

Existing Relationship Between Morphological Predictors and Home Range Size of the Amazon River Dolphin (*Inia* spp.) in the Amazon and Orinoco Basins?

Federico Mosquera-Guerra^a, Fernando Trujillo^a, Jairo Pérez-Torres^p, Hugo Mantilla-Meluk^{co}, Nicole Franco-León^y, Paul André Van Damme^s, Elizabeth Campbell^x, Joanna Alfaro-Shigueto^v, José Luis Mena^z, Jeffrey C. Mangel^e, José Saulo Usma Oviedo[€], María Jimena Valderrama^f, Estefany Acosta-Lugo[€] & Dolores Armenteras-Pascual^g

ABSTRACT

*The evaluation of the relationship between morphological predictors and home range size in aquatic mammals has been a tool used to understand the ecological requirements of the species, as well as provide relevant information for the construction of conservation actions and management of populations and aquatic habitats. We evaluated the relationship between the home range size of 34 Amazon River dolphin individuals (*Inia* spp.), and three explanatory variables reported in the scientific literature (1) body mass, (2) body length, and (3) sex. Home range sizes were calculated as the univariate kernel density estimates at 95% (K_{95}) for the *Inia* spp. individuals monitored through satellite telemetry across four rivers of the Amazon basin (Bolivia, Brazil, Colombia, and Peru) and five rivers of the Colombian Orinoco basin. Out of three home range predictors evaluated, only the sex predictor showed statistical significance in the Kruskal – Wallis test ($p = 0,037$). This research also calls attention to the vulnerability of the *Inia* spp. to human impacts on aquatic landscapes such as the massive construction of dams on a regional scale regulating the flooding pulse and limiting the access of Amazon river dolphins to the different habitat types mainly in the Amazon basin.*

Keywords: body length · body size · flood pulse kernel density estimates · neotropical rivers · top predator.

Author ^a: Departamento de Biología, Laboratorio de Ecología Funcional (LEF), Unidad de Ecología y Sistemática (UNESIS), Facultad de Ciencias, Pontificia Universidad Javeriana, Bogotá D.C., Colombia.

^a ^o ^y [€]: Fundación Omacha, Bogotá, D.C, Colombia.

^a ^p [€]: Departamento de Biología, Grupo de Ecología del Paisaje y Modelación de Ecosistemas (ECOLMOD), Facultad de Ciencias, Universidad Nacional de Colombia, Bogotá D.C., Colombia.

^{co}: Programa de Biología, Centro de Estudios de Alta Montaña (CEAM), Facultad de Ciencias Básicas y Tecnologías, Universidad del Quindío, Armenia, Colombia.

^{co}: Programa de Biología, Grupo de Investigación en Desarrollo y Estudio del Recurso Hídrico y el Ambiente (CIDERA), Facultad de Ciencias Básicas y Tecnologías, Universidad del Quindío, Armenia, Colombia

^s: Faunagua, Sacaba, Cochabamba, Bolivia.

^x ^v ^z: ProDelphinus, Lima, Perú.

^y ^v: University of Exeter, School of BioSciences, Penryn, Cornwall, United Kingdom.

^y ^v: Carrera de Biología Marina, Universidad Científica del Sur, Lima, Perú.

[€]: Museo de Historia Natural “Vera Alleman Haeghebaert”, Universidad Ricardo Palma, Lima, Perú.

^e: World Wildlife Fund (WWF), Colombia, Gland, Switzerland.

F: Departamento de Biología Aplicada, Semillero de Ecología y Conservación (SEC), Facultad de Ciencias Básicas y Aplicadas, Universidad Militar Nueva Granada, Bogotá D.C., Colombia.

I. INTRODUCTION

Home ranges are defined as areas in which animals carry out their day-to-day activities and acquire the necessary resources to survive (e.g. Burt 1943; Buskirk 2004; Dahle et al. 2006; Péron 2019). Tucker et al. (2014) analyze the home range of 429 mammalian species including two coastal cetacean species (*Orcaella heinsohni*; McGowen 2011), and *Sotalia guianensis* (Caballero et al. 2008). They conclude that home range size is influenced by a range of factors such as body mass, diet, and the environment. Among the various potential consequences of allometry, an animal's home range size provides valuable information on a variety of ecological determinants, including resource use, social behavior and predator avoidance (Knight et al. 2009).

Home range analyses have been historically biased towards terrestrial mammals. Over the last two decades knowledge has grown about the spatial estimates of aquatic species, as represented in the scientific literature (Mosquera-Guerra et al. 2021). It is also unclear if factors driving home range size among mammals are the same in terrestrial and aquatic environments (Tucker et al. 2014). The size of an animal's home range is usually correlated with productivity, the species' biological requirements, and habitat heterogeneity (McNab 1963). Most animals do not use their entire home range with equal intensity but tend to concentrate their time in core areas (Dixon and Chapman 1980; Samuel et al. 1985; Oshima et al. 2010).

Previous studies on the spatial ecology of terrestrial mammals have suggested that home range sizes can be influenced by several factors as follow (1) mating system, (2) spatial distribution of resources (e.g. Boutin 1990; Dahle et al. 2006), (3) body mass (e.g. Harestad and Bunnell 1979; Dahle et al. 2006), (4) age and reproductive status (e.g. Dahle and Swenson 2003a, 2003b; Dahle et al. 2006); (5) population density and interactions with same-species neighbors (e.g. Dahle and Swenson 2003a; Buskirk 2004; Dahle et al. 2006); (6) morphological variation between subspecies (e.g. Kie et al. 2002); (7) intra- or (e.g. Riley and Dood 1984) interspecific competition (e.g. Loft et al. 1993); (8) foraging and predation avoidance (e.g. Krebs and Kacelnik 1991; Tufto et al. 1996; Powell et al. 1997; Relyea et al. 2000); (9) trophic level (e.g. Harestad and Bunnell 1979); (10) season (e.g. Nicholson et al. 1997); and (11) anthropogenic landscape fragmentation (e.g. Kie et al. 2002; Bejder et al. 2006; Pirota et al. 2013; Bas et al. 2014).

In the case of aquatic mammals, studies of home range variation in the coastal bottlenose dolphin (*Tursiops truncatus*) have been focused on the influence of environmental predictors such as productivity levels and tidal cycles (see, e.g., Wells et al. 1980; Defran et al. 1999; Wells and Scott 1999; Connor et al. 2000; Wells et al. 2017), highlighting the spatial complexity of the three-dimensional nature of aquatic environments (see, e.g., Alexander 2003; Shurin et al. 2006; Rip and McCann 2011; Pawar et al. 2012). Aquatic organisms experience high physiological challenges related to greater individual health decline (Tucker et al. 2014) as well as difficulties in detecting resources (see, e.g., Jetz et al. 2004; McGill and Mittelbach 2006; Pawar et al. 2012) that can result in variations of their home range.

The quantification of those elements that influence the selection and use of spatial mammalian ecology is technically challenging for aquatic species, and particularly for those inhabiting river systems characterized by greater hydrological dynamics. Home range studies in small cetaceans have been successfully conducted using different techniques and analyses for several coastal and oceanic species, including (1) the harbor porpoise (*Phocoena phocoena*, Sveegaard et al. 2011), (2) Hector's dolphin (*Cephalorhynchus hectori*, Rayment et al. 2009; Bräger and Bräger, 2018), (3) common bottlenose

dolphin (*Tursiops truncatus*, Mazzoil et al. 2008; Martínez-Serrano et al. 2011; Nekolny et al. 2017; Passadore et al. 2017; Wells et al. 2017; Genoves et al. 2018), (4) Atlantic spotted dolphin (*Stenella frontalis*, Hill 2014), (5) the franciscana dolphin (*Pontoporia blainvillei*, Bordino et al. 2008), and (6) Guiana dolphin (*Sotalia guianensis*, Flores and Bazzalo 2004; Rossi-Santos et al. 2006; Azevedo et al. 2007; Wedekin et al. 2007; Oshima et al. 2010). Currently, home range estimates are available only for the *Inia geoffrensis* with data derived from different methods (1) satellite tracking of adult individuals in the Amazon (Colombia and Peru), San Martín (Bolivia), Jurueña (Brazil), and Orinoco (Colombia and Venezuela) rivers (e.g. Mosquera-Guerra et al. 2021); (2) VHF radio-tagging and capture, recapture, and marking of adult individuals in the Japurá and Solimões rivers (Mamirauá Sustainable Development Reserve, Brazil) e.g. Martin and da Silva, 1998, 2004a,b; Mintzer et al. 2016); (3) photo-identification techniques of previously identified individuals (Pacaya-Samiria Reserve in Peru, e.g. McGuire and Henningsen 2007), and the Cuyabeno and Lagartococha rivers (Cuyabeno Reserve, Ecuador; e.g. Denkinger 2010).

Inia geoffrensis is the largest of the river dolphins (Martin and da Silva 2006) and is also considered one of the top predators of the aquatic trophic webs of the Amazon, Orinoco, and Araguaia-Tocantins basins (McGuire and Winemiller 1998; Gómez-Salazar et al. 2012). The species has the smallest group sizes known among cetaceans (Gómez-Salazar et al. 2011a, 2011b; Mosquera-Guerra et al. 2018a), and its use of space is strongly conditioned by its ecological position as the top predator inhabiting dynamic systems characterized by seasonal variability (Frère et al. 2010) and food availability (Mares et al. 1982).

