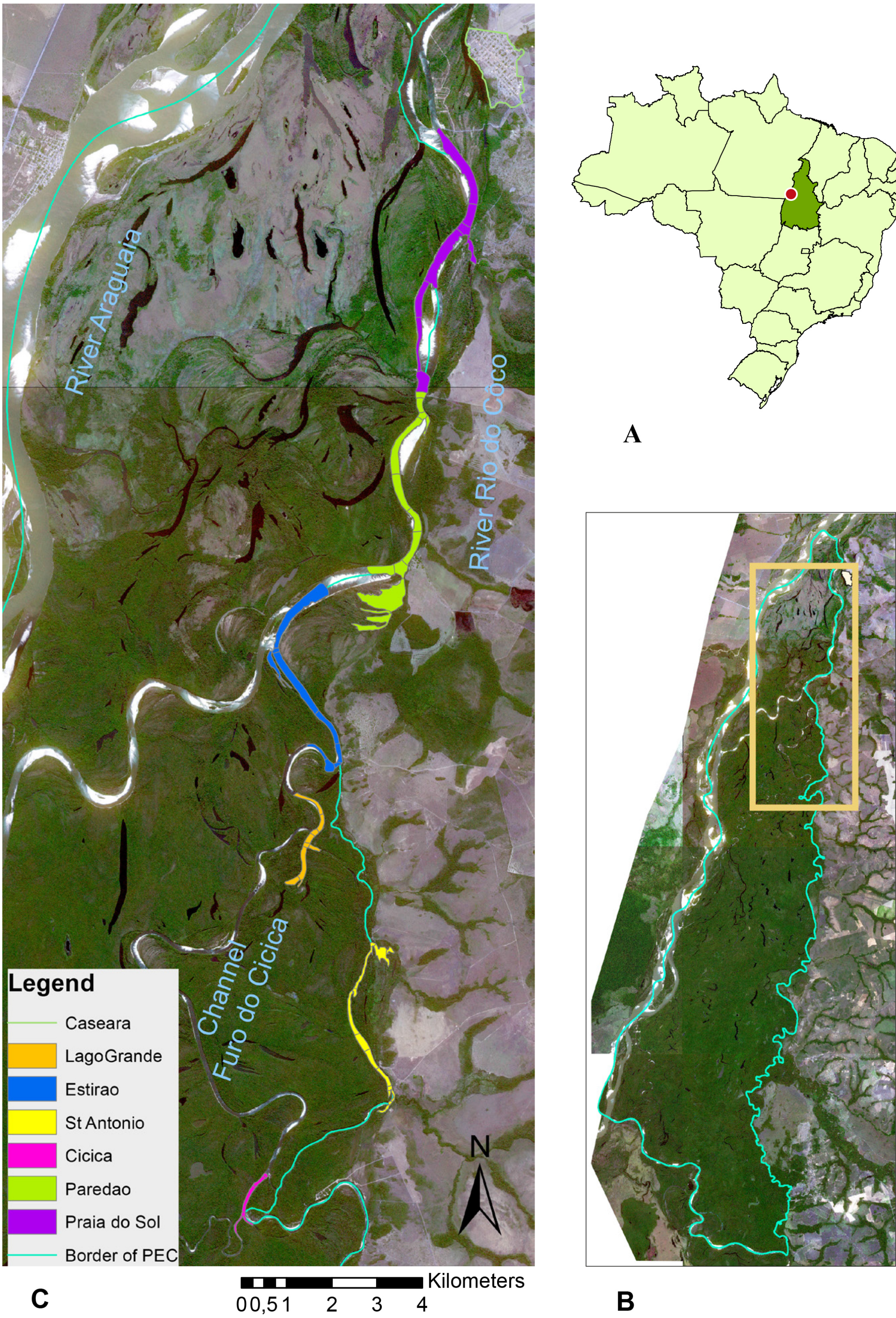

Figure 1 Map of the study site
A: State of Tocantins in Central Brazil. **B**: Cantão State Park (green line), showing the area where the study was carried out (orange frame). **C**: Study site with the sectors where the river dolphins were counted (sections along the channel Furo do Cicica and the river Rio do Côco and some river arms and lakes). Source of satellite images: Rapid Eye, July 2015.

2.2 Study Species

Besides the distribution in the Central Araguaia and Tocantins river basins, *Inia araguaiaensis* probably occur in approximately 1500 km of the Araguaia River (Hrbek et al., 2014) and in some stretches in the Tocantins River, which is fragmented by seven hydroelectric dams (Araújo & Wang, 2012). Based on the population estimate conducted during the environmental impact evaluations prior the licensing of the hydroelectrical project Santa Isabel (2010), Hrbek et al. (2014) suggest approximately 1525 individuals in the Araguaia river basin. Araújo (2010) suggests a population of 791 dolphins in the Araguaia River. More surveys of this poorly studied species are essential. *Inia araguaiaensis* are frequently killed by fishermen. In 2009, in just one month (July), 10 dolphins were registered as killed in the region of Aruanã (Araújo & da Silva, 2014). In the dry season of 2015, in the region of Caseara, local people have seen some dolphins with the head cut off or with bullet marks (personal communication). Also, industrial agriculture and overfishing are threats for *Inia araguaiaensis.*

Araguaian river dolphins have a lower number of teeth (Hrbek et al., 2014) and appear to have a less corpulent body than *Inia geoffrensis* (personal observation). In the rainy season, the river dolphins use the entire area of PEC and disperse into the flooded forest (Araújo 2010). In the dry season, their habitat in PEC becomes reduced to sections of rivers, some channels and a few lakes that are hydrologically connected, which become isolated only during the height of the dry season. During this time, *Inia araguaiaensis*, which are very maneuverable, often hunt for fish in shallow areas. In the year 2015 the dolphins most likely remained in isolated water bodies from August 15^{th} to November 25^{th}. *Inia araguaiaensis* do not occur in lakes that remain isolated during the entire dry season, as the NGO Instituto Araguaia confirmed in 15 small, isolated lakes.

Figure 2 Adult Araguaian river dolphin (*Inia araguaiaensis*)

2.3 Sampling Design

The surveys were conducted in the dry season, from mid August to the end of November 2015. At this time, river dolphins are more visible because they cannot be hidden under vegetation at the margins due to the low water level (Gomez-Salazar et al., 2012). The surveys were carried out using two boats simultaneously, to be able to compare aerial view with visual sighting counts. The length covered by this study was 32,7 km and the area 4.27 km^2. Including all replicates, a total area of 21.9 km^2 were surveyed during 26 survey days. The surveys were conducted on 20,3 km along the river Rio do Côco, in some lakes and arms connected to Rio do Côco (6,5 km), on 2 km of the channel Furo do Cicica, in the lake Lago Grande (1.9 km), and a section of the channel Furo do Cicica that merges with Rio do Côco (2 km). The surveyed sections were subdivided into six sectors, called Lago Grande, Estirão, Santo Antônio, Cicica, Paredão and Praia do Sol (see Figure 1). The length of the sectors varied between 2 and 8.9 km. Due to manpower limitations and logistical problems, some sectors that were easier to reach were repeated more times than others. Lago Grande was replicated 11 times, Estirão 11 times, Cicica, Paredão and Praia do Sol three times and Santo Antônio twice.

The surveys were strip–transects, which had the total width of the water bodies. It was assumed that all dolphins within the strip were seen. The boats travelled in the center of the strip, except for one surveyed lake, which had the maximum width of 490 m. There the boats travelled in 100 m distance of the shore around the whole lake to cover all the area. The maximum width of the rest of the surveyed water bodies varied between 40 and 300 m and the mean width was 137.7 m. The range of vision of the blimp was comparable to the vision field of the observers, as both covered the entire width and approximately 150 m forward and backward.

During the surveys, both boats were powered by 44lb electric trolling motors, connected to automotive batteries. An outboard motor was used to get to the study areas and get back to the research base. The surveys were carried out early in the morning (7 to 9:30am) before strong winds started to blow, sun glare or the chance of rain increased and when the water surface was calm (not over 10 cm of ondulations). Only in Lago Grande 2 surveys were also done in the afternoon (4 to 6pm). Each of the six sectors could be surveyed at a stretch.

The duration of counts depended on wind, the amount of time required to determine the presence or absence of dolphins, the habitat, and the durability of the power of the available automotive batteries.

2.3.1 Visual Survey

The boat in which observers counted visually was a 4.5 m fiberglass canoe. It was always piloted in the middle of the water bodies and the observers could clearly see to both riverbanks. The presence of dolphins was identified visually, or by the sound of exhalation and subsequently visually confirmed. Two observers counted dolphins forward and one observer counted backwards. The first observer was sitting in the prow, watching ahead and to the sides. The second observer was in the middle of the canoe, watching to the rear and taking notes and the third was watching ahead and aside and piloted the canoe. A binocular was only used to confirm dolphin sightings to avoid missing the range of vision. The boat was stopped or piloted in reduced speed for at maximum 2-3 minutes only when it was necessary for the observers to determine the group size of dolphins at a sighting. Dolphins were counted at first sight and all observers communicated about the sightings to avoid double counting and to make sure about group size.

In a pilot study, the inter-blow-interval of the Araguaian river dolphin was surveyed to test the optimal speed for counting dolphins. The maximum time dolphins stayed under water was 2.25 minutes and the maximum distance in which dolphins could be sighted was 150 m. Consequently, the speed of the canoe was tried to be maintained between 4.0 and 5.0 km/h, to make sure that all dolphins surface at least once in the field of vision.

2.3.2 Aerial Survey

A blimp (3.9 m long, 1.6 m diameter, 4.8 cubic m, 1.4 kg net lift) with a four tail fin made by The Blimp Works and normally used as an advertising balloon, was filled with helium gas to count dolphins from aerial view (Figure 3). A piece of styrofoam was tied at the front of the blimp and a stabilizer (FY-G4 Handheld Steady Gimbal) that held a GoPro camera (Hero 4) was inserted into the styrofoam, secured by lines. A tether line was fixed underside of the blimp to be able to hold the blimp by hand during the surveys.

The boat was a 5 m aluminium boat in which the blimp was being held. It was piloted in the way that the blimp flew right above the boat in which the observers counted visually to have the boat in the center of the videos. Depending on the wind direction it was sometimes necessary to navigate the boat near the margins so that the blimp could fly in the center.

The speed depended on the speed of the canoe with which visual survey was carried out. The GoPro camera on the blimp continuously took videos in 1920x1440p resolution (4:3). The stabilizer held the GoPro camera straight downwards. Thus, the area below the blimp could still be filmed when the wind turned the blimp or slewed it. The height of the blimp was adjusted in the way that both shores of the water body were always visible in the video and that river dolphins could be clearly recognized. The blimp was held at the height of 70-80 m.

