Distribution and encounter rates of the river dolphin (*Inia geoffrensis boliviensis*) in the central Bolivian Amazon

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ABSTRACT

The ecology and conservation status of river dolphins (*Inia* sp.*)* distributed in the lowland rivers of Bolivia are poorly understood and only recently have basic studies been conducted to investigate their population size, taxonomic status, distribution, behaviour, environmental threats and ecology in this region. This paper examines the distribution and encounter rates of the bufeo (*Inia* sp.) in the middle reach of the Bolivian Amazon and was conducted in the Mamoré River and four of its tributaries during the low water season. Methods were employed which can be replicated during future surveys of Bolivian river dolphins and the results can be compared with those from surveys of *Inia* throughout its range. Sixty-two hours were spent surveying for dolphins, with 68% of the effort in Mamoré River and 32% in its tributaries. The *Inia* encounter rates reported here (1.6-5.8 dolphins km^{-1}) are the highest recorded anywhere in its broad geographic range; and indicate the importance of continuing and expanding surveys in this area. The mean group size was greatest in the Tijamuchi River (3.3±2.96) and smallest in the Yacuma River (1.8±0.75) and the maximum group size was 14. The high bufeo encounter rates in the central Bolivian Amazon can be taken as a reflection of the general environmental status of the region; however, a growing human population, associated with an increase in boat traffic and fishing activity, poses a future threat to bufeos and their aquatic habitats.

KEYWORDS: BOLIVIA; RIVER DOLPHIN; DISTRIBUTION; ABUNDANCE ESTIMATE; MAMORÉ RIVER; HABITAT; SURVEY-VESSEL

INTRODUCTION

River dolphins of the genus *Inia* are widely distributed in the low-lying areas of the Orinoco and Amazon basins and are the only exclusively freshwater cetaceans in South America. Our knowledge of the basic ecology of *Inia* comes from research conducted in Brazil (Magnusson *et al.*, 1980; Best and da Silva, 1984; 1989; Best and da Silva, 1989; Best and da Silva, 1993; da Silva, 1994; da Silva and Martin, 2000), Colombia (Layne, 1958; Trujillo, 1992; Hurtado Clavijo, 1996; Vidal *et al.*, 1997), Ecuador (Utreras, 1995; Herman *et al.*, 1996), Peru (Leatherwood, J.S., 1996; Henningsen, 1998; Reeves *et al.*, 1999; Zúñiga, 1999; Leatherwood, S. *et al.*, 2000; McGuire, 2002) and Venezuela (Trebbau and Van Bree, 1974; Trebbau, 1978; Pilleri *et al.*, 1982; Meade and Koehnken, 1991; Schnapp and Howroyd, 1992; McGuire, 1995; McGuire and Wienemiller, 1998).

While *Inia* is considered vulnerable by the IUCN[1], the populations appear to be in good condition relative to the other obligate freshwater dolphin taxa, such as the endangered South Asian river dolphins (*Platanista gangetica*) and the critically endangered baiji (*Lipotes vexillifer*). With multiple, potentially adverse development pressures occurring in the major river basins of South America, such as mining, logging and oil and gas exploration, a more detailed understanding of the ecology of *Inia* throughout its range is important to ensure populations remain in good condition.

Little is known about the status of the *Inia* population inhabiting the lowland rivers of Bolivia. The first studies were conducted by Pilleri (1969) and Pilleri and Gihr (1977) and consisted of informal surveys of various waterways, descriptions of behaviour and preliminary population estimates. They speculated that there had been a dramatic reduction in the population size due to anthropogenic influences. More recently, Yañez (1999) described the general behaviour and ecology of the *Inia* in the Iténez and Paragua rivers of the Noel Kempff Mercado National Park. The work presented here forms part of a longer-term project by Aliaga-Rossel (2000; Aliaga-Rossel, 2002), who studied the ecology and conservation status of bufeos in the Tijamuchi River throughout four hydroclimatic seasons (i.e. high, low, falling and rising water).

