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Distribution and abundance of the river dolphin (*Inia geoffrensis*) in the Tijamuchi River, Beni, Bolivia

Enzo Aliaga-Rossel

Bolivian Collection of Fauna, Institute of Ecology, Universidad Mayor de San Andres, PO Box 3182, La Paz, Bolivia

Abstract

Very few studies have been conducted in Bolivia regarding the distribution, behavior, or ecology of the Amazon river dolphin (*Inia geoffrensis*). The only published studies of bufeo in Bolivia are from Pilleri (1969) and Pillieri & Gihr (1977) and were not quantitative investigations of river dolphin abundance or distribution. The work presented here consists of an estimate of abundance and description of the seasonal distribution of the bufeo in the Tijamuchi River, Beni, Bolivia. The study was conducted during January 1998–September 1999 and represents four hydro-climatic seasons (i.e., low, high, rising, and falling waters). Two hundred and twelve h were spent in survey effort. The total study area was approximately 185 km along the river. Strip transects were used to survey for dolphins. Dolphin distributions among three habitats were compared; these habitats were riverine-blackwaters, riverine-mixed waters (black and white), and oxbow lakes of the river system. Group size and age structure were recorded. Any dead dolphins were necropsied. On average, 208 bufeos were observed in the Tijamuchi River, with an average encounter rate of 1.12 dolphins/linear km. Dolphins were seen most frequently during low and falling water (56% of total observations) and least often during high waters (22% of total observations). These seasonal differences were statistically significant. Dolphins were seen most often in oxbow lakes, and next often in confluences. Differences in dolphin abundance according to water colour were not statistically significant. There was some evidence of associations between group size and season, and group size and water colour. Forty-two per cent of observations were of solitary dolphins, 32% were of pairs, and maximum group size was 19. Calves were seen most often during falling and low waters. Causes of mortality of dolphins in the study area were identified as entanglement in fishing nets, intra-specific aggression, and collisions with outboard motors.

Key words: river dolphin, *Inia geoffrensis*, bufeo, boto, abundance, distribution, mortality, photo-identification, Tijamuchi river, Bolivia.

Introduction

There are few studies that have been conducted in Bolivia regarding the distribution, behaviour, or ecology of the boto or Amazon river dolphin 'bufeo', *Inia geoffrensis*. The only published work consists of that of Pilleri (1969) and Pilleri & Gihr (1977). This work was descriptive in nature and lacked quantitative analysis of river dolphin abundance. Despite this, Pilleri & Gihr (1977) concluded that their survey of river dolphin populations in various rivers and lagoons of Bolivia revealed a visible reduction in river dolphin population size in some regions, which they attributed to changes in the ecosystem or to anthropogenic pressure. Based on this, they recommended that immediate action be taken to establish nature reserves to actively protect the Bolivian bufeo. One additional study of river dolphins in Bolivia was conducted by Yañez (1999) and consisted of a description of the behavior and general ecology of the bufeo in the Iteñez River and the Paragua River of the Noel Kempff Mercado National Park.

Laws that explicitly protect the bufeo do not currently exist in Bolivia. Some protection is afforded by the Veda General Indefinida (D.S. 25458), enacted in July of 1999, which is a general decree that prohibits the harassment, capture, harvest, and training of wild animals and their derivatives. Debate exits over the effectiveness of this law, but it continues to be in effect in the absence of more stringent or specific laws. Throughout South America, *Inia geoffrensis* is classified as 'vulnerable' by the IUCN.

Uncertainty exists with respect to the taxonomy of *Inia geoffrensis*. The genus *Inia* is considered monospecific with three subspecies: *Inia g. humboldtiana* found in the Orinoco Basin, *I. g. geoffrensis* in the Amazon Basin, and *I. g. boliviensis* found in the rivers of the Bolivian Amazon (Best & Da Silva, 1989*a*; Da Silva, 1993). The Bolivian bufeo may be isolated from dolphin populations in the rest of the Amazon Basin due to geographic barriers, such as the waterfalls that are found in the north of Bolivia. These falls extend more than 200 km between Guayanamerin and Porto Velho in Brazil. These geographic barriers may have led to the separation of the *I.g. humboldtiania* and *I. g. geoffrensis* on one side, and *I.g. boliviensis* on the other. In addition, this theory is supported by the fact that *I. g. boliviensis* differs from the other subspecies of *Inia* in some morphological characteristics, such as number of teeth, body size, and skull size (Anderson, 1997; Emmons & Feer, 1997). Based on these morphological differences and the geologic barriers formed during the late Pliocene, which supposedly isolated the Bolivian bufeo, some taxonomists proposed the classification of two species, *Inia geoffrensis* and *Inia boliviensis.* This distinction of a new species has been disputed based on the fact that the characteristics used to differentiate the species are highly variable and also the small sample size. Currently, the systematics of *Inia* have been revised with molecular studies, which suggest that the genus of *Inia* found in Bolivia is a distinct species, *Inia boliviensis* (Banguera *et al*., 2000). The recognition of a new river dolphin species endemic to Bolivia increases the importance and necessity of protecting this species (Klinowska, 1991).

The current conservation status of the bufeo in the Amazon Basin of Bolivia is poorly known, and baseline population information is lacking. The work presented here estimates the abundance and distribution of the bufeo in a section of the Tijamuchi River of the Bolivian Amazon, taking into account three ecosystem types (i.e., blackwaters, mixed white and blackwaters, and oxbow lakes of the river system), four habitat types (i.e., river channel, confluences, bends/curves/and lagoons) and four hydro-climatic seasons (i.e., high, low, rising and falling waters). This work contributes to the knowledge of the bufeo in Bolivia, and provides important baseline information that can be used to aid in their conservation, the creation of management plans, and the initiation of active protection of the bufeo in this country. Standardized methods were used in the present study, and these can be replicated and used for future investigation in Bolivia and elsewhere.