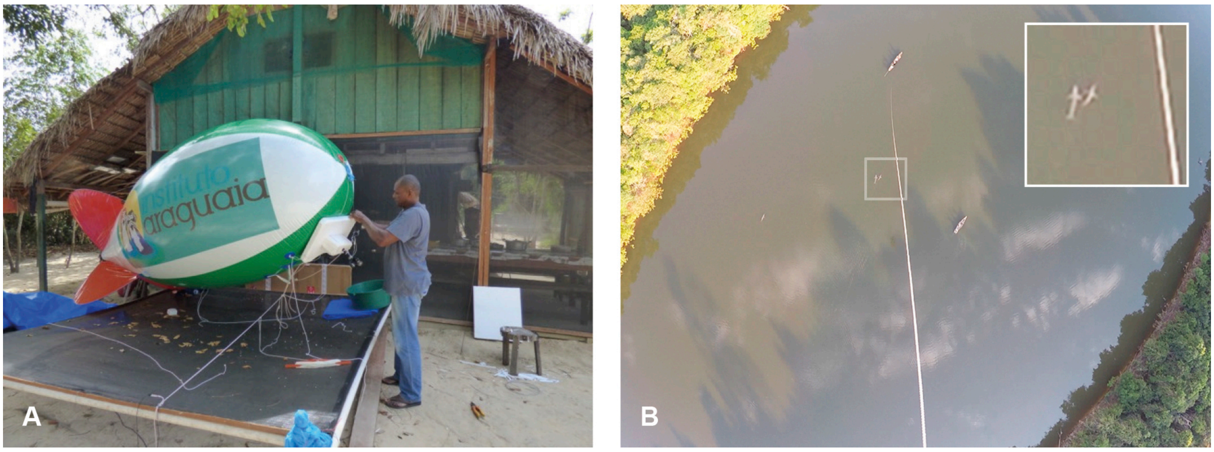

Figure 3 Pictures showing the blimp and river dolphin survey
A: Field assistant makes adjustments of the styrofoam system that held the GoPro camera on the blimp. **B**: Screen shot of a video recorded by the blimp to count *Inia araguaiaensis* in the sector Estirao. Three dolphins are visible: a pair showed in the enlarged picture detail, and a solitary one further down, near the left margin. In the middle of the river is the boat that conducted visual survey and on the left is the boat in which the blimp was held with a tether line.

2.3.3 Recorded Data

The following data were recorded by one observer during the surveys: Date, starting and ending time of the surveys, names of observers, group size, number of all sighted dolphins, time a dolphin was sighted, time the boat stopped at a sighting, number of dolphins that called attention by exhaling sound and notes about behavior or any interesting event. In this study the term group was defined as the total number of dolphins in the immediate vicinity of each other (about 20 m). Often they interacted or emerged together. The term group does not imply that the sighted dolphins are in a social cohesion (Aliaga-rossel, 2002; McGuire & Winemiller, 1998). The number of sighted calves and young juveniles was also recorded. However, due to the difficulty of distinguishing juveniles that were almost as big as adults, especially in a group of dolphins, juveniles and calves were not differentiated in the data. Thus, the term calves refers to all young dolphins that were spotted and that were clearly smaller than the mother.

The condition of wind, sun glare, water surface and cloud cover were recorded every 30 minutes or when the conditions changed. For wind and sun glare the scale 0 = none, 1 = small effect, 2 = large effect was used. Due to the lack of any device, such as an anemometer, the wind speed could not be recorded. Thus the condition of wind was determined by observer perception. When the wind force was at the level 2, the blimp could not fly. The undulation of the water surface was estimated as: 0 = no undulation, 1 = < 5 cm undulation and 2 = < 10 cm undulation. The amount of clouds was estimated in percentage of sky cover: 0 = 0 – 25%, 1 = 25 – 70% and 2 = 70 – 100%.

A Garmin GPS was used to record the time of each dolphin sighting and to record the survey tracks by marking the positions of the visual survey boat every 20-30 seconds.
After the surveys I watched and analyzed the videos of the blimp. I noted the time of the moment in which dolphins are visible in the videos as well as the number of dolphins visible in each moment in order to compare the aerial counts with the visual counts.
Nine habitat categories were identified (Table1).

Table 1 Description of the habitat categories used in this study

Habitat Categories	Characteristics
Arm	Narrow river arms with vegetated shores and dead end
Bank	Shores with steep and high mud/sand bank, the typical edge type in the Amazon (Martin et al., 2004)
Beach	Sandy beach at the margins
Confluence	Meeting of two channels/rivers
Lake	Lentic water bodies surrounded with vegetation
Mouth	Mouth of a lake or river arm
Rocks/bank	Rocks covered parts of the ground, shores were bank
Rocks/beach	Rocks covered parts of the ground, shores were beach
Sand bank	Sand banks were under water, but no beach

2.4 Data Analysis

I transformed the data in Microsoft Excel and in the statistical software R (2014), including calculation of mean values, corrections and conversions of the values. I divided all sectors into subsectors according to habitat types and similar width of the surveyed water bodies. Hence, the subsectors had homogeneous characteristics and also the power for regression analysis increased. I plotted the sectors and subsectors in the Geographic Information System program ArcGIS, and measured their area, width and length. I also marked the positions of all sighted dolphins in the map to be able to quantify the sightings in each subsector.
In order to investigate the effects of the main predictor variable survey method (blimp versus canoe) and the other predictors (confounding factors) on the response variables number of dolphins, number of groups and number of calves, I used Generalized Linear Mixed Models

with Poisson distribution in R. For testing the effects of the predictor variables on the response variable average group size, I used Linear Mixed Models. Confounding factors were habitat type, area (m^2), maximum width (m), survey start time, sun glare, cloud cover, the condition of wind, the condition of water surface and survey date.

Before fitting the models, I tested the relations among all variables by means of Pearson`s correlation (Figure A.2, Appendix B). Strong positive or negative correlations were indicated by coefficients ≥ (-) 0.5. I did not include variables that were significantly correlated together in one model to avoid interfering in the real effects of each variable. Sectors and subsectors were included as random intercept in the models, to account for replicated observations. After running the models, I tested the model residuals for overdispersion, which is the presence of greater variance in a data set than the models can deal with.

I identified the models best predicting number of dolphins, groups, calves and group size by selecting those with the lowest Akaike information criterion (AIC) value (Appendix C). Subsequently, with each model, I used the method step AIC to select the final models, in order to find the model with minimum AIC by removing variables. Effects of variables in the models, which differed from the best and final model by a higher AIC value with the difference of <2 (Δ AIC <2), were considered important and were presented. Results of statistical tests were considered significant at the $P \leq 0.05$ level.

3 Results

3.1 Overview of River Dolphin Sightings

The main results of river dolphin sightings are summarized in Table 2. Including the resightings of all replicates, 390 river dolphins were sighted by the blimp, of which 7.9 % were calves and 289 dolphins were counted by the observers in the canoe, of which 4.8 % were calves. Hence, the observers in the canoe counted 74.1% of all dolphins recorded by the camera on the blimp. Average number of dolphins per sector ranged from 4 to 36.6 by blimp and from 3.8 to 23.3 by canoe (Figure 4). The lowest dolphin count by the canoe method compared to the blimp method occurred in the sector Paredão, which was the largest and widest sector and had the highest average number of dolphins and calves, the highest average number of groups and the highest dolphin density per km transect. Santo Antônio was the only sector where the total canoe and blimp count was the same, and it was also the sector with the fewest replicates. In all sectors, average numbers of calves sighted by the blimp method were higher than the sightings by the canoe method. In the videos it was confirmed that the observers in the canoe counted in total three river dolphins by mistake. 39 out of 289 dolphins (13,5%) called the attention of the observers by exhaling sounds and were then confirmed by sighting.

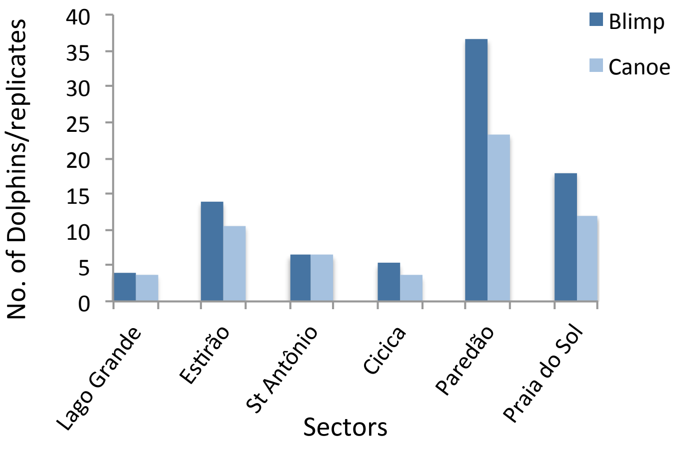

Figure 4 Number of river dolphins per replicates
counted by blimp and canoe method in each sector

Table 2 Main results of aerial and visual strip-transect surveys of *Inia araguaiaensis* carried out in six sectors

Sector	Area (km^2)	Length (km)	Avg. width (m)	No. of repl.	Method	No. of dolphins	% visual count	No. of dolphins/ repl.	No. of calves	No. of calves/ repl.	% calves	No. of groups	Avg. no. of groups	Avg. group size
Lago Grande	0.28	3	98.8	11	Blimp	44		4	11	1	25	24	2.2	1.83
					Canoe	42	95.4	3.8	10	0.9	23.8	23	2.1	1.83
Estirão	0.9	6.6	142.1	11	Blimp	153		13.9	9	0.8	5.9	85	7.7	1.8
					Canoe	117	76.5	10.6	0	0	0	71	6.5	1.66
St Antônio	0.39	5.1	92.7	2	Blimp	13		6.5	1	0.5	7.7	8	4.0	1.62
					Canoe	13	100	6.5	0	0	0	8	4.0	1.62
Cicica	0.12	2	68.5	3	Blimp	16		5.3	0	0	0	4	1.3	4
					Canoe	11	68.7	3.6	0	0	0	4	1.3	2.75
Paredão	1.4	8.9	202,2	3	Blimp	110		36.6	6	2	5.4	51	17.0	2.16
					Canoe	70	63.6	23.3	2	0.6	2.8	41	13.7	1.72
Praia do Sol	1.18	7.1	199.4	3	Blimp	54		18	4	1.3	7.4	28	9.3	1.92
					Canoe	36	66.6	12	2	0.6	5.5	22	7.3	1.63
Total	4.27	32.70	137.7	33	Blimp	390		11.82	31	0.94	7.9	200	6.1	1.95
					Canoe	289	74.1	8.76	14	0.42	4.8	169	5.1	1.72

Repl. = Number of replicates

3.2 Effects of Survey Methods on River Dolphin Sightings

In this section, after presenting the results of model selection, I first depict general findings of sightings for each response variable and subsequently I present the effects of both blimp and canoe method, while considering confounding factors expected to influence dolphin presence and/or visibility.

3.2.1 Model Selection

The correlation coefficients showed that all collinear variables were positively correlated. Among the predictor variables, a strong correlation was found between width and area (r = 0.66), between sun glare and start time (r = 0.58) and between water and wind (r = 0.76) (Figure A.2, Appendix B). In consequence, I fitted eight different alternative full models with each response variable (number of dolphins, number of groups, group size and number of calves), containing the respective non-collinear predictor variables (Tables A.1, A.3, A.5, A.7, Appendix C). Interactions between method and area/width, glare/start time, wind/water and cloud were included in the models. The Step AIC procedure on each full model that had the lowest AIC value is shown in Tables A. 2, A.4, A.6, A.8, Appendix C.

3.2.2 Dolphin Abundance

General Findings

Clearly a higher number of adult dolphins and calves were counted by the aerial survey than by the visual survey (Figure 5).

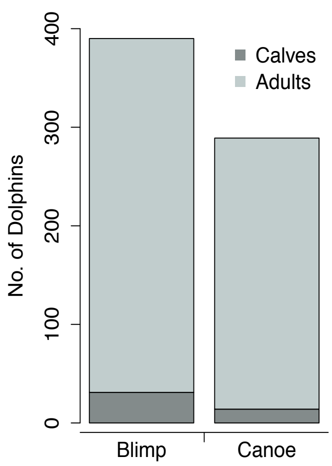

Figure 5 Number of river dolphins, subdivided into calves and adults, counted by blimp and canoe methods

Higher dolphin abundance was encountered by the blimp method than by the visual survey method in all habitat types (Table 3).

