An Analysis of Ecological Factors Influencing Tucuxi (*Sotalia fluviatilis*) and Boto (*Inia geoffrensis*) Behaviour and Habitat Use in the Pacaya-Samiria National Reserve, Peru

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Front page photograph: Boto (*Inia geoffrensis)* & Tucuxi (*Sotalia fluviatilis*) (Author, 2018; Isaac Rice, 2018)

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Abstract

The pink (*Inia geoffrensis*) and grey (*Sotalia fluviatilis*) river dolphins were, until recently, both listed as data deficient on the IUCN Red List, with limited knowledge on population trends, distribution and ongoing threats. Following *Inia'*s reclassification to endangered with evidence of population decline in 2018, research into both sympatric species has become more urgent. Within two distinct areas of the Pacaya-Samiria National Reserve in Peru, this study aimed to investigate and compare factors that may influence the distribution, behaviour and ecology of both endemic riverine species. Data collection was performed between June and August in different freshwater habitats of each study sites along the Samiria river, recording dolphin abundance, behaviour, water depth and fish abundance. Results showed that the region appears to be an ecologically complex system, where the influence of depth and fish abundance on dolphin distribution and behaviour varies between sites. Both species showed abundance and fishing activity similarities across habitats in the downriver study site but showed differing habitat preferences in the upriver site. Upriver, pink dolphins may take advantage of higher fish densities in the shallowest waters, whereas greys occurred in deeper main rivers even though fish was less abundant. As higher abundances of dolphin and fish were recorded in the downriver site, yearly seasonal fluctuations need to be carefully monitored. The rate at which both sites will be affected by precipitation shifts and climate change is bound to differ. Although dolphins in one site did not seem to be dictated by water levels, dolphin populations in another may increasingly become so. This study highlights the vital importance of freshwater systems for riverine dolphins dependent upon viable habitats and prey availability. Conclusions drawn from the study emphasize the need to mediate anthropogenic disturbance and sustainable resource use in the area in the face of increasingly unstable climatic conditions.

Keywords: Amazon river dolphin, Pacaya-Samiria National Reserve, freshwater systems, habitat preference, fish abundance, seasonal fluctuations, climate change

1. Introduction

Extending over an area of 6.9 million km2, the Amazon basin is the largest hydrographical basin in the world, of which between 14 and 29% is constituted of freshwater ecosystems such as floodplains and lakes (Castello et al., 2013). Moisture blown from the Atlantic Ocean falls as precipitation over the basin, where 65% of it returns to the atmosphere via evapotranspiration (Castello et al., 2013). The Amazon river is composed of over 1 100 tributaries, including 16 longer than 1 600 km, originating mainly from the Ucayali and Marañon rivers, sourced from the glaciers of the Peruvian Andes (FAO, 2016). With an approximate discharge of 226 000 m3/s per year, the Amazon river exceeds the combined discharge of some of the world's largest rivers (FAO, 2016). Maintained by seasonal flood pulses in the upstream catchment, the floodplain system, along with its diverse and dynamic habitats, shelters productive aquatic macrophyte communities and is subject to important water level fluctuations of 10 to 15 m across the year (Petry et al., 2003).

Located in the far western Amazon basin in the department of Loreto, the Pacaya-Samiria Reserve of 2 080 000 hectares is the largest reserve in Peru comprising over 10, 000km of linear waterways (McGuire & Henningsen, 2010). The reserve encompasses a unique range of animal and plant diversity and is the largest patch of nutrient-rich white water várzea floodplain forest (Bodmer et al., 2017). Indeed, 86% of the area is constituted of a complex mosaic of water bodies including inundated forest (51%), seasonally flooded forest (34%), rivers and oxbow lakes (1%) all interconnected during the wet season (Correa, 2005). Quantity and quality of available habitat is dictated by four distinct seasons of water level fluctuations: high water, falling water, low water and rising water, each around three months long (Gomez Salazar et al., 2012). For instance, up to 5 to 10 times less habitat is available as waters begin to recede throughout July and August, eventually reaching the lowest depth levels in September (Gomez Salazar et al., 2012). Directly impacted by depth changes are fish migratory movements along the Samiria River, where, as waters rise, large fish populations aggregate and reproduce in flooded forests (Bodmer et al., 2014). In contrast, as waters recede from flooded habitat, fish migrate back into deeper main rivers and become spatially concentrated in shallow waters, benefiting predation by aquatic wildlife (Bodmer et al., 2014).

As the ecology of most terrestrial and aquatic species is impacted by the river's seasonal water levels, certain animals and plants are used as key indicators of the ecosystem's health in the reserve (Shostell & Ruiz-García, 2010). For example, river dolphins are used to monitor the health of aquatic habitats as their abundance and distribution are often indicative of water quality levels (Shostell & Ruiz-García, 2010).

Two species, the grey dolphin (*Sotalia fluviatilis*) and pink dolphin (*Inia geoffrensis*) are found sympatrically throughout the Amazon river basin and the reserve, with both their population frequently encountering one another (Martin et al., 2004). Limited information exists on the differences between the two cetacean species' dispersal and use of habitat, but consistency appears, amongst published observations, that neither one occurs in random patterns along riverine habitats (Martin et al., 2004). Both species may be found to cluster where rivers meet and present particular physical and productivity features ideal for prey aggregations.

1.1 Boto (*Inia geoffrensis*)

The pink river dolphin or boto of the Iniidae family diversifies itself into three recognized subspecies: *Inia geoffrensis geoffrensis* and *I. g. humboldtiana* in the Amazon and Orinoco basins, and *I. g. boliviensis* in the Amazon and Madeira upper basins (Bolivia) (da Silva, 2018).

1.1.1 Distribution

Botos are widely distributed across 6 countries of South America including Bolivia, Brazil, Colombia, Ecuador, Peru, and Venezuela, encompassing an area of about 7 million km2 (da Silva, 2018) (Appendix I). The species is physically able to reach almost anywhere whilst staying outside of marine waters. Studies have suggested that density was low in Ecuador rivers and parts of the Orinoco River. In comparison, relatively high densities have been found in rivers of the Brazilian border, Bolivia and the Samiria River in Peru (da Silva et al., 2018).

1.1.2 Biology

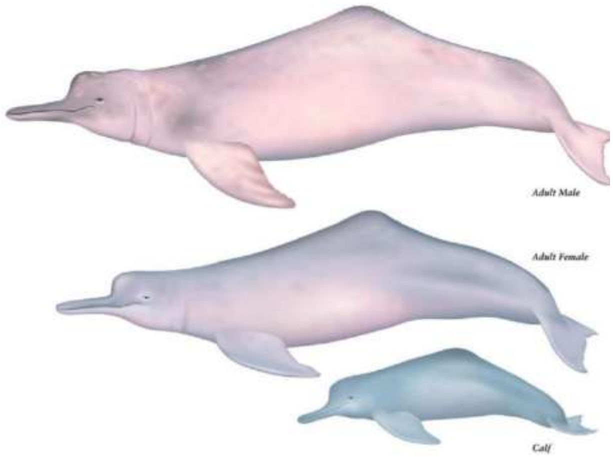


Figure 1. Inia geoffrensis (da Silva & Martin, 2018).

Inia geoffrensis, known as the pink dolphin due to its distinctive light pink colour, sometimes grey, blue or white, is recorded to be the largest river dolphin species reaching on average a length of 2.6 m and weighing up to 160 kg (Shostell & Ruiz-García, 2010). Body colour varies with age (Figure 3), with males becoming pinker than females due to scarring caused by intermale aggression (da Silva, 2018). Morphologically, they are adapted to exploit seasonal availability of prey by making use of their flexible bodies in different habitats more or less accessible. Their large pectoral fins, low dorsal ridge, long rostrum, and unfused cervical vertebrae allowing movement of the head in all directions, allow these animals to follow and predate upon fish populations in confined areas, from in between tangled roots to forest branches (Martin & da Silva, 2004). However, these characteristics restrict fast and speedy swimming (da Silva, 2018).

The species distribution is restricted to a complex freshwater riverine system dramatically fluctuating across the year, from low to high water, where main rivers take over sandbanks, forests flood with depths of several metres and spill-overs lead to the formation of oxbow lakes (Martin & da Silva, 2004). The dolphin’s habitat availability and quality are thus dependent upon seasons, areas considerably shrinking during the dry period (Shostell & Ruiz-García, 2010). Commonly observed in main river channels, lakes and confluences, individuals occur mostly alone or in pairs and travel up to hundreds of kilometres whilst still showing great site fidelity and eventually returning (Shostell & Ruiz-García, 2010).

Large group aggregations have been observed at confluences and riverbends due to significant concentrations of fish (da Silva, 2018). Indeed, *Inia* is piscivorous and consumes a large diversity of fish, where analysis of stomach content has revealed traces of up to 11 fish species in one animal (da Silva, 2018). Prey biomass and availability for the species will largely be determinant upon water level fluctuations influencing migratory movement between water bodies (McGuire & Aliaga-Rossel, 2007).

1.1.3 Conservation status & threats

Currently, its population is said to be decreasing and severely fragmented, and its conservation status has recently been reclassified from data deficient to endangered (da Silva et al., 2018). It is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Multiple threats have been identified such as incidental catch in fishing gear, dam construction, intentional killing and chemical contamination (Shostell & Ruiz-García, 2010). Dam construction and development of commercialization networks increasing road access and accessibility, are bound to restrict and fragment dolphin movement as well as fish diversity. Separating and isolating dolphin populations is likely to reduce the gene pool and increase local extinction risks (da Silva, 2018). Unregulated gold mining activities have resulted in heightened risks of mercury accumulation in Brazil and Orinoco basin, with traces found in dolphin milk and body tissues. Although the bioaccumulation effects of mercury and chemical contaminants are unknown, high levels reported in the Amazon Basin are cause for concern (da Silva, 2018). Perhaps the most documented threats are the accidental drowning of the species in fishing gear and deliberate killing using dead animals as bait in the Piracatinga fisheries causing widespread mortality (da Silva et al., 2018). Dolphins are intentionally killed and left to rot by fishermen to attract catfishes and deliberately persecuted in areas where they have caused damage to nets and seen as competing for fishery resources (da Silva et al., 2018). The species is deeply embedded within Amazonian people’s folklore and culture contributing to its protection over the years, with many legends and myths recounted throughout its distribution involving personification and supernatural abilities (Shostell & Ruiz-García, 2010). Its extensive cultural symbolism may have protected the species from harm but may also threaten its survival as its body parts have been harvested for medicinal and spiritual concoctions (Shostell & Ruiz-García, 2010).

1.2 Tucuxi

Included in the Delphinidae family, the *Sotalia* genus was once believed to encompass five different species (Flores et al., 2018). Only since the 20th century was it reduced to two species: the riverine grey dolphin *Sotalia fluviatilis* and the marine *Sotalia guianensis* (Flores et al. 2018). The grey river dolphin or tucuxi represents the only exclusively freshwater delphinid in the world (Shostell & Ruiz-García, 2010)

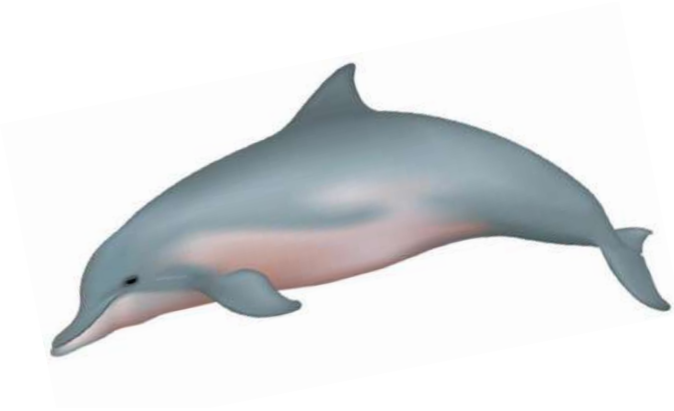
1.2.1 Distribution

Sotalia fluviatilis occurs throughout most of the Amazon River main tributaries, Brazil, south-eastern Colombia, Ecuador and north-eastern Peru (Shostell & Ruiz-García, 2010) (Appendix I). It has not been found in the Beni/Mamoré River basin in Bolivia and in the upper Rio Negro (Flores et al., 2018). Numbers in the Samiria River system in Peru have been estimated to be around 350 individuals with evidence of stable population numbers between 1991 and 2000 (Secchi, 2012).