The taxonomic status of *Inia* in Bolivia is unresolved. The Bolivian river dolphin is geographically isolated from main stem Amazon *Inia* populations by a series of rapids between Guayaramerin, Bolivia and Porto Velho, Brazil. While some studies suggest the Bolivian *Inia* is sufficiently morphologically disparate to warrant separate species status (Pilleri and Gihr, 1977; da Silva, 1994), others interpret the morphological variation more conservatively (Casinos and Ocaña, 1979; Best and da Silva, 1989). Currently the Bolivian form of *Inia* is recognised as the subspecies *Inia geoffrensis boliviensis* (Rice, 1998). Recently, comparative mitochondrial DNA sequence analysis has been used to investigate taxonomic relationships within *Inia* (Hamilton *et al.*, 2001; Banguera-Hinestroza *et al.*, 2002) and these studies find substantial sequence divergence between Bolivian *Inia* and *Inia geoffrensis* in the Amazon and Orinoco rivers. Banguera *et al.* (2002) further suggest that the *Inia* population in Bolivia warrants status as a separate species (*Inia boliviensis*) or evolutionary significant unit[2] (*Inia geoffrensis boliviensis*). The morphologic and molecular data clearly indicate the uniqueness of Bolivian *Inia*, highlighting the importance of obtaining further knowledge of its distribution, abundance, ecology and

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[1] *www.iucnredlist.org/info/categories_criteria2001.html*
[2] As defined by Mortiz (1994).

conservation status. In order to reflect the distinctness of *Inia* in Bolivia, we hereafter refer to it by the local name of bufeo; the present IWC-designated common name of 'boto' is of Brazilian origin and is not used by Bolivians. *Inia* is the only cetacean in this land-locked country.

This paper examines the distribution and encounter rates of the bufeo in the middle reach of the Bolivian Amazon and was conducted in the Mamoré River and four of its tributaries during the low water season. The study employed standardised methods which can be replicated in future surveys of Bolivian river dolphins. This work contributes to our knowledge of the cetaceans in Bolivia and provides baseline data that may aid in the creation of management plans and more active protection of the bufeo in Bolivia.

METHODS

Description of the study area

The study area is located in the Department of Beni, in the region known as the 'Llanos de Mojos' (Fig. 1). The region is characterised by two types of water: white waters of Andean origin which are non-acidic, turbid and of medium conductivity; and black waters, which are of local origin, acidic, poor in suspended sediments and have low conductivity (Loubens *et al.*, 1992). The vegetation along the riverbanks is characteristic of a tropical gallery forest. Much of the region is flooded during the high-water season. The principal economic activities for human settlements along the riverbanks are cattle ranching, fishing and small-scale agriculture. The average air temperature for the region is 26.5°C, although between May and September sporadic southern cold fronts known as 'surazos' may cause temperatures to fall to 15°C. The relative humidity ranges between 64% in August and 77% in January and February.

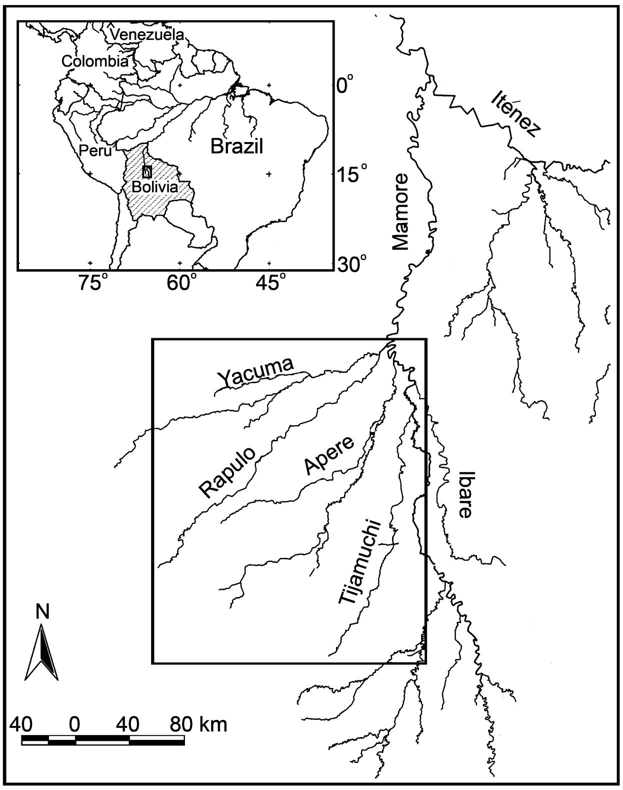

Fig. 1. Map of the study area, Central Mamoré Basin. Beni, Bolivia.

Between August and September of 1998 (the low water season), the bufeo survey was conducted along the middle reaches of the white-water Mamoré River, the most important navigable river in the region, from 14°35′60"S, 65°00′26"W downriver to the town of Santa Ana del Yacuma, 13°43′54"S, 65°25′08"W. Four mixed black and white water tributaries of the Mamoré River were also surveyed: the Tijamuchi, the Apere, the Yacuma and its tributary, the Rapulo (Fig. 1). This field work was conducted as a pilot study of bufeo ecology in the Mamoré Basin, with the goal of selecting one tributary to be the site of a year-long study (Aliaga-Rossel, 2000; Aliaga-Rossel, 2002). Logistical constraints necessitated a rapid assessment of the area and survey areas were selected based on their accessibility from the main survey route along the Mamoré River.