Table 3 Total counts of river dolphins by blimp and canoe method in each habitat type

No. of dolphins	Arm	Bank	Beach	Confluence	Lake	Mouth	Rocks /bank	Rocks /beach	Sand bank
Blimp	52	74	93	8	40	64	14	9	36
Canoe	43	54	66	7	30	49	13	7	20

Table 4 shows the densities of *Inia araguaiaensis* found in each sector. The highest density/km^2 was found in the sector Cicica, which was a very small sector. The highest density/km was found in the sector Paredão. The difference between densities found by the two survey methods is especially high in larger sectors (see areas in Table 2).

Table 4 Densities of *Inia araguaiaensis* found in each surveyed sector by the blimp and canoe methods.

Sector	Method	Max. no. of dolphins	Max. no. of dolphins /km^2	Max. no. of dolphins /km	Avg. no. of dolphins	Avg. no. of dolphins /km^2	Avg. no. of dolphins /km
Lago Grande	Blimp	4	14.1	1.3	4	14.1	1.3
	Canoe	4	14.1	1.3	3.8	13.4	1.3
Estirão	Blimp	17	18.9	2.6	13.9	15.4	2.1
	Canoe	15	16.6	2.3	10.6	11.8	1.6
St Antonio	Blimp	7	17.9	1.4	6.5	16.6	1.3
	Canoe	7	17.9	1.4	6.5	16.6	1.3
Cicica	Blimp	8	68.8	4	5.3	45.6	2.6
	Canoe	5	43	2.5	3.6	30.9	1.8
Paredão	Blimp	41	29.3	4.6	36.6	26.2	4.1
	Canoe	25	17.9	2.8	23.3	16.9	2.6
Praia do Sol	Blimp	24	20.3	3.4	18	15.2	2.5
	Canoe	18	15.2	2.5	12	10.1	1.7
Total	Blimp	101	23.6	3.1	84.3	19.7	2.6
	Canoe	74	17.3	2.3	59.8	13.9	1.8

Max. no. of dolphins: maximum number of dolphins counted in each sector
Avg. no. of dolphins: Number of counted dolphins divided by the number of replicates of each sector
(Area (km^2) and length (km) of each sector and total area and length are shown in Table 2)

Effects

A strong significant dependency of number of dolphins on area became evident (Table 5). The larger the area of the water body, the more dolphins were counted (Figure 6). Furthermore, a significant difference is shown between the effects of survey methods on the number of dolphins. A significantly higher number of dolphins were counted by the blimp (Figure 7). Cloud cover had a negative effect, but did not predict number of dolphins significantly. However, a trend was shown that with increasing cloud cover fewer dolphins were counted (Figure 8). No interaction with method was retained in the best model; thus, in all circumstances more dolphins are counted by the blimp method than by the canoe method.

Table 5 Best Generalized Linear Mixed-Effects Model fitted to explain the variation of number of dolphins depending on survey method and confounding factors (see Tables A.1 and A.2 for model selection)

Model3 = glmer(dolphins ~ scale(area) + method + scale(cloud) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)

Random effects:				
	Groups	Name	Variance	Std.Dev.
	over	(Intercept)	0.27438	0.5238
	subsector:sector	(Intercept)	0.97759	0.9887
	sector	(Intercept)	0.01701	0.1304

Number of obs: 594, groups: over, 594; subsector:sector, 56; sector, 6

Fixed effects:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.38559	0.18033	-2.138	0.032499 *
scale(area)	0.67885	0.17892	3.794	0.000148 ***
Method [canoe]	-0.26317	0.09962	-2.642	0.008252 **
scale(cloud)	-0.10392	0.06548	-1.587	0.112460

** 0.05 > p > 0.01; ** 0.05 > p < 0.01; *** p < 0.001*
Random effects are sector and subsector, "over" controls for overdispersion by fitting a random intercept for each line of the database
Area: area of subsectors in m^2
Method: canoe and blimp. Blimp is the reference category

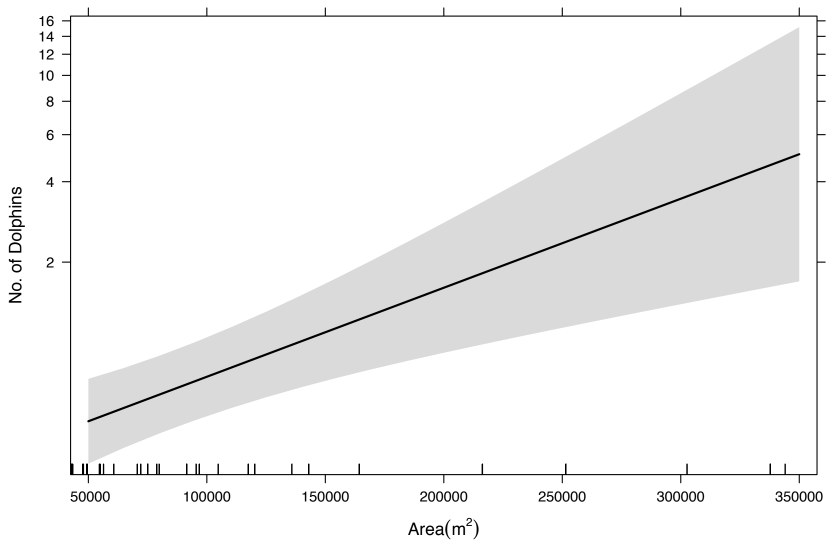

Figure 6 Effect of area on total number of sighted river dolphins

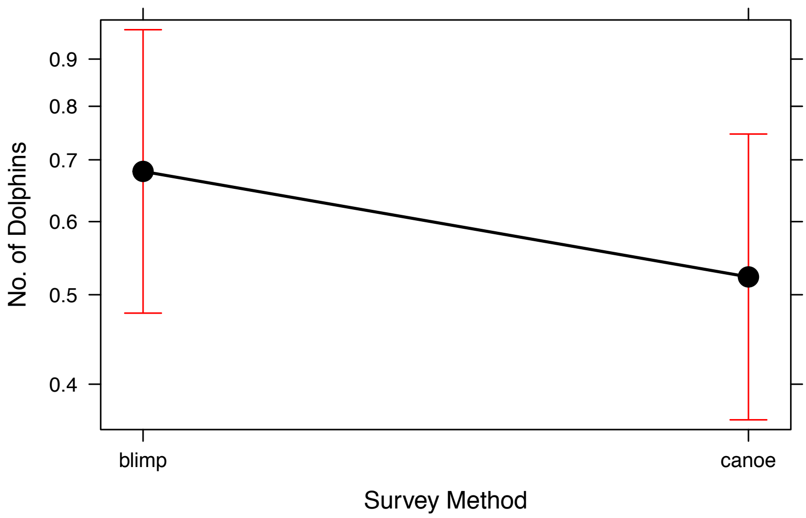

Figure 7 Effect of survey methods on total number of sighted river dolphins

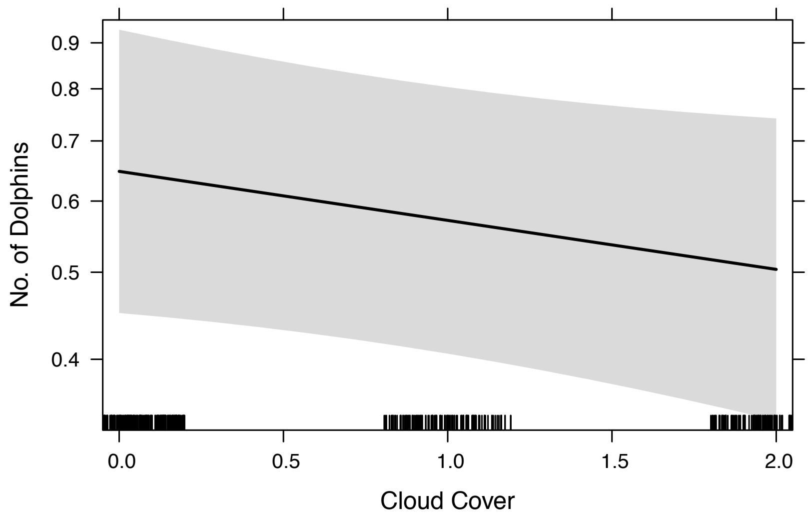

Figure 8 Effect of cloud cover on total number of sighted river dolphins

Considering the difference of ∆ AIC <2, the interaction of method and area in the third ranked model (AIC differed 0.6 from best model) showed a trend that the blimp method counted more river dolphins in larger area than the canoe method. Furthermore, the predictor habitat was retained in the second ranked model (AIC differed 0.2 from best model). The habitat beach had a significant negative effect in relation to the habitat arm, and indicated the lowest number of dolphins compared to the other habitat types (Figure 9). Mouth of river arms and lakes was the habitat with highest dolphin abundance considering all confounding factors, followed by arms.

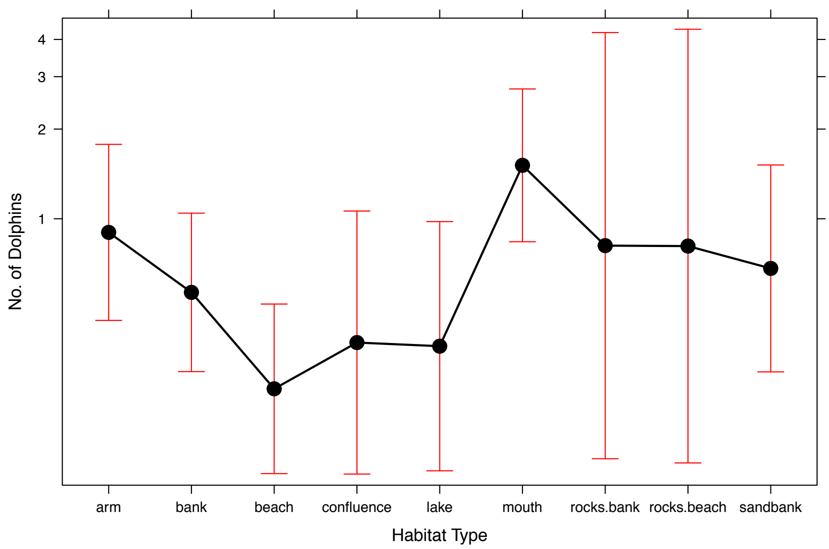

Figure 9 Effect of habitat types on total number of sighted river dolphins

3.2.3 Number of Groups

General Findings

The blimp recorded 200 dolphin groups, of which 15.5 % were groups with calves. The observers in the canoe sighted 169 groups, of which 8.3 % were groups with calves. Apparently, there is not much difference in average number of groups between the survey methods, regarding habitat types (Table 6). It appears that in lakes the highest average number of groups was sighted, followed by beach.

Table 6 Average number of groups encountered by blimp and canoe method in each habitat type

Avg. no. of groups	Arm	Bank	Beach	Confluence	Lake	Mouth	Rocks /bank	Rocks /beach	Sand bank
Blimp	1.42	1.48	1.93	1	2	1.24	1.67	1.25	1.45
Canoe	1.26	1.29	1.63	0.75	1.77	1.09	1.5	1.25	1.62

Effects

Area has a highly significant effect on number of groups (Table 7). More dolphin groups were found in water bodies of larger area (Figure 10). Number of groups was not significantly predicted by survey method. The blimp recorded slightly more groups than the canoe, but the difference was small (Figure 11). Regarding habitat types, significantly fewer groups were sighted in bank, beach and confluence sections than in arms (Figure 12). In confluences a high variation of number of sighted groups is shown The highest number of groups was sighted in mouths, followed by arms.