1.2.2 Biology

Sotalia is a small light grey dolphin with maximum length of 152cm and body mass of 53kg (Flores et al., 2018). It is dark grey on the dorsum and white to light pink on the ventral area, possesses a triangular, short curved dorsal fin as well as a small rounded melon (da Silva & Best, 1996). Aerial and vertical jumps, somersaults and diving with the tail out of the water, have been behaviours reported in the wild (da Silva & Best, 1996). *Sotalia* is described as a faster and more efficient swimmer displaying superior agility than *Inia geoffrensis* (Shostell & Ruiz-García, 2010).

Figure 2. Sotalia fluviatilis (Flores et al., 2018).



They have shown preferences for main river channels, larger lakes and river junctions over narrow and shallow water bodies, where access and mobility are restricted (Secchi, 2012). Tucuxis have not been found in rivers shallower than 3 m deep or in lakes shallower than 1.8 m (Secchi, 2012). They have tended to avoid flooded forests by exiting lake systems as waters recede, to avoid being trapped (Flores et al., 2018).

Occurring often in groups of one to six individuals, the species maximum range is estimated to be of 130 km in the Pacaya-Samiria Reserve likely limited by seasonally small and shallow channels (Secchi, 2012). Larger group aggregations are usually the result of cooperative feeding, where at least 28 species of small schooling fish are predated on by tucuxis in the Amazon region (Flores et al., 2018). As habitat expands during rising water season, many fish species venture into flooded forests and become out of tucuxi’s reach restricting dolphins’ predation success (Secchi, 2012). Possibly associated with fish availability is the calving period, occurring between September and November, during low water season, where fish are concentrated in main water bodies making predation more successful (Flores et al., 2018).

1.2.3 Conservation status & threats

Sotalia remains listed as data deficient by the IUCN and in Appendix I of CITES, with no estimates of its total population size but reported as being relatively abundant throughout most of its range. According to the IUCN, its endemism jeopardizes the species continued occurrence in its natural habitat as it is restricted to areas becoming increasingly impacted on by human populations (Secchi, 2012). Threats to tucuxis, like ones of *Inia*, include habitat deterioration and population fragmentation caused by dam construction (Secchi, 2012). However, the species is thought to be the most accidently captured dolphin along certain Amazonian rivers where gillnet entanglement constitutes the most important threat (Shostell & Ruiz-García, 2010). Intentional killing for organs also presents a threat, although the species is not sought after for spiritual and mythological reasons compared to *Inia*. Other threats, including metal contamination and coastal development, have urged the need to potentially consider the species as endangered (Shostell & Ruiz-García, 2010).

1.3 Aims and objectives

This study aimed to investigate and compare ecological factors that may influence the distribution, behaviour and ecology of pink and grey river dolphins within two distinct areas of the Pacaya-Samiria National Reserve, Peru.

The objectives were to test whether:

- The abundance of both species varies between different habitat types
- The abundance of both species varies with depth in different habitats types
- A relationship between fishing behaviour of both species and fish abundance in related habitats exists in PV1 and PV2
- Fish abundance and water levels impact upon both species distribution in different habitat types in PV1 and PV2

1.4 Justification

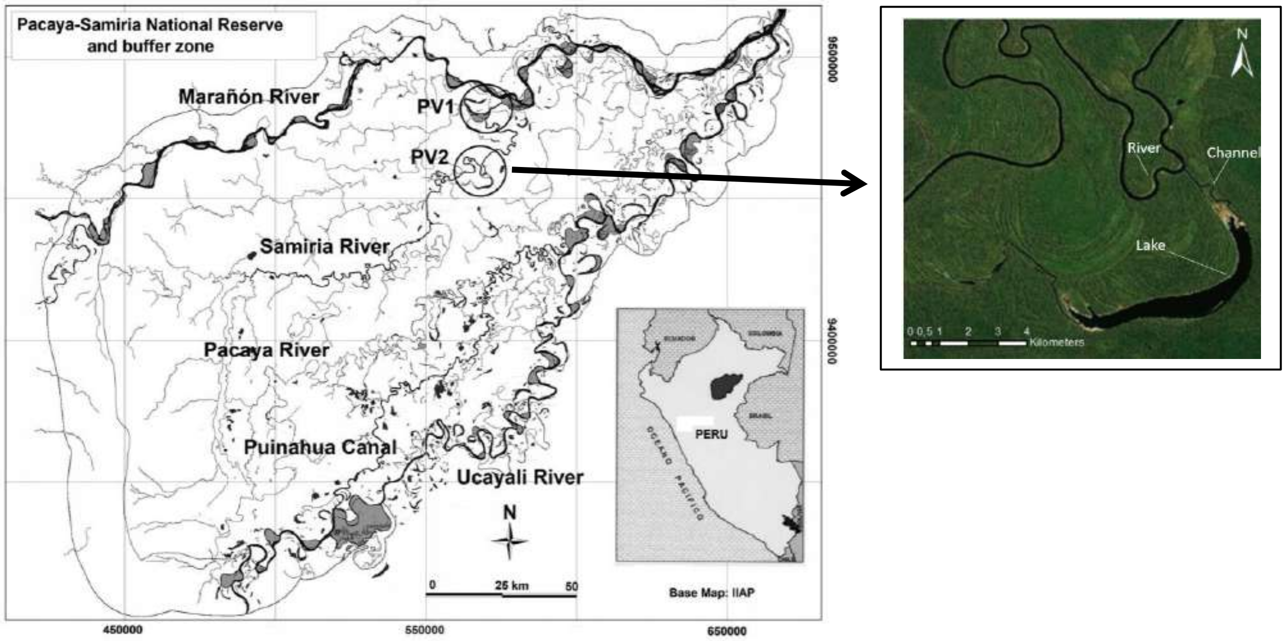
Among the least understood cetaceans in the world are riverine dolphins, where the lack of information largely remains in estimating population distribution and in descriptions of their physical size and appearance (da Silva & Martin 2006). Endemic to the Amazon-Orinoco river basin, these riverine species are known to be significantly impacted by human disturbance and yet, comprise the most important research gaps in cetacean conservation. Predominantly concealed from human observation under turbid obscure waters challenges our understanding of these animals' biology and relation to their environment, ecologically and socially (da Silva & Martin 2006). These large freshwater vertebrates and apex predators may offer potential indication on historical trends and patterns of regional biodiversity in freshwater systems. Positioned at the top of the food chain, they have acted as sentinel species for environmental quality and micropollutant contamination (Lailson-Brito et al., 2008). Indeed, both species may act as indicator species of river systems encompassing high levels of endemic biodiversity and providing essential food security and water availability to people and wildlife (Turvey et al., 2012).

2. Methods

2.1 Study site

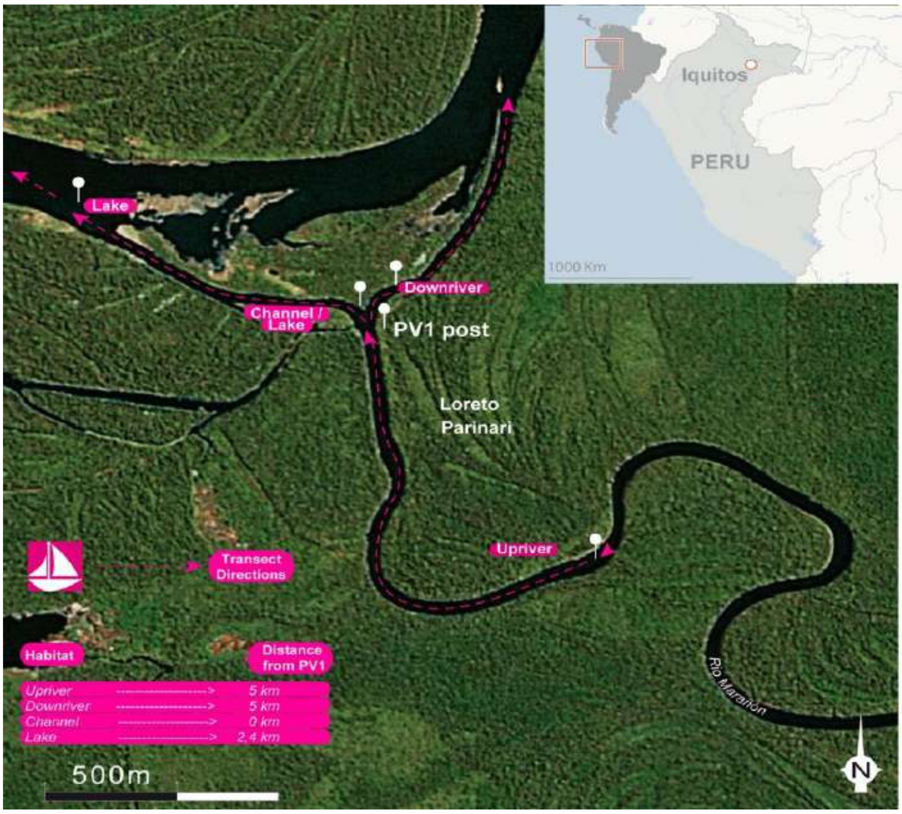
The study took place in the Pacaya-Samiria National Reserve, Peru. Researchers were assigned to a boat and a specific location along the Samiria river. One research boat was moored at the PV1 Shiringal guard post, and the other at PV2 Tacshacocha, where both sites performed transects daily.

Figure 3. Pacaya-Samiria National Reserve and study areas (PV1 and PV2) (Instituto de Investigaciones de la Amazonia Peruana; Bodmer et al., 2017).



Stationed at PV1, researchers performed four distinct transects, named according to the section of river they encompassed in relation to the position of the research boat, which was used as starting point (Upriver, Downriver, Channel/Lake and Lake). Each transect reflected a different habitat type, where environmental variables may differ and impact species differently.

Figure 4. Habitat types and corresponding transect directions at PV1 (Google Earth imagery)



Transects were a standardised 5km length including the channel measuring 3.5km that encompassed the mouth of the lake (1.5km). Data collection was conducted from a small outboard motor-powered boat operated by a guide. The boat would drift, engine off, along each transect, following the speed of the current. This year, the current was particularly slow, and so the engine was turned on to speed the transects along. If transect were performed against the current, the motor was switched on to a speed of 3km/h. Using a Global Positioning System (GPS) receiver, the location of each transect starting point (0km) and ending point were marked, allowing us to return to the same river section (Figure 4.). Two transects were performed: one in the morning and one in the afternoon almost every day between the 12th June and 1th of August. From the 11th of July, the research boat was moved 10 km further down the river due to low water levels and changed the location of dolphin transects. For the sake of analyses to follow, any transect performed below the original PV1 location were considered as downriver habitat.

2.2 Dolphin observations

Data collection recorded the date, time of day, weather conditions, group size, group composition and behaviour. Five observers were present every day consistently during most of the expedition, increasing the chance of dolphin detection. Observants were positioned at the back and front of the boat, communicating between each other dolphins seen in every direction, in order to track the total number of dolphins over breaches surrounding the boat. Dolphins may travel back or start playing at the rear of the boat and navigate in circles increasing the risk of double counting, making the number of observants present an important factor influencing precision. Once an individual or group was spotted, the time would be recorded, as well as the GPS location once the boat reached the point where the dolphins were first seen. If the same individual or group was not sighted again, we assumed they had travelled out of the area and individuals seen after that time were new.