From August to September 1998, 222km of the central Mamoré River and approximately 65km of tributaries were surveyed (Fig. 1). Surveys consisted of two transects of the same river reach and the elapsed time between surveys was two weeks on the Mamoré River and one week each on the Tijamuchi and Apare rivers (bad weather prevented repeat transects of the Yacuma and Rapulo Rivers).

Surveys were conducted between 08:00 and 17:15, with a one-hour break around midday. Surveys of the Mamoré River were divided into upriver and down river transects. Each transect was further divided into six legs of 37km each. Legs were determined by the length of river that could be surveyed during a morning or afternoon work period and actual leg length varied as observations were suspended when weather conditions were unfavourable for detecting dolphins, such as high winds (>13km h^{-1}), waves, or heavy rain. Survey were conducted using a 100% strip width transect, from a vessel with a 70 horsepower (hp) engine, with an average speed of 11.3km h^{-1} and observer eye height of 3.5m above water level. The boat travelled along the centre of the river, except when prevented from doing so by obstacles. Because of the reduction in river width during the low water season, it was possible to detect dolphins from edge-to-edge of the river. One observer was stationed at either side of the bow of the boat, each with an angle of detection of 60° (120° total of coverage with two observers). Occasionally a third person observed dolphins behind the boat in order to confirm group size. For each sighting, observers used a GPS to determine the coordinates of the vessel, vessel speed and time of day and laser rangefinder to measure the width of the river. River width was measured on the downstream transect, but not on the returning upstream transect. When a dolphin or group of dolphins was sighted, the observers noted the numbers of dolphins per group. The term group was used to refer to the number of animals observed in association or apparent aggregation and could refer to a solitary animal, or to multiple animals.

Surveys of the four tributaries (the Tijamuchi, Apere, Yacuma and Rapulo rivers) were conducted with 100% strip-width transects from a skiff with 25hp outboard motor, with two observers watching for dolphins in front of and along side of the boat. The standing observer eye height was approximately 2m above water level and the mean survey speed was 10km h^{-1}, although this varied somewhat according to the sinuosity of the river, water depth and obstacles present.

The aquatic habitat of the tributaries was characterised every km by measuring the pH, water transparency (with Secchi disk), surface temperature and at 2m depth and water depth (with sounding line). The Apere River was the deepest and widest of the four tributaries, while the Rapulo River

Table 1

Encounter rates (bufeo km^{-1}), survey effort, and channel width for different rivers.

River	Mean velocity of survey vessel (km hr^{-1})	Area surveyed (km)	Mean channel width (m) and CV	Number of bufeos (SD)	Encounter rates (bufeos km^{-1}) and CV
Main river					
Mamoré*	11.3	222.2	329.0 (0.39)	361 (±32.23)	1.6 (0.06)
Mamoré upstream (6 legs combined)	9.3	222.2	329.0 (0.39)	384 (NA)	1.7 (0.40)
Mamoré downstream (6 legs combined)	13.4	222.2	NA	337 (NA)	1.5 (0.51)
Tributaries					
All tributaries combined	10.2	64.0	81.8 (0.23)	229 (±42.1)	3.41 (0.46)
Tijamuchi*	10.8	19.8	80.6 (0.17)	115 (±17.67)	5.8 (0.19)
Apere*	11.2	18.5	96.0 (0.21)	52 (±11.31)	2.9 (0.24)
Yacuma	10.4	20.4	75.0 (0.17)	48 (NA)	2.4 (NA)
Rapulo	8.3	5.3	63.7 (0.22)	14 (NA)	2.6 (NA)

was the narrowest and shallowest. The Mamoré River was approximately four times as wide and deep as the tributaries. All of the tributaries were mildly acidic and pH varied little between locations.

RESULTS

Encounter rates

In the Mamoré River, mean encounter rates and mean river widths were calculated for each of the six legs of the two transects. The mean encounter rate, mean river width and the associated coefficients of variance were then determined for each transect and then for both transects combined. Results were further stratified according to hydrologic habitat (i.e. main river or tributary). Sixty-two hours were spent conducting systematic surveys for dolphins, with 68% of the effort in the Mamoré River and 32% in its tributaries. This does not include time spent exploring the study area, photographing dolphins, or maintaining survey vessels.

Dolphin encounter rates were higher in the tributaries than in the main river; encounter rates were highest in the Tijamuchi River, lowest in the Mamoré River and intermediate in the Apere, Yacuma and Rapulo rivers (Table 1).