Table 7 Best Generalized Linear Mixed-Effects Model fitted to explain the variation of number of groups depending on survey method and confounding factors (See Table A.3 and A.4 for model selection)

Model1 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + habitat + (1|sector/subsector) + (1|over), data = mydata, family = poisson)

Random effects:

Groups	Name	Variance	Std.Dev.
over	(Intercept)	5.049e-06	0.002247
subsector:sector	(Intercept)	1.401e-01	0.374255
sector	(Intercept)	7.727e-03	0.087903

Number of obs: 594, groups: over, 594; subsector:sector, 56; sector, 6

Fixed effects:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.1547	0.2379	-0.650	0.51550
scale(area)	1.0767	0.2743	3.925	8.69e-05 ***
I(scale(area)^2)	-0.1497	0.0886	-1.690	0.09106 .
methodcanoe	-0.1671	0.1036	-1.613	0.10682
habitatbank	-0.6454	0.3241	-1.991	0.04646 *
habitatbeach	-0.9002	0.3225	-2.791	0.00525 **
habitatconfluence	-1.3525	0.5440	-2.486	0.01290 *
habitatlake	-0.6922	0.3725	-1.858	0.06315 .
habitatmouth	0.1245	0.2993	0.416	0.67740
habitatrocks.bank	-0.1614	0.5179	-0.312	0.75534
habitatrocks.beach	-0.2164	0.5388	-0.402	0.68797
habitatsandbank	-0.3182	0.3485	-0.913	0.36130

** 0.05 > p > 0.01; ** 0.05 > p < 0.01; *** p < 0.001*
Random effects are sector and subsector, "over" controls for overdispersion by fitting a random intercept for each line of the database
Area: area of subsectors in m^2
Method: canoe and blimp. Blimp is the reference category
Habitat types: Arm is the reference category

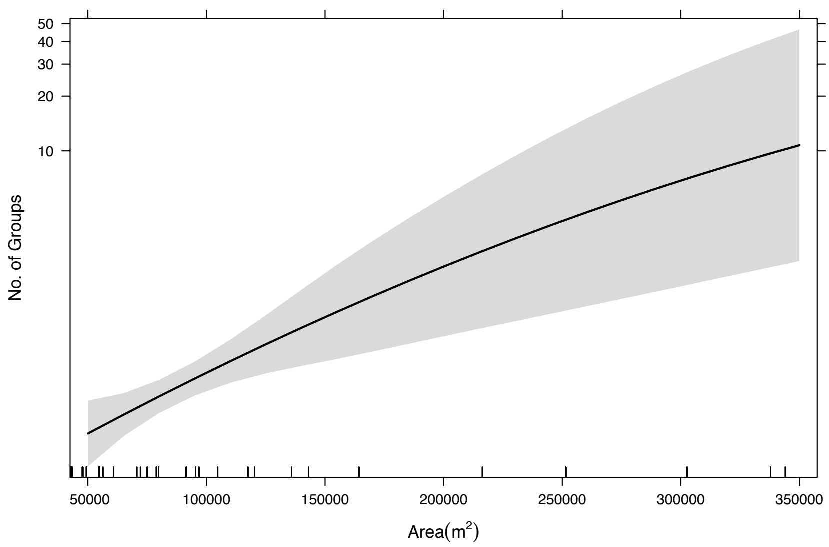

Figure 10 Effect of area on number of river dolphin groups

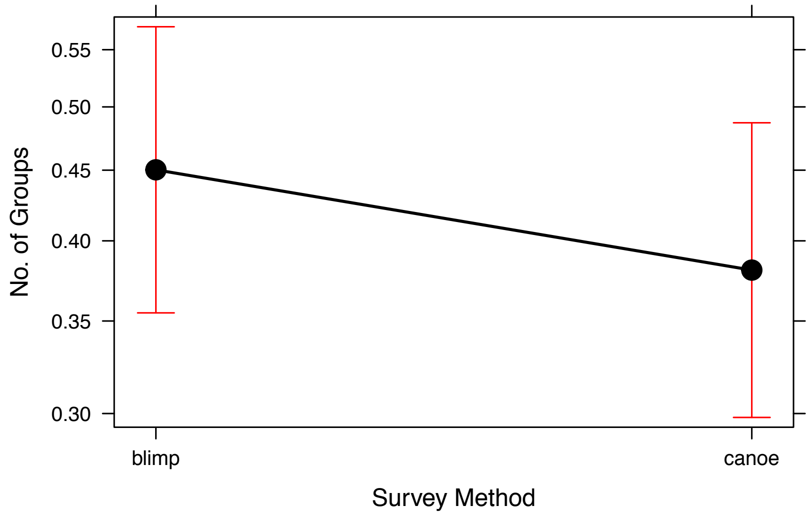

Figure 11 Effect of survey method on number of river dolphin groups

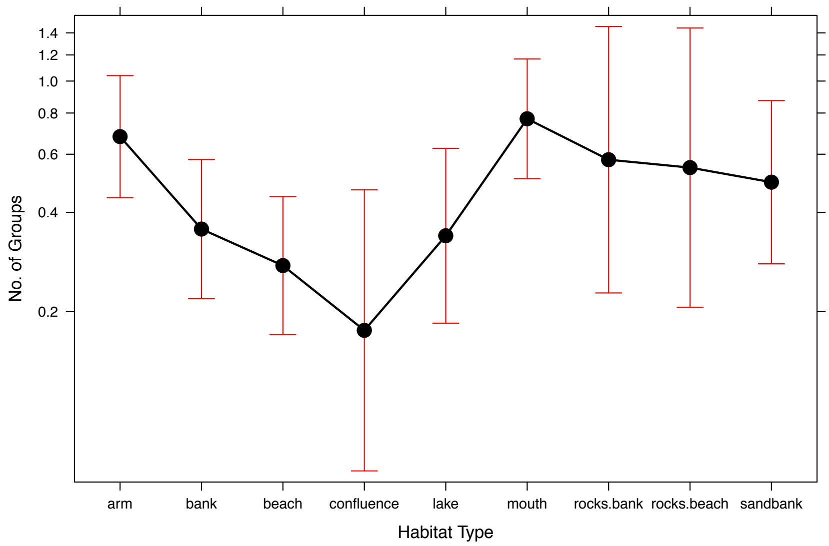

Figure 12 Effect of habitat types on number of river dolphin groups

3.2.4 Group Size

General Findings

The total average group size recorded by the blimp was 1.95 and by the observers in the canoe was 1.72. Solitary dolphins account for 47% of all group observations by the blimp method, followed by groups of two dolphins (31.3%) and groups of three dolphins (13.4%). The largest observed group consisted of nine dolphins. This group and both groups of seven dolphins were sighted in the sector Paredão in the mouth of two small arms. The only group of eight dolphins was also recorded in Paredão, in a section with sand banks, and both groups of six dolphins were recorded in a large lake in Paredão. The absolute numbers of frequency of each group size compared between the blimp and the canoe method is shown in Figure 13. The observers in the canoe did not record any groups of more than five dolphins. Only the group of five dolphins was encountered more frequently by the canoe method (three times) than by the blimp method (twice).

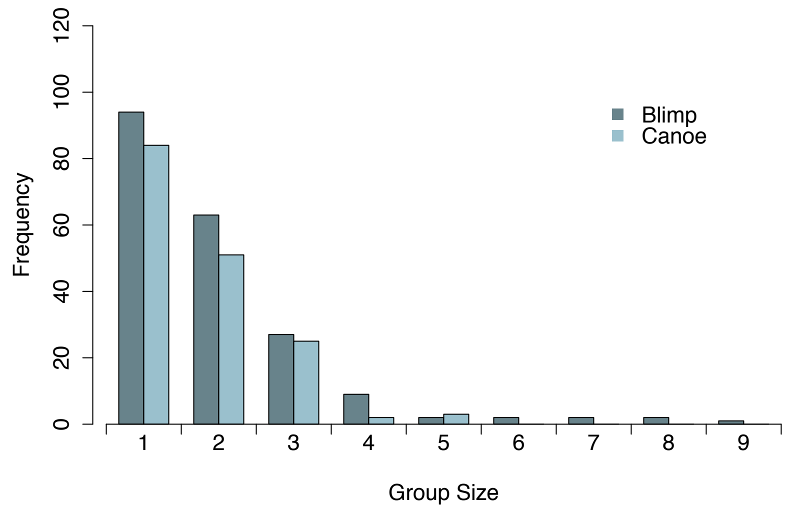

Figure 13 Size of river dolphin groups sighted by blimp and canoe method

The largest average group size according to the blimp data (4) was encountered in confluences, followed by mouths (2.46). According to the visual survey, the largest average group size was recorded in mouths (2.04), closely followed by confluences (Table 8).

Table 8 Average group size of all river dolphin groups recorded by blimp and canoe method in each habitat type

Avg. Group Size	Arm	Bank	Beach	Confluence	Lake	Mouth	Rocks /bank	Rocks /beach	Sand bank
Blimp	1.93	1.85	1.66	4	2.22	2.46	1.4	1.8	2.25
Canoe	1.79	1.77	1.51	2	1.93	2.04	1.44	1.4	1.54

Effects

Group size is strongly predicted by water body width, as dolphin groups were significantly larger in wider sections (Table 9). Group size is also shown to be significantly dependent on the interaction of width and method (Table 9, Figure 14). The observers in the canoe apparently missed more dolphins within the groups in wider water bodies. The blimp generally recorded slightly larger group size than the canoe, although the difference was not statistically significant. In contrast to the effect on dolphin abundance and groups, habitat type did not influence group size. It was the first variable that was removed from the model.

Table 9 Best Linear Mixed-Effects Model fitted to explain the variation of average group size depending on survey method and confounding factors (See Table A.5 and A.6 for model selection)

Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + (1|sector/subsector), data = mydata)

Random effects:

Groups	Name	Variance	Std.Dev.
subsector:sector	(Intercept)	0.3670	0.6058
sector	(Intercept)	0.0000	0.0000
Residual		0.8966	0.9469

Number of obs: 594, groups: 594; subsector:sector, 56; sector, 6

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	0.91931	0.10165	65.30000	9.044	4.01e-13 ***
scale(width)	0.49055	0.08933	80.00000	5.492	4.58e-07 ***
methodcanoe	-0.14559	0.07770	531.50000	-1.874	0.0615 .
scale(width):methodcanoe	-0.17459	0.07777	531.50000	-2.245	0.0252 *

** 0.05 > p > 0.01; ** 0.05 > p < 0.01; *** p < 0.001*

Random effects are sector and subsector, “over” controls for overdispersion by fitting a random intercept for each line of the database

Width: width of subsectors in m

Method: canoe and blimp. Blimp is the reference category

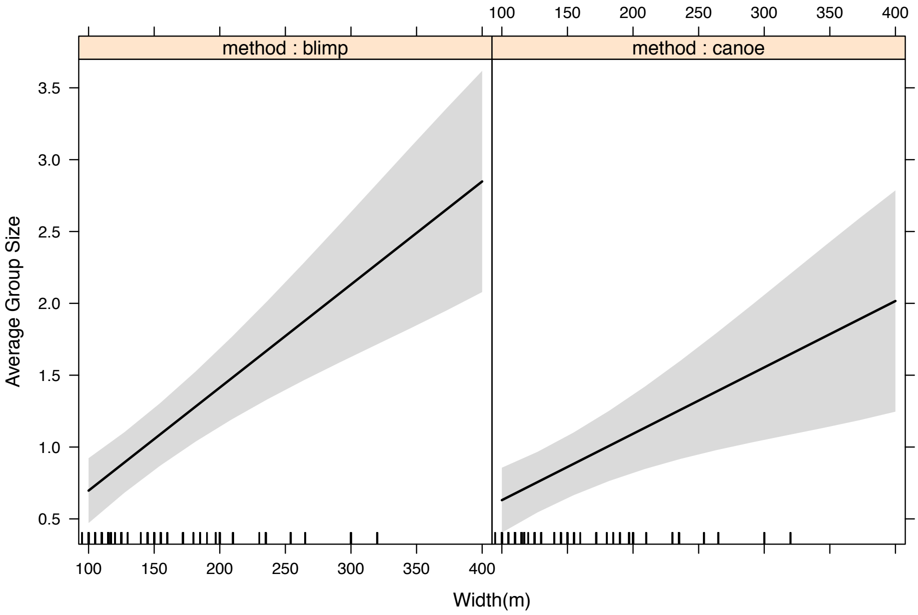

Figure 14 Effect of the interaction between width of water bodies and survey methods on average group size of river dolphins

3.2.5 Number of Calves

General Findings

In total 31 calves (7.9% of all counted dolphins) were counted by the blimp method and 14 (4.8%) by the visual survey. The highest average number of calves according to the blimp was recorded in beach sections (0.16) and the highest calve number sighted by the visual survey method was in mouths of lakes and arms (0.9) (Table 10).