Inia geoffrensis is subdivided into two subspecies (Committee on Taxonomy 2021); *I. g. geoffrensis* distributed across the Amazon, and Orinoco basins and *I. g. boliviensis*, found along the Mamoré, Iténez, and Madeira rivers (Aliaga-Rossel 2002; Aliaga-Rossel et al. 2006; Gravena et al. 2014; da Silva and Martin 2014; da Silva et al. 2018; Aliaga-Rossel and Guizada, 2020). *Inia geoffrensis* is listed as Endangered (da Silva et al. 2018) by the International Union for Conservation of Nature (IUCN), and is included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; da Silva and Martin 2018). The species is considered among the most threatened aquatic mammals globally (Reeves et al. 2003; Trujillo et al. 2010). In recent years, threats affecting aquatic ecosystems such as the construction of hydropower dams, mining, and bycatch of individuals river dolphins have increased in the major river basins of South America (e.g. Trujillo et al. 2010; Mitzer et al. 2014; da Silva et al. 2018; Mosquera-Guerra et al. 2019a; Barbosa et al. 2021; Campbell et al. 2020; Brum et al. 2021).

Understanding the way in which *I. geoffrensis* home range size is influenced by morphological factors constitutes an important tool for planning management and conservation actions for populations and habitats. This study represents an important collaboration between researchers from multiple organizations from four South American countries. We aimed to evaluate the relationship between a set of morphological predictors and the home range sizes for the *I. geoffrensis* individuals in the four major rivers in Amazon and five rivers in Orinoco basins.

II. MATERIALS & METHODS

2.1 Study area

This study was conducted from October 2017 to June 2021 in the Amazon and Orinoco river basins. A total of 34 (♀: 11 and ♂: 23) *I. geoffrensis* individuals were tagged with SPOT-299A and SPOT6-F single-point fin mounted satellite tags (Wildlife Computers, Redmond, WA) in four rivers of the Amazon basin and five rivers of the Colombian Orinoco basin (Fig. 1).

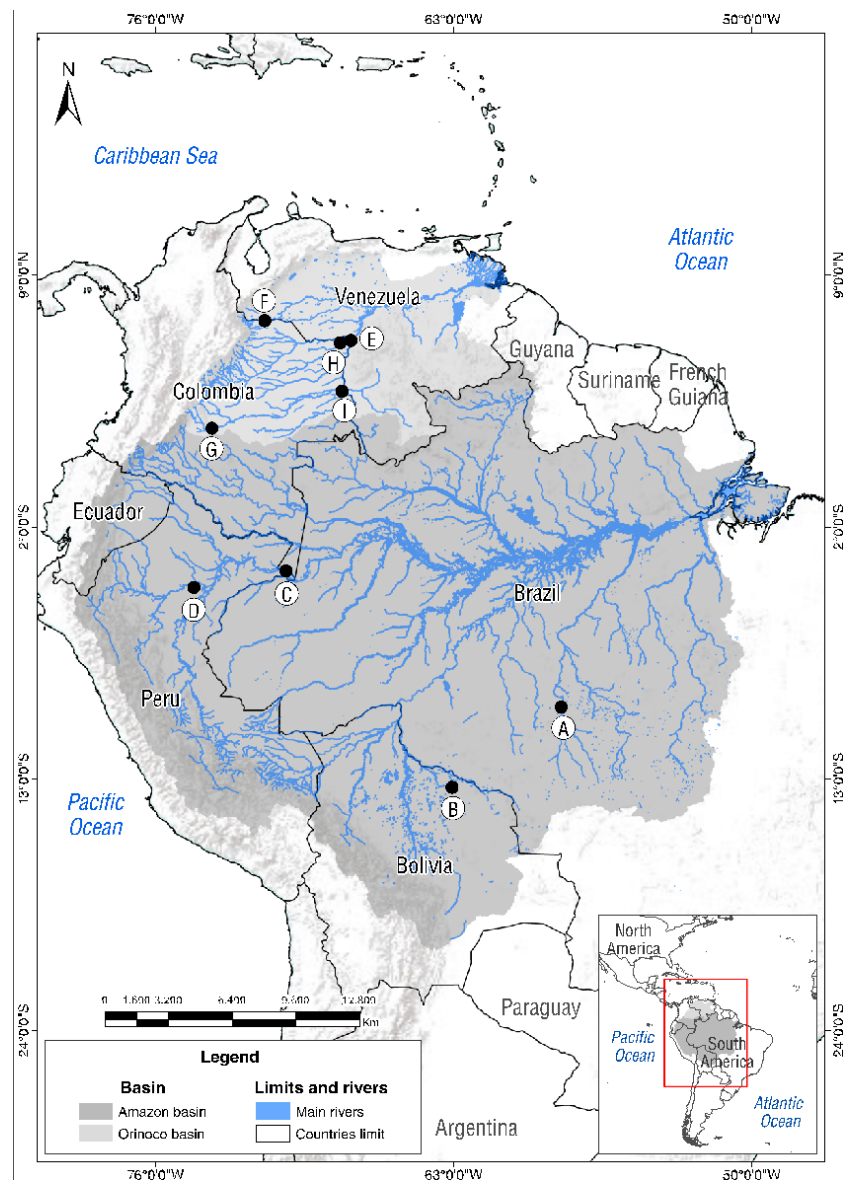


Figure 1: Amazon River dolphins satellite tagging: Amazon basin (A) Juruena River, Brazil, (B) San Martín River, Bolivia, (C) Amazon River, Colombia, and (D) Marañón River, Peru and rivers in the Colombian Orinoco basin (E) Orinoco River, (F) Arauca River, (G) Guayabero River, (H) Bitá River, and (I) Guaviare River.

2.2 Dolphin capture protocol and measurement recording

Only adult individuals were selected for tagging, and their ages classes were estimated based on body length, following the methods of da Silva (2009) and Martin and da Silva (2018), and avoiding females with calves. As part of our protocol, a veterinary team was present throughout the capture procedure to monitor the health of the animals according to cardiac and respiratory rates. There was no evidence that individuals experienced excessive stress. No increase in heart and respiratory rates, or sudden movements of head or caudal fins were noted that had been previously documented as signs of stress (Martin et al. 2006). In the event of excessive stress, our safety protocol required that the capture operation would immediately be halted and the dolphin released, but in none of the procedures was it necessary to do this. Our sample size was limited by the number of satellite tracking devices.

2.3 Spatial Analyses

The spatial analyses of the home range sizes of the *I. geoffrensis* followed the process of Mosquera-Guerra et al. (2021). The locations of the tagged river dolphins were determined using the ARGOS satellite system, maintained by ARGOS Service. Locations were classified by the ARGOS system into one of six location classes (LCs) based on the level of accuracy, measured in kilometers of uncertainty for latitude and longitude. ARGOS classifies location quality relative to an estimated error radius in the following location classes: 3 (accurate to <250 m), 2 (accurate to 250–500 m), 1 (accurate to 500–1500 m), and A and B (1–2 messages received but no accuracy estimation). In our study, we used only the most accurate data, LCs 3 and 2, after filtering the data with SAS-routine and the ARGOS-Filter (Witt et al. 2010; Wells et al. 2017; Dolton et al. 2020). Data with low accuracy, LC1 (500–1500 m), and data in classes A and B with no accuracy estimations were not used in our analyses (Mosquera-Guerra et al. 2021). Kernel density estimates at a 95% probability utilization distribution (UD) (K_{95}) were used to calculate home ranges (Powell 2000; Oshima et al. 2010; Wells et al. 2017; Mosquera-Guerra et al. 2021).

2.4 Predictors

In our study, the statistical analyses included three morphological explanatory predictors reported in the scientific literature for large terrestrial and aquatic mammals (Table 1). The morphological predictors were obtained from the 34 individuals tagged (10 individuals in this study and 24 Mosquera-Guerra et al. 2021; Supplementary material), and the Table 2 list the range (mean +/- SE) of these predictors. Satellite tagging was conducted under research permits for each country (Bolivia: DGBAP/MEG No. 0515/2017; Brazil: SISBIO 60171-1; Colombia: No. DTA 0898/2018; Peru: RD 515-2018 PRODUCE, RJ 003-2018).

Table 1: Summary of morphological explanatory predictors used in the Kruskal – Wallis test and significance values of the Shapiro-Wilk test

Category	Explanatory	Type	p Value	References
Morphological	Body mass (kg).	Continuous	0,001*	Harestad and Bunnell (1979); Dahle et al. (2006); Knight et al. (2009), and Tucker et al. (2014).
	Body length (cm).	Continuous	0,05*	Knight et al. (2009), and Tucker et al. (2014).
	Sex (♀ and ♂).	Categorical	-	Dahle and Swenson (2003a; b), and Dahle et al. (2006).