Group size

The mean group size was greatest in the Tijamuchi River and smallest in the Yacuma River (Table 2). Median group size differed significantly according to river (Kruskal-Wallis $H=21.18$, $p=0.0003$) and median group size was significantly higher in the Tijamuchi River than in the others (Bonferroni multiple range test). The largest group comprised 14 dolphins and occurred in the Tijamuchi River. The majority of observations were of pairs, triplets or solitary individuals.

Table 2

Mean and maximum bufeo group size on different rivers.

River	Mean group size (SD)	Maximum group size	No. of groups
Mamoré	2.1 (±1.34)	11	340
Tijamuchi	3.3 (±2.96)	14	71
Apere	2.3 (±0.98)	5	47
Yacuma	1.8 (±0.75)	3	27
Rapulo	2.0 (±0.81)	3	7

DISCUSSION

Encounter rates

The *Inia* encounter rates reported here of 1.6-5.8 dolphins km^{-1} are the highest reported anywhere in its broad geographic range. In comparison, other studies have reported river dolphin encounter rates of 0.13-1.50 dolphins km^{-1} in Peru (Leatherwood, J.S., 1996; Henningsen, 1998; McGuire, 2002), 0.28-0.40 dolphins km^{-1} in the Colombian Amazon (Trujillo, 1992; Vidal *et al.*, 1997), 0.02-1.16 dolphins km^{-1} in Venezuela (Pilleri *et al.*, 1982; Schnapp and Howroyd, 1992; McGuire and Wienemiller, 1998), 0.08-0.40 dolphins km^{-1} in Brazil (Best and da Silva, 1989; da Silva and Martin, 2000) and 0.23-0.40 dolphins km^{-1} in Ecuador (Utreras, 1995; Deniker, 1998), although, as is later discussed, different methods employed by different researchers undoubtedly account for some of the differences in encounter rates.

In the Bolivian Amazon, these high densities may be due in part to the region's relatively low human population. Motorised boat traffic in the area is light and there seem to be few other human activities that would negatively impact the population status of bufeos. The region has little commercial fishing activity beyond locally important subsistence fishing (pers. obs.). Humans are therefore unlikely to be competing with bufeos for fish and consequently prey abundance may be high. In addition, bufeo encounter rates may be influenced by hydroclimatic seasons. During the low water season, the average river width and volume decrease, which may facilitate bufeo sightings. During his 17-month study in the same region and using the same methods described in this paper, Aliaga-Rossel (2000; 2002) found that bufeo encounter rates were highest during the low water season and lowest during the high water season, although these differences were not statistically significant. However, even after combining all observations across all seasons (with equal sampling effort within seasons) Aliaga-Rossel (2000; 2002) still calculated a mean encounter rate of 1.12 bufeos km^{-1} in the Tijamuchi River, which remains high in comparison to other study areas both within and outside Bolivia.

The high dolphin encounter rates for the Tijamuchi River in comparison with the other rivers may in part be because the Tijamuchi River is a mixed black and white water river, with multiple connections in the middle area to the white water Mamoré River. Similar rivers with exceptionally high dolphin encounter rates were reported by McGuire (2002) in the Peruvian Amazon. She speculated that the mix of white and black waters may result in higher than average productivity, as well as greater diversity and abundance of fishes from the physical connection between two different aquatic habitat types along the ecotone. Boat traffic may be another factor influencing encounter rates: the Tijamuchi had the least amount of boat traffic and the highest dolphin encounter rates; while the Yacuma had the highest boat traffic and lowest dolphin encounter rate. Boat traffic was described qualitatively in this study, however, future studies should quantify rate and type of boat traffic in order to investigate their possible effects on bufeo distribution and abundance.

In this study, downriver transects were slightly faster than upriver transects of the same river; 0.6km h^{-1} in the Tijamuchi River; and 2.0km hr^{-1} in the Apere River. Although the survey speeds in the Mamoré River differed by 4.1km hr^{-1}, dolphin encounter rates from upriver and downriver transects were very similar (1.7 and 1.5 respectively), which suggests that these differences in survey speed had very little effect on our ability to detect dolphins.

Encounter rates are presented rather than density estimates, as standard line transect techniques were not employed due to logistical constraints in sampling. The addition of correction factors (to account for dolphins missed along the trackline) used in standard line transect density estimates (Leatherwood, J.S., 1996; Vidal *et al.*, 1997; McGuire, 2002), as well as the addition of rear-facing observers used in some river dolphin surveys (Henningsen, 1998; da Silva and Martin, 2000) undoubtedly would have led to increases in encounter rates; therefore the encounter rates presented here should be considered ‘minimum counts’ (da Silva and Martin, 2000). We believe the use of strip-surveys was warranted, given the narrowness of the rivers surveyed: in the main stem Mamoré River our mean effective strip width was 164m and was comparable to strip widths used in similar studies of *Inia* elsewhere in its range (e.g. 150m in the Amazon and Japurá rivers (Martin and da Silva, 2004) and 245m on the Amazon River (Vidal *et al.*, 1997). In the tributaries, the effective strip width ranged 32-48m; in comparison, others have used widths of 75m (McGuire, 2002) and 35m (Martin *et al.*, 2004). It is difficult to compare *Inia* encounter rates among different studies because differences in survey methods, such as number and experience of observers, vessel height and speed, season, habitat, width of survey angle, track line (mid-line or zigzag) and effective strip width all influence encounter rates (see McGuire, 2002 for further discussion).

These results are preliminary and limited in that they represent one season with few replicates within the same river. However, we believe their presentation is justified as they are among the first of their kind for this species in this region and may be viewed in the context of a resulting longer-term study of one of the tributaries surveyed (the Tijamuchi River; Aliaga-Rossel, 2000; 2002).

Group size and structure

Mean group size in the study area was found to be within the range of 1.2-6.1 *Inia* per group as has previously been reported for their entire geographic distribution (Magnusson *et al.*, 1980; Trujillo and Diazgranados, 2000). For a review of *Inia* group size from different regions and of the variation due to different operational definition of groups by different researchers, see McGuire (2002). During this pilot study and in the earlier longer-term study (Aliaga-Rossel, 2000; 2002), bufeos were generally encountered as solitary animals, pairs, or triplets. More dolphins were seen in pairs during the low and falling water seasons, which were found to coincide with the peaks in the calving and mating seasons (Aliaga-Rossel, 2000; 2002).

As with bufeo encounter rates, the Tijamuchi River is markedly different from the other rivers surveyed because of its larger group sizes (mean and maximum). The mean group size was greatest in the Tijamuchi River and smallest in the Yacuma (Table 2), which is notable as these rivers are of comparable width. The Yacuma River has much more boat traffic than the Tijamuchi River, as one of the largest human settlements in the region is found along its banks and perhaps this disrupts bufeo social structure. In addition, we hypothesise that the Tijamuchi River, with its influx of white water from the Mamoré, is richer in nutrients and prey than the primarily black water Yacuma River and thus better able to support large groups. However, care must be taken in interpreting the results of this pilot study, as sampling effort in the Yacuma and Rapulo rivers was relatively small and reported differences in group size may actually be artefacts of uneven sampling between rivers.

Bufeos of all age classes (i.e. neonates, calves, juveniles, adults; inferred by body length and behaviour) were observed in the Mamoré River and in the tributaries. This study occurred during low water, which was later found to be the peak of a year-round bufeo calving season (Aliaga-Rossel, 2000; 2002). It was often difficult to distinguish age class, as relative differences in body size were difficult to discern from glimpses from a moving vessel of these low-surfacing animals and because little is known about their size relative to their age/maturity. We recommend that future studies of bufeos include investigations of animals from strandings, fisheries by catch and capture during marking/tagging operations, in order to correlate age with length.

Aquatic habitat

Little variation in water temperature existed within a single river, although temperatures varied between rivers (24-32°C). These differences were most likely temporal due to a cold-weather system that moved into the area mid-study, rather than spatially-related to hydrologic differences. Water transparency and pH likewise varied minimally between rivers and seem unlikely to directly affect bufeo distribution and abundance. Indeed other studies have not detected significant associations between *Inia* abundance and water transparency, pH, or temperature (da Silva, 1994; Hurtado Clavijo, 1996; Zúñiga, 1999; Aliaga-Rossel, 2000; McGuire, 2002). Although not directly examined in this study, biotic factors such as prey biomass and availability probably have more of a direct influence on *Inia* abundance and distribution (McGuire and Wienemiller, 1998).

This study provides baseline data regarding river dolphins in Bolivia and highlights the importance of continuing and expanding a long-term study of the distribution, abundance and basic ecology of this unique Bolivian dolphin. Due to its exceptionally high bufeo encounter rates and large group sizes compared with studies from elsewhere in *Inia’s* range, the Tijamuchi River is an area that merits further investigation. The high bufeo encounter rates in the central Bolivian Amazon can be taken as a reflection of the general environmental status of the region; however, a growing human population, with its associated increases in boat traffic and fishing activity, may pose a future threat to bufeos and their aquatic habitat. We believe that attention to environmental management and biodiversity conservation in the Bolivian Amazon is merited at the present time.

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