Table 10 Average number of calves counted by blimp and canoe method in each habitat type

Avg. no. of calves	Arm	Bank	Beach	Confluence	Lake	Mouth	Rocks /bank	Rocks /beach	Sand bank
Blimp	0.13	0.08	0.16	0	0.07	0.14	0	0.09	0.12
Canoe	0.1	0.02	0.03	0	0.04	0.09	0	0	0.04

Effects

I found a significant dependency of number of calves on the size of the surveyed water bodies (Table 11). The larger the area, the more calves were counted. The interaction of survey method and area also predicts number of calves significantly. The blimp method counted clearly more calves in larger area than the canoe method (Figure 15). Also, number of calves is strongly predicted by sun glare. The more sun glare the higher number of calves was counted. The counts of calves were not significantly dependent on survey days, but during the first part of the survey more calves were counted. The predictor habitat was not included in the models, because a very low number of calves were sighted and the regression models had not enough power to deal with the zero values.

Table 11 Best Generalized Linear Mixed-Effects Model fitted to explain the variation of number of calves depending on survey method and confounding factors (See Table A.7 and A.8 for model selection)

Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + scale(glare) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)

Random effects:

	Groups	Name	Variance	Std.Dev.
	over	(Intercept)	1.113e-05	0.003337
	subsector:sector	(Intercept)	7.726e-01	0.878958
	sector	(Intercept)	5.787e-05	0.007607

Number of obs: 594, groups: over, 594; subsector:sector, 56; sector, 6

Fixed effects:

	Estimate	Std. Error	Z value	Pr(>|z|)
(Intercept)	-3.6368	0.6142	-5.922	3.19e-09 ***
scale(area)	1.4213	0.5761	2.467	0.01362 *
I(scale(area)^2)	-0.3221	0.2067	-1.558	0.11916
methodcanoe	-0.5744	0.3427	-1.676	0.09373 .
scale(glare)	0.4835	0.1839	2.629	0.00856 **
scale(days)	-0.6821	0.3811	-1.790	0.07350 .
I(scale(days)^2)	0.7048	0.3762	1.874	0.06097 .
scale(area):methodcanoe	-0.7678	0.3816	-2.012	0.04422 *

** 0.05 > p > 0.01; ** 0.05 > p < 0.01; *** p < 0.001*
Random effects are sector and subsector, “over” controls for overdispersion by fitting a random intercept for each line of the database
Area: area of subsectors in m^2
Method: canoe and blimp. Blimp is the reference category
Habitat types: Arm is the reference category

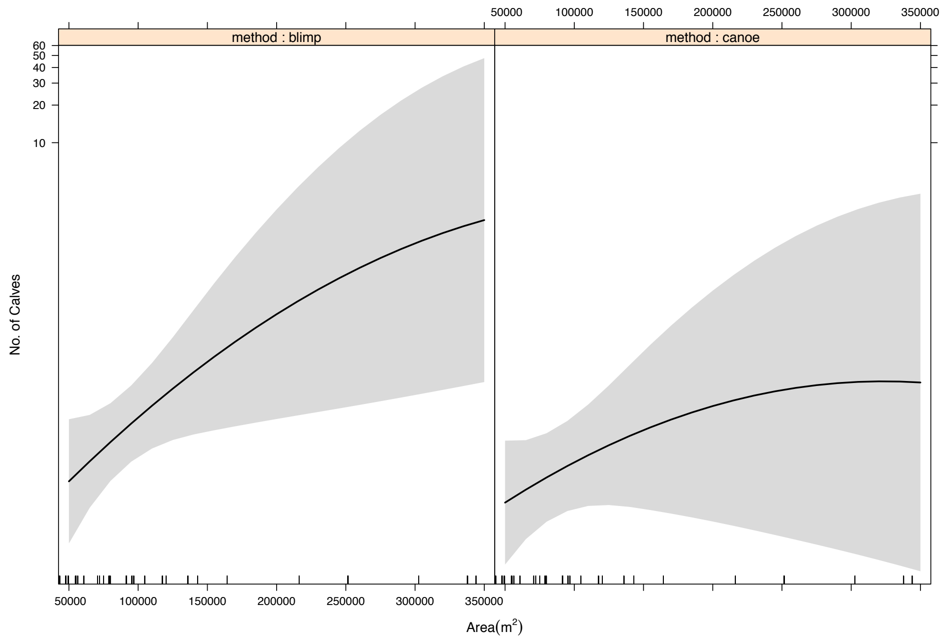

Figure 15 Effect of the interaction between area of water bodies and survey method on number of calves

4 Discussion

The results of this study show that the aerial survey recorded significantly more Araguaian river dolphins than the visual survey, whereas both survey methods counted similar numbers of dolphin groups. The larger and wider the sections, the more dolphins (both adults and calves) and dolphin groups were sighted, and the larger was the group size. Comparing to the aerial survey, the visual survey missed more dolphins in larger than in smaller sections, and recorded smaller group size in wider sections than the blimp method. A high dolphin density in PEC was found by both survey methods. Considering habitat types, this study found the highest dolphin abundance in mouths of arms and lakes, followed by arms. Group size was not associated with habitat type.
In the following sections, general findings of dolphin sightings and effects of survey method on dolphin sightings are discussed, followed by limitations and suggestions about methodology.

4.1 Findings of River Dolphin Sightings

4.1.1 Dolphin Abundance

Density
The Araguaian river dolphin density found in the present study (19.7/km^2 by the blimp) is high compared to *Inia geoffrensis* densities encountered in other studies (Table 12). Araújo (2010) found a density of only 0.84/km^2 in the Araguaia River in the low water season. In PEC, habitat becomes extensively reduced during the dry season and the dolphins are concentrated in a few channels and lakes. Also, fish are much more concentrated during that time so that dolphins find high density of available resources (NGO Instituto Araguaia, personal communication). Additionally, habitat in PEC is protected with less boat traffic and disturbances or killing, and provides low current waters. According to Martin and da Silva (2004b), river dolphins occur preferentially in floodplain lake systems. They reported that in the Mamirauá lake system, for periods of the year, densities are extremely high and routinely higher than in the large rivers. Martin et al. (2004) encountered a similar high dolphin density (18/km^2) in the Mamirauá reserve as the present study in PEC. Aliaga-Rossel et al. (2006) found more dolphins/km in tributaries than in the larger main river and Vidal et al. (1997) and Martin et al. (2004) found higher densities along the river margins than in the center of the rivers, probably because of higher fish density and low current near the banks.

Table 12 *Inia araguaiaensis* densities found in the present study compared to *Inia geoffrensis* densities found in other studies

Study	Location	Water season	Transect type	Survey information	No. of dolphins /km^2	No. of dolphins /km
Present study	Cantão State Park, Brazil	low	strip	blimp	19.7	2.6
				canoe	13.9	1.8
Vidal et al., 1997	Amazon River, Colombia, Peru, Brazil	falling	strip	margins	1.5 - 4.8	0.3 - 0.6
			line	center	0.6	-
Martin et al., 2004	Japuré,Soli-mões Rivers, Brazil	all seasons	strip	margins	3.7	0.6
			line	center	0.6	-
Martin & da Silva, 2004	Mamirauá Reserve, Brazil	rising	strip	-	18	4.2
Leatherwood et al., 1997	Samiria-Yanayacu Rivers, Peru	low	strip	-	2.7 - 4.8	-
Aliaga-Rossel, 2002	Tijamuchi River, Bolivia	all seasons	strip	-	-	1.1
Aliaga-Rossel et al., 2006	Mamoré River, Bolivia	low	strip	main river	-	1.6
				tributaries	-	3.4
Araújo, 2010	Araguaia River	low	line	-	0.84	0.19

Habitat

In this study, we counted the highest number of dolphins in mouths, followed by arms. Many studies of river dolphins in the Amazon found the highest dolphin abundance in confluences, where rivers/channels meet tributaries or lagoons/lakes (e.g. Leatherwood, 1996, McGuire & Winemiller, 1998, Martin et al., 2004). Confluences usually provide deep water and hold high density of fish, which enter and leave lagoons and tributaries (McGuire & Winemiller, 1998). Moreover, the low current in these areas allows low energy costs for dolphins (Martin et al., 2004). The low abundance found in confluences in this study could be explained by the fact that in the dry season with many sand banks and rocks, the only four confluences present in the study site consisted of very narrow and shallow water. The habitat category mouth in this study may be quite similar to confluences in other studies, as fish passed to enter and leave river arms and lakes. Also the water in the mouths was deep and calm. Araújo (2010), who surveyed dolphins in the Araguaia River, also encountered most dolphins in mouths. River arms in PEC may also provide high fish density due to calm and deep water, surrounded by protecting vegetation.

We counted a significantly higher number of dolphins in sections of larger area than in water bodies that were smaller. This finding is not supported or not analyzed by other studies of river dolphins. According to da Silva & Martin (2010), in major rivers in the Brazilian Amazon, width appears to have no impact on the number of *Inia geoffrensis*. There, higher density was found along the margins than in the center of rivers, whereas in PEC and on the Araguaia River (Araújo, 2010) such difference was not found, probably because the water bodies are much narrower.

Effects on sighting

The results of this study show clearly that the aerial survey by means of the blimp recorded a significantly higher number of Araguaian river dolphins than the visual survey. *Inia araguaiaensis* often emerge quickly and quietly, and three observers could not cover the whole field of vision all the time comparing to the filming camera on the blimp. Communication problems, distraction and different observer experiences were limitations, as also stated in Reeves et al. (2000) and Dawson et al. (2008). Two dolphins were confounded with the large freshwater fish Arapaima, which similar to a dolphin emerges to exhale. In the videos dolphins often could be seen below the water surface shortly before they emerged and when they where near the water surface. This facilitated the identification of individuals. Additionally, dolphins could be detected earlier in the videos than by observing visually, which allows following the movements of dolphins and reduces the bias caused by attraction of river dolphins to boats (Dawson et al., 2008). Also, ripples of the water surface did not affect detection of dolphins in the videos.

More dolphins were recorded by the aerial survey method in all habitat types. I did not test the association between survey method and habitat type, since an influence of habitat on different efficiency of both methods was not expected. A trend was found that the blimp counted more dolphins than the canoe in sections of larger area. Hence, the canoe method performed better in narrower areas of the study site. This may be due to the fact that generally fewer dolphins occurred in narrower sections than in wider ones, and the distance of dolphins from the canoe might have been shorter and therefore sighting was facilitated.