Those significant for the explanatory predictors are marked with an asterisk ().*

2.5 Statistical analyses

We used a Shapiro-Wilk normality test performed on the explanatory variables (Table 1) and subsequently a Kruskal-Wallis to assess the interactions between K_{95} and the three predictors (Table 3). Statistical analyses were carried out with the open-source software R.4.0.3 (R Core Team 2020) for the

graphical representation using the R software package ggplot2. In all cases, a value of $p < 0,05$ was considered statistically significant.

III. RESULTS

3.1 Home range (K_{95}) and explanatory predictors

The calculated values of the dependent variable and the morphological predictors considered in the statistical analyses are presented in Table 2 (Supplementary material).

Table 2: Range (mean $\pm$ SE) and description of the values calculated for the dependent variable and explanatory predictors for the Kruskal – Wallis test.

Variable / predictors	Range (mean $\pm$ SE) / Description
Dependent variable	
Amazon River dolphins home range sizes (K_{95}).	5,59–234 km ² (mean = 53 $\pm$ 57,53 km ²).
Morphological predictors	
Body mass (kg).	49– 200 kg (mean = 102 $\pm$ 37).
Body length (cm).	162– 227 cm (mean = 192 $\pm$ 20).
Sex (♀ and ♂).	Males analyzed (n = 23, 68%) and females (n = 11, 32%).

The results of the statistical significance values for the interaction between the dependent variable (K_{95}) and the three predictors considered are presented in Table 3. These results show the influence of the sexual condition of the individuals on the size of the home range (Figures 2a-c, 3).

Table 3: Statistical significance values of the Kruskal-Wallis test

Interactions	X ²	df	p Value
$K_{95} \sim$ Body mass (kg)	2,65	3	0,44
$K_{95} \sim$ Body length (cm)	3,11	3	0,37
$K_{95} \sim$ Sex (♀ and ♂)	4,32	1	0,037*

Those significant for the explanatory predictors are marked with an asterisk (*).

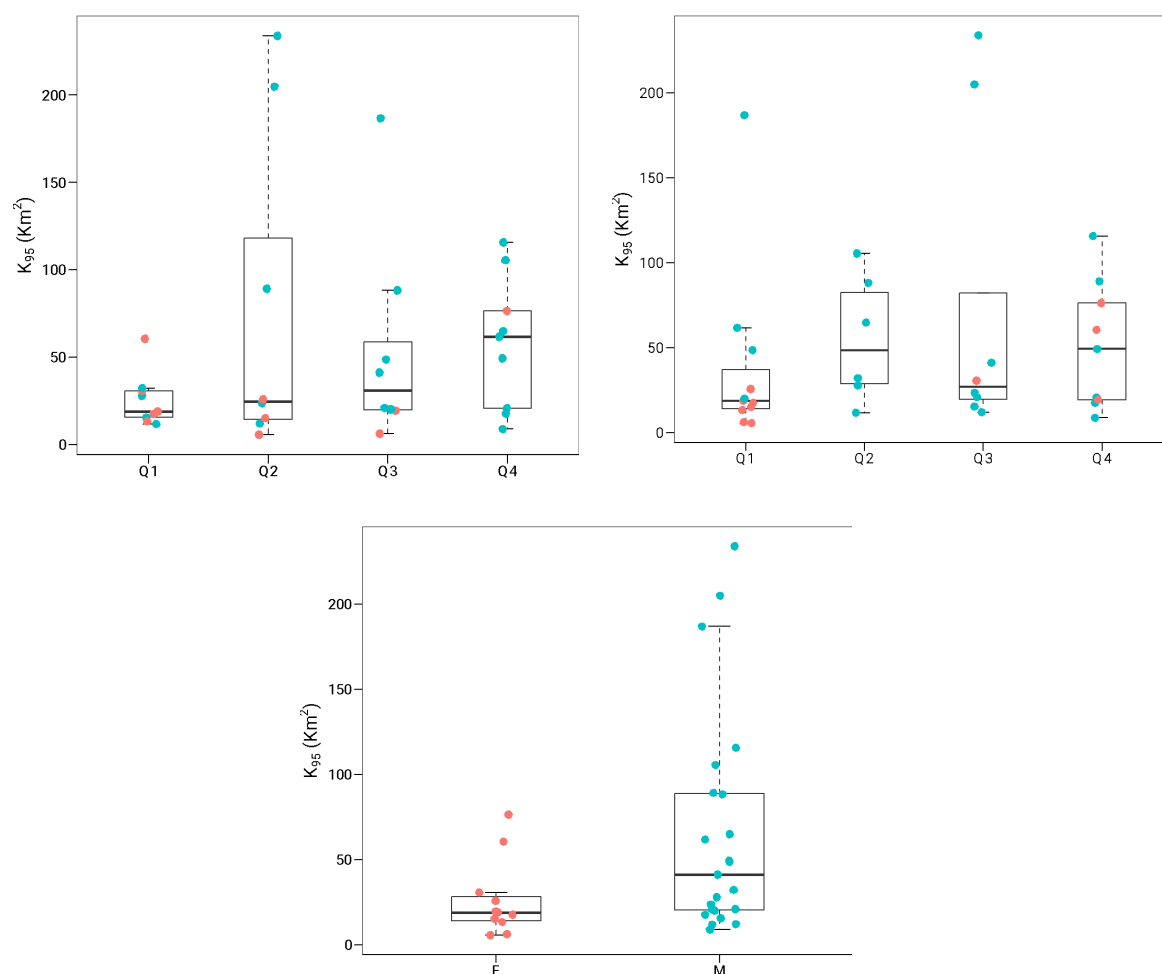


Figure 2: Box plot of the variation in home range size (K_{95}) by sex for the three predictors assessed: (A) body mass (kg), (B) body length (cm), and (C) sex (♀ and ♂). The red circles correspond to females and the blue circles to males.

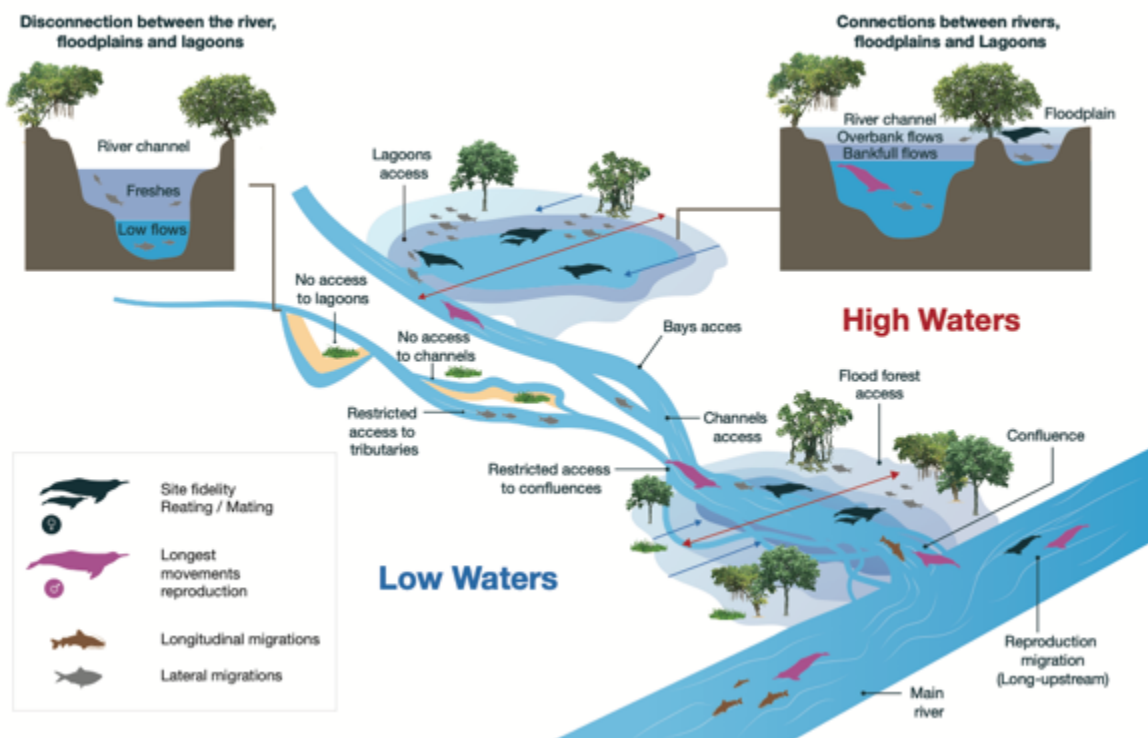


Figure 3: Flood pulse effects on *Inia geoffrensis* spatial ecology, highlighting variations in density, habitat availability, and fish prey migrations. During the high-water season, the rise in water levels causes the connection between the main river and the floodplains and lagoons. During this period fish and individuals of *I. geoffrensis* gradually access these new environments. In the season of the flood pulse, fission behaviors of dolphin groups occur, i.e., females with calves settle in the lagoons and confluences and males instead use more habitat types such as the main river and channels behind fish that make upstream breeding migrations. Conversely, during the low water season of flood pulse, the decrease in water levels disconnects the floodplains and lagoons from the main river, in this season dolphin groups merge again and individuals of *I. geoffrensis* converge in the confluence and channel habitat types to breed; some adult males move hundreds of kilometers to look for groups of females settled in other confluences along the basin.