Materials and Methods

Study area

The study was conducted on the Tijamuchi River, Moxos province, Department of Beni, Bolivia. The study area is located from where the San-Borja-Trinidad Road crosses the Tijamuchi River to where the Tijamuchi River empties into the Mamoré River (Fig. 1), and is approximately 185 linear km. Three oxbow lakes adjoining the Tijamuchi were also surveyed.

The area surrounding the Tijamuchi River belongs to the life zone of the subtropical humid forest. Gallery forests border the river, and are interspersed with savannas, some of which are natural and others are a result of deforestation from cattle ranches. The mean temperature in the Llanos de Mojos is 26.5°C and the annual precipitation varies between 1200 mm and 2400 mm per year. The months of November, December, January, and February are always rainy, with maximum rainfall of 100–500 mm per month. The hydrologic regime is tightly linked to precipitation, and displays a unimodal curve, with the highest water levels occurring between December and April, and the lowest water levels from June to October (Loubens *et al*., 1992; Guyot, 1993; Hanagarth, 1993).

The Tijamuchi River is born in the Llanos de Moxos, and is classified as blackwater from its headwaters to its middle reaches. Blackwaters are characteristically low in nutrients and suspended sediments, and are stained dark from the tannic acids of decaying vegetation. As the Tijamuchi River flows, it receives input from small channels and rivers that originate in whitewaters (whitewaters are turbid waters of Andean origins that are high in nutrients and suspended sediments). The Tijamuchi River is eventually transformed into mixed black-and-whitewaters, until it empties into the whitewater Mamoré River. The width of the Tijamuchi River is between 35 and 200 m. The annual water temperature varies between 25 and 27°C, dissolved oxygen is 20–23% and depth varies from 0 to 5 m (Loubens *et al*., 1992).

During the rainy season, the lagoons that are low for part of the year are converted into enormous bodies of water. Lagoons are places of high fish abundance, as nutrients that were incorporated in the soil are released into the water column, allowing for the accelerated development of phyto- and zooplankton (Lara, 1996). The diversity of wildlife (including fish) in the Mamoré River system is high. More than 320 species of fish have been reported in the region (Lara, 1996), of which humans consume at least 40 species, and many have commercial value in the ornamental market. The principal human activity in the region is cattle ranching.

Fieldwork

Fieldwork took place between January 1998 and September 1999. Four surveys were conducted during different hydro-climatic seasons: low water (between August and September); rising

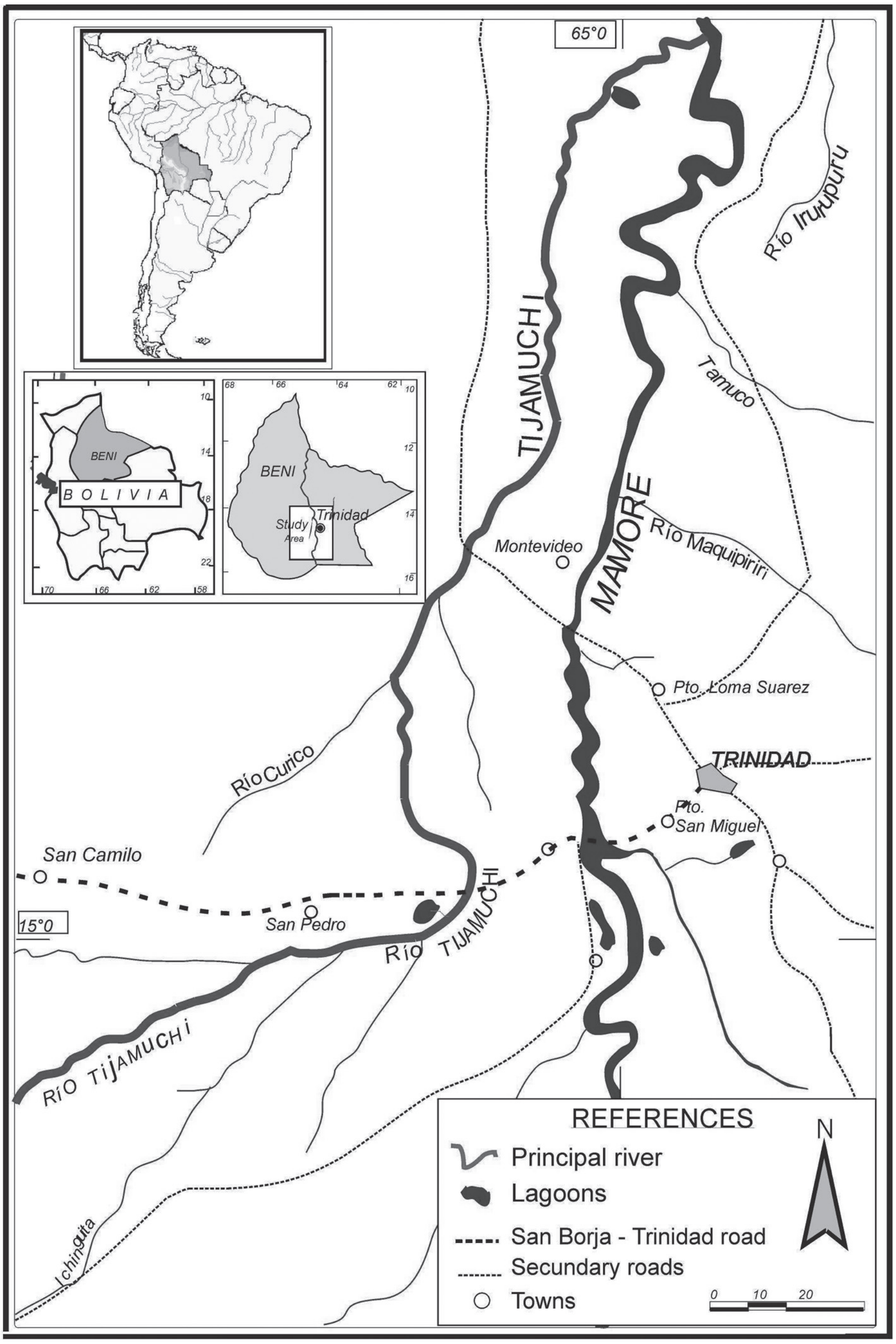


Figure 1. Map of the study area, Tijamuchi River, Department of Beni, Bolivia.

water (the end of October and December); high water (January); and falling water (May and the beginning of June). In each season an upriver/downriver transect of approx. 3 weeks was conducted. Approximately 185 km of river were surveyed during each season.