The factors wind, glare, water and cloud had no significant effect on the dolphin counts. However, the results demonstrated a trend that with increased cloud cover, lower number of dolphins was counted. The reflection of clouds in the water made it more difficult to detect dolphins in the videos, and clouds might have affected the vision of the observers. It was expected that sun glare and water surface/wind affected detection negatively as well. Although the surveys were conducted when the water was calm, small ripples could already interfere in the ability to sight dolphins. The same applies to sun glare that reflects in the water (Dawson et al., 2008) and fog that limited the field of vision. However, no trend was found in the present study.

4.1.2 Groups

The group patterns of Araguaian river dolphins observed in this study correspond to the findings of studies about *Inia geoffrensis*, which are mostly solitary (e.g. McGuire & Winemiller, 1998, Aliaga-Rossel, 2002). River dolphins do not form stable groups, except for mother and calve, and come together for alimentation and socialization and then disperse (Dos Santos et al., 2012). However, during all replicates in the sector Lago Grande, a group of three dolphins consisting of one calve and two other dolphins was sighted. Kendall & Trujillo (2000) reported that in Colombia *Inia geoffrensis* formed groups in which calves were cared for by one or two adults.

The groups we encountered in PEC seemed to be generally larger than the groups sighted in the Araguaia River by Araújo (2010), also in the low water season. In PEC, groups of three dolphins represented 13.4% in contrast to 1.9%, and clearly less solitary dolphins and more pairs were sighted in PEC than in the Araguaia River. The average group size recorded by the aerial method in this study (1.95) is similar to the average group size of *Inia geoffrensis* found by McGuire & Winemiller (1998) in Venezuela (2), and higher than in the Araguaia River (1.23) found by Araújo (2010). PEC might offer higher variability of habitat than the Araguaia River, enhancing aggregations for resources and socialization. However, definitions of groups are subjective (Vidal et al. 1997).

In this study, group size was not statistically associated with habitat type. The largest group was encountered in wider sections and in confluences and mouths, which corresponds to the findings of Aliaga-Rossel (2002) in Bolivia. More groups were encountered in surveyed sections of larger area, especially in a mouth section and in a large lake (both in sector Paredão), These findings may be related to high fish abundance, calm waters and socialization in large areas.

The blimp detected slightly more number of groups as the observers in the canoe, but the difference was small. Consequently, the observers missed a significant number of dolphins within the groups. For the observers it was difficult to distinguish individual dolphins in a group due to the facts that most dolphins looked similar and they moved in unpredictable directions under water with variable inter-blow intervals, similar to *Inia geoffrensis* (Reeves et al., 2000). Therefore, the observers apparently underestimated the group size, especially in wide sections, as the dolphin groups tended to be larger and the distance of the groups to the canoe longer. In the videos taken by the camera on the blimp, the dolphins could be more easily distinguished in the groups, as movements of individuals could be better accompanied.

4.1.3 Calves

According to the data obtained by the blimp method, 7.9% of all counted dolphins were calves, which point to high calve abundance compared with 5.37% calves encountered by Aliaga-Rossel (2002) in the low water season in the Bolivian Amazon. Females with calves may concentrate in lake systems like PEC (Martin and da Silva, 2004b). However, calve definition is subjective and this study did not distinguish calves and juveniles. Possibly some calves counted in PEC would be referred to juveniles in the study conducted by Aliaga-Rossel. Births of *Inia araguaiaensis* probably occur in the end of the flood season (Best & da Silva 1993), and in the low water season many calves could be sighted. Aliaga-Rossel (2002) sighted more *Inia geoffrensis* calves in the low water season and McGuire & Winemiller (1998) in the end of the dry season/beginning of flooded season.

The highest average number of calves was encountered in beach sections, but differences between habitat types were small and data of calves were not sufficient to provide any evidence of habitat type influencing occurrence of calves. McGuire & Winemiller (1998) found no variation in calve sightings according to habitat, but more juveniles in lagoons, whereas Aliaga-Rossel (2002) found the lowest calve abundance in lagoons.

We counted more calves in water bodies of larger area, which coincides with the findings of total number of dolphins and groups. The finding that higher number of calves was associated with higher level of sun glare was unexpected. The activity of river dolphins related to time of day is not studied. Possibly, sections with higher calve occurrence were reached later in the day or the sun light facilitated calve detection.

More calves were detected by the aerial survey method, although not significantly. Compared with the blimp data, the observers missed significantly more calves in larger water bodies. When two or three dolphins emerged close together simultaneously, it happened that they were counted as only one dolphin, especially when a calve emerged very closely to its mother. Differences in body size of low-surfacing river dolphins are difficult to discern in visual surveys (Aliaga-Rossel et al., 2006).

4.2 Limitations

4.2.1 Blimp

The blimp system used in this study was kept very simple to first test its efficiency in PEC and to compare it to visual survey. Everyone could build the system, which held the camera on the blimp, and the equipment was inexpensive.

Like Harris et al. (1996) experienced, best conditions to use the blimp were until noon, before convective air currents started, which cause turbulences, and before the sun was very hot, which can reduce the endurance of the blimp material. The blimp could only be utilized with wind speed not higher than 10 km/h, as also found by Flamm et al. (2000). Murden & Risenhoover (2000) reported that wind gusts higher than 16 km/h caused the blimp to become unstable. In PEC, approximately 12,5 km was the maximum distance that could be covered per day before winds got too strong. Though, for the visual counting that distance was also the limit because of the rippled water surface caused by the wind. Hodgson (2007), who studied dugongs, developed an alternative blimp design which could be a model for future studies: an ovoid shaped, smaller blimp (2.5 m diameter, 11.3 m^3), which could be used in winds up to 15 knots (27.78 km/h).
Another major limitation is the risk of the blimp being blown into trees or become entangled, causing leaks (Harris et al., 1996), therefore the blimp should not be used in too narrow, vegetated river arms (< 25 m). A more resistant material, especially for tropical regions, would be favorable. Furthermore, the blimp has to be refilled with a small amount of gas before every usage. The transportation of the blimp to remote areas is risky, unless the blimp is deflated, which can lead to expensive helium gas consumption. In this regard, the visual survey using a canoe is more flexible and cheaper. The blimp operated by Hodgson (2007) provided greater lift for the same amount of helium as the blimp used in this study.
During the surveys, the blimp had to be lowered after 1 hour and 20 minutes, to change the batteries of the camera. During that time, dolphins could pass and bore the risk to be double counted. Therefore, batteries should be changed quickly at locations without many dolphins.

4.2.2 General Methodology

Initially, the idea was to replicate at least one isolated sector containing a relatively high number of dolphins (Estirão), to see the variation of blimp counts. For this purpose, it was tried to close a river arm with a net, but it did not work as the dolphins jumped over it. Thus, the variations of counts could not be tested, except for Lago Grande, which was isolated by sand banks during the whole survey but only contained four dolphins, which were counted by the blimp method in all replicates.
Furthermore, in this study it was not possible to accompany the videos of the aerial survey live and the height of the camera was too high for wireless connection. Flamm et al. (2000), Nowacek et al. (2001) and Hodgson (2007) had camera systems that transmitted footage via cables to a monitor in the boat, and the camera could be controlled. To ensure proper detection after the surveys of the present study, it was necessary to watch all videos at least twice or together with another person, especially when dolphins were in a group and when

visibility was affected by fog, clouds, sun glare or smoke in the air caused by large burnings of forest outside the park.
Two sections of the survey, a part of a mouth and a lake, were too wide for conducting strip transect (>300 m) for both aerial and visual methods. There, it probably would have been appropriate to apply zig-zag transects, such as Aliaga-Rossel (2002) did in lagoons. In this study, the boats travelled in 100 m distance of the shore around the lake, which made it difficult to distinguish individuals due to movements and attraction of dolphins to the boats.
When the boats had to enter and leave arms with dead end or lakes, river dolphins could be missed or double counted when the boats came back to the main channel, especially when they were attracted to the boats. Most studies of river dolphins used a platform to increase the ability of sighting (e.g. Vidal et al., 1997, Martin et al., 2004, Gomez-Salazar et al., 2012), but in narrow river systems like PEC boats have to be small and light, since they often have to be dragged over sand banks in the dry season (Dawson et al., 2008).

4.3 Suggestions about Methodology

In the present study, strip transects were warranted, as the study site consisted mostly of narrow waterways (mean width 137.7). With 100 meters on each side of the boat the likelihood that all dolphins are seen is already relatively high (Dawson et al., 2008). According to Vidal et al. (1997) and Dawson et al. (2008), line transects with distance sampling requires much training estimating distance, since it is hard to use water ripples left by dolphin surfacing as reference, and the optical rangefinder may not work, especially in small boats with low observing elevation. Although line-transect methods correct for missed animals, the assumption that all river dolphins are detected on the track line is often violated, due to their erratic surfacing behavior. Also, river dolphins may not meet the assumption that they are uniformly distributed (Dawson et al., 2008). Nevertheless, distance sampling could be a reliable method in wider rivers because sightings outside the effective strip width are not ignored (Reeves et al., 2000, Dawson et al., 2008). In further studies, line transects could be compared to the aerial survey method. To ensure detection of dolphins in the videos, the maximum height the blimp could fly was 80 meters, thus the maximum width that could be covered was about 350 meters. Vidal et al. (1997), Martin et al. (2004) and Gómez-Salazar et al. (2012) used strip transects parallel to the banks along the river and additionally 45° cross-river line transects in the Amazon in Orinoco basins. Martin et al. (2004) and Vidal et al. (1997) concluded that it may be more effective to conduct strip transects along the margins and use a correction factor for dolphins mid-river, because higher dolphin density were encountered along margins. This might not be true for narrower rivers like Araguaia River, where densities near margins and in the center are similar (Araújo, 2010).

For river systems with relatively low currents and calm water, using boats with an electric motor instead of outboard motors used in most river dolphin studies has proven to be advantageous. Electric motors are quiet, allowing to hear exhalation sounds of dolphins. The observers sighted 13.5% of all dolphins due to exhalation sound. Also, in PEC dolphins sometimes seemed to be disturbed by outboard motors, which makes it more difficult to see them. The electric motor is very easy to handle. The pilot of the visual survey boat could be an active observer without being limited and the pilot in the other boat could hold the blimp without needing another person.

The speed of 4 - 5 km/h used in this study was not too low to allow dolphins to pass the boat and increase the risk of double counting, but ensured that dolphins surfaced within visual range at least once in 2 minutes. The speed in many river dolphin surveys ranges up to 12 km/h (e.g. Aliaga-Rossel et al., 2006, Martin & da Silva, 2004b, Da Silva & Martin, 2000, Araújo & da Silva, 2014) and was considered too high for proper detection of dolphins in this study.

To achieve more efficient visual counting, a lot of training of all observers is necessary before starting the survey (Vidal et al., 1997). Like Dawson et al. (2008) stated, even local people that know the ecosystem for their lifetime, often lack the experience of systematic study and should be well trained before countings. Active observation to the rear was very important in our study like Vidal et al. (1997) suggested, because many dolphins were attracted by the boats and emerged behind them, without having been sighted ahead.

In ecosystems like PEC, it could be considered to carry out abundance surveys in the transition of low and high water seasons when lakes are still connected, in order to facilitate transportations of blimp and boats in remote areas with less sand banks having to be passed (Gomez-Salazar et al., 2012, Williams et al., 2016). To obtain abundance data, surveyed areas could be extrapolated to unsurveyed areas and conduct annual surveys to detect population trends. The distribution of river dolphins is most likely not uniform across rivers, thus extrapolation of population estimates has to be done with caution (Araújo, 2010, Gómez-Salazar et al., 2012).