The species was identified using certain morphological features (such as colour and shape of dorsal fin) and behaviour. Localized water ripples, also known as footprints, were good indicators of dolphin presence in the area. Rarely performing aerial behaviour, identification of pink dolphins is usually done by observing the breach of the melon and distinctive pink dorsal ridge. However, the most direct indication is the unique breaching sound performed when surfacing. Grey dolphins have a curved/rounder back when breaching the surface, and an indicative dorsal fin, resembling bottlenose dolphins. Age category was determined visually, based on approximate observed size: smaller individuals travelling alongside adults were classed as juveniles and all others were recorded as adults.

When recording behaviour of pink and grey dolphins, the Blackburn (2002) ethogram was used (Appendix II) to identify five types of behaviours: fishing, travelling, resting, playing, and mating. Feeding, where both species surface less often, but round their backs and dive deep. They do not move in a horizontal line, they move sideways and in circle. Playing was observed mostly when dolphins followed the boat closely and interacted with the engine's waves, behaviour almost exclusively seen in pink dolphins. Travelling was identified by both species' frequent breaches in linear like movement. Resting is recorded when species are seen seemingly drifting, carried by the current. Mating is a very rare sighting, where two individuals are in stationary positions, entangling themselves on each other, often near river banks.

2.3 Water depth & other variables

Fish populations are surveyed to determine the impact of climate change on this resource vital not only for local people but for entire wildlife populations. Surveys focused on species commonly used by the local indigenous people. Each day, one survey was performed in the afternoon and in the evening. A standard gill net of green nylon measuring 30m long, 3m deep with a 3inch mesh was used. The net is set for 1 hour in locations chosen by fisherman in the area. Nets are set in river, channel, and lake habitats with GPS point recorded in each net location. All fish caught are removed from the net with weight and standard length (total length minus the tail fin) recorded. Fish are then released back into the water.

Water depth was measured on an auxiliary boat using a portable 100m depth sonar sensor fish finder, independently from the dolphin transect days, as depth could not be measured whilst the survey boat was moving. On each of the dolphin transect habitats, depth was taken from three sections per point (right bank, middle, left bank). For the river and channel habitats, depth was measured first on the right and left bank in order to calculate the middle section position, dividing the distance between left and right by two. GPS was used to calculate distances in metres. The GPS was reset when moving to the next point 500m away each time. GPS locations of each middle point were taken in order to perform the same measurements at the same place week by week. In riverine habitats, 10 estimates of water depth were taken per point, each point being at 500m distance for 5km totalling 11 points. In the channel, only 5 points were covered due to the habitat’s reduced length. With the lake being significantly larger in width, the starting point and first measurement was taken at the end of the channel on the left-hand side. With the right bank being too far from the left, the right bank was given an assigned edge location and a fixed 200 m distance away from the right bank.

Measurements methods were thought of in a way that corresponded as much as possible to areas covered by dolphin surveys. After week 2 of measurements, GPS location of river bank edges had become land and amounted to 0m. Through a trial and error situation we proceeded to only measure middle sections of each point along each habitat.

2.4 Past data

In order to compare abundance of both dolphin species at PV1 and PV2 across years, I was granted access to Operation Wallacea and Fund Amazonia's entire database starting from July 2006 to August 2017. Data entry and formatting was performed the same way as the data I collected in 2018, but presented inconsistencies in sampling effort, habitat surveyed and study site along the Pacaya-Samiria reserve.

2.5 Data analysis

Dolphin Abundance

Calculated for each habitat and each species: $A = N/(T \times L)$

Where: N= Total number of individuals recorded

T= Total number of transects performed

L= Combined length (in km) of all the transects performed

- Perform a Chi-square test to analyse if there is a statistically significant difference in mean abundance of the pink and grey river dolphins within the habitat types at PV1 and PV2.

The statistical hypotheses for both species were:

Null Hypothesis (H0): There is no statistically significant difference in mean dolphin abundance within the habitat types.

Alternative Hypothesis (H1): There is a statistically significant difference in mean dolphin abundance within the habitat types.

- Perform a Chi-square test to analyse if there is a statistically significant difference in mean abundance of the pink and grey dolphin demonstrating fishing behaviour within the habitat types at PV1 and PV2.

The statistical hypotheses for both species were:

Null Hypothesis (H0): There is no statistically significant difference in mean dolphin abundance of fishing behaviour within the habitat types.

Alternative Hypothesis (H1): There is a statistically significant difference in mean dolphin abundance of fishing behaviour within the habitat types.

Fish Abundance

Calculated for each habitat: A= G/min/net

Where: G= Total grams of fish caught in each transects

min= Total combined number of minutes spent in each transects

net= Total number of nets of the same size in each transects

- Perform a Chi-square test to analyse whether the variation between the observed frequencies can be accounted for by sampling error or whether there really is a significant difference between the frequencies at PV1 and PV2.

The statistical hypotheses were:

Null Hypothesis (H0): The observed frequencies are homogeneous, and the departure is merely due to sampling error or scatter.

Alternative Hypothesis (H1): The observed frequencies depart from those expected of a homogeneous distribution by an amount that cannot be explained by sampling error.

3. Results

3.1 Total observations

Table 1. Total observations of species in each habitat at PV1 and PV2

PV1	**Downriver**	**Upriver**	**Lake**	**Channel/Lake**	**Total**
Pink	399	126	134	56	**715**
Grey	175	88	48	27	**338**
PV2	**River**	**/**	**Lake**	**Channel**	**Total**
Pink	52	/	14	58	**124**
Grey	57	/	11	28	**96**

Table 1. demonstrates that, at PV1, the total of recorded pink dolphins amounted to 715 individuals, more than double of what was observed for the grey dolphins (338). Pink dolphins occurred in greater numbers in all 4 habitat types, with downriver harbouring the highest number of observations for both species, with 399 pinks and 175 greys. The channel and mouth of the lake habitat presented the least pink and grey dolphins. However, pink dolphins were found in significant numbers in the lake, with 134 being observed, in comparison to grey dolphins (48).

At PV2, a total of 124 pink and 96 grey dolphins were recorded during the study period. Pinks were recorded to occur in the river nearly as much as grey dolphins (52; 57). Both species were observed in their lowest numbers in the lake, but pink dolphins dominated observations in the channel (58) marking the biggest recorded difference with grey dolphin numbers (28).

Comparing potential relationships between variables requires to account for this study's sampling effort, including the number and length of each transect performed in each habitat across this study's duration. Total observations have thus been corrected to account for sampling effort.

3.2 Mean abundance

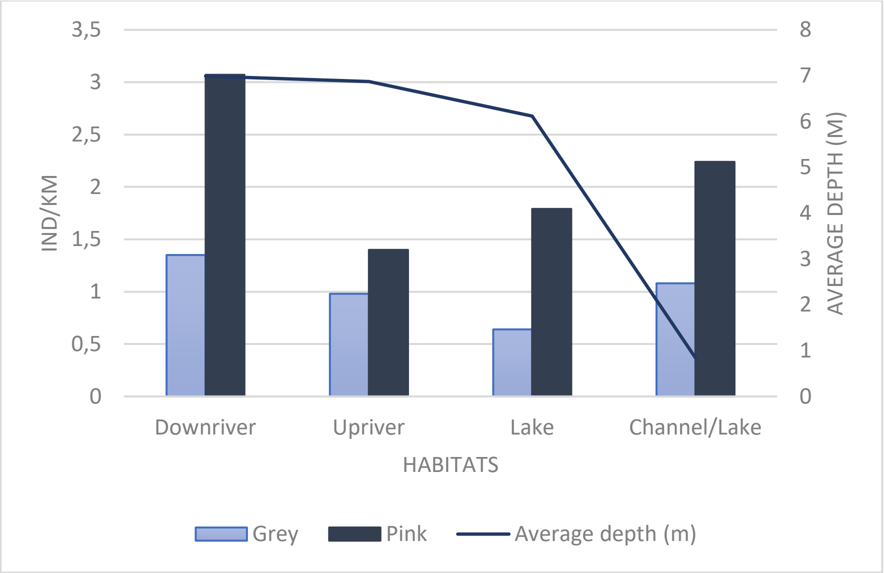
In this study, 'abundance' refers to dolphin density in a certain area or habitat surveyed. This was calculated by determining the number of individuals per kilometre for each of the habitats across the study's entire duration at both study sites. By doing so, the data will be standardised and can account for the differences in sampling effort seen during this study, such as differences in the number and length (km) of transects performed for each of the different habitats along PV1 and PV2.

3.2.1 PV1 station

3.2.2 Dolphin abundance & depth

Average depth along the dolphin survey habitats was calculated by me and offered supplementary information for comparisons and analysis at PV1 station.

Figure 5. Mean dolphin abundance and average water depth in four habitat types in PV1



The chi-square test was used to analyse if there is a was a statistically significant difference in mean abundance of the pink and grey river dolphins within the different habitat types at PV1.

The statistical hypotheses for both species were:

Null Hypothesis (H0): There is no statistically significant difference in mean dolphin abundance within the four habitat types.

Alternative Hypothesis (H1): There is a statistically significant difference in mean dolphin abundance within the four habitat types.

There was found to be a statistically significant difference in the mean abundance of both species ($\chi 2=13.2$, df=3 $P< 0.01$) within the four different habitat types, so the Null Hypothesis can be rejected for both species in favour of the Alternative Hypothesis.

The abundance of pink and grey dolphins was higher downriver in comparison to all other habitats (3.07) (Figure 6.). Pink dolphins were least abundant upriver (1.4), and greys were least abundant in the lake (0.64). Although pink and grey dolphins are found most abundantly downriver where depth is the highest (6.99 m), the channel/lake shows the second highest abundance for both species (pinks: 2.24, greys: 1.08) where waters were the shallowest (0.84 m). It can be noted that although depths between downriver and upriver are similar (6.99/6.87 m), dolphins are of relatively low abundance upriver (pinks: 1.4, greys: 0.98).

3.2.1 Dolphin behaviour & depth

Figure 6. GPS coordinates of observed pink (pink points) and grey (grey points) dolphin fishing activity in PV1