Because the Tijamuchi River has an average width of 70 m, and an observer stationed mid-river can see clearly to both banks, 100% strip-width transects were used to survey for dolphins. For all of the transects, a wooden boat with a 15-HP outboard motor was used, with two observers plus a boat driver. Standing eye-height of observers was approx. 2.5 m above the water. The boat travelled at a constant velocity between 7 and 9 km/hr. The transects were conducted between 0800 and 1715 h, which gave enough daylight for good visibility. A rest period of 1–2 h was taken during this time, usually around noon. The transect was suspended if climatic conditions were unfavourable, since factors such as rain or strong winds (>13 km/hr) impaired visibility. Two transects (i.e., upriver and downriver) were repeated in the same area each season. The boat navigated in the middle of the river, except when hazardous obstacles necessitated a temporary course alteration. The observers searched for dolphins in front of the boat and along either side of the boat. Observations were only made from the rear of the boat to confirm numbers and size classes of dolphins previously detected in front of or alongside the boat. This was done to reduce the probability of recounting the same dolphin, as dolphins often dove in front of the boat and resurfaced behind it. The presence of dolphins was determined visually, or by listening to the noise of the exhalation and then by visual confirmation. To avoid duplication in the count, the two observers communicated and did not record the same dolphin. Each time one or more dolphins were detected, it was considered to be a sighting. When a sighting was made, the geographic coordinates and the speed of the boat were recorded using a GPS. River width was estimated using telemetric binoculars. A wind meter was used to measure the velocity of the wind.

For every sighting the number of dolphins, group size, and age classes were recorded on a datasheet. When observers were unable to determine the exact number of individuals present, the lowest reliable count was registered (McGuire & Winemiller, 1998; Vidal *et al*., 1997). The term 'group' was used to refer to the total number of animals observed, singles or in or an apparent aggregation. This was defined as the total number of dolphins observed during a period of observation within a 25-m radius of the boat. This is different than the conventional definition of a group, and does not imply anything about the social cohesion or interactions of the observed dolphins (McGuire & Winemiller, 1998).

Age class was categorized in the following way: Adults had a total length (snout to tail) between 1.5 to 2.5 m, and were whitish, pink, or grey with patterns of shades of pink. Adults often had scars on the body (principally on the fins), and pink coloration on the melon, Juveniles were 1–1.5 m in length, had narrow beaks, and were dark grey with few scars and patches of colour. Calves were less than 1 m total length, were uniform gray in colour, had very short beaks with visible vibrissae on the lower jaw, and were almost always accompanied by an adult. The criteria employed to define age class is subjective due to the difficulty in estimating the size of a dolphin in the water. All of the lengths were visually estimated, and the designation of adult or juvenile does not necessarily indicate sexual maturity or immaturity (Hurtado, 1996; McGuire & Winemiller, 1998).

The aquatic habitat was characterized by measuring the following environmental parameters every 100 m of a transect: pH (with pH paper); transparency of the water (with Secchi disk); temperature of the water surface and temperature of the water at 1 m depth (with electronic thermometer); and water depth (with weighted line).

In each hydro-climatic season, ecosystem and habitat type were noted. Ecosystem type was defined as the type of water, such as blackwater, mixed white- and blackwater, and lagoons. Habitat types were categorized as main river, confluences (places on the river where a tributary discharges its water into the Tijamuchi), curves or bends (places where the river bed is wide and has a higher than average current), and lagoons (attached to the river, but with unique physical and chemical characteristics). Lagoons were unique in their water characteristics (e.g., water colour, pH, transparency) and their geomorphology, and were therefore classified as distinct habitat types and ecosystems types. Zigzag transects were used to survey lagoons, as these bodies of water were too wide for effective use of a mid-line transect. Lagoon transects did not include an estimate of group size.

To learn more about the causes of dolphin mortality, informal interviews were conducted with people who live along the river, and with fishermen of the region. When a dead dolphin was encountered, a necropsy was conducted to determine possible cause of death, based on the protocol of Norris (1961).

Data analysis

The associations between group size, season, and ecosystem, and age structure and season were examined with a chi-square test. ANOVA analysis was used to examine the effect of habitat (i.e., lagoons, confluences, bends, or the river proper) on dolphin distribution, and using the following factorial model:

$$\gamma_{ijk=}\mu\ \alpha_i\ \beta_j\ \delta_k\ (\alpha\beta)_{ij}\ (\alpha\delta)_{jk}\ (\beta\delta)_{ijK}\ \varepsilon_{ijk}$$

where, i = season (low, falling, high, rising); j = ecosystem (blackwaters, mixed white- and blackwaters, lagoons); and k = habitat (river channel,

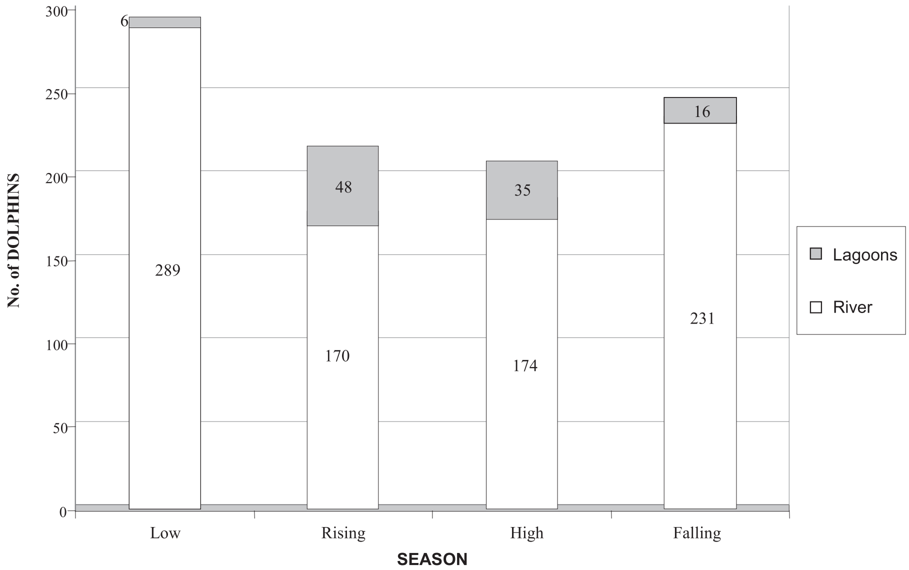


Figure 2. Seasonal averages of dolphins by season.

confluences, bends/curves, lagoons). When the ANOVA indicated a significant difference, a Tukey test was used to identify the differences. Because the data did not have normal distribution they were first transformed to ranks. Statistical results were considered significant at the $P \leq 0.05$ level.

Results

Two-hundred and twelve h were spent surveying dolphins. This was only the time spent searching for and following dolphins, and does not take into account the time spent on photo-identification or reconnaissance of the study area.

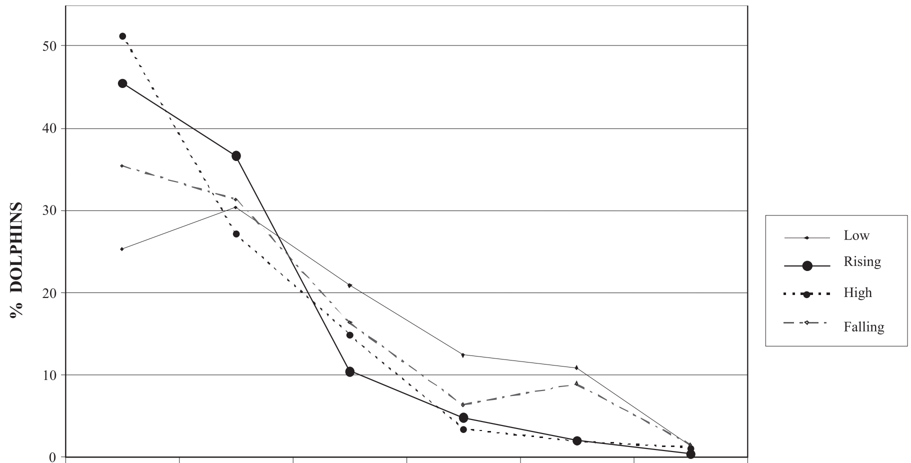
Abundance
In total, there were 2040 sightings of bufeos (*I. geoffrensis*) in the Tijamuchi River, including resightings from the lagoons. There was a density index of 1.12 individual dolphins per km transect. The total distance surveyed was approximately 185 linear river km. The average total estimate of dolphins for the four seasons combined was 208 (SE ± 28) individuals.

The population estimated varied among seasons, as well as within each season, depending if the dolphins were seen in the main river or in the lagoons (Fig. 2). Dolphins were observed most often during the seasons of low and falling water. The maximum number of bufeos corresponds to the low water season, with 295 individuals (30.4% of the total), and the minimum number was obtained during high water, with 209 (21.5% of total). Sampling effort did not vary by season. Differences in dolphin abundance among all seasons were statistically significant ($F = 80.55$, $df = 3,4$, $P = 0.0005$). Pair-wise differences between seasons were also significant, with the exception of rising and high waters ($P = 0.66$).

In the rivers, dolphins were most likely to be observed during falling and low waters. In the lagoons, dolphins were most frequently seen during rising and high waters. The number of dolphins in the lagoons declined during low water, until they were often entirely absent from the lagoons, as the channels that connected some lagoons to the rivers were reduced to depths of 50 cm, or became totally low, and the bufeos left the lagoons for the main river.

Group Size
In total, there were 920 groups of bufeos seen (including lonely animals). The predominate group size was of solitary individuals, which were 41% observations. Next were groups of two individuals, which were 32% observed (3% of all groups were mothers and calves), followed by groups of three dolphins (15%). The largest group observed was 19 dolphins, and was encountered during falling water at the confluence of the river and a small lagoon channel where bufeos feeding on numerous, medium-sized (100–300 mm) fish that were travelling from the lagoon to the river.

The frequency of group size varied significantly by season. The chi-square analysis indicated that there was a significant association (Fig. 3) between group size and season with 31% ($\chi^2 = 73.67$; $df = 15$; $P = 0.00$). Solitary individuals were seen most



	1	2	3	4	5 to 10	11 or more
Low	25.3	30.4	20.89	12.38	10.86	1.4
Rising	45.56	36.69	10.48	4.83	2.02	0.4
High	51.3	27.2	14.94	3.44	1.91	1.14
Falling	35.44	31.34	16.41	6.34	8.92	1.48

GROUP SIZE

Figure 3. Group size by season.

frequently in all seasons, with the exception of low water, during which time pairs were seen more often than other group sizes. Maximum group size was 14 individuals during low and rising waters, 13 individuals during high water, and 19 individuals during falling water. The greatest concentrations of bufeos were observed in the lagoons, where more than 30 individuals were encountered in a single lagoon, but these were not considered in the calculation of group size and were seen instead as temporary groups due to the restricted area (except for mother/calf pairs).

Group size was associated with ecosystem (i.e., whitewater, blackwater, and lagoons). Chi-square analysis indicated a significant differences in group size between white water and mixed water ($\chi^2=12.26$; $df=5$; $P=0.03$). Black waters and mixed waters were predominated by solitary animals. Groups of five or more individuals were seen in lagoons, and smaller groups were not seen in these ecosystems.

Age structure

Of the total observations, the majority of dolphins were adults (93.9%), then calves (3.27%), and juveniles (2.81%). There were individuals of unknown age, due to ambiguity of size (especially between juveniles and adults), and these were not analyzed.

The frequency with which age classes (Fig. 4) were observed varied according to season ($\chi^2=19.74$; $df=6$; $P=0.003$). Calves were seen least frequently during high water (1.6% of the total seasonal population), and most frequently during falling water (5.37% of the total seasonal population).

Ecosystem and habitat preference

With respect to ecosystems, the Tukey test indicated that differences in dolphin abundance between blackwaters and mixed waters were not significant (Table 1). However, it did appear that dolphins exhibited a statistically significant preference for lagoons. Dolphins were encountered indiscriminately between blackwaters and whitewaters, while there was a greater tendency to encounter them in lagoons (except when the lagoons are dry).

The variation in mean dolphin abundance between the different habitats suggests that there is a preference for lagoons, then the confluences, then curves/bends, and finally the main channel of the river. Significant differences in dolphin abundance among all habitats, as indicated by the Tukey test, existed for all comparisons, except for the difference between rivers and curve/bends. (Table 2).

Dolphin preferences according to the factorial model

The results of the analysis using a factorial model to examine the association of dolphin abundance with season, ecosystem, and habitat (Table 3) indicated that season and habitat were significant factors, while ecosystem was not. The interaction of season with habitat was significant, as was the interaction of ecosystem and habitat, while the interaction of

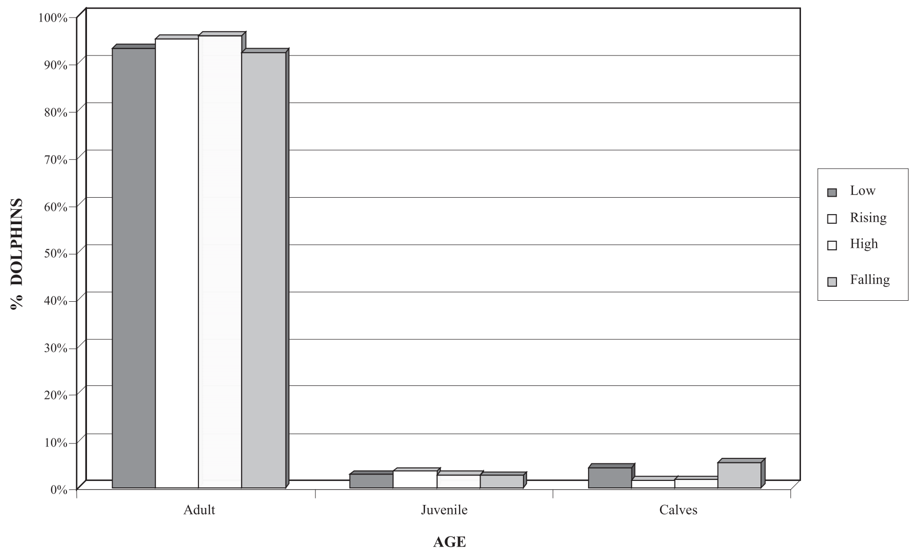


Figure 4. Seasonal age distribution.

Table 1. Tukey test indicates the differences in dolphins abundance between blackwaters and mixedwaters.

Ecosystem (I)	Ecosystem (J)	Mean difference (I–J)	Std. error.	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Whitewaters	Mixedwaters	9.80E+01	0.94	− 0.59	0.79	
	Lagoons	− 10.80*	0.90	0.00	− 129.24	− 86.92
Mixedwaters	Whitewaters	− 9.80E − 02	0.29	0.94	− 0.79	0.59
	Lagoons	− 10.90*	0.92	0.00	− 130.78	− 87.34
Lagoons	Whitewaters	10.81*	0.90	0.00	86.92	129.24
	Mixed-black	10.91*	0.93	0.00	87.34	130.78

*The mean difference is significant at the 0.05 level.

season and ecosystem was not. The three-way interaction of season, ecosystem, and habitat was not statistically significant.

Dolphin preferences according to the physical-chemical characteristics of the Tijamuchi River

The physical-chemical characteristics of the Tijamuchi River were measured in each season (Table 4). The distance of the dolphin to the nearest shore was not taken into account, owing to the fact that the width of the river in some places was less than 30 m, and a group was defined as those individuals that were within a 25-m radius. With respect to depth of the river, 94% all of the sightings within the Tijamuchi were between 1 and 18 m depth, with an average depth of 7 m. There was little variation in pH or water temperature and it does not appear that these factors or transparency affect the distribution of the dolphins (none of the Pearson correlation coefficients were statistically significant at the $P \leq 0.05$ level). Water depth and width are determined by season and habitat, which do affect dolphin distribution.

Causes of mortality

Two dead *Inia* were encountered. The first was encountered during the low season at the confluence of the Tijamuchi River and the Mamoré River. The second dead dolphin was encountered during falling water, near a bend in the Tijamuchi River. Both events were photographed.

The first death may have been due to sexual aggression. One day before the carcass was discovered, reproductive activity among various individuals (approximately 12) was observed along

Table 2. Tukey test indicates the differences in dolphin abundance among all habitats.

Habitat (I)	Habitat (J)	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
River	Confluences	− 2.09*	0.411	0.000	− 31.50	− 10.36
	Curves/bends	− 0.49	0.380	0.565	− 14.7	0.4835
	Lagoons	− 11.12*	0.874	0.000	− 133.6	− 88.72
Confluences	River	2.09*	0.411	0.000	10.36	31.50
	Curves/bends	1.60*	0.522	0.012	0.259	29.41
	Lagoons	− 9.02*	0.945	0.000	− 114.52	− 65.98
Curves/bends	River	0.49	0.380	0.565	− 0.48	14.7
	Confluences	− 1.60*	0.522	0.012	− 29.41	− 0.259
	Lagoons	− 10.62*	0.931	0.000	− 130.18	− 82.32
Lagoons	River	11.12*	0.874	0.000	88.72	133.63
	Confluences	9.02*	0.945	0.000	65.98	114.51
	Curves/bends	10.62*	0.931	0.000	82.32	130.18

*The mean difference is significant at the 0.05 level.

Table 3. Factorial model test to examine the association of dolphin abundance with season, ecosystem and habitat.

Source	Type III Sum of squares	df	Mean Square	F	Sig.
Corrected model	1698.43[a]	27	62.91	13.66	0.00
Intercept	2065.03	1	2065.03	448.51	0.00
Season	150.14	3	50.05	10.87	0.00
Ecosystem	0.80	1	0.804	0.175	0.68
Habitat	159.99	2	79.99	17.37	0.00
Season* ecosystem	19.23	3	6.41	1.39	0.25
Season* habitat	69.29	6	11.55	2.51	0.02
Ecosystem* habitat	49.52	2	24.76	5.38	0.005
Season* ecosystem* habitat	28.56	6	4.76	1.03	0.40
Error	1643.71	357	4.60		
Corrected total	3342.14	384			

*R^2=0.508 (adjusted R^2=0.47).

a sandy beach at the confluence. There was a great deal of splashing, chasing, playing, and interactive contact between the dolphins. This activity continued throughout the night, accompanied by abnormally loud exhalations and labored breathing by at least one dolphin. The following morning the dead body of a male *Inia*, 2.25 m in total length, was encountered on the beach. Its pectoral and caudal fins displayed numerous deep tooth scars from other *Inia* (determined by scar depth, shape, and spacing), bleeding from the anal slit (from internal hemorrhaging), and heavy bruises and swelling around the blowhole, the injuries to the blow hole may have resulted in the labored breathing of the previous night.

The second dead dolphin was a 2.15-m long male, and possibly struck by an outboard motor, as the left side of the beak was heavily cut and the lower left jaw was broken. This animal was discovered in the river, snagged in debris. (Note: the debris did not cause the death of the dolphin, as it had been in the water long before the dolphin died. It simply impeded the downstream movement of the carcass).

Interviews with fishermen indicated that the season of greatest fish abundance is between May and September (period of falling and low water). During this time, the fishermen place their nets at the mouths of the lagoons and affluents and fish leaving these areas for the main river are caught. In these months, fishermen frequently encounter dolphins trapped in their nets. They are more likely to trap the younger dolphins, as these animals are the least experienced with nets. Generally,

Table 4. Physical–chemical characteristics of the Tijamuchi River in the different hydro climatic seasons.

	T°C (sup)	T° (depth)	Depth (m)	Transp (cm)	Width (m)	pH
Low	28.54	27.045	4.4	11.125	54	6.8
Rising	28.45	28.3	7.5	15.351	58.88	6.4
High	28	27.8	11.2	24.256	84.62	6.5
Falling	23	23	5.25	14.46	73	6.5
Average	27	26.5	7.08	16.298	67.625	6.55

Where: T°C (sup): Temperature at water's surface. ± 15 cm
T°C (depth): Temperature at depth. ± 1.5 m.

fishermen release the dolphins, although in some cases they leave the dolphins to die or kill them with machetes to prevent the destruction of their nets. The fishermen may use the dolphin meat as bait to attract fish, or use the oil to cure maladies of the lungs. At times, the dolphins are fired on with guns for amusement, or by sports hunters practising their aim.

Local people report that during one year in the study area, six dolphins (three calves, two juveniles, and one adult) died in fishing nets. Two calves, one juvenile, and the adult were captured in the months of May to September, which corresponds to the seasons of falling and low water. The nets were located across the mouth of a lagoon. One of the fishermen indicated that the calf died because there was not time to free it, but that an adult dolphin (believed to be the mother) was seen hovering around it and was heard loudly exhaling for about 20 m after the calf died. Eventually, the adult left the scene.

Photo identification

Twenty-seven photographs were of sufficient quality to use for photo identification of individuals (Trujillo, 1994). From these photographs, two individuals were identified. One animal was resighted once, The day after it was first identified. The other animal was resighted four times, with 239-day range between the initial and final sighting. Photo identification effort was limited due to time and economic considerations.

Discussion

The density of dolphins in the Tijamuchi River is high (1.12 dolphins/km), especially compared with the rivers of Colombia and Venezuela, where the reported densities are below 1 (Trujillo, 1992; McGuire & Winemiller, 1998). The greater abundance of dolphins in the Tijamuchi River could be due to many factors, including the fact that the region has very little motorized boat traffic and or human fishing activity, since human activity in the study area is primarily limited to cattle ranching.

The average number of dolphins in the Tijamuchi River varied according to season, although these differences were not statistically significant. The low season had the majority of sightings. During the low season, the river width decreased to an average width of 50 m and the reduced area could facilitate the increase in dolphin sightings. Researchers in the Brazilian Amazon reported more dolphins during high waters than any other season (Best & Da Silva, 1989*a*). Although dolphin abundance peaks at opposite water levels in the Bolivian and Brazilian study areas, the calendar months (May to July) are the same. The number of dolphins in the study area decreased during the high water season, perhaps due to the dispersion of individuals in the inundated forest, or migrations of the dolphins to the Mamoré River and its numerous lagoons. This decrease in bufeo abundance during high water was also observed by McGuire & Winemiller (1998) in the Venezuelan Orinoco. As the waters began to rise in the Tijamuchi River, heavy rainstorms occurred which greatly increased the river current and washed out many logs and fallen trees. This could have caused the dolphins to temporarily abandon the Tijamuchi River and move to the Mamoré River, where the deluge is attenuated by the size of the river and the dolphins could find refuge from the current in wide river bends or adjacent lagoons. During high and rising waters, dolphin aerial activity is very low, and thus it is more difficult to encounter them.

Groups

Throughout the year, dolphins were generally encountered as solitary animals or in pairs. During the high water seasons the dolphins were dispersed and were most frequently seen as small aggregations of 1 or 2 individuals. During falling and low water seasons, larger groups were encountered, principally in the mouths of the small tributaries or the mouths of the lagoons. This coincides with the findings of Best & Da Silva (1989*a*) and Magnusson *et al.* (1980). The largest group was of 19 individuals, and was encountered in a confluence, near the mouth of the Mamoré River. Large dolphin aggregations were found in areas that presented optimal conditions for fishing or swimming, such as confluences with their greater abundance of fish, or the more tranquil waters of wide river bends. The groups were more numerous in the confluence areas than in the main river channel. Confluences have a greater density of fish than do the river channels (Lara, 1996).