IV. DISCUSSION

Our study had two limitations: the first related to small sample size, a condition that is a common limitation in satellite tracking studies due to factors such as the number of satellite devices available, and the low success rate in the capture process of the individuals (Taczanowska et al. 2008), especially in aquatic organisms that inhabit in contrasting ecosystems and are strongly influenced strongly by climatic variability. The second limitation is the representativeness of the individuals monitored by satellite in relation to the *Inia* populations size in the evaluated areas; for example in the case of the upper Amazon river basin of the 1,763 individuals that have been reported (Trujillo et al. 2019; Paschoalini et al. 2021) only 12 individuals were monitored, or for the upper Orinoco river basin of 1,573 individuals (Trujillo et al. 2019; Mosquera-Guerra et al. 2019b; Paschoalini et al. 2021) only 8 individuals were studied. The relevance of this study in data collection is the high resolution of data collected about *I. geoffrensis* individual home range size behavior obtained at a regional scale that allowed ecological analyses in an important part of the *Inia*'s distribution (Mosquera-Guerra et al. 2018b). In addition, the satellite monitoring of individuals provided fundamental information for spatial analyses (e.g. locations used in the calculation of the home range size) that contribute to an understanding of the home range sizes for this threatened mammals.

4.1 Body mass and length

The evolution of home range size appears to have been driven mainly by the energetic requirements and costs or benefits associated with a given body mass (see *e.g.*, Nagy [2005](#)). Ecologists have sought to understand the principles underlying how mammals optimize their space requirements (Buskirk [2004](#)). The body-size hypothesis has been used to explain differences in home range size among different species (see, *e.g.*, Harestad and Bunnell [1979](#); Kelt and Van Vuren [2001](#); Dahle et al. [2006](#)). Many ecological studies on terrestrial and aquatic mammals employ linear models to establish the relationships between home range size and body mass (see, *e.g.*, Buskirk [2004](#); Tucker et al. [2014](#); Kelt and Van Vuren [2001](#)). Early attempts to understand the relation between body mass and home range size suggest that home range increases at the same rate as metabolism (Kleiber, [1961](#)). The strong positive relationship between home range size and body mass reflects the balance between the cost of locomotion and metabolic requirements with increasing body mass (McNab [1963](#)). In the most taxonomically comprehensive analyses of home range size predictors, body mass is the principal predictor in mammals, accounting for 53–85% of the observed variation in home range size among species (Tucker et al. [2014](#)). However, in neotropical mammals, environmental ecosystemic variables such as seasonality, productivity levels, prey supply, sexual condition, gestation status, and presence of young, are perhaps greater influential predictors of home range size. Our statistical analyses failed to establish any relationship between mass and home range size, confirming Fahrig ([2013](#)).

In addition, the non-relationship between home range size and allometry of monitored river dolphins could also be explained by morphological variations among subspecies of the genus *Inia* reported in the scientific literature, even to the point of currently proposing three species (1) *I. geoffrensis* (Amazonas and Orinoco basins); da Silva and Martin [2014](#); da Silva et al. [2018](#)), (2) *I. boliviensis* (Madeira, Iténez, Mamoré, Blanco, and Grande rivers); Banguera-Hinestroza et al. [2002](#); Ruíz-García et al. [2008](#)), and (3) *I. araguaiaensis* (Araguaia-Tocantins river basins); Hrbek et al. [2014](#); Brum et al. [2021](#)). However, the Taxonomy Committee of the Marine Mammal Society only recognizes to date the subspecies considered in this study (Committee on Taxonomy [2021](#)).

Among the main morphological features that differentiate these two subspecies are the total length and the number of teeth. *Inia. g. geoffrensis* has an overall total length of 219–255 cm (males) and 182–225 cm (females), and the total number of upper jaw teeth range from 23–35 (mean = 26.6) while the lower jaw has from 24–35 (mean = 27.1). In the case, *I. g. boliviensis* the total length is 230 cm (males) and 208–216 cm (females), and the total number of upper jaw teeth ranges from 31–35 (mean = 33.3) while the lower jaw ranges from 31–34 (mean = 32.3); da Silva and Martin [2014](#)).

4.2 Sex and reproductive status

Sexual dimorphism has been documented in *I. geoffrensis* with males weighing between 113.5–207 kg, while females weigh between 72–154 kg (da Silva and Martin [2014](#)). Males are likely to be growing marginally faster than females of the same age in the months after birth (Martin and da Silva [2006](#); [2018](#)). We found a statistical relation between *I. geoffrensis* sex and home ranges (Table 3, Fig. 2c). Our results are in line with those proposed by Lindstedt et al. ([1986](#)) and Folkens et al. ([2008](#)) in relation to the differences in home range sizes between males and females for both marine cetaceans (bottlenose dolphin) and terrestrial carnivorous mammals. The documented pattern is concordant with those in fission-fusion societies, such as those seen in many dolphin species, where individuals in the same population may have greatly different ranging patterns (*e.g.* Defran et al. [1999](#)); and individuals may alternate between local site-fidelity and longer ventures away from the site of their first identification (*e.g.* Rako-Gospić et al. [2017](#)).

Our mean values for male home range values are also within the *I. geoffrensis* home ranges reported by Martin and da Silva (1998; 2004a,b) and Mosquera-Guerra et al. (2021), and may represent dominant male individuals in their search for females throughout the basin. Mosquera-Guerra et al. (2021) suggest that sexual status may determine home range sizes and the most extensive movements for individuals of the populations distributed in the Amazon (Colombia), San Martín (Bolivia), and Marañón (Peru) rivers in the Amazon and Orinoco river basins.

Similar results have been reported for male bottlenose dolphins that presumably have larger home ranges than females, a situation that is thought to allow males to increase their reproductive access to females (see, e.g., Eisenberg 1966; Wells et al. 1987; Wells 1991; Sprogis et al. 2016). Previous studies on the behavioral ecology of common bottlenose dolphins (*T. truncatus*) have revealed great variability in their home range characteristics (see, e.g., Connor et al. 2000; Defran et al. 1999; Wells et al. 1999) that may be due to habitat heterogeneity or to differences in the use of space between the genders (see, e.g., Connor 2000; Wells et al. 1980). Some authors also suggest that the period of parental care of the calf (1.5-5.8 years, Martin and da Silva 2018) for Amazon River dolphins of the genus *Inia* limits the movement of the female during this period of time when the calf reaches the right physical condition to perform the different movements along the different aquatic landscapes (see, e.g., Mosquera-Guerra et al. 2021). Additionally established correlations are known between age and reproductive status with home range size (see, e.g., Dahle and Swenson 2003a, b; Dahle et al. 2006; Rako-Gospic et al. 2017).

4.3 Conservation implications

In terms of conservation, Mintzer et al. (2016) and Mosquera-Guerra et al. (2022a) report on the relationship between spatial use, sexual status and the level of exposure to hazards for individuals of *Inia* spp. This sexual segregation differentially exposes males and females to targeted or incidental captures as well as other types of threats (see, Mintzer et al. 2016). Interactions between Amazon River dolphins and fisheries generally occur in highly productive habitats, such as (1) confluences, (2) channels, and (3) lagoons, where capturing mostly sexually mature individuals and possibly larger numbers of females that have minor movements and are restricted to specific habitats where they care for their calves (see, Mosquera-Guerra et al. 2022a). These factors contribute strongly to the drastic population decline of *Inia* spp. in its occurrence range of occurrence (see, Williams et al. 2016; Martin and da Silva 2021).

Also, a major human activity that affecting the spatial and movement ecology of *I. geoffrensis* and the possible adaptation of their populations to climate change is the presence of hydroelectric dams throughout the dolphins' range. In the Amazon basin, 158 hydroelectric dams are either in operation or under construction; and 351 more dams have been proposed (Forsberg et al. 2017; Almeida et al. 2019; Anderson et al. 2019). Many aquatic species are affected by hydroelectric dams (Lees et al. 2016). Among the direct effects caused by hydroelectric dams is the fragmentation of both *I. geoffrensis* and fish prey populations, resulting in disruptions to gene flow that cause diminishing genetic variability and increased vulnerability (Trujillo et al. 2010; Gravena et al. 2014; Pavanato et al. 2016; Mosquera-Guerra et al. 2018b; Paschoalini et al. 2020; Mosquera-Guerra et al. 2022b). Indirectly, the dams can decrease limiting nutrients for aquatic food webs such as nitrogen and phosphorus downstream of the dam, decreasing levels of productivity and biomass, thus reducing prey availability for the dolphins (Trujillo et al. 2010; Mosquera-Guerra et al. 2018b; Araújo and Wang 2015).

Fragmentation of river networks by hydroelectric dams and other infrastructure constrains potential range shifts of aquatic species for coping with expected temperature rise under climate change (Myers et al. 2017; Mosquera-Guerra et al. 2019b). Range shifts of fish to higher altitudes as a result of climate changes have already been documented, but river fragmentation by hydroelectric dams will block this

form of adaptation (Herrera-R et al. 2020). Aquatic species, distributed in the Andean countries such as the *I. geoffrensis* populations in Peru and Bolivia are thought to be particularly impacted because most hydroelectric dams have been built or planned on Andean tributaries such as the Maderia river basin (Forsberg et al. 2017; Mosquera-Guerra et al. 2018b; Anderson et al. 2019; Tognelli et al. 2019). The ecology and conservation of *I. geoffrensis* are complex in the Amazonian and Tocantins basins in the current context of transformation, and this urgently requires transforming the energy matrix of the Amazonian countries from hydropower to sustainable production based on solar, wind, and geothermal energies.

Our results do not support the previously established allometric relationship between the body length and mass on the home range sizes of large aquatics mammals, possibly due to the morphological variations of the subspecies of the genus *Inia* and the influence of the sexual status of monitored individuals on this spatial metric. We suggest the possible influence of non-evaluated predictors such as productivity levels of the aquatic ecosystems assessed (e.g., white, black, clear, and mixed water systems), availability of prey, and the presence of highly productive habitats (e.g., lagoons and confluences).

This research also calls attention on the possible vulnerability of the Amazon River dolphins to human impacts at a regional scale, such as the regulation of the flood pulse and its influence on the lateral and longitudinal movements of these cetaceans in the Amazon mainly. Finally, this paper warns about the negative effects of dam construction as physical barriers that alter prey migration and artificially regulate hydrological processes. These limit species' adaptations to climate change, increasing the risk of extinction of some populations that are located in the areas of influence of these infrastructure projects such as the individuals monitored in this study on the Tapajos River in Brazil.

ACKNOWLEDGEMENTS

This program is part of the strategic plan defined by the South American River Dolphin Initiative (SARDI) supported by the World Wildlife Fund (WWF) in Brazil, Colombia, Peru, Ecuador, and Bolivia. Partial support for two tags from Peru was from the Rufford Foundation through RSG. Special gratitude goes to Marcelo Oliveira da Costa, Daphe Willems, Karina Berg, Lilia Sainz, José Rivas, Jordi Surkin, Roberto Maldonado, Dick Ember, Verónica Téllez, and Monica Wulms from WWF. Federico Mosquera Guerra received a Postdoctoral Fellowship from Pontificia Universidad Javeriana (ID project: 20389 to 2021). EC received a doctoral scholarship from WWF-EFN. Aldo Echeverría, Leslie Cordova, and Adriana Salinas are acknowledged for their support during tagging campaigns in Bolivia and Miriam Marmontel in Brazil. We acknowledge the fishing communities and the local and national authorities for participating in the *I. geoffrensis* individuals capture process.

Funding: This work was supported by the Whitley Fund for Nature (WFN), World Wildlife Fund (WWF), CORMACARENA, CORPORINOQUIA, CORPOAMAZONIA, Projects Design and Development (PDD), and Pontificia Universidad Javeriana (PUJ).

Author contributions: Federico Mosquera-Guerra, Fernando Trujillo, Jairo Pérez Torres, Hugo Mantilla-Meluk, Nicole Franco, Paul André van Damme, Elizabeth Campbell, Joanna Alfaro-Shigueto, José Luis Mena, Jeffrey C. Manguel, María Jimena-Valderrama, Estefany Acosta-Lugo, and Dolors Armenteras-Pascual conceived the study and designed the methodology. Fernando Trujillo and José Saulo Usma Oviedo acquired the data, Federico Mosquera-Guerra interpreted the results and wrote the first draft of the paper, and all the authors contributed to its writing.

Availability of data and material: The datasets generated during the current study are available from the corresponding author on reasonable request.

Code availability: The R code used during the current study is available from the corresponding author on reasonable request.

Data availability: Data are available upon request.

Declarations

Ethics approval: All procedures involving animals were conducted with the appropriate permits and following ASM guidelines (Sikes 2016).

Open Access: This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

REFERENCES

1. Alexander RM (2003) Principles of Animal Locomotion. Princeton University Press, New Jersey
2. Aliaga-Rossel E (2002). Distribution and abundance of the pink river dolphin, bufeo (*Inia geoffrensis*) in the Tijamuchi River, Beni-Bolivia. Aquat. Mamm J 28:312–323.
3. Aliaga-Rossel E, McGuire TL, Hamilton H (2006) Distribution and encounter rates of the river dolphin (*Inia geoffrensis boliviensis*) in the central Bolivian Amazon. Cetacean. Res. Manag 8:87–92.
4. Aliaga-Rossel E, Guizada Duran, L.A. (2020). Four decades of research on distribution and abundance of the Bolivian river dolphin *Inia geoffrensis boliviensis*. Endang Species Res 42:151–165. <https://doi.org/10.3354/esro1041>.
5. Almeida RM, Shi Q, Gomes-Selman JM, Wu X, Xue Y, Angarita H, Barros N, Forsberg BR., García-Villacorta R, Hamilton SK, Melack JM, Montoya M, Perez G, Sethi SA, Gomes CP, Flecker AS (2019) Reducing greenhouse gas emissions of Amazon hydropower with strategic dam planning. Nature Comm 10:1–9. <https://doi.org/10.1038/s41467-019-12179-5>.
6. Anderson EP, Osborne T, Maldonado-Ocampo JA, Mills-Novoa M, Castello L, Montoya M, Encalada AC, Jenkins CN (2019) Energy development reveals blind spots for ecosystem conservation in the Amazon Basin. Front. Ecol. Environ 17:521–529. <https://doi.org/10.1002/fee.2114>
7. Araújo CC, Wang, JY (2015) The dammed river dolphins of Brazil: Impacts and conservation. Oryx 49:17–24. <https://doi.org/10.1017/S0030605314000362>
8. Azevedo AF, Oliveira AM, Viana SC, Sluys MV (2007) Habitat use by marine tucuxis (*Sotalia guianensis*) (Cetacea: Delphinidae) in Guanabara Bay, south-eastern Brazil. Mar. Biol. Assoc. UK 87:201–205. <https://doi.org/10.1017/S0025315407054422>
9. Banguera-Hinestroza E, Cárdenas H, Ruíz-García M, Marmontel M, Gaitán E, Vázquez R, García-Vallejo F (2002) Molecular identification of evolutionary significant units in the Amazon river dolphin *Inia* sp. (Cetacea: Iniidae). J. Heredity 5:312–322. <https://doi.org/10.1093/jhered/93.5.312>
10. Barbosa MS, Carvalho DP, Gravena W, de Almeida R, Mussu MH, Sousa EA, Holanda IBB, de Sousa-Filho IF, Bastos WR (2021) Total mercury and methylmercury in river dolphins (Cetacea:

- Iniidae: *Inia* spp.) in the Madeira River Basin, Western Amazon. Environ. Sci. Pollut. Res. Int 33:861423. <https://doi.org/10.1007/s11356-021-13953-z>
11. Bas AA, Öztürk AA, Öztürk B (2014) Selection of critical habitats for bottlenose dolphins *Tursiops truncatus* based on behavioral data, in relation to marine traffic in the Istanbul Strait, Turkey. Mar. Mamm. Sci 31: 979–997. <https://doi.org/10.1111/mms.12202>
12. Bejder L, Samuels A, Whitehead H, Gales N, Mann J, Connor R, Heithaus M, Watson-Capps J, Flaherty C, Krützen M (2006) Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conserv. Biol 20:1791–1798. <https://doi.org/10.1111/j.1523-1739.2006.00540.x>
13. Bordino P, Wells RS, Stamper MA (2008) Satellite tracking of franciscana dolphins *Pontoporia blainvillei* in Argentina: Preliminary information on ranging, diving and social patterns. SC60/SM14. 1–10.
14. Boutin S (1990) Food supplementation experiments with terrestrial vertebrates: patterns problems, and the future. Can. J. Zool 68:203–220. <https://doi.org/10.1139/z90-031>
15. Bräger S, Bräger, Z (2018) Range Utilization and Movement Patterns of Coastal Hector's Dolphins (*Cephalorhynchus hectori*). Aquat. Mamm 6:633–642. <https://doi.org/10.1578/AM.44.6.2018.633>
16. Brum S, Rosas-Ribeiro P, de Souza Amaral R, de Souza DA, Castello L, Ferreira da Silva VM (2021) Conservation of Amazonian aquatic mammals. Aquat. Conserv: Mar. Freshw. Ecosyst 1:1–19. <https://doi.org/10.1002/aqc.3590>
17. Burt WH (1943) Territoriality and home range concepts as applied to mammals. J. Mamm 24:346–352. <https://doi.org/10.2307/1374834>
18. Buskirk S (2004) Keeping an Eye on the Neighbors. Science 306:238–239. <https://doi.org/10.1177/0032258X18768397>
19. Caballero S, Jackson J, Mignucci-Giannoni AA, Barrios-Garrido H, Beltrán-Pedrerros S, Montiel-Villalobos MG, Robertson KM, Baker CS (2008) Molecular systematics of South American dolphins *Sotalia*: sister taxa determination and phylogenetic relationships, with insights into a multi-locus phylogeny of the Delphinidae. Mol. Phylogenet. Evol 46:252–268. <https://doi.org/10.1016/j.ympev.2007.10.015>
20. Campbell E, Mangel JC, Alfaro-Shigueto J, Mena JL, Thurstan RH, Godley BJ (2020) Coexisting in the Peruvian Amazon: Interactions between fisheries and river dolphins. J. Nat. Conserv 56:125859. <https://doi.org/10.1016/j.jnc.2020.125859>
21. Committee on Taxonomy (2021) List of marine mammal species and subspecies 2019. Society for Marine Mammalogy. <https://marinemammalscience.org>. Accessed 1 November 2022
22. Connor RC, Wells RS, Mann J, Read AJ (2000) The bottlenose dolphin: social relationships in a fission–fusion society. In: Connor RC, Tyack PL, Whitehead H (eds) Cetacean Societies: Field Studies of Dolphins and Whales. Mann J, University of Chicago Press, Chicago, pp 91–126.
23. da Silva VMF (2009) Amazon river dolphin: *Inia geoffrensis*. In Perrin WF, Würsig B, Thewissen JGM (eds) Encyclopedia of marine mammals. Academic Press, Cambridge, pp 26–28.
24. da Silva VMF, Martin AR (2014) Family Iniidae (Amazon river dolphins). In Wilson DE, Mittermeier RA (eds) Handbook of the Mammals of the World. Lynx Edicions, Barcelona, pp 364–379
25. da Silva V, Trujillo F, Martin A, Zerbini AN, Crespo E, Aliaga-Rossel E, Reeves R (2018) *Inia geoffrensis* Assessment. <https://www.iucnredlist.org>. Accessed 7 November 2022.
26. Dahle B, Swenson JE (2003a) Home ranges in adult Scandinavian brown bears *Ursus arctos*: effect of population density, mass, sex, reproductive status and habitat type. J. Zool 260:329–335. <https://doi.org/10.1017/S0952836903003753>
27. Dahle B, Swenson JE (2003b) Seasonal range size in relation to reproductive strategies in brown bears. J. Anim. Ecol 71:660–667. <https://doi.org/10.1046/j.1365-2656.2003.00737.x>
28. Dahle B, Ole-Gunnar S, Swenson JE (2006) Factors influencing home-range size in subadult brown bears. J. Mammal 87:859–865. <https://doi.org/10.1644/05-MAMM-A-352R1.1>

47. Hrbek T, da Silva,VMF, Dutra N, Gravena W, Martin AR, Farias IP (2014) A new species of river dolphin from Brazil or: how little do we know our biodiversity. PloS One 9:e83623. <https://doi.org/10.1371/journal.pone.0083623>
48. Jetz W, Carbone C, Fulford J, Brown JH (2004) The scaling of animal space use. Science. 306:266–268. <https://doi.org/10.1126/science.1102138>
49. Kelt DA, Van Vuren, D.H. (2001). The ecology and macroecology of mammalian home range area. J. Amer. Nat. 157:637–645. <https://doi.org/10.1086/320621>
50. Kie JG, Bowyer RT, Nicholson MC, Boroski BB, Loft ER (2002) Landscape heterogeneity at differing scales: effects on spatial distribution of mule deer. Ecology 83:530–544. <https://doi.org/10.2307/2680033>
51. Kleiber M (1961) The Fire of Life, New York.
52. Knight CM, Kenward RE, Gozlan RE, Hodder KH, Walls SS, Lucas MC (2009) Home range estimation within complex restricted environments: importance of method selection in detecting seasonal changes. Wildl. Res. 36:213–224. <https://doi.org/10.1071/WR08032>
53. Krebs JR, Kacelnik A (1991) Decision-making. In: Krebs JR and Davies NB (eds) Behavioural Ecology. Blackwell Scientific Publications, Cambridge, pp 105-136
54. Lees AC, Peres CA, Fearnside PM, Schneider M, Zuanon, JAS (2016) Hydropower and the future of Amazonian biodiversity. Biodivers. Conserv. 25:451–466. <https://doi.org/10.1007/s10531-016-1072-3>
55. Linstedt SL, Miller BJ, Buskirk SW (1986) Home range, time, and body size in mammals. Ecology 67:413–418. <https://doi.org/10.2307/1938584>
56. Loft ER, Kie JG, Menke JW (1993) Grazing in the Sierra Nevada: home range and space use patterns of mule deer as influenced by cattle. Calif. Fish Game. 79:145–166. <http://arc.lib.montana.edu/range-science/item/721>
57. Mares MA, Lacher TE, Willig MRJr, Bitar NA (1982) An experimental analysis of social spacing in *Tamias striatus*. Ecology 63:267–273. <https://doi.org/10.2307/1938940>
58. Martin AR, da Silva VMF (1998) Tracking aquatic vertebrates in dense tropical forest using VHF telemetry. Mar. Technol. Soc. J. 32:82–88.
59. Martin AR, da Silva VMF (2004a) River dolphins and flooded forest: seasonal habitat use and sexual segregation of botos (*Inia geoffrensis*) in an extreme cetacean environment. J. Zoo. Lond. 263:295–305. <https://doi.org/10.1017/S095283690400528X>
60. Martin AR, da Silva VMF (2004b) Number, seasonal movements, and residency characteristics of river dolphins in an Amazonian floodplain lake system. Canad. J. Zool. 82:1307–1315. <https://doi.org/10.1139/z04-109>
61. Martin AR, da Silva VMF (2006) Sexual dimorphism and body scarring in the boto (Amazon River dolphin) *Inia geoffrensis*. Mar. Mamm. Sci 22:25–33. <https://doi.org/10.1111/j.1748-7692.2006.00003.x>
62. Martin AR, da Silva, VMF (2018) Reproductive parameters of the Amazon river dolphin or boto, *Inia geoffrensis* (Cetacea: Iniidae); an evolutionary outlier bucks no trends. Biol. J. Linn. Soc 123:666–676. <https://doi.org/10.1093/biolinnean/bly005>
63. Martin AR, da Silva VMF (2021) Amazon River Dolphins *Inia geoffrensis* are on the Path to Extinction in the Heart of Their Range. Oryx 33:1–5.
64. Martin AR, da Silva VMF, Rothery PR (2006) Does radio tagging affect the survival or reproduction of small cetaceans? A test. Mar. Mamm. Sci 22:17–24. <https://doi.org/10.1111/j.1748-7692.2006.00002.x>
65. Martínez-Serrano I, Serrano A, Heckel G, Schramm Y (2011) Distribution and home range of bottlenose dolphins (*Tursiops truncatus*) off Veracruz, Mexico. Cien. Mar 37:379–392. <https://doi.org/10.7773/cm.v37i4A.1860>

66. Mazzoil M, Reif JS, Youngbluth M, Murdoch ME, Bechdel SE, Howells E, McCulloch SD, Hansen LJ, Bossart GD (2008) Home ranges of bottlenose dolphins (*Tursiops truncatus*) in the Indian River Lagoon, Florida: environmental correlates and implications for management strategies. *EcoHealth*. 5:278–288. <https://doi.org/10.1007/s10393-008-0194-9>
67. McGill BJ, Mittelbach GG (2006) An allometric vision and motion model to predict prey encounter rates. *Evol. Ecol. Res* 8:691–701.
68. McGowen MR (2011) Toward the resolution of an explosive radiation – a multilocus phylogeny of oceanic dolphins (Delphinidae). *Mol. Phylogenet. Evol* 60:345–357. <https://doi.org/10.1016/j.ympev.2011.05.003>
69. McGuire TL, Henningsen T (2007) Movement patterns and site fidelity of river dolphins (*Inia geoffrensis* and *Sotalia fluviatilis*) in the Peruvian Amazon as determined by photo-identification. *Aqua. Mamm* 33:359–367. <https://doi.org/10.1578/AM.33.3.2007.359>
70. McGuire TL, Winemiller K (1998) Occurrence patterns, habitat associations, and potential prey of the river dolphin, *Inia geoffrensis*, in the Cinaruco River, Venezuela. *Biotrop* 30:625–638. <https://doi.org/10.1111/j.1744-7429.1998.tb00102.x>
71. McNab BK (1963) Bioenergetics and the determination of home range size. *Am. Nat.* 97:133–140. <https://doi.org/10.1086/282264>
72. Mintzer VJ, Schmink M, Lorenzen K, Frazer TK, Martin AR, da Silva VMF (2014) Attitudes and behaviors toward Amazon River dolphins (*Inia geoffrensis*) in a sustainable use protected area. *Biodivers. Conserv* 24: 247–269. <https://doi.org/10.1007/s10531-014-0805-4>
73. Mintzer VJ, Lorenzen K, Frazer TK, da Silva VMF, Martin AR (2016) Seasonal movements of river dolphins (*Inia geoffrensis*) in a protected Amazonian floodplain. *Mar. Mamm. Sci* 32:664–681. <https://doi.org/10.1111/mms.12298>
74. Mosquera-Guerra F, Trujillo F, Parra CA, Carvajal-Castro JD, Mantilla-Meluk H (2018a) Aspectos poblacionales y biogeográficos de la tonina o delfín de río, *Inia geoffrensis humboldtiana* Pilleri & Gühr, 1978 (Cetartiodactyla, Iniidae) en los ríos Guayabero y Losada, sierra de La Macarena, Meta, Colombia. In: Lasso CA, Morales- Betancourt MA, Escobar-Martínez ID (eds) V. Biodiversidad de la sierra de La Macarena, Meta, Colombia. Parte I. Ríos Guayabero medio, bajo Losada y bajo Duda. Serie Editorial Fauna Silvestre Neotropical. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá D.C., pp 289–305
75. Mosquera-Guerra F, Trujillo F, Danni P, Oliveira-da-Costa M, Marmontel M, Armenteras-Pascual D, Usma S, Willems D, Carvajal-Castro JD, Mantilla-Meluk H, Franco N, Amorochio D, Maldonado R, Berg K, Sainz L, Van Damme PA, Cambell E (2018b) Analysis of distribution of river dolphins (*Inia* and *Sotalia*) in protected and transformed areas in the Amazon and Orinoco basins. *SC/67B/SM/16*. Bled, Slovenia.
76. Mosquera-Guerra F, Trujillo F, Parks D, Oliveira da Costa M, Van Damme PA, Echeverria A, Franco N, Carvajal-Castro JD, Mantilla-Meluk H, Marmontel M, Armenteras-Pascual D (2019a) Mercury in Populations of River Dolphins of the Amazon and Orinoco basins. *EcoHealth* 4:743–759. <https://doi.org/10.1007/s10393-019-01451-1>
77. Mosquera-Guerra F, Trujillo F, Aya-Cuero C, Franco-León N, Valencia K, Vásquez A, Duran-Prieto C, Morales MDJ, Pachón-Bejarano GA, Mantilla-Meluk H, Armenteras-Pascual D (2019b) Population estimates and identification of major conservation threats for the river dolphin (*Inia geoffrensis humboldtiana*) at the Colombian Orinoquia. *Therya* 11:9–21. <https://doi.org/10.12933/therya-20-854>
78. Mosquera-Guerra F, Trujillo F, Oliveira-da-Costa M, Marmontel M, Van Damme PA, Franco N, Córdova L, Campbell E, Alfaro-Shigueto J, Mena JL, Mangel JC, Usma Oviedo JS, Carvajal-Castro JD, Mantilla-Meluk H, Armenteras-Pascual D (2021) Home range and movements of Amazon River dolphins (*Inia geoffrensis*) in the Amazon and Orinoco river basins. *Endang. Species. Res* 45:269–282. <https://doi.org/10.3354/esr01133>

79. Mosquera-Guerra F, Trujillo F, Pérez-Torres J, Mantilla-Meluk H, Franco-León N, Paschoalini M, Valderrama MJ, Usma Oviedo JS, Campbell E, Alfaro-Shigueto J, Mena JL, Mangel JC, Gillemann C, Zumba, M, Briceño Y, Valencia KY, Torres-Forero PA, Sánchez L, Ferrer A, Barreto S, van Damme PA, Armenteras-Pascual D (2022a) Strategy to Identify Areas of Use of Amazon River dolphins. *Front. Mar. Sci* 9:838988. <https://doi.org/10.3389/fmars.2022.838988>
80. Mosquera-Guerra F, Trujillo F, Pérez-Torres J, Mantilla-Meluk H, Franco N, Valderrama MJ, Acosta-Lugo E, Torres-Forrero P, Usma-Oviedo JS, Barreto S, Armenteras-Pascual D (2022b) Identifying habitat preferences and core areas of Amazon River dolphin activity using spatial ecology analysis. *Landsc Ecol* 21: 1-21. <https://doi.org/10.1007/s10980-022-01470-4>
81. Myers BJE, Lynch AJ, Bunnell DB, Chu C, Falke JA, Kovach RP, Krabbenhoft TJ, Kwak TJ, Paukert CP (2017) Global synthesis of the documented and projected effects of climate change on inland fishes. *Rev. Fish Biol. Fish* 27:339–361. <https://doi.org/10.1007/s11160-017-9476-z>
82. Nagy AN (2005) Field metabolic rate and body size. *J. Exp. Biol* 208:1621–1625. <https://doi.org/10.1242/jeb.01553>
83. Nekolny SR, Denny M, Biedenbach G, Howells EM, Mazzoil M, Durden WN, Moreland L, Lambert JD, Gibson QA (2017) Effects of study area size on home range estimates of common bottlenose dolphins *Tursiops truncatus*. *Curr. Zool* 63:693–701. <https://doi.org/10.1093/cz/zox049>
84. Nicholson MC, Bowyer RT, Kie JG (1997) Habitat selection and survival of mule deer: tradeoffs associated with migration. *J. Mammal* 78:483–504. <https://doi.org/10.2307/1382900>
85. Oshima JEDF, Oliveira Santos MCD, Bazzalo M, Carvalho Flores PAD, Nascimento Pupim FD (2010) Home ranges of Guiana dolphins (*Sotalia guianensis*) (Cetacea: Delphinidae) in the Cananeia estuary, Brazil. *J. Mar. Biol. Ass. UK* 90:1641–1647. <https://doi.org/10.1017/S0025315410001311>
86. Paschoalini M, Almeida RM, Trujillo F, Melo-Santos G, Marmontel M, Pavanato HJ, Mosquera-Guerra F, Ristau I N, Zerbini AN (2020) On the brink of isolation: Population estimates of the Araguaian river dolphin in a human-impacted region in Brazil. *PLoS ONE* 15: e0231224. <https://doi.org/10.1371/journal.pone.0231224>
87. Paschoalini M, Trujillo F, Marmontel M, Mosquera-Guerra F, Paitach RL, Pavanato HJ, Melo-Santos GA, Van Damme PA, Coelho AGA, Escobar-WW M, Novaes-Zerbini A (2021) Density and Abundance Estimation of Amazonian river Dolphins: Understanding Population Size Variability. *J. Mar. Sci. Eng* 9: 1184. <https://doi.org/10.3390/jmse9111184>
88. Passadore C, Möller L, Díaz-Aguirre F, Parra GJ (2017) High site fidelity and restricted ranging patterns in southern Australian bottlenose dolphins. *Ecol. Evol* 8:242–256. <https://doi.org/10.1002/ece3.3674>
89. Pavanato H, Melo-Santos G, Lima D, Portocarrero-Aya M, Paschoalini M, Mosquera F, Trujillo F, Meneses R, Marmontel M, Maretti C (2016) Risk of dam construction for South American River Dolphins: a case of study of the Tapajós River. *Endang. Species. Res* 31:47–60. <https://doi.org/10.3354/esr00751>
90. Pawar S, Dell AI, Savage VM (2012) Dimensionality of consumer search space drives trophic interaction strengths. *Nature* 486:485–489. <https://doi.org/10.1038/nature11131>
91. Péron G (2019) The time frame of home-range studies: from function to utilization. *Biol. Rev* 6:1974–1982. <https://doi.org/10.1111/brv.12545>
92. Pirotta E, Laesser BE, Hardaker A, Riddoch N, Marcoux M, Lusseau D (2013) Dredging displaces bottlenose dolphins from an urbanized foraging patch. *Mar. Pollut. Bull* 74:396–402. <https://doi.org/10.1016/j.marpolbul.2013.06.020>
93. Powell RA, Zimmerman JW, Seaman DE (1997) Ecology and behavior of North America black bears: home ranges, habitat and social organization. Chapman. Hall. *Wildl. Ecol. Behaviour. Series*. 1:204.