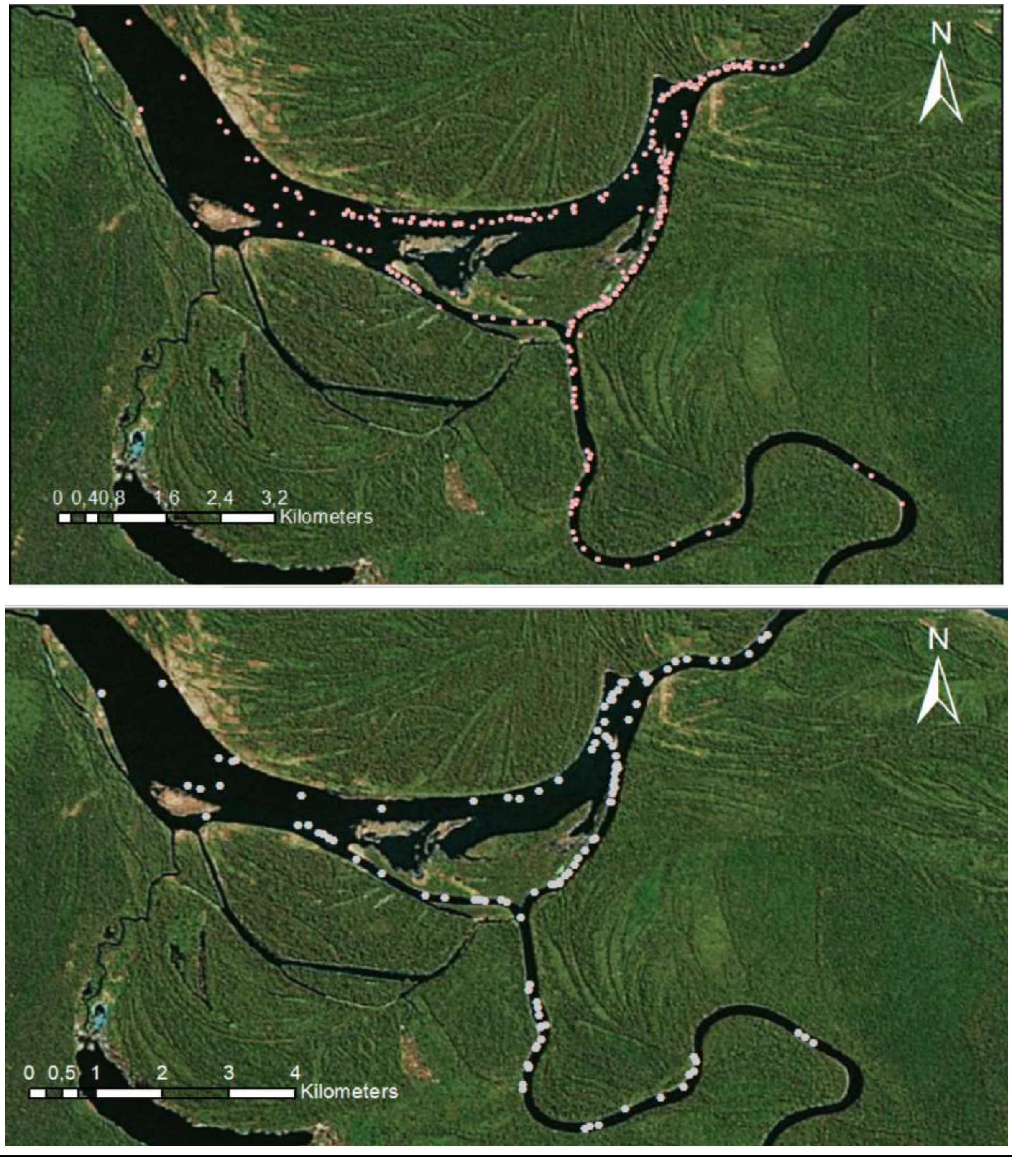
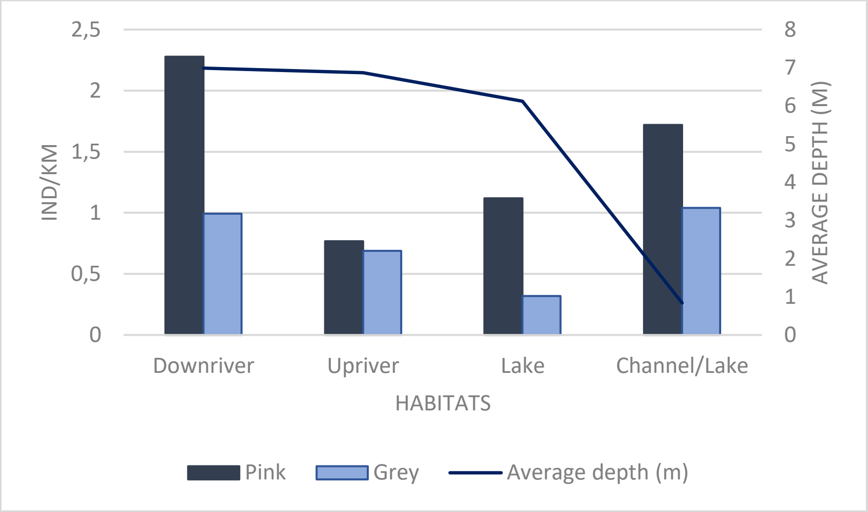


Figure 6. shows similar distribution of fishing activity for both species, with a significantly dense repartition downriver from the lake and from the channel. Considerably less greys were observed fishing in the lake, sparsely distributed similarly to pink dolphin fishing activity. Although both species occurred on the upriver transect, observations were far

more numerous downriver past the PV1 station. Clearly identifiable is the aggregation of both species close to river edges rather than at the centre of water bodies, especially in the lake. However, many anomalies and recording errors are likely to have occurred when reporting GPS points of each dolphin group observed.

Figure 7. Relationship between depth and dolphin fishing behaviour in PV1



The chi-square test was used to analyse if there is a was a statistically significant difference in mean abundance of the pink and grey river demonstrating dolphin fishing behaviour within the different habitat types at PV1.

The statistical hypotheses for both species were:

Null Hypothesis (H0): There is no statistically significant difference in mean dolphin abundance of fishing behaviour within the four habitat types.

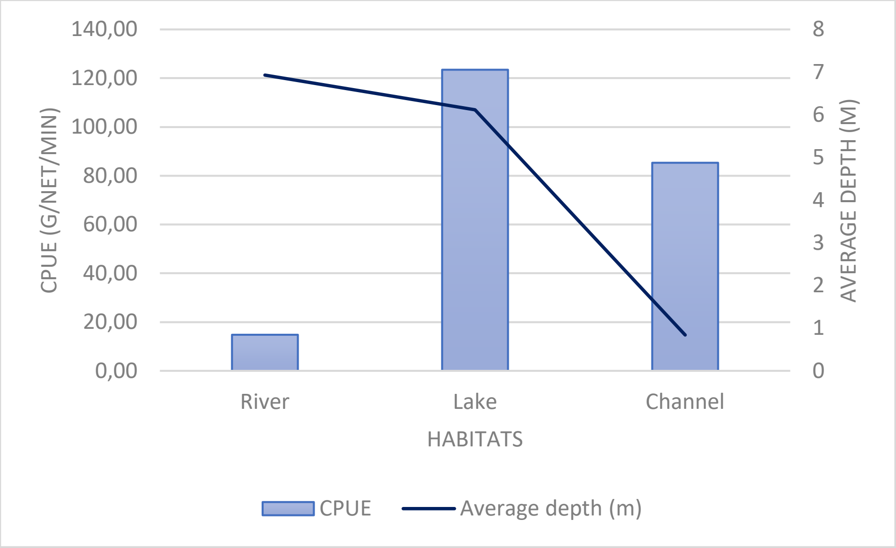
Alternative Hypothesis (H1): There is a statistically significant difference in mean dolphin abundance of fishing behaviour within the four habitat types.

There was found to be a statistically significant difference in the mean abundance of both species recorded fishing ($\chi2=24$, df=3 $P< 0.01$) within the four different habitat types, so the Null Hypothesis can be rejected for both species in favour of the Alternative Hypothesis

Similar comparisons can be made between the abundance of dolphins showing fishing behaviour and water depth (Figure 7.). Indeed, although fishing behaviour was mostly recorded in the downriver habitat for pink dolphins (2.28) where depth is greatest, the second highest levels of fishing behaviour were recorded in the channel and the mouth of the lake combined (channel/Lake) (1.72) where depth was the lowest. Grey dolphin fishing behaviour abundance was, surprisingly, the highest in the channel/lake (1.04).

3.2.2 Fish abundance & depth

Figure 8. Relationship between fish abundance and habitat water depth in PV1



Calculating the catch per unit effort (CPUE) can enable approximate estimations of fish abundance within each of the habitats covered by this year's fishing surveys. Using available fishing data collected during my time at PV1, the number of grams of fish caught per min per net of the same size was calculated (Appendix II & IV).

The chi-square test was used to analyse whether the variation between the observed fish frequencies of can be accounted for by sampling error or whether there truly is a significant difference between the frequencies in each habitat.

The statistical hypotheses were:

Null Hypothesis (H0): The observed frequencies are homogeneous, and the departure is merely due to sampling error or scatter.

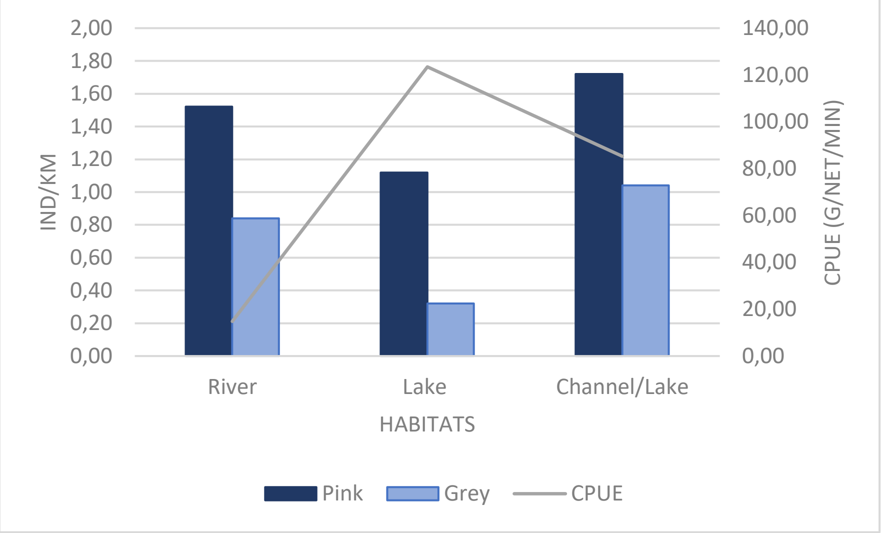
Alternative Hypothesis (H1): The observed frequencies depart from those expected of a homogeneous distribution by an amount that cannot be explained by sampling error.

There was found to be a statistically highly significant departure from homogeneity between the four habitats ($\chi 2$=81.57, df=2 P< 0.01), where fish abundance was found higher in the lake and the channel than expected, we may infer that there are significantly more fish in the lake than any other habitat in favour of the Alternative Hypothesis.

The CPUE was highest in the lake with approximately 123.5 g/min of fish caught, and lowest in the river with 14.8 g/min of fish caught (Figure 8.). A negative relationship is found between fish abundance and average water depth.

3.2.5 Dolphin behaviour & fish abundance

Figure 9. Relationship between fish and dolphin fishing behaviour abundance



Comparisons between fish and dolphin abundance are complicated as fishing surveys remained stationary along any area of each habitat. Furthermore, fishing surveys along the channel may not account for fish presence at the mouth of the lake (channel/lake habitat) as dolphin surveys included. Nevertheless, comparing both variables can indicate potential patterns of dolphin distribution and behaviour.

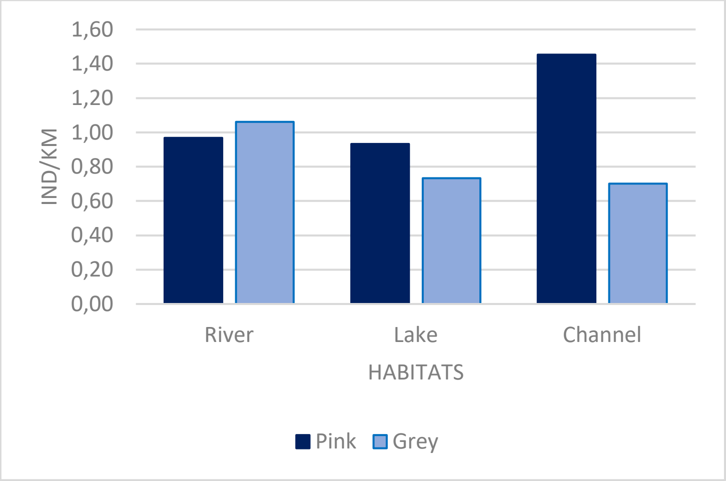
Figure 9. shows that the average amount of fish caught per hour per net in a habitat does not seem to correlate with the number of dolphins present fishing. No relationship has been found between these variables in this study.

3.2.6 PV2 station

3.2.7 Dolphin abundance

As I was stationed almost exclusively at PV1 station, water depth data could not be recorded at PV2 station and could not enable me to perform the same comparisons as with PV1.

Figure 10. Mean abundance of two dolphin species in three habitat types in PV2



The chi-square test was used to analyse if there is a was a statistically significant difference in mean abundance of the pink and grey river dolphins within the different habitat types at PV2.

The statistical hypotheses for both species were:

Null Hypothesis (H0): There is no statistically significant difference in mean dolphin abundance within the three habitat types.