Kendall (1994) reported that in Colombia river dolphins that appeared to be solitary actually belonged to a dispersed group, and these animals may regroup for fishing or socializing and then disperse again. When large aggregations in the Tijamuchi River were observed the dolphins were generally in subgroups of one to three dolphins.

A statistical correlation between the type of water (whitewater or blackwater) and the size of the group was not detected, and it appears that the dolphins did not exhibit a preference for water type.

In the seasons of low and falling water, there was a higher percentage of dolphins in pairs. This coincided with the period of reproduction and the calving period, indicated by the increased sightings of mother/calf pairs.

Age structure

More that 90% of total sightings were adults, while the rest were of calves and juveniles. There were slight variations in the age-class rations according to season. The proportion of calves increased in the months between May and September. This is the same period reported by Da Silva (1993) as the calving season of the bufeo in central Brazil, although they attribute the calving season to the maximum height of the water level of the Brazilian rivers. In the Tijamuchi River, these same months correspond to falling and low waters, when fish are concentrated in the channels of the rivers and tributaries. According to Louzanne (personal communication), this is when the commercial fisheries have their maximum catch. The greater abundance and ease of capture of fish in these months may represent favourable conditions for the period of mating and pregnancy of the river dolphins. Gestation is believed to be as long as 10 to 11 months (Kendall, 1994), which would indicate that the mating season coincides with the calving season of the following year. In the Tijamuchi River, this is corroborated by an increase in observations of both calves and mating activity between adults during these seasons. This was also observed in Venezuela by McGuire & Winemiller (1998). Sadly, the increase in the proportion of calves during falling and low water periods also coincides with the greatest number of calf deaths in fishing nets.

In the seasons of rising and high water, calves and juveniles were observed. It could not be determined if the same young dolphins had also been observed in the previous seasons, or if they were recent births. In the encounters with bufeo calves, the mother/calf bond was always observed. In general, these pairs were observed in areas, such as wide bend and curves, that were protected from the current. The proportion of pairs of mothers and calves was lower in the lagoons than in the other bodies of water. Kendall (1994) reported the existence of 'nurseries', where groups of calves and young dolphins were cared for by one or two adults, while the other adults travelled to the mouths of the rivers. These nurseries were never observed in the Tijamuchi River or in the vicinity of its confluence with the Mamoré River.

Juveniles were encountered more often in the meanders and lagoons, especially in periods of falling and rising water. These places have deeper and slower water and are therefore easier places for the juveniles to swim and fish.

Distribution

The distribution of the bufeo in the Tijamuchi River includes all habitats, but dolphins were most likely to be found in lagoons, confluences, and mouths of lagoons; all places of greater prey availability. The same was observed by Trujillo (personal communication) for the bufeos of the upper Amazon River and the Arauca River in the Colombian Orinoco.

Dolphins were always observed in the confluences of the rivers, where fish are concentrated as they leave the channels for the principal rivers and also because masses of water meet at confluences and create whirlpools and eddies that cause the fish to become disoriented and thus more easily trapped by the dolphins (Best & Da Silva, 1989*b*). It is interesting to note that few dolphins were seen in the middle reach of study area, which is a stretch of river without confluences for many kilometres.

Dolphins appeared to prefer lagoons to the main river channel. This may be due to the greater biomass and diversity of fish found in the lagoons. Fishery yields are maximum in the lagoons during low water; when the average catch of fish is between 16.5 to 38.6 kg/100 m^2/24 h (Lara, 1996).

There was little variation in water temperature along the river itself, although the range of temperatures among the water bodies was broad (between 24 and 32°C). It was not surprising that water temperature did not appear to affect dolphin distribution. As mammals, dolphins have internal homeostasis which keeps their general body temperature independent of the environment in which they find themselves. The pH and the transparency of the water did not appear to affect the distribution and abundance of the dolphins. Although it was not directly examined in this study, it would seem that the primary productivity of the water, which is low in zones with few fish and highest in the zones where the fish are abundant, might have an important effect on dolphin abundance.

The dolphins were seen in a range of river widths, for example from a channel 25-m wide to a lagoon more than 200 m. The largest dolphin aggregations occurred at the widest confluences.

Mortality

Humans are the principal 'predators' of river dolphins and of many of the species of the study area. Human activities in the area directly and indirectly affect river dolphin populations. The people of the zone use river dolphin oil as a traditional treatment for respiratory problems (such as tuberculosis) or weakness of the lungs. There is no evidence that people of the Bolivian Amazon kill river dolphins as a source of protein.

According to interviews with fishermen, the major cause of dolphin mortality is accidental death caused by the use of fishing nets. The same was reported for Colombia (Trujillo, personal communication). Although fishermen usually release the dolphins that are trapped in their nets, in some cases the same fishermen will leave the dolphins to die in the net, or will kill them to prevent the destruction of their nets. Fishermen use the meat of dolphins they have killed as bait to attract fish. The fishermen of the Tijamuchi River say that they do not consider themselves to be in competition with the dolphins. In Peru's Pacaya-Samiria Reserve, fishermen do consider the dolphins as competition, and some fishermen poison dolphins to protect their nets and their catch (McGuire & Zúñiga 1997, Würsig & Reeves 1998). The death rate in nets is greatest for calves and juveniles, which may be due to their lack of experience with nets and to their curiosity. The seasons of falling and low waters coincide with an increase in human fishing activity in the zone, as well as the bufeo calving season.

The increase in boat traffic in rivers, such as those investigated by Pilleri & Gihr (1977), is very dangerous for the dolphins. This was demonstrated by the second dead *Inia* that was encountered, in which the lower jaw was destroyed by the propeller of a boat. This danger was observed to increase during low water, when the space available to the dolphins was limited to only a few centimetres to spare in a channel that is used by fishing boats.

Published studies regarding aggression among bufeos do not exist and thus, it is not known how usual the aggressive behaviour is in association with the death of the first necropsied *Inia*.