94. Powell RA (2000) Animal home ranges and territories and home range estimators. In: Boitani L and Fuller TK (eds). Research and techniques in animal ecology: controversies and consequences. Columbia University Press, E.U., pp 1:65–110
95. R Core Team (2020) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.
96. Rako-Gospić N, Radulović M, Vučur T, Pleslić G, Draško H, Mackelworth P (2017) Factor associated variations in the home range of a resident Adriatic common bottlenose dolphin population. Mar. Pollut 1: 234–244. <https://doi.org/10.1016/j.marpolbul.2017.07.040>
97. Rayment W, Dawson S, Slooten E, Bräger S, Du Fresne S, Webster T (2009) Kernel density estimates of alongshore home range of Hector's dolphins at Banks Peninsula, New Zealand. Mar. Mamm. Sci 25:537–556. <https://doi.org/10.1111/j.1748-7692.2008.00271.x>
98. Reeves RR, Smith B, Crespo EA, Notarbartolo Di Sciara G (2003) Dolphins, whales and porpoises. 2002–2010 Conservation Action Plan for the World's Cetaceans. Gland.
99. Relyea RA, Lawrence RK, Demarais S (2000) Home range of desert mule deer: testing the body-size and habitat-productivity hypotheses. J. Wildl. Manag 64:146–153. <https://doi.org/10.2307/3802984>
100. Riley SJ, Dood AR (1984) Summer movements, home range, habitat use, and behavior of mule deer fawns. J. Wildl. Manage. 48:1302–1310. <https://doi.org/10.2307/3801790>
101. Rip JMK, McCann KS (2011) Cross-ecosystem differences in stability and the principle of energy flux. Ecol. Lett 14:733–740. <https://doi.org/10.1111/j.1461-0248.2011.01636.x>
102. Rossi-Santos MR, Wedekin LL, Sousa-Lima RS (2006) Distribution and habitat use of small cetaceans off Abrolhos Bank, eastern Brazil. LAJAM 5:23–28. <https://doi.org/10.5597/lajam00088>
103. Ruíz-García M, Caballero S, Martínez-Agüero M, Shostell JM (2008) Molecular differentiation among *Inia geoffrensis* and *Inia boliviensis* (Iniidae: Cetacea) by means of nuclear intron sequences. In: Koven VT (ed). Population Genetics Research Progress. Nova Science Publishers, New York, pp 177–203
104. Samuel MD, Pierce DJ, Garton EO (1985) Identifying areas of concentrated use within the home range. J. Anim. Ecol 54:711–719. <https://doi.org/10.2307/4373>
105. Shurin JB, Gruner DS, Hillebrand H (2006) All wet or dried up? Real differences between aquatic and terrestrial food webs. Proc. R. Soc 273:1–9. <https://doi.org/10.1098/rspb.2005.3377>
106. Sikes RS, the Animal Care and Use Committee of the American Society of Mammalogists (2016) 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. J Mammal 97:663–688. <https://doi.org/10.1093/jmammal/gywo78>
107. Sprogis KR, Raudino HC, Rankin R, MacLeod CD, Bejder L (2016) Home range size of adult Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in a coastal and estuarine system is habitat and sex-specific. Mar. Mamm. Sci. 32:287–308. <https://doi.org/10.1111/mms.12260>
108. Sveegaard S, Teilmann J, Tougaard J, Dietz R, Mouritsen KN, Desportes G, Siebert U (2011) High-density areas for harbor porpoises (*Phocoena phocoena*) identified by satellite tracking. Mar. Mamm. Sci. 27: 230–246. <https://doi.org/10.1111/j.1748-7692.2010.00379.x>
109. Taczanowska K, Muhar A, Brandenburg C (2008) Potential and limitations of GPS tracking for monitoring spatial and temporal aspects of visitor behaviour in recreational areas. In: Raschi A and Trampetti S (eds).
110. Management for Protection and Sustainable Development, Montecatini Terme, pp 451-455
111. Tognelli MF, Anderson EP, Jiménez-Segura LF, Chuctaya J, Chocano L, Maldonado-Ocampo JA, Mesa-Salazar L, Mojica JI, Carvajal-Vallejos FM, Correa V, Ortega H, Rivadeneira Romero JF, Sánchez-Duarte P, Cox NA, Hidalgo M, Jiménez Prado P, Lasso CA, Sarmiento J, Velásquez MA, Villa-Navarro FA (2019) Assessing conservation priorities of endemic freshwater fishes in the tropical Andes region. Aquat. Conserv. 29:1123–1132. <https://doi.org/10.1002/aqc.2971>

112. Tucker MA, Ord TJ, Rogers TL (2014) Evolutionary predictors of mammalian home range size: body mass, diet and the environment. *Global. Ecol. Biogeogr* 23:1–10. <https://doi.org/10.1111/geb.12194>
113. Tufto J, Andersen R, Linnell JDC (1996) Habitat use and ecological correlates of home range size in a small cervid: the roe deer. *J. Anim. Ecology* 65:715–725. <https://doi.org/10.2307/5670>
114. Trujillo F, Crespo E, Van Damme P, Usma JS (2010) The Action Plan for South American River Dolphins 2010–2020, Bogotá D.C
115. Trujillo F, Mosquera-Guerra F, Franco N (2019) Delfines de río: especies indicadoras del estado de salud de los ecosistemas acuáticos de la Amazonia y la Orinoquia. *RACCEFYN* 43:199–211. <https://doi.org/10.18257/raccefyn.765>
116. Wedekin LL, Daura-Jorge FG, Piacentini VQ, Simoes-Lopes PC (2007) Seasonal variations in spatial usage by the estuarine dolphin, *Sotalia guianensis* (van Beneden, 1864) (Cetacea; Delphinidae) at its southern limit of distribution. *Braz. J. Biol* 67:1–8. <https://doi.org/10.1590/S1519-69842007000100002>
117. Wells RS, Irvine AB, Scott MD (1980) The social ecology of inshore odontocetes. In: Herman LM (ed). *Cetacean Behaviour: Mechanisms and Functions*. John Wiley and Sons Inc, Honolulu, pp 263–317
118. Wells RS, Scott MD, Irvine AB (1987) The social structure of free-ranging bottlenose dolphins. In: Genoways HH (ed). *Current Mammalogy*. Springer, Boston, pp 407–416
119. Wells RS (1991) The role of long-term study in understanding the social structure of a bottlenose dolphin community. In: Pryor K and Norris KS (eds). *Dolphin Societies: Discoveries and Puzzles*. University of California Press, Los Angeles, pp 199–225
120. Wells RS, Scott MD (1999) Bottlenose dolphin *Tursiops truncatus* (Montagu, 1821). In: Wells RS and Scott MD (eds). *Second Book of Dolphins and Porpoises*. Academic Press, San Diego, pp 137–182.
121. Wells RS, Schwacke LH, Rowles TK, Balmer BC, Zolman E, Speakman T, Townsend FI, Tumlin MC, Barleycorn A, Wilkinson KA (2017) Ranging patterns of common bottlenose dolphins *Tursiops truncatus* in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. *Endang. Species. Res* 33:159–180. <https://doi.org/10.3354/esr00732>
122. Williams R, Moore JE, Gómez-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. *Biol. Conserv* 195:136–145. <https://doi.org/10.1016/j.biocon.2015.12.037>
123. Witt MJ, Åkesson S, Broderick AC, Coyne MS, Ellick J, Formia A, Graeme CH, Luschi P, Stroud S, Godley, BJ (2010) Assessing accuracy and utility of satellite-tracking data using Argos-linked Fastloc-GPS. *Anim. Behav* 80:571–581. <https://doi.org/10.1016/j.anbehav.2010.05.022>

SUPPLEMENTARY MATERIAL

Appendix S1: Summary of the ecological predictors and home range sizes of the *Inia geoffensis* used in the GAMLSS, including as follow: locations, subspecies, platform transmitter terminal identification number (PPT ID); *I. geoffensis* home range sizes: K_{95} : home range 95% utilization distribution (UD) sizes. Morphological predictors: body mass (kg), body length (cm), and sex: ♀: female and male: ♂.

Locations / Subspecies	PTT ID	K_{95} (km ²)	Body Mass (kg)	Body Length (cm)	Sex	References
Amazon River (Colombia)						
<i>I. g. geoffensis</i>	40679	30,7	78,4	199	♀	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	40691-1	61,7	118	176	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	181675	48,7	109	174	♂	This study satellite tracking data
<i>I. g. geoffensis</i>	181676	105,5	112	178	♂	This study satellite tracking data
Jurueña River (Brazil)						
<i>I. g. geoffensis</i>	171926	23,6	89	197	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	40663	17,6	49	162	♀	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	40687	27,9	60	182	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	40681	15,5	56	193	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	40693	12,1	91	205	♂	Mosquera-Guerra <i>et al.</i> , 2021
Marañón River (Peru)						
<i>I. g. geoffensis</i>	55305	20,9	97	197	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	175587	32,2	63,9	177	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	55298	11,8	72,5	182	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	55306	6,2	101,9	173	♀	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	55309	20,1	92,6	170	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	55312	64,9	111,7	182	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	55319	186,8	99	176	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffensis</i>	175588	88,3	97	180	♂	Mosquera-Guerra <i>et al.</i> , 2021

Locations / Subspecies	PTT ID	K ₉₅ (km ²)	Body Mass (kg)	Body Length (cm)	Sex	References
<i>I. g. geoffrensis</i>	40688	8,8	180	214	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffrensis</i>	40691	18,9	68	159	♀	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffrensis</i>	171927	41,2	107	188	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffrensis</i>	40641	76,4	200	227	♀	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. geoffrensis</i>	181019	15,1	83	176	♀	This study satellite tracking data
<i>I. g. geoffrensis</i>	181020	13,3	82	175	♀	This study satellite tracking data
<i>I. g. geoffrensis</i>	181015	17,59	149	235	♂	This study satellite tracking data
<i>I. g. geoffrensis</i>	201339	20,75	129	224	♂	This study satellite tracking data
Bita River (Colombia)						
<i>I. g. geoffrensis</i>	181017	5,59	85	174	♀	This study satellite tracking data
Arauca River (Colombia)						
<i>I. g. geoffrensis</i>	181018	25,8	88	175	♀	This study satellite tracking data
Guayabero River (Colombia)						
<i>I. g. geoffrensis</i>	40641	49,38	180	214	♂	This study satellite tracking data
<i>I. g. geoffrensis</i>	181013	115,7	176	223	♂	This study satellite tracking data
Guaviare River (Colombia)						
<i>I. g. geoffrensis</i>	181016	19,43	110	210	♀	This study satellite tracking data
San Martín River (Bolivia)						
<i>I. g. boliviensis</i>	40640	233,9	91,2	204	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. boliviensis</i>	40662	89,2	83	209	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. boliviensis</i>	40674	204,9	85,4	208	♂	Mosquera-Guerra <i>et al.</i> , 2021
<i>I. g. boliviensis</i>	171928	60,5	69,2	211	♀	Mosquera-Guerra <i>et al.</i> , 2021