Alternative Hypothesis (H1): There is a statistically significant difference in mean dolphin abundance within the three habitat types.

There was found to be a statistically significant difference in the mean abundance of both species ($\chi 2=16.8$, df=2 $P< 0.01$) within the three different habitat types, so the Null Hypothesis can be rejected for both species in favour of the Alternative Hypothesis

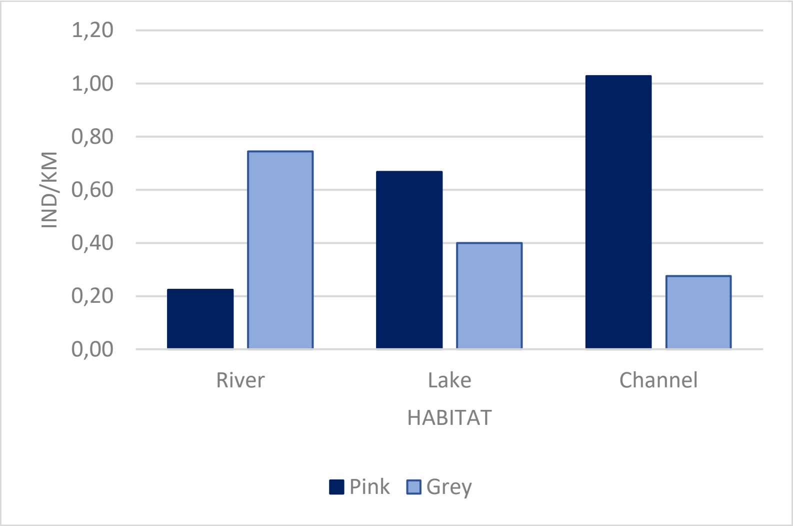
As demonstrated by Figure 10., the abundance of pink dolphins was highest in the channel (1.45) and the lowest in the lake (0.93). Contrastingly, grey dolphins were least abundant in the channel (0.70), closely followed by abundance found in the lake (0.70), and most abundant in the river (1.06).

3.2.8 Dolphin behaviour

Figure 11. GPS coordinates of observed pink (pink points) and grey (grey points) dolphin fishing activity in PV2

The maps shows quite contrasting occurrences of fishing activity between the two species of dolphins. Grey dolphins were observed predominately fishing along the main river whilst avoiding most of the channel and lake. Contrastingly, pink dolphins were observed mainly at the start and along the channel and lake. Along the main river, pink dolphins are unevenly and sparsely distributed.

Figure 12. Fishing behaviour of both species in PV2



The chi-square test was used to analyse if there is a was a statistically significant difference in mean abundance of the pink and grey river dolphin demonstrating fishing behaviour within the different habitat types at PV2.

The statistical hypotheses for both species were:

Null Hypothesis (H0): There is no statistically significant difference in mean dolphin abundance of fishing behaviour within the three habitat types.

Alternative Hypothesis (H1): There is a statistically significant difference in mean

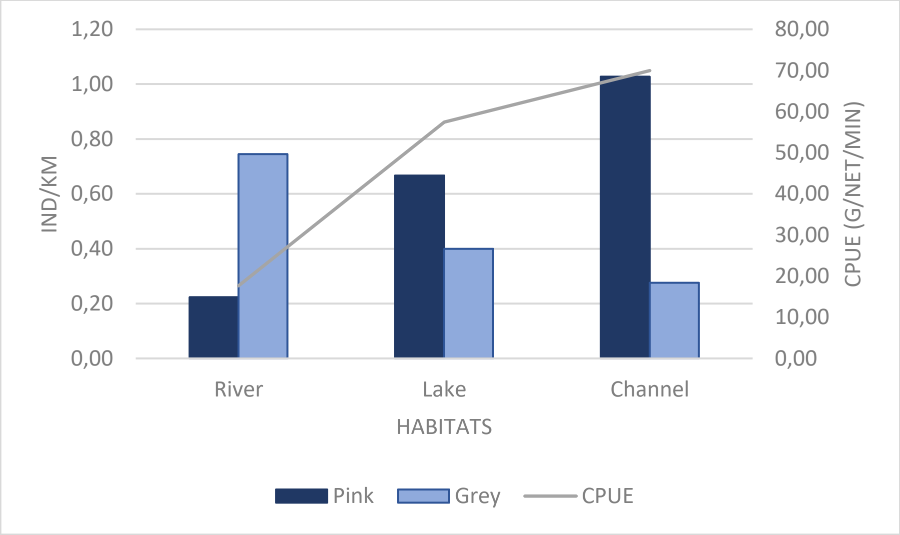
dolphin abundance of fishing behaviour within the three habitat types.

There was found to be a highly statistically significant difference in the mean abundance of both species recorded fishing ($\chi 2=72.3$, df=2 $P< 0.01$) within the three different habitat types, so the Null Hypothesis can be rejected for both species in favour of the Alternative Hypothesis.

The abundance of pink dolphins showing fishing behaviour in Figure 12. was highest in the channel (1.03) and lowest in the river (0.22). Inversely, fishing behaviour of greys was the most abundant in the river (0.74) and lowest in the channel (0.28). Although pink dolphins were the most observed in PV2, fishing behaviour in the river was even lower than grey dolphin fishing behaviour in the channel.

3.2.9 Dolphin behaviour & fish abundance

Figure 13. Relationship between fish and dolphin fishing behaviour abundance in PV2



The chi-square test was used to analyse whether the variation between the observed frequencies can be accounted for by sampling error or whether there truly is a significant difference between the frequencies in each habitat.

The statistical hypotheses were:

Null Hypothesis (H0): The observed frequencies are homogeneous, and the departure is merely due to sampling error or scatter.

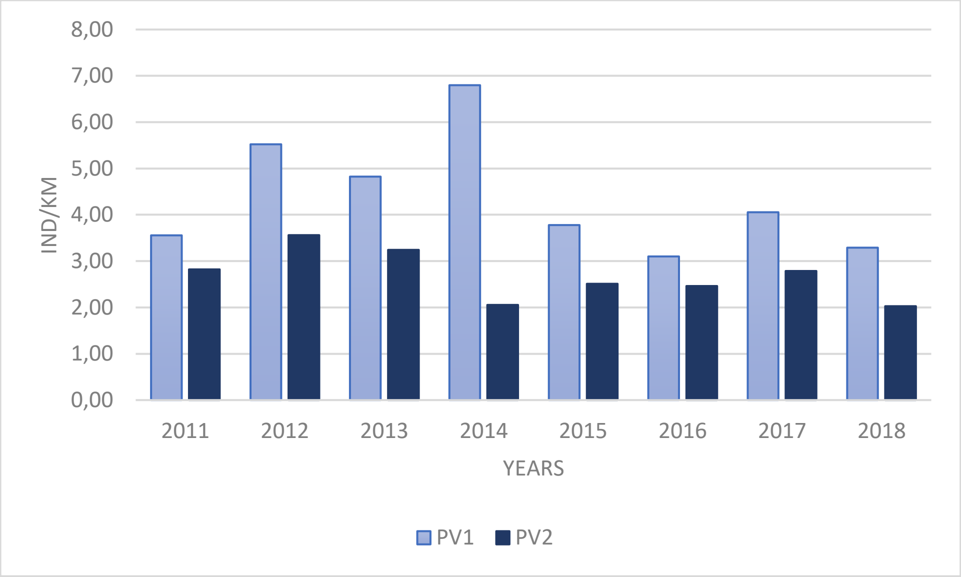
Alternative Hypothesis (H1): The observed frequencies depart from those expected of a homogeneous distribution by an amount that cannot be explained by sampling error.

There was found to be a statistically significant departure from homogeneity between the three habitats ($\chi2=30.88$, df=2 $P< 0.01$), where fish abundance was found higher in the channel and the lake than expected, we may infer that there are significantly more fish in the channel than any other habitat in favour of the Alternative Hypothesis.

Figure 13. shows that PV2 presents a positive relationship, where the more grams of fish are caught, the more pink dolphins there are. Indeed, the CPUE in the river, in comparison to the lake and channel (57.48 & 69.96 g/min), was significantly lower with 17.65 g of fish caught per minute (Appendix II). An inverse relationship appears for grey dolphins, where the lower CPUE is, the more grey dolphins there are.

3.3 Past data

Figure 14. Overall dolphin abundance from January 2011 to July 2018 at both study sites



Across both sites, Figure 14 shows that high fluctuations in dolphin abundance exist, with a record high in 2014 at PV1, and lowest levels at PV2. PV1 study site has had considerably higher dolphin abundance across all years in comparison to PV2. Overall, dolphin abundance appears to be decreasing along the Samiria river.

4. Discussion

4.1 Mean abundance

Overall, dolphin abundance for both species was significantly higher at PV1 than PV2, likely caused by PV2 observed rapid receding water levels impacting upon survey efficacity during the study period. Pink dolphins were more frequently observed and abundant than greys at both sites. PV1 also presented the highest calculated fish abundance in the lake across the entire study period and out of all habitats surveyed. Trends in dolphin abundance from 2011 to 2018 reveal fluctuations across years and overall declines between the two sites, with PV1 largely and continuously surpassing PV2 in dolphin abundance. Intensified variations in water levels have been known to impact dolphin population, where severe droughts result in decreasing numbers, whereas floods cause numbers to steadily increase (Bodmer et al., 2014). Indeed, Figure 14. shows that, between 2011 and 2012, which were years of record high floods, dolphin abundance in both sites increased. High floods also resulted in an increasing fish population with an associated increase of dolphins in 2012 (Bodmer et al., 2014). Water levels were still unusually high in 2013 but less so than the two years before, potentially explaining the slight decrease in dolphin abundance across the two sites (Bodmer et al., 2014).

4.2 Habitat preference

Previous studies have shown and contributed different observations in the study of habitat preferences in river-dwelling dolphins. Some have argued that preferences lie in quiet waters near shore, river banks, and wide lagoons with shaded calm deep water, whilst others noted that dolphins appeared to prefer areas of high turbidity, junctions of rivers and sharp river bends (McGuire & Winemiller, 1998).

This study found a statistically significant difference in the mean abundance of both species across the four different habitat types at PV1. Both species were found in significantly higher densities downriver, where depth was recorded to be the deepest in comparison to all other habitats. This preference of deep water contradicts most common finding; Alston (2015) found that pink river dolphins were at their highest densities in the shallowest habitats during the dry season. However, no clear relationship appeared to exist between average water depth and dolphin abundance for both species, suggesting that other factors may be more influential in determining patterns of dolphin distribution.

The dolphin's high abundance downriver may be explained by the river's junction with the channel at PV1, as well as a meeting of rivers further downriver (10k down at the new PV1 site). Known as confluences, the merging of white and black acidic waters creates a visible ecological transition offering high productivity to both rivers' fish assemblages. Large rivers merging (observed downriver from our study site), has been known to contribute to the persistence of unique biotas of rivers, over considerable distances downstream (Röpke et al., 2016). Indeed, what appears as 'swirling currents' are often common at confluences (McGuire & Winemiller, 1998), a phenomenon observed downriver from the lake where fishing activity was the most densely distributed (Figure 6.). Confluences were not observed upriver from our study site, where pink dolphin abundance was the lowest in comparison to all other habitats.

Another potential factor in influencing higher densities at higher depths, is the current. During the study period, it was noted that the current was particularly slow, therefore not necessarily impacting the botos usual energy requirements along the river. High current areas often result in elevated energy costs for pink dolphins which resulting in lower dolphin densities in these areas (Martin et al., 2004). Exceptions to this arises only when confluences and river merging are described (Martin et al., 2004). Two pink dolphins were even recorded mating downriver from the channel, representing a very rare sighting, especially in the main river where currents are supposedly the strongest.

The second highest pink dolphin abundance was observed in the channel/lake habitat where depth is at its shallowest, followed by abundance in the lake. The channel/lake habitat includes the mouth of the channel and junction with the downriver transect (confluence) as well as the start of the lake. As fishing was the most observed behaviour amongst both species, dolphin distribution and abundance along habitats was most likely influenced by prey distribution. In Figure 6, observed fishing activity was relatively high for both pink and grey dolphins throughout the river down from the lake, where fish populations may have migrated down. Indeed, CPUE was recorded to be the highest in the lake and may not have accounted for the movement of fish between the lake and the adjacent river.

Grey dolphins have been shown to have a higher preference for deep water habitats than the pink dolphins due to their fast-swimming ability, thus making them more able to exist in areas of high water flow (Martin et al., 2004). Our study agrees with this, as the highest density of grey dolphins was recorded downriver where depth is the greatest. However, similarly to pink dolphins, grey dolphin abundance does not seem to be dictated by depth in each habitat which contradicts many of the previous studies. In comparison to previous studies where abundance was highest in the deepest habitats, the second highest abundance of this species was calculated to be in the channel/lake habitat, results possibly due to the channel's junction with two different habitats (mouth of the lake and river). Other surveys in Colombia, Peru and Venezuela have also demonstrated that the estimated population size was higher in main rivers and confluences in comparison to other habitats (Gomez-Salazar et al., 2012).

Finally, similarities in habitat preference were found between the two species of dolphins. This potentially suggests that the pink and grey dolphin co-exist in closer proximity than originally thought. Martin el al. (2004) also found that the two different cetaceans showed more similarities than differences in habitat preference along main rivers.

At the PV2 site, our study found a statistically significant difference in the mean abundance of both species within the three different habitat types. The abundance of pink dolphins was the highest in the channel. Although no depth measurements were recorded during this study period, similar trends in abundance were found in comparison to a 2015 study performed at the same site during the same months (Alston, 2015). When keeping in mind that depth is recorded to be the lowest in the channel and deepest in the river, depth at PV2 may have more of an influence on dolphin population than at PV1 station. Indeed, as depth decreased at PV2, the abundance of pink dolphins increased, in agreement with our study results (Alston, 2015). Abundance was second highest in the river, and lowest in the lake which may have been the result of (observed) very low depth levels in the lake, of which portions became dry near the end of the expedition.

In comparison, grey dolphins were least abundant in the channel and most abundant along the river. Indeed, grey dolphin abundance was higher than pink dolphin abundance in the river. When considering depth records from 2015 in identical habitats, it suggests that there may be a positive relationship between water level and grey dolphin abundance (where abundance increases with depth) (Alston, 2015). However, water levels fluctuate across years, therefore the relationship between grey dolphin abundance and depth are only assumptions.

When recording dolphins along our study site, miscalculations and double counting may have occurred and may not have accounted for pods routinely returning or remaining in the same habitats. As McGuire & Henningsen's (2010) observations conclude, identified dolphins were not seen moving between different tributaries of the Marañón River, and were instead always observed within the same system. For instance, 33% of dolphins sighted more than once in a lake were never seen outside of that lake (McGuire & Henningsen 2010).

4.3 Fishing behaviour & depth

This study found a statistically significant difference in the mean abundance of both species fishing within the four different habitat types at PV1. The density of pink dolphin fishing behaviour was the highest downriver, observed also in Figure 6., where fishing activity is more densely distributed in that area. The second highest density was in the channel/lake, where the mouth of the lake and the intersection of the channel with the river could have explained higher fish concentrations and consequently higher fishing activity. A study recorded, for instance, a large group of 19 dolphins observed during falling water, seasonal phenomenon corresponding with our study period, at the confluence of the river and a small channel, feeding on a significant number of medium-sized fish travelling down from the channel to the river (Aliaga-Rossel, 2002). Similar observations to that of pink dolphin fishing activity are seen for grey dolphins that appear more sparsely distributed in the lake (Figure 6.) where fishing behaviour density was the lowest.

There was a statistically significant difference in the mean abundance of both species recorded fishing within the three different habitat types at PV2. The density of pink dolphin fishing behaviour was highest in the channel and lowest in the river. Dense aggregation of pink dolphins is found at the mouth of the channel, as displayed in Figure 11. Contrastingly, grey dolphins fishing were most abundant in the river and least in the channel. It is found that the seasonality of water depth impacts diets of river dolphin, which are responding to shifts in available habitats. During high water periods, dolphin diet is said to be broader because fish become more difficult to find and catch in the expanding aquatic habitat (McGuire & Winemiller, 1998). Inversely, dolphins potentially become more selective foragers in water receding months with prey becoming constricted and confined to specific areas, predictable and consequently easier to catch (McGuire & Winemiller, 1998). In this instance, pink dolphins at PV2 may have taken advantage of higher fish densities in the shallowest habitat (channel) made possible by their morphological adaptation to confined areas, increasing their likelihood of finding fish. Greys, on the other hand, remained in more accessible habitats.

4.4 Prey abundance & habitat

As both dolphin species abundance and fishing behaviour do not appear to show a relationship with depth, looking at fish density may offer further insight into dolphin presence and movement. Indeed, food availability constitutes an important environmental component, specifically fish availability, which is thought to influence movements of river dolphins between habitat types (McGuire & Winemiller, 1998). Our results at PV1 have shown there were significantly more fish in the lake than any other habitat, and significantly less fish in the river than expected. Ultimately, in relation to depth in each habitat, fish abundance does not seem to be directly dictated by water levels. Depth does not seem to be an influencing factor as fishes were caught in great quantities in both relatively deep waters like the lake and very shallow waters like the channel. However, along the Samiria river reports have indicated that, during water receding months, fish populations travel out of small rivers and into larger ones, migrating through channels, lakes and confluences (Bodmer et al., 2014). During the dry season, receding shorelines leave most vegetation stranded and contribute to the decline of structural cover for fish, forcing them to aggregate and become concentrated in a more open environment (Petry et al., 2003). Indeed, our study period (June-August) may have influenced the CPUE data we collected, since, with the dry season falling between June and December, fish were only just starting to migrate back into deeper main rivers through channel and lake connections (McGuire & Winemiller, 1998). Depth has been known to influence levels of fish abundance in survey samples, where depending on the season, available fish habitat declines or expands. For instance, during the flood season, abundance is reported to be lower in response to aquatic habitat expansion reducing per-unit-area densities of fishes (Röpke et al., 2016). Additionally, McGuire & Winemiller (1998) recorded gill net CPUE to be at its maximum in lagoons (lentic bodies or oxbows located in the river flood plain) during low water, in agreement with our results at PV1 of a similar water body (lake). Further evidence has found a tendency towards greater fish biomass caught in lakes associated with the habitat’s greater environmental stability and lower water level variations in the Brazilian Amazon (Silvano et al., 2000).

The study site at PV2 was high up the Samiria river and the research boat had to travel back down the river to be stationed at PV1, as water levels were receding seemingly faster than further down the river. Our CPUE results may suggest that the rate at which water depths were decreasing was affecting fish populations faster. Indeed, PV2 had a lower recorded fish abundance in comparison to PV1, where there was found to be significantly more fish in the channel than any other habitat. This could possibly indicate that fish were already migrating out of the lake through the channel faster than at PV1, to reassemble into the deeper main river. However, results could likely be influenced by the reduced habitat available for fish in the shallowest habitat (channel) increasing the likelihood of catch through gill net.

4.5 Fishing behaviour & prey abundance

According to McGuire, T. & Winemiller, K. (1998), river dolphins are top predators known to prey upon more than 50 species of fish from 19 families, thus potentially capable of influencing entire fish communities and structure of aquatic systems. In relation to dolphin fishing behaviour and prey abundance, elements such as prey size, habitat preference, and capture efficiency have proven to be more important for dolphins than prey taxonomic identity. Indeed, fish availability is believed to be driving river dolphin movement between habitat types (Gomez-Salazar et al., 2011). As fish abundance declines with periods of falling and low water depths, ease of capture is increased for predators as prey is spatially concentrated in reduced water volume which would explain a higher CPUE in the channel than the river at PV2. Other findings, potentially indicative of PV1 dolphin fishing activity, have reported on the accumulation of fish species in lakes and close to river banks along main rivers and channels, providing vegetative refuge, resources and slower currents (Goulding, 1980). Fish species diversity has also been associated with shorelines' macrophytes structural complexity and floating vegetation, along with dense and complex root systems providing shelter against predation (Petry et al., 2003). Indeed, at PV1, both dolphin species showed similar fishing activity observed to occur closer to river edges rather than in the centre of water bodies (Figure 6.). Additionally, the highest fish abundances were found in lake and channel habitats at both PV1 and PV2, areas characterized by slower currents and of confined available habitat. At PV1, however, the relationship between the abundance of dolphin species fishing and fish CPUE did not exist, most likely due to the study's very limited fish samples and differing survey methods making accurate spatiotemporal comparisons unlikely.

4.6 Evaluation & limitations

Our study was carried out between June and August only, where the falling water season was just beginning and cannot be representative of yearlong trends in dolphin distribution, fish abundance and water depth.

When measuring water depth using the fish finder, it was desired to measure fish abundance at the same time, but the equipment was out of date and needed replacing to provide accurate readings of fish presence during dolphin surveys. Thus, direct comparisons between fish and dolphin abundance could not be made as fish surveys were not always performed on the same day, time, and in the exact location along each habitat as the dolphin surveys.

Accurate weekly water depth estimations were also limited due to areas of the channel becoming inaccessible and river bends becoming dry. Comparisons with PV2 were impossible this year as daily depth measurements were not recorded on site.

As mentioned before, daily surveys attempted to record a total number of observed individuals and dolphin pods instead of counting the number of breaches. Errors in identifying behaviours as well as in estimating the correct number of dolphins by double counting are likely to have occurred.

Any comparisons between this study's results and previous years proved to be challenging due to discrepancies in sampling effort and habitats surveyed each year. As two sites (PV1 & PV2) along the river Samiria were discussed and compared in this study for the first time, comparisons of this distinction across years could not be done.

4.7 Conservation implications

The extent of the Amazon Basin and its uneven seasonal rainfall distribution contributes to inundating parts of the river system at different times, prolonging the duration of overall floods in the process (WWF, 2019). Cause for concern are recent models' predictions of intensification of the hydrological cycles in the western Amazon basin, fluctuating between the increased duration and severity of floods in the wet season, and the receding water levels and lower precipitation rates during the dry season (Bodmer et al., 2017). Resulting from consecutive years of greater than normal floods (2009-2015) and drought of 2010, abundance and distributional shifts in fish and terrestrial mammal populations have occurred (Bodmer et al., 2017). Terrestrial populations suffered decreases of up to 95% as flooding intensified, consequently impacting upon local people's livelihoods, initiating a shift in resource use towards greater reliance on fish (Bodmer et al., 2017). Contrastingly, as waters recede, a continuously increasing competition and predation upon restricted and condensed fish populations occurs between dolphins, wading birds and other aquatic predators, including local fishermen (Bodmer et al., 2014). For instance, river dolphins are known to selectively occur in areas where gill net deployment by fishermen is optimal (Martin et al., 2004). As droughts may become more severe, wildlife and people dependent upon the river's productivity and available habitat are likely to face increased pressure and fragmentation. Indeed, in 2009, fish mortality was high and required two years of intensive flooding for its population to recover to sustainable levels (Bodmer et al., 2017). Increased severity of floods may benefit fish reproductive capacity but can also make fish more difficult to prey upon by predators due to available habitat expansion. Droughts on the other hand can increase the likelihood of finding fish but reduce their capacity to recover. Thus, including spatial and temporal climatic variations, along with subsequent changes in wildlife distribution into frameworks of conservation planning, is vital in maintaining sustainable levels of biodiversity and human resource use in the area.

5. Conclusions

Conclusions drawn from this study have shown that the region appears to be an ecologically complex system, with differences in dolphin habitat preference and predatory behaviour between two relatively close sites along the Samiria River. The influence of fish abundance and depth on dolphin distribution has been shown to vary between sites, where pink dolphins may potentially take advantage of higher fish densities in shallow habitats at PV2, and where at PV1, both species present similarities in habitat preference and predatory behavior distribution. With dolphin and fish abundance recorded to be significantly greater at PV1 compared to PV2, seasonal fluctuations along the river need to be carefully monitored year-round. Indeed, the rate to which both sites will be affected by precipitation shifts and climate change is bound to differ. Fluctuating water levels are said to have a profound impact on dolphin distribution, allowing or preventing access into prey-rich areas, influencing abundance and migratory movement of fish populations (Martin et al., 2004). Although both dolphin species at PV1 do not seem to be dictated by water level differences across habitats, dolphin populations at PV2 may increasingly become so.

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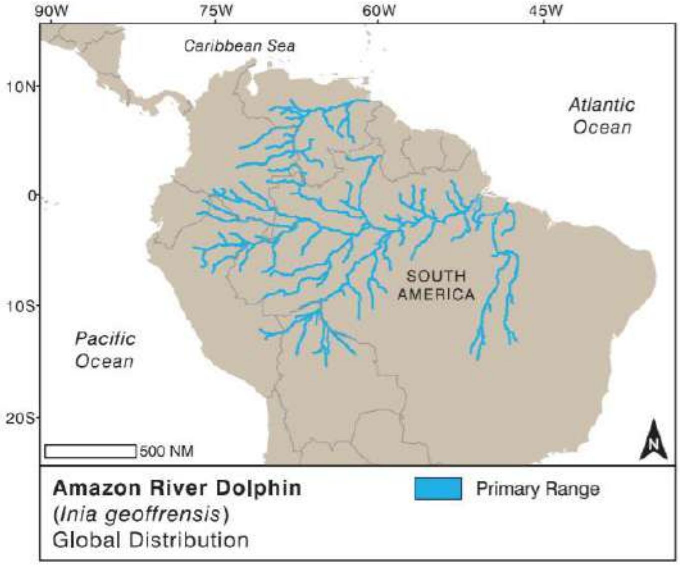
Appendix I: Species distribution maps

1) Boto distribution (da Silva & Martin, 2018):



2) Tucuxi distribution (Secchi, 2012):

Appendix II: Surveys

1) Dolphin data sheet example

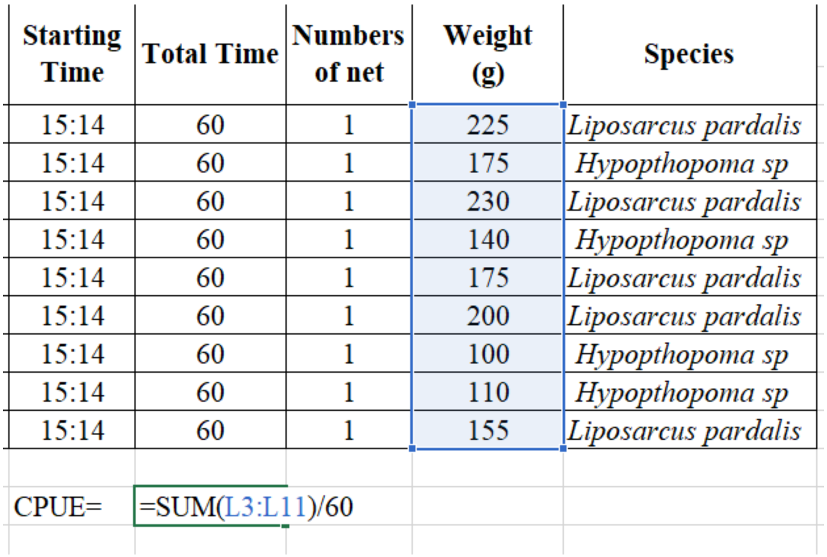
Zone or Pv	PV1
Date	14/07/2018
Transect (Up/Down)	Up
Body of Water	River
Start G.P.S (18M)	573842
Start G.P.S (UTM)	9482249
End G.P.S (18M)	571579
End G.P.S (UTM)	9478568
Distance travelled (km)	5
Weather conditions	Clear
Starting Time	09:19
Ending Time	10:10
Species	*Sotalia fluviatilis*
Group Size	4
Group Composition	
Baby	0
Young	1
Adult	3
Behavior	Fishing
Time	09:27
Location in the River (km)	0,545
Section of River	Center
GPS Point(18M)	573365
GPS Point(UTM)	9482068
Group (school/university)	School&Dissertation

No. Guides	1
No. Biologists	1
No. Students	11
No. Others	1

2) Fish data set example

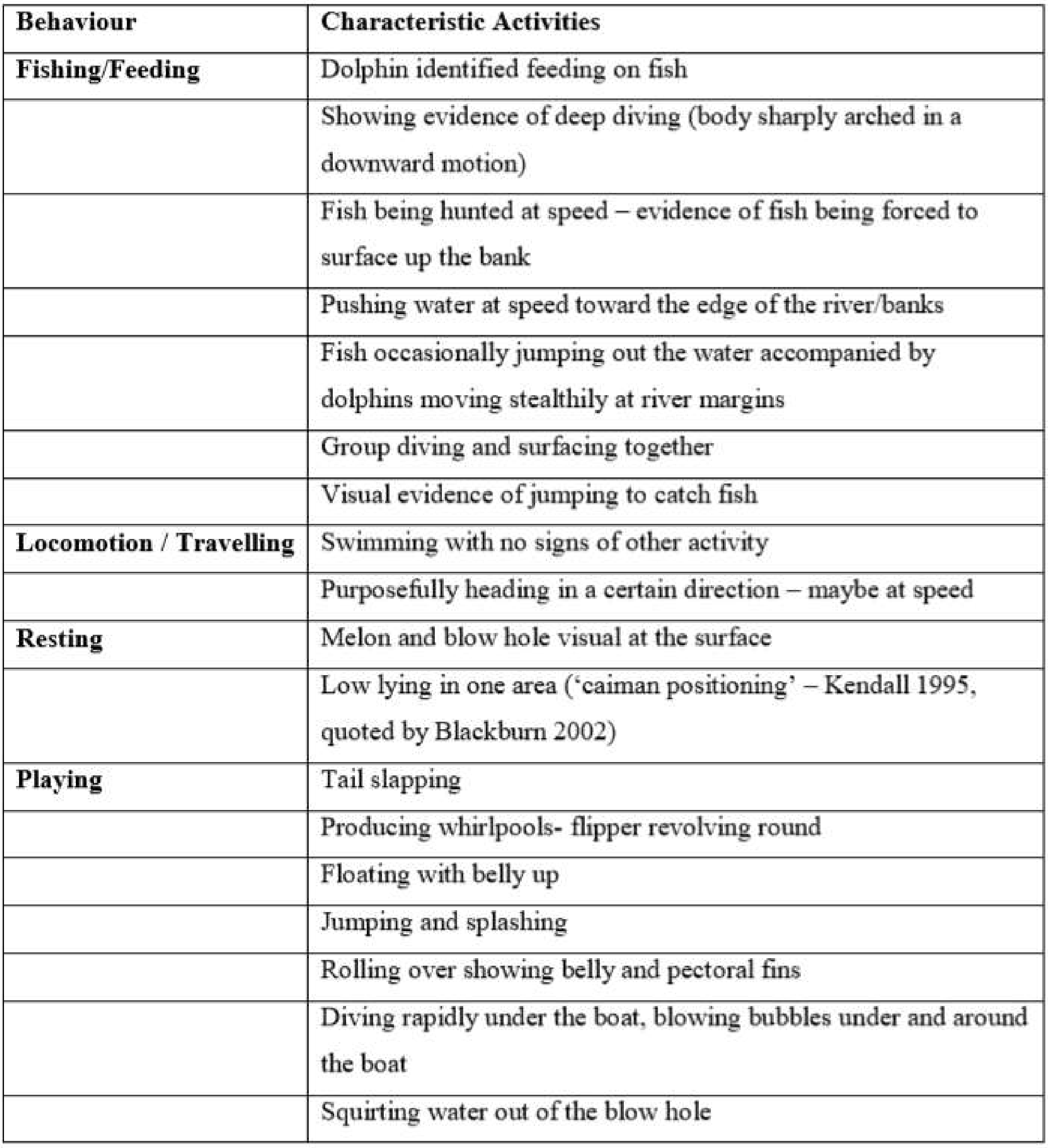
Zone or PV	Date	Body of Water	Starting Time	Total Time	Numbers of net	Weight (g)	Species
PV1	17/06/2018	River	15:14	60	1	225	*Liposarcus pardalis*
PV1	17/06/2018	River	15:14	60	1	175	*Hypopthopoma sp*
PV1	17/06/2018	River	15:14	60	1	230	*Liposarcus pardalis*
PV1	17/06/2018	River	15:14	60	1	140	*Hypopthopoma sp*
PV1	17/06/2018	River	15:14	60	1	175	*Liposarcus pardalis*
PV1	17/06/2018	River	15:14	60	1	200	*Liposarcus pardalis*
PV1	17/06/2018	River	15:14	60	1	100	*Hypopthopoma sp*
PV1	17/06/2018	River	15:14	60	1	110	*Hypopthopoma sp*
PV1	17/06/2018	River	15:14	60	1	155	*Liposarcus pardalis*

3) CPUE calculation example:

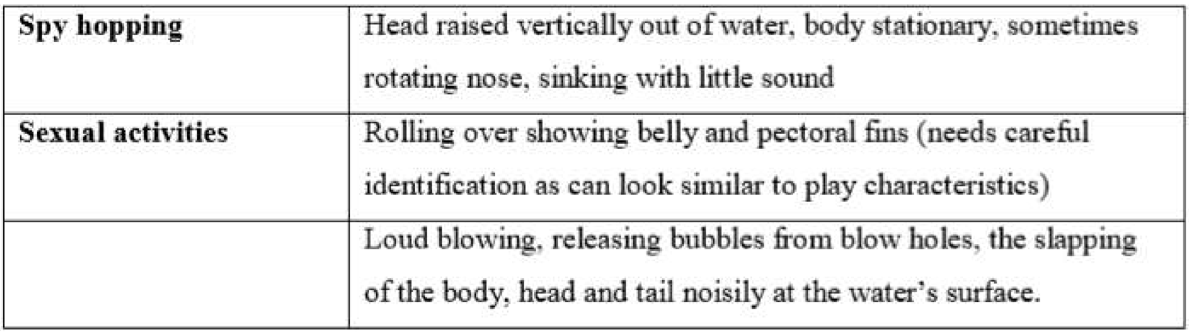


Starting Time	Total Time	Numbers of net	Weight (g)	Species
15:14	60	1	225	*Liposarcus pardalis*
15:14	60	1	175	*Hypopthopoma sp*
15:14	60	1	230	*Liposarcus pardalis*
15:14	60	1	140	*Hypopthopoma sp*
15:14	60	1	175	*Liposarcus pardalis*
15:14	60	1	200	*Liposarcus pardalis*
15:14	60	1	100	*Hypopthopoma sp*
15:14	60	1	110	*Hypopthopoma sp*
15:14	60	1	155	*Liposarcus pardalis*
CPUE=	=SUM(L3:L11)/60			

4) Blackburn 2002 Ethogram for the Boto (Pink dolphin)