This study provides important baseline data regarding river dolphins in Bolivia and underscores the importance of continuing and expanding the study to learn more about the ecological and behavioural aspects of this charismatic species.

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Literature Cited

Anderson, S. (1997) Mammals of Bolivia, Taxonomy and Distribution. *Bulletin of the American Museum of Natural History*. Number **231,** 652.

Banguera-Hinestrozoa, E., Cardenas-Henao, H., Hamilton, H., Ruiz-Garcia, M., Vasquez, R. & Garcia-Vallejo, Y. F. (2000) Variabilidad genética de la región d-loop del cyt-b (600) y D-loop 570(bp) mitocondrial en poblaciones del delfín del río de *Inia* ssp (Cetacea:Inidae) en las cuencas del los ríos Orinoco, Amazonas y Beni-Mamoré. Pg. 7. Abstracts, *9th reunión de trabajo de especialistas en mamíferos acuáticos de América del Sur. Oct/Nov. 2000*, Buenos Aires, Argentina.

Best, R. C. & Da Silva, V. M. F. (1989*a*) Amazon River Dolphin Boto *Inia Geoffrensis* (De Blainville. 1817). In: S. H. Y. Ridgway & R. Harrison (eds.) *Handbook Of Marine Mammals*. Vol. **4**, River Dolphins And Larger Toothed Whales, pp. 1–23. Academic Press. London.

Best, R. C. & Da Silva, V. M. F. (1989*b*) Biology, Status and Conservation of *Inia geoffrensis* in the Amazon & Orinoco River Basins. In: W. F. Perrin, R. L. Brownell, Jr., Z. Kaiya & Y. L. Jiankang (eds.) *Biology and Conservation of the River Dolphins*, pp. 24–34. IUCN/ Species Survival Commission (SSC) Occasional Papers No. **3**, Gland, Switzerland.

Da Silva, V. M. F. (1993) *Inia geoffrensis. Mammalian Species*. **426**, 1–8.

Emmons, L., Feer, Y. F. (1997) *Neotropical Rainforest Mammals, A Field Guide*, 2nd edn. The University of Chicago Press, U.S.A. 170–171.

Guyot, J. L. (1993) *Hydrogéochimie des Fleuves de l'amazonie Bolivinne*. ORSTOM, Paris.

Hanagarth, W. (1993) *Acerca De La Geoecología de las Sábanas del Beni en el Noroeste Bolivia*. Instituto de Ecología, La Paz, Bolivia.

Hurtado, L. A. (1996) Distribución, uso de hábitat, movimientos y organización social del bufeo colorado *Inia geoffrensis* (cetacea: iniidae) en el Alto Río Amazonas. Instituto tecnológico y estudios Superiores De Monterrey. Campus Guaymas. Tesis De Maestría. México.

Kendall, S. (1994) *Los Delfines de la Amazonia y la Orinoquia*. Fundación Omacha, Bogotá- Colombia.

Klinowska, M. (1991) *Dolphins, Porpoises and Whales of the World*. The IUCN Red Data Book. Published by IUCN, Gland, Suize, Cambridge, UK. Pp. 52–60.

Lara, M. (1996) Observación del estado gonadal de *Hoplosternum Thoracatum* y de *Hoplosternum. Littorale* (Callyctyidae). En el Área de Trinidad—Beni—Bolivia, de Agosto A Octubre. Universidad Del Beni 'Mariscal José Ballivian'. Tesis De Licenciatura.

Loubens, G., Lauzanne, L. & Le Guennen, B. (1992) Les Milleux Aquatiques de la Region de Trinidad (Béni, Bolivie). *Rev Hydrobiol. Trop.* **25,** 3:21.

Magnusson, W., Best, R. C. &. Da Silva, V. M. F. (1980) Numbers and behaviour of Amazonian dolphins, *Inia geoffrensis* and *Sotalia fluviatilis*, in the río Solimoes, Brasil. *Aquatic Mammals* **8,** 27–32.

McGuire, T. L & Winemiller, K. O. (1998) Ocurrence patterns, habitat associations, and potencial prey of the river dolphin, *Inia geoffrensis*, in the Cianuco river, Venezuela. Biotropica **30,** 625–638.

McGuire, T. L. & Zúñiga, E. (1997) River dolphin and fishery interactions in South America. 1997. Abstract, annual meeting of the society for conservation biology. Fort Collins Colorado.

Norris, K. (1961) Standardized methods for measuring and recording data on the smaller cetaceans. By Committee on Marine Mammals—American Society of Mammalogists. *Journal of Mammalogy* **42,** 471–476.

Pilleri, G. (1969) On the behaviour of the Amazon Dolphin, *Inia geoffrensis* in Beni Bolivia. *Revue Suisse de Zoologie* **76,** 57–74.

Pilleri, G. & Gihr, M. (1977) Observations on the Bolivian (*Inia geoffrensis* d'Orbigny, 1834) and the amazonian bufeo (*Inia geoffrensis* de Blainville, 1817) with description of a new subspecies (*Inia geoffrensis humboldtiana*). *Invest. Cetacea* **8**, 11–76.

Trujillo, F. (1992) Estimacion poblacional de las especies dulceacuícolas de delfines *Inia geoffrensis* y *Sotalia fluviatilis* en el sistema lacustre de Tarapoto y El Correo, Amazonia Colombiana. Special report. Vol. **49**. Centro de Investigaciones Científicas, Universidad Jorge Tadeo Lozano, Bogotá-Colombia 199 pp.

Vidal, O., Barlow, J., Hurtado, L., Torre, J., Cendon, 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

Würsig, B. & Reeves, R. (1998) Dolphin ecology in the Peruvian Amazon. *Whale*. Oceanic society expedition.

Yañes, M. (1999). Etología, ecología y conservación del delfín *Inia geoffrensis* en los ríos Itenez y Paragua del Parque Nacional Noel Kempff Mercado. Universidad Mayor de San Andres. Facultad de Ciencias Puras y Naturales. Tesis de Maestría.