5 Conclusions

The Cantão State Park holds a high density of *Inia araguaiaensis* in the low water season and provides important habitat for this species. Besides mitigating overfishing and implementing environmental education, for conservation of this species it is crucial to estimate the population of Araguaian river dolphins and detect population trends. For this purpose, and for obtaining reliable abundance and distribution data of all other river dolphin species, an inexpensive, simple and efficient survey method is favorable. This study indicates that aerial surveys are efficient to study river dolphins. The blimp performed better in counting *Inia araguaiaensis* than the visual method, having detected more adults, calves, groups and larger group size. Especially in wide and large sections the difference between the two survey methods was considerable. However, a more resistant and economic blimp than the one used in this study should be considered. The development of drones for field studies is promising and the prices are decreasing, but the control has to be easy enough to be operated by local people and the flight endurance has to be increased. With lower flight height than used in this study, aerial survey methods could be used to observe behavior of river dolphins. Also, by taking images from aerial view, the size of river dolphins could be measured with the help of reference objects. Future studies should confirm if aerial surveys provide stable data and test them in wider rivers.

6 References

Aliaga-Rossel, E. 2002. Distribution and abundance of the river dolphin *(Inia geoffrensis*) in the Tijamuchi River, Beni, Bolivia. *Aquatic Mammals*, 28 (3): 312–323.

Aliaga-Rossel, E., McGuire, T. L., & Hamilton, H. 2006. Distribution and encounter rates of the river dolphin (*Inia geoffrensis boliviensis*) in the central Bolivian Amazon. *Journal of Cetacean Research and Management*, 8 (1): 87–92.

Araújo, C. C. 2010. Distribuição e estimativas populacionais do boto *Inia geoffrensis* (de Blainville , 1817) (Iniidae) no médio Rio Araguaia (Brasil central). Dissertation, INPA, Manaus, Xii, 69 pp.

Araújo, C. C., & da Silva, V. M. F. 2014. Spatial distribution of river dolphins, *Inia geoffrensis (Iinidae),* in the Araguaia River (central Brazil). *Mammalia*, 78 (4): 481–486.

Araújo, C. C., & Wang, J. Y. 2012. Botos (*Inia geoffrensis*) in the upper reaches of the Tocantins river (Central Brazil) with observations of unusual behavior, including object carrying. *Aquatic Mammals*, 38 (4): 435–440.

Best, R. C., & da Silva, V. M. F. 1993. *Inia geoffrensis* (de Blainville, 1817). *Mammalian Species*, 426: 1-8.

Committe on Taxonomy 2015. List of marine mammal species and subspecies. *Society for Marine Mammalogy,* www.marinemammalscience.org, consulted on 07 March 2016.

Da Silva, V. M. F. & Martin, A. R. 2000. A study of the Boto, or Amazon river dolphin (*Inia geoffrensis*), in the Mamirauá Reserve, Brazil: Operation and Techniques. In: Reeves, R. R., Smith, B. D., & Kasuya, T. (Eds.) 2000, *Biology and Conservation of Freshwater Cetaceans in Asia*, IUCN, Gland, Switzerland and Cambridge, UK, 23: 121-131.

Da Silva, V. M. F. & Martin, A. R. 2010. Status, threats, conservation initiatives and possible solutions for *Inia geoffrensis* and *Sotalia fluviatilis* in Brazil. In: Trujillo, F., Crespo, E., Van Damme, P. A., and Usma, J. S. (Eds.) 2010. *The Action Plan for South American River Dolphins* 2010–2020. WWF, Fundación Omacha, WDS, WDCS, Solamac. Bogotá, D.C., Colombia : 123-143.

Dos Santos, G. M. A., Quaresma, A. C., Barata, R. R., Martins, B. M. L., Siciliano, S., de Souza e Silva JR, J. & Emin-Lima, R. 2012. Etho-ecological study of the Amazon River dolphin, *Inia geoffrensis* (Cetacea : Iniidae), and the dolphins of the genus *Sotalia* (Cetacea : Delphinidae) in Guamá River, Amazonia. *Marine Biodiversity Records 5* (e23): 1–5.

Dawson, S., Wade, P., Slooten, E., & Barlow, J. (2008). Design and field methods for sighting surveys of cetaceans in coastal and riverine habitats. *Mammal Review*, 38 (1): 19–49.

Ferreira, E., Zuanon, J., dos Santos, G & Amadio, S. 2011. A ictiofauna do Parque Estadual do Cantão, Estado do Tocantins, Brasil. *Biota Neotropica*, 11(2): 277–284.

Flamm, R. O., Owen, E. C. G., Owen, C. F. W., Wells, R. S., Nowacek D. 2000. Aerial videogrammetry from a tethered airship to assess manatee life-stage structure. *Marine Mammal Science*, 16 (3): 617–630.

Gomez-Salazar, C., Trujillo, F., Portocarrero-Aya, M., & Whitehead, H. 2012. Population, density estimates, and conservation of river dolphins (*Inia* and *Sotalia*) in the Amazon and Orinoco river basins. *Marine Mammal Science*, 28 (1): 124–153.

Gomez-Salazar, C., Trujillo, F., & Whitehead, H. 2011. Photo-identification: A reliable and noninvasive tool for studying pink river dolphins (*Inia geoffrensis*). *Aquatic Mammals*, 37(4): 472-485.

Harris, N. R., Johnson, D. E., Righetti, T. L., & Barrington, M. R. 1996. A blimp borne camera system for monitoring rangelands, riparian zones, or critical areas. *Geocarto International*, 11(3): 99–104.

Hodgson, A. 2007. "BLIMP-CAM": Aerial video observations of marine animals. *Marine Technology Society Journal*, 41 (2): 39–43.

Hodgson, A., Kelly N., Peel D. 2013. Unmanned Aerial Vehicles (UAVs) for surveying marine fauna: A dugong case study. *PLOS ONE*, 8 (11): e79556.

Hrbek, T., da Silva, V. M. F., Dutra, N., Gravena, W., Martin, A. R., & Farias, I. P. 2014. A new species of river dolphin from Brazil or: How little do we know our biodiversity. *PLOS ONE*, 9 (1): e83623.

IUCN 2015. The IUCN Red List of Threatened Species. Version 2015-4, www.iucnredlist.org. Downloaded on 04 March 2016.

IUCN - Crocodile Specialist Group 2015. Conservation Status, www.iucncsg.org/pages/Conservation-Status.html. Downloaded on 12 March 2016.

Kendall, S. & Trujillo, F. (2000) *Los Delfines de la Amazonia y la Orinoquia*. Fundación Omacha, Bogotá- Colombia, 32 pp.

Koh, L. P., & Wich, S. A. 2012. Dawn of drone ecology: low-cost autonomous aerial vehicles for conservation. *Tropical Conservation Science*, 5 (2): 121–132.

Leatherwood, S., Reeves, R. R., Würsig, B., Shearn, D., 1997. Habitat preferences of river dolphins in the Peruvian Amazon. In: Reeves, R.R., Smith, B. D., Kasuya, T. (Eds.), *Biology and Conservation of Freshwater Cetaceans in Asia* 2000. IUCN, Gland, Switzerland and Cambridge, UK, 23: 131-144.

Linchant, J., Lisein, J., Semeki, J., Lejeune, P. & Vermeulen, C. 2015. Are unmanned aircraft systems (UASs) the future of wildlife monitoring? A review of accomplishments and challenges. *Mammal Review*, 45 (2015): 239–252.

Loch, C., Marmontel, M., & Simões-Lopes, P. C. 2009. Conflicts with fisheries and intentional killing of freshwater dolphins (Cetacea: Odontoceti) in the Western Brazilian Amazon. *Biodiversity and Conservation*, 18: 3979–3988.

Martin, A. R., & da Silva, V. M. F. 2004a. Number, seasonal movements, and residency characteristics of river dolphins in an Amazonian floodplain lake system. *Canadian Journal of Zoology*, 82: 1307–1315.

Martin, A. R., & da Silva, V. M. F. 2004b. River dolphins and flooded forest: seasonal habitat use and sexual segregation of botos (*Inia geoffrensis*) in an extreme cetacean environment, *Journal of Zoology, London*, 263: 295–305.

Martin, A. R., Da Silva, V. M. F., & Salmon, D. L. 2004. Riverine habitat preferences of botos (*Inia geoffrensis*) and tucuxis (*Sotalia fluviatilis*) in the central Amazon. *Marine Mammal Science,* 20 (2): 189-200.

Martin, J., Edwards, H. H., Burgess, M. A., Percival, H. F., Fagan, D. E., Gardner, B. E., Ortega-Ortiz, J. G., Ifju, P. G., Evers, B. S. & Rambo, T. J. 2012. Estimating distribution of hidden objects with drones: from tennis balls to Manatees. *PLOS ONE*, 7 (6): e38882.

McGuire, T. L., & Winemiller, K. O. 1998. Occurrence patterns, habitat associations, and potential pey of the river dolphin, *Inia geoffrensis*, in the Cinaruco River, Venezuela. *Biotropica*, 30 (4): 625–638.

Murden, S. B., & Risenhoover, K. L. 2000. Blimp system to obtain high-resolution, low-altitude aerial photography and videography. *Wildlife Society Bulletin*, 28 (4): 958–962.

Nowacek D., Tyack P., Wells R. 2001. A platform for continuous behavioural and acoustic observation of free-ranging marine mammals: Overhead video combined with underwater audio. *Marine Mammal Science*, 17 (1): 191–199.

Parque Estadual do Cantão 2000. Avaliação Ecológica Rápida, 133 pp.

Pinheiro, R. T., & Dornas, T. 2009. Distribuição e conservação das aves na região do Cantão, Tocantins: ecótono Amazônia/Cerrado. *Biota Neotropica*, 9 (1): 187-205.

Reeves, R. R., Smith, B. D., & Kasuya, T. 2000. *Biology and Conservation of Freshwater Cetaceans in Asia*. IUCN, Gland, Switzerland and Cambridge, UK, 23: 152 pp.

Turvey, S. T., Pitman, R. L., Taylor, B. L., Barlow, J., Akamatsu, T., Barrett, L. A., Zhao, X., Reeves, R. R., Stewart, B. S., Wang, K., Wei, Z., Zhang, X., Pusser, L. T., Richlen, M., Brandon, J. R. & Wang, D. 2007. First human-caused extinction of a cetacean species?. *Biology Letters*, 3: 537-540.

Vidal, O., Barlow, J., Hurtado, L. A., Torre, J., Cendón, P. & Ojeda Z. 1997. Distribution and abundance of the Amazon river dolphin (*Inia geoffrensis*) and the tucuxi (*Sotalia fluviatilis*) in the upper Amazon river. *Marine Mammal Science*, 13 (3): 427–445.

Williams, R., Moore, J. E., Gomez-Salazar, C., Trujillo, F., & Burt, L. 2016. Searching for trends in river dolphin abundance: Designing surveys for looming threats, and evidence for opposing trends of two species in the Colombian Amazon. *Biological Conservation*, 195: 136–145.