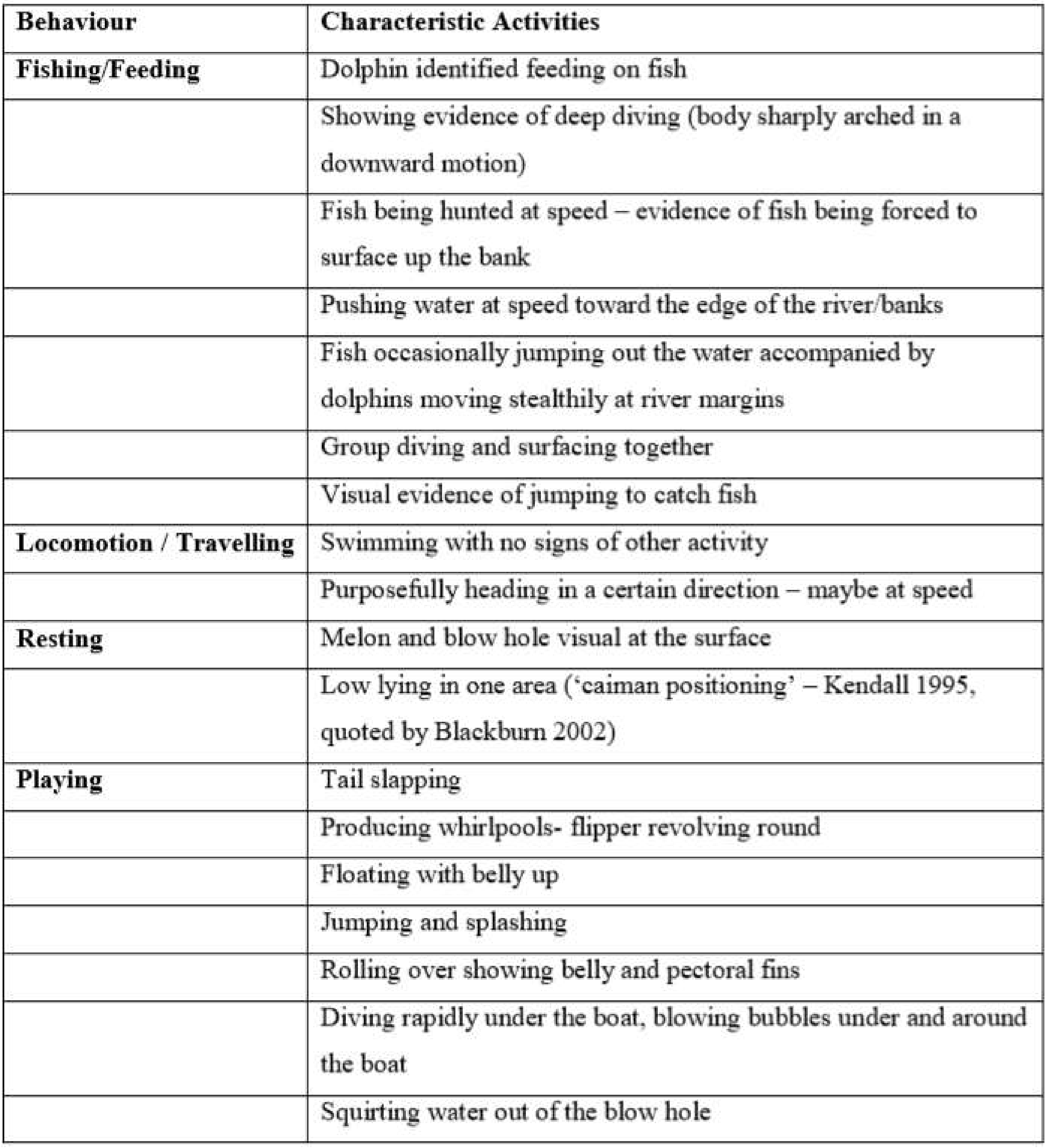


Behaviour	Characteristic Activities
Fishing/Feeding	Dolphin identified feeding on fish
	Showing evidence of deep diving (body sharply arched in a downward motion)
	Fish being hunted at speed – evidence of fish being forced to surface up the bank
	Pushing water at speed toward the edge of the river/banks
	Fish occasionally jumping out the water accompanied by dolphins moving stealthily at river margins
	Group diving and surfacing together
	Visual evidence of jumping to catch fish
Locomotion / Travelling	Swimming with no signs of other activity
	Purposefully heading in a certain direction – maybe at speed
Resting	Melon and blow hole visual at the surface
	Low lying in one area ('caiman positioning' – Kendall 1995, quoted by Blackburn 2002)
Playing	Tail slapping
	Producing whirlpools- flipper revolving round
	Floating with belly up
	Jumping and splashing
	Rolling over showing belly and pectoral fins
	Diving rapidly under the boat, blowing bubbles under and around the boat
	Squirting water out of the blow hole



Spy hopping	Head raised vertically out of water, body stationary, sometimes rotating nose, sinking with little sound
Sexual activities	Rolling over showing belly and pectoral fins (needs careful identification as can look similar to play characteristics)
	Loud blowing, releasing bubbles from blow holes, the slapping of the body, head and tail noisily at the water's surface.

3) Blackburn 2002 Ethogram for the Tucuxi (Grey dolphin)



Behaviour	**Characteristic Activities**
Fishing/Feeding	Dolphin identified feeding on fish
	Showing evidence of deep diving (body sharply arched in a downward motion)
	Fish being hunted at speed – evidence of fish being forced to surface up the bank
	Pushing water at speed toward the edge of the river/banks
	Fish occasionally jumping out the water accompanied by dolphins moving stealthily at river margins
	Group diving and surfacing together
	Visual evidence of jumping to catch fish
Locomotion / Travelling	Swimming with no signs of other activity
	Purposefully heading in a certain direction – maybe at speed
Resting	Melon and blow hole visual at the surface
	Low lying in one area ('caiman positioning' – Kendall 1995, quoted by Blackburn 2002)
Playing	Tail slapping
	Producing whirlpools- flipper revolving round
	Floating with belly up
	Jumping and splashing
	Rolling over showing belly and pectoral fins
	Diving rapidly under the boat, blowing bubbles under and around the boat
	Squirting water out of the blow hole

Appendix III: PV1 Behaviour Data

1) Total pink river dolphin behaviour observations in each habitat (PV1)

	Travelling	Fishing	Resting	Playing	Mating
Downriver	48	296	29	24	2
Upriver	32	69	18	7	0
Lake	20	84	1	29	0
Channel/Lake	9	43	0	4	0
Totals	**109**	**492**	**48**	**64**	**2**

2) Total grey river dolphin behaviour observations in each habitat (PV1)

	Travelling	Fishing	Resting	Playing	Mating
Downriver	32	129	3	11	0
Upriver	19	62	7	0	0
Lake	18	24	0	6	0
Channel/Lake	1	26	0	0	0
Totals	**70**	**241**	**10**	**17**	**0**

Appendix VI: Raw data

1) Depth day by day

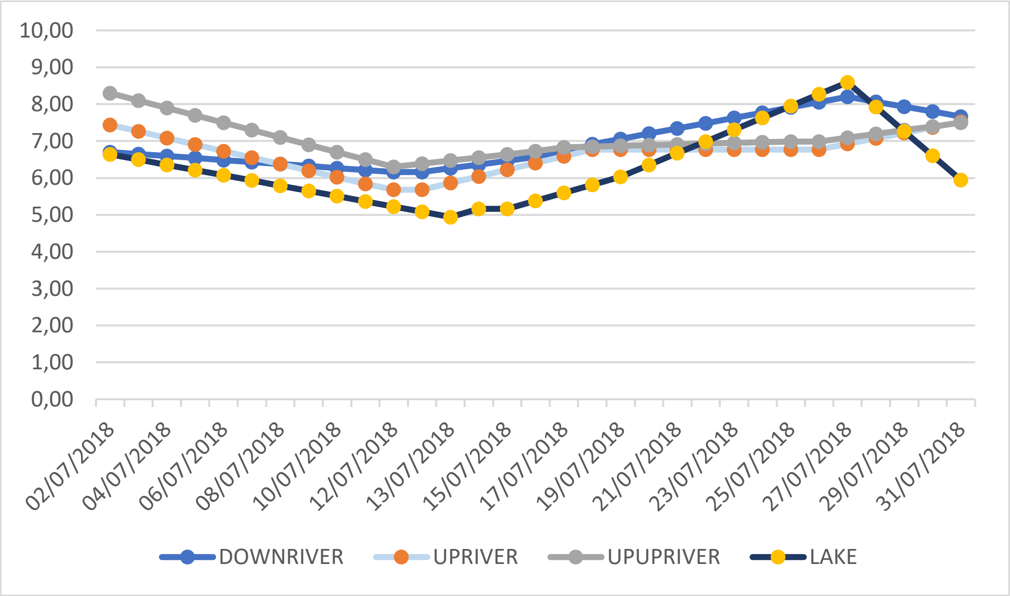
	DOWNRIVER	UPRIVER	UPUPRIVER	LAKE	CHANNEL
02/07/2018	6,70	7,44	8,30	6,64	3,24
03/07/2018	6,65	7,26	8,10	6,50	3,08
04/07/2018	6,59	7,08	7,90	6,36	2,92
05/07/2018	6,54	6,91	7,70	6,21	2,75
06/07/2018	6,49	6,73	7,50	6,07	2,59
07/07/2018	6,43	6,55	7,30	5,93	2,43
08/07/2018	6,38	6,37	7,10	5,79	2,27
09/07/2018	6,32	6,20	6,90	5,65	2,11
10/07/2018	6,27	6,02	6,70	5,51	1,94
11/07/2018	6,21	5,84	6,50	5,36	1,78
12/07/2018	6,16	5,68	6,30	5,22	1,62
12/07/2018	6,16	5,68	6,39	5,08	0
13/07/2018	6,26	5,86	6,47	4,94	0
14/07/2018	6,36	6,04	6,56	5,16	0
15/07/2018	6,47	6,23	6,64	5,16	0
16/07/2018	6,57	6,41	6,73	5,38	0
17/07/2018	6,67	6,59	6,83	5,59	0
18/07/2018	6,91	6,77	6,85	5,81	0
19/07/2018	7,06	6,77	6,87	6,03	0
20/07/2018	7,20	6,77	6,89	6,35	0
21/07/2018	7,34	6,77	6,91	6,67	0

22/07/2018	7,49	6,77	6,93	6,99	0
23/07/2018	7,63	6,77	6,95	7,31	0
24/07/2018	7,77	6,77	6,97	7,63	0
25/07/2018	7,91	6,77	6,99	7,95	0
26/07/2018	8,06	6,77	6,99	8,27	0
27/07/2018	8,20	6,92	7,09	8,59	0
28/07/2018	8,07	7,07	7,19	7,93	0
29/07/2018	7,93	7,22	7,30	7,27	0
30/07/2018	7,80	7,37	7,40	6,60	0
31/07/2018	7,66	7,52	7,50	5,94	0
01/08/2018	7,53	7,67	7,60	0,00	0

2) Average depth (Upriver habitats combined)

Habitat	**Downriver**	**Upriver**	**Lake**	**Channel**
Average depth (m)	6,99	6,87	6,12	0,84

3) Graph showing water level trends over the study period:



4) Catch Per Unit Effort calculations from 13/06/2018 to 31/07/2018

	PV2			***PV1***		
Habitats	**LAKE**	**CHANNEL**	**RIVER**	**LAKE**	**CHANNEL**	**RIVER**
	32,50	152,08	38,50	3,75	74,00	25,17
	26,67	147,73	17,50	26,67	58,87	31,17
	141,58	147,60	7,50	19,85	46,74	12,75
	4,83	109,20	7,08	45,17	48,17	6,06
	82,50	79,58		195,54	80,91	5,63
	68,75	61,25		151,95	57,66	14,93
	100,83	16,50		245,45	123,89	15,00
	39,96	37,72		167,63	192,30	14,08
	53,42	7,50		288,72		2,50
	23,75	49,83		545,08		30,63
		104,50		73,31		5,49
		49,58		69,88		12,08
		13,17		233,08		11,25
		42,62		7,92		14,29
		30,60		7,42		24,53
				8,80		17,90
				8,75		9,87
						5,58
						3,92
						7,08
						40,83

5) CPUE average per habitat

	LAKE	**CHANNEL**	**RIVER**
PV1	123,47	85,32	14,80
PV2	57,48	69,96	17,65