Appendices

Appendix A. Pictures of Araguaian River Dolphin Survey

Figure A.1 Pictures of expeditions, recording of an Araguaian river dolphin and test of blimp flight **A**: On the way from the research base to the riverside of Rio do Côco, to leave for an expedition to the sector St Antônio. **B**: Boats and equipments had to be dragged over remaining water and sand banks to get to more remote study areas. **C**: Screen shot of a video filmed by the GoPro camera on the blimp. The blimp was lowered down to film an Araguaian river dolphin that was swimming very near around the boats for 10 minutes. **D**: Test of suitable flight height of the blimp

Appendix B. Correlations of Predictor Variables

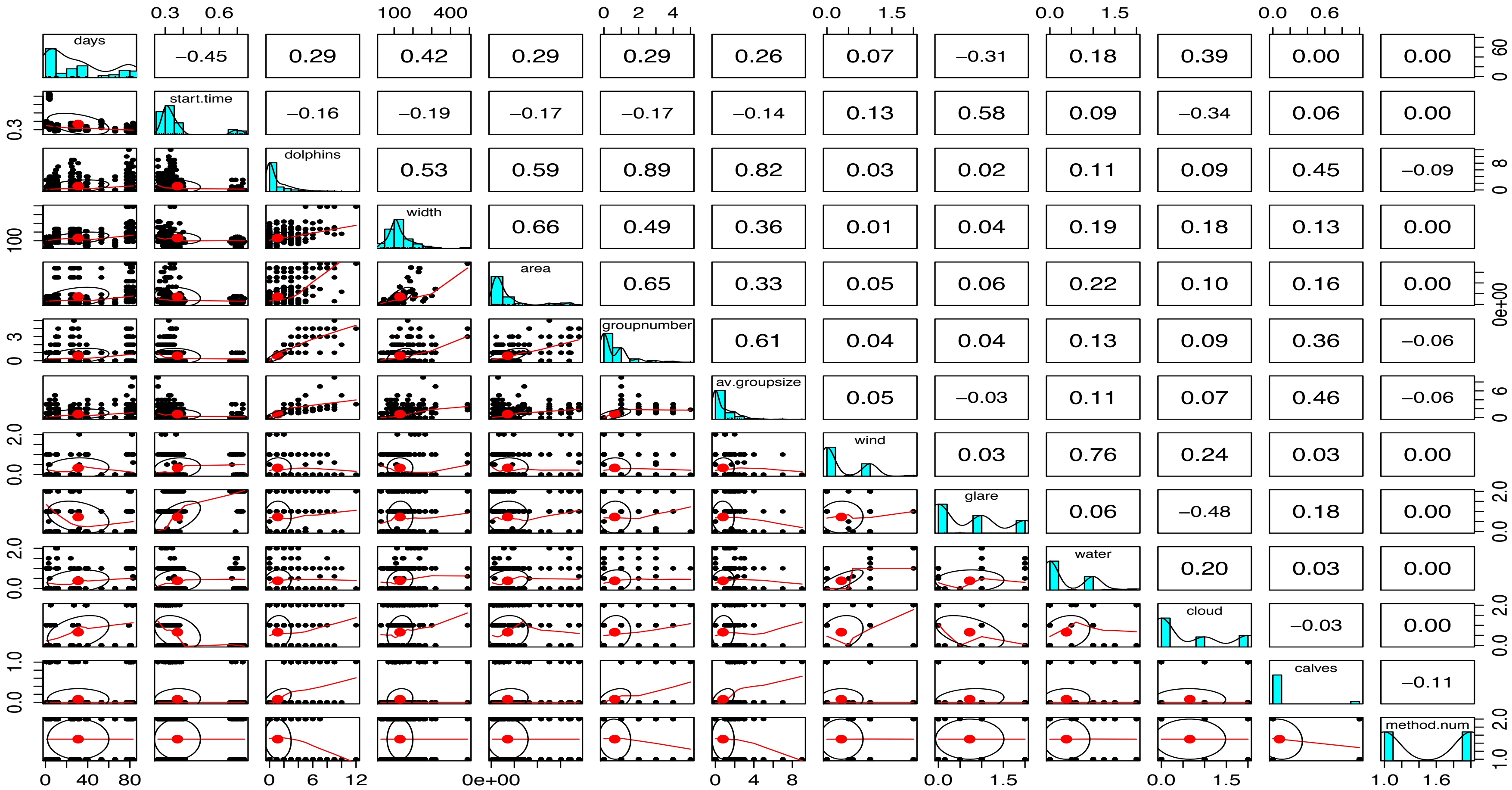

Figure A.2 Pearson`s correlations between all variables

Appendix C. Model Selection

Table A.1 All alternative full models with number of river dolphins as response variable

<table>
<tr><td>Model1 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1523.5</td></tr>
<tr><td>Model2 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1523.7</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1522.3</td></tr>
<tr><td>Model4 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1522.3</td></tr>
<tr><td>Model5 = glmer(dolphins ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1532.2</td></tr>
<tr><td>Model6 = glmer(dolphins ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1532</td></tr>
<tr><td>Model7 = glmer(dolphins ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1530.9</td></tr>
<tr><td>Model8 = glmer(dolphins ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1530.9</td></tr>
</table>

For the legend: see at the end of the Appendix

Table A.2 Step AIC to obtain the final model with number of river dolphins as response variable

<table>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + ~~method * scale(water)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1522.3</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + ~~method * scale(start.time)~~ + scale(cloud) + method * scale(cloud) + scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1520.4</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + scale(cloud) + method * scale(cloud) + ~~scale(water)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1518.4</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + scale(cloud) + ~~method * scale(cloud)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1516.4</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + ~~method * I(scale(area)^2)~~ + habitat + scale(start.time) + scale(cloud) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1514.8</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + ~~I(scale(area)^2)~~ + method + method * scale(area) + habitat + scale(start.time) + scale(cloud) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1513.2</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + method + method * scale(area) + habitat + scale(start.time) + scale(cloud) + scale(days) + ~~I(scale(days)^2)~~ + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1511.8</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + method + method * scale(area) + habitat + scale(start.time) + scale(cloud) + ~~scale(days)~~ + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1510.9</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + method + method * scale(area) + habitat + ~~scale(start.time)~~ + scale(cloud) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1509.8</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + method + ~~method * scale(area)~~ + habitat + scale(cloud) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1509.4</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + method + ~~habitat~~ + scale(cloud) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1509</td></tr>
<tr><td>Model3 = glmer(dolphins ~ scale(area) + method + scale(cloud) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 1508.8</td></tr>
</table>

Table A.3 All alternative full models with number of river dolphin groups as response variable

Model1 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1054.6
Model2 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1055
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC **1053.6**
Model4 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1053.9
Model5 = glmer(groupnumber ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1069.6
Model6 = glmer(groupnumber ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1069.2
Model7 = glmer(groupnumber ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1068.9
Model8 = glmer(groupnumber ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1069.1

Table A.4 Step AIC to obtain the final model with number of river dolphin groups as response variable

Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + ~~method * scale(start.time)~~ + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1053.6
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + ~~method * scale(water)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1051.6
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + scale(cloud) + ~~method * scale(cloud)~~ + scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1049.7
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + ~~method * I(scale(area)^2)~~ + habitat + scale(start.time) + scale(cloud) + scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1047.8
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + habitat + scale(start.time) + scale(cloud) + scale(water) + scale(days) + ~~I(scale(days)^2)~~ + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1046.0
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + habitat + scale(start.time) + scale(cloud) + ~~scale(water)~~ + scale(days) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1044.2
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + ~~method * scale(area)~~ + habitat + scale(start.time) + scale(cloud) + scale(days) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1042.5
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + habitat + scale(start.time) + ~~scale(cloud)~~ + scale(days) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1041.3
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + habitat + ~~scale(start.time)~~ + scale(days) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1040.5
Model3 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + habitat + ~~scale(days)~~ + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1039.6
Model1 = glmer(groupnumber ~ scale(area) + I(scale(area)^2) + method + habitat + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 1039.4

Table A.5 All alternative full models with average group size as response variable

<table>
<tr><td>Model1 = lmer(av.groupsize ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.34</td></tr>
<tr><td>Model2 = lmer(av.groupsize ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.165</td></tr>
<tr><td>Model3 = lmer(av.groupsize ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.594</td></tr>
<tr><td>Model4 = lmer(av.groupsize ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.371</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.055</td></tr>
<tr><td>Model6 = lmer(av.groupsize ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.342</td></tr>
<tr><td>Model7 = lmer(av.groupsize ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.822</td></tr>
<tr><td>Model8 = lmer(av.groupsize ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + habitat + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.458</td></tr>
</table>

Table A.6 Step AIC to obtain the final model with average group size as response variable

<table>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + ~~habitat~~ + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1788.055
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + ~~method * I(scale(width)^2)~~ + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1780.581
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + ~~I(scale(width)^2)~~ + method + method * scale(width) + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1773.756
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + ~~method * scale(wind)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1766.958
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + scale(glare) + method * scale(glare) + scale(cloud) + ~~method * scale(cloud)~~ + scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1761.794
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + scale(glare) + method * scale(glare) + scale(cloud) + ~~scale(wind)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1756.911
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + scale(glare) + method * scale(glare) + ~~scale(cloud)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1750.969
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + scale(glare) + ~~method * scale(glare)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1745.397
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + ~~scale(glare)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector), data = mydata)</td><td>AIC 1740.42
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + scale(days) + ~~I(scale(days)^2)~~ + (1|sector/subsector), data = mydata)</td><td>AIC 1734.384
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + ~~scale(days)~~ + (1|sector/subsector), data = mydata)</td><td>AIC 1732.372
↙</td></tr>
<tr><td>Model5 = lmer(av.groupsize ~ scale(width) + method + method * scale(width) + (1|sector/subsector), data = mydata)</td><td>AIC 1728.061</td></tr>
</table>

Table A.7 All alternative full models with number of calves as response variable

<table>
<tr><td>Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 296.4</td></tr>
<tr><td>Model2 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 296.9</td></tr>
<tr><td>Model3 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 303.5</td></tr>
<tr><td>Model4 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 303.9</td></tr>
<tr><td>Model5 = glmer(calves ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 303.4</td></tr>
<tr><td>Model6 = glmer(calves ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 303.1</td></tr>
<tr><td>Model7 = glmer(calves ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(water) + method * scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 309.7</td></tr>
<tr><td>Model8 = glmer(calves ~ scale(width) + I(scale(width)^2) + method + method * scale(width) + method * I(scale(width)^2) + scale(start.time) + method * scale(start.time) + scale(cloud) + method * scale(cloud) + scale(wind) + method * scale(wind) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)</td><td>AIC 310.2</td></tr>
</table>

Table A.8 Step AIC to obtain the final model with number of calves as response variable

Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + scale(glare) + method * scale(glare) + scale(cloud) + method * scale(cloud) + scale(water) + ~~method * scale(water)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 296.4
Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + scale(glare) + method * scale(glare) + scale(cloud) + ~~method * scale(cloud)~~ + scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 294.4
Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + method * I(scale(area)^2) + scale(glare) + ~~method * scale(glare)~~ + scale(cloud) + scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 292.5
Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + ~~method * I(scale(area)^2)~~ + scale(glare) + scale(cloud) + scale(water) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 291.1
Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + scale(glare) + scale(cloud) + ~~scale(water)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 290.6
Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + scale(glare) + ~~scale(cloud)~~ + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 289.5
Model1 = glmer(calves ~ scale(area) + I(scale(area)^2) + method + method * scale(area) + scale(glare) + scale(days) + I(scale(days)^2) + (1|sector/subsector) + (1|over), data = mydata, family = poisson)	AIC 288.3

Legend
Area: Size of the subsectors (m^2)
Width: Width of the subsectors (m)
Method: Blimp and canoe
Glare: Sun glare
Start.time: Time of the day when surveys started
Water: State of water surface
Cloud: Cloud cover
Days: Date of survey days
Colored variables: The predictor variables with the same color correlated with each other
AIC (Akaike information criterion): Best fitted models have lowest AIC values. In the tables of all full models: Lowest AIC values are in bold.

Declaration of Authorship

I, Julia Fürstenau, herewith declare that I have written this paper on my own and that I have not used any other sources and materials than those indicated. I properly cited the materials I have relied upon. I have not submitted this document as a master thesis elsewhere.

Date:

Signed: