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Abstract

Anthropogenic disturbances on wildlife populations are a growing problem worldwide and populations of large carnivores are often subject to human wildlife conflicts. Some disturbances are well documented, for example habitat destruction or poaching. Non-lethal disturbances, for instance boat-traffic, are less widely recognized. The order Crocodilia are characterised as large, semi-aquatic carnivores living in freshwater habitats in the tropical and warm temperate regions of the world. Response to disturbances such as boat-traffic can directly affect the survival of aquatic animals. This study investigates the effect of non-lethal human disturbances on the abundance and distribution of saltwater crocodiles (*Crocodylus porosus*) in the Kinabatangan River, Borneo. The results indicated that these disturbances have a small effect on the distribution and number of crocodiles. It also indicated that larger crocodiles are more sensitive and wary regarding boat traffic and fishing. Although, it is likely that these studied disturbance factors are far from the only factors affecting crocodile abundance and distribution.

Key words: Saltwater crocodile, estuarine crocodile, Kinabatangan River, human disturbances, night counts

Introduction

Crocodilian ecology and threats

The order crocodilia consists of 23 species of crocodiles, alligators, caimans and gharials. They are characterised as large, semi-aquatic carnivores living in freshwater habitats in the tropical and warm temperate regions of the world. (Martin 2008, Webb *et al.* 2010). Many of the crocodilian populations where subjected to over-hunting in the 20th century and some species are still critically endangered due to this. Other populations and species have gone through remarkable recoveries. (Martin 2008). Many species are also exploited for their skin. Moreover, Crocodilians are highly threatened by alteration and loss of habitats. Crocodilians depend on wetland habitats and the species' considerable size and its increase in size during maturation makes them dependent of both large and diverse wetlands. For large populations to persist hundreds of square kilometers of undisturbed or low disturbed wetlands is usually required. The most common reason for habitat loss, destruction or alteration of wetlands is drainage, infilling, deforestation, pollution and conversion to agricultural land (Webb *et al.* 2010). Crocodilian populations easily become threatened by humans and the level of threat is proportionate to the density of humans (Ross 1998). On the other hand, many crocodilian species are ecologically robust and relatively adaptable to changes in their ecosystems and as long as some minimal demands, such as suitable nesting habitat and prey, are present populations can usually persist in habitats altered by humans (Ross 1998, Webb *et al.* 2010). Crocodilians have an ontogenetic shift in diet, where hatchlings primarily consume insects and arachnids and when increasing in size to juveniles and subadults the diet changes to consist of crustaceans, amphibians and fish instead. Adult diet consists almost entirely of fish (Wallace & Leslie 2008). Crocodilians are considered “keystone species” since their activities help to maintain the structure and function of ecosystems (Ross 1998).

Night counts – a method for inventories of crocodilians

To assess the abundance of crocodiles in an area, night counts along transects are commonly used. This method includes using a spotlight to locate the eye shine of crocodiles swimming in the water or resting at the river banks (Hutton & Woolhouse 1989, Bayliss *et al.* 1986, Montague 1983). The tapetum, a specific layer of tissue of the crocodiles eyes, reflects a red shine when being exposed to a light source at night, making it possible to locate individuals and count them (Montague 1983). These type of counts gives a minimum number of the crocodiles in the population of a given area. (Hutton & Woolhouse 1989). Low water level and high water temperature have been shown to be the most favourable conditions to get correct estimates of crocodiles abundance using spotlight counts (Hutton & Woolhouse 1989). Moon phase and presence/absence of the moon can influence night count results as well (Sarkis-Goncalves *et al.* 2004). In a study by Montague (1983) it was shown that during night counts 12.9 times more crocodiles were spotted compared to surveying the same area during day time, and thus allowing for a better approximation of the number of crocodiles in a given area. Crocodiles are nocturnal and moves almost exclusively when it is dark (Hutton & Woolhouse 1989). Usually night counts include an inventory of the population structure by trying to determine the size of each spotted crocodile. Thereby the crocodiles get put into different size classes which represent the different life stages of the species, undetermined individuals get put into a class commonly called “Eyes Only” (Webb & Messel 1979, Gramentz 2008). Wariness of light and boats have been shown to be different for crocodiles of different sizes. In a study by Webb and Messel (1979) the proportion that could be approach within 1.5 m decreased with increased size. It was also shown that wariness differs between different regions (water systems). It has been suggested that wariness is primarily learned but that a natural increase in wariness occurs when hatchlings become juveniles (Webb & Messel 1979). It has also been suggested that most Eyes Only observations is larger individuals (Webb & Messel 1979).

Human – crocodile conflict

Protection of crocodilians, especially larger species, often creates problems. Many larger species are considered dangerous and are usually unwanted by people in close proximity (Ross 1989). When crocodilian populations increase due to protection and management actions human crocodile conflict usually increases and without any incentives (economic) for the people concerned by this the crocodile population increase will be difficult to uphold (Ross 1989, Webb *et al*. 2010). The IUCN crocodile specialist group, which coordinate conservation regimes for crocodilians, state that the most successful ways of conserving these species are conservation programmes based on the engagement of the local community together with education (Ross 1998).

In areas where people live along rivers and use them for transportation and fishing crocodilian populations can be largely affected even though the riverine habitat is highly intact and the density of humans is low. In the Philippines, two species of crocodile went extinct due to crocodiles being killed by people along with being caught or stuck in fishing nets. (Webb *et al.* 2010).

Effect of anthropogenic disturbances on crocodilians

Impacts of anthropogenic disturbances, such as habitat destruction or pollution, on wildlife populations are well known and documented. Impacts of other disturbances such as boat traffic, are less widely recognized. Disturbance from boat-traffic can have non-lethal effects on wildlife such as changes in behaviour or reproductive success (Grant & Lewis 2010). These disturbances can eventually lead to increased mortality rates (Grant & Lewis 2010). Changed behaviour due to disturbance from boat-traffic has been reported in several species such as dugongs (*Dugong dugon*), killer Whales (*Orcinus orca*) and several species of dolphins (Delphinidae). A study by Grant & Lewis (2010) showed that Spectacled caiman (*Caiman crocodilius*) was extremely wary of boats and light (from spotlights or torches) in areas with high amount of high speed boat-traffic compared to areas with low amounts of boat traffic and speed limitations. They also found non-lethal injuries on this species in areas of high speed boat-traffic but none in the areas with slower speed and less number of boats. These injuries can lead to reduced fitness and higher metabolic cost which can affect the individual's reproductive success negatively (Grant & Lewis 2010). Response to disturbance from boat-traffic such as avoidance of collision can directly affect the survival of aquatic animals (Frid & Dill 2002, Williams *et al.* 2006).

Project aim

The purpose of this project was to quantify human disturbance along a part of the Kinabatangan River in Borneo. The study aimed to investigate if some areas along the river have higher amount of human disturbance than other and also to investigate at what time of the day these disturbances are greatest. The purpose was also to survey saltwater crocodiles, using night-counts, to asses the abundance of crocodiles in the same areas as where the human disturbances were measured. Using the data from these two surveys the study aims to assess whether the abundance and distribution of crocodiles is affected by human disturbances and if the proportion of crocodiles in different size classes are affected differently.

This study is an important case study examining anthropogenic impacts on wildlife and has global applicability. The Kinabatangan River is important both to the crocodile population and humans living in the area (for fishing, transport and eco-tourism) (Hai *et al.* 2001). It is also important since human-crocodile conflicts are common and showing if and what type of disturbances that affects crocodiles might facilitate a better understanding and greater respect of crocodile populations.

Study area

The Kinabatangan River

The Kindabatangan is located in Sabah, a Malaysian state located in the north east of Borneo just north of the equator. The length is 560 km, is the second longest in Malaysia. It has a catchment area of 16 800 km^2. The area boasts a north-easterly monsoonal climate with a main annual precipitation of 3000 mm (Estes *et al.* 2012) and diurnal air temperatures of 22 to 32 degrees Celsius (Boonratana & Sharma 1997). Rainfall is highest between October and March. The area around the Kinabatangan River is a matrix of several different habitat types such as riparian forest, swamp forest, diepterocarp forest and seasonally flooded forest (Estes *et al.* 2012). The landscape is highly fragmented with smaller forest lots surrounded mainly by oil palm plantation (Bruford *et al.* 2010). The Kinabatangan floodplains are a unique ecosystem with a wide range of habitats. The wildlife in the area is particularly diverse and of high concentration. The area is home to over 50 species of mammals, eight species of hornbill and is one of two areas in the world harbouring ten primate species. The floodplains serves as a passage between the terrestrial and aquatic environment. The Kinabatangan River is also of critical value to the people living in the area. Apart from that, the Lower Kinabatangan has been characterised as a key spot for eco-tourism by the World Wildlife Fund (WWF) (Hai *et al.* 2001).

The floodplains of Kinabatangan is one of the most important wetlands is Malaysia. It boosts high levels of biodiversity despite the fairly high levels of habitat degradation and fragmentation

(Bruford *et al.* 2010). Forested land (i.e. not oil palm plantation or other land uses) covers approximatley 52 000 ha of the Lower Kinabatagan floodplains, these forested areas comprises of the Lower Kinabatangan Wildlife Sanctuary (LKWS), seven Virgin Forest Reserves (VFR) along with private and state own land currently under forest cover (Ancrenaz *et al.* 2004). Some of these forest lots are connected by corridors of riparian forest and some are totally isolated. The LKWS was established in 1999 and consists of 10 separate lots more or less connected or totally separated by oil palm plantation and other types of land use.

Study sites

In the LKWS lies the Danau Girang Field Centre (DGFC) which is a research facility co-managed by Cardiff University and Sabah Wildlife Department. The facilities are comprised of five buildings, a water cleaning facility and a jetty from where motor boats are used to reach the areas of several different research projects. The DGFC Jetty is the first study site. Along the Kinabatangan River just outside lot 6 of the LKWS and approximately 17 km upstream along the river from DGFC lies the village Batu Putih, the second study site. The village has a high density of settlements and a large jetty. An eco-tourism community co-operative also operates in the village and has several larger tourist-boats. The village is adjacent to a busy road, which crosses the river via a bridge. The second study site was situated 6.2 km from DGFC (upstream) and is a forest patch and river called Kampung Monyet (Monkey village). The final site, 8.1 km from DGCF (downstream) was located at the entrance to a large tributary, Sungai Koyah (figure 1).

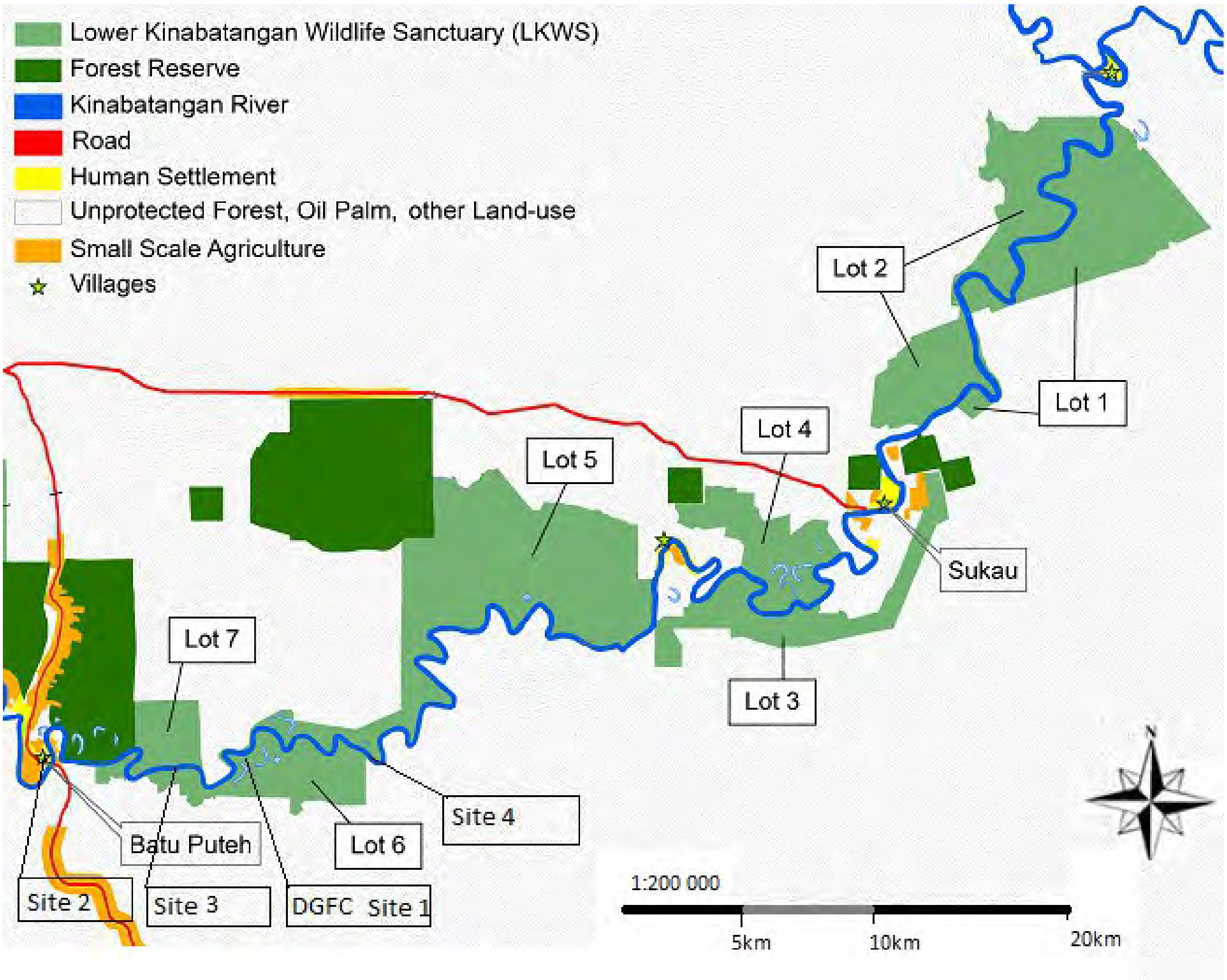

Figure 1. *Kinabatangan River and the Lower Kinabatangan Wildlife Sanctuary (LKWS), map showing eight of the ten lots. In lot 6 lies study site 1 (DG Jetty), site 3 (Kampung Monyet) and site 4 (Koyah). Study site 2 (Batu putih) lies outside of the LKWS. Map taken from Estes et al. 2012 and modified.*

Studied species

The saltwater crocodile (*Crocodylus porosus)*

The saltwater crocodile (*Crocodylus porosus*), also known as the estuarine crocodile, is the largest extant reptile species and the most widely distributed of all crocodilians (Whitaker & Whitaker 1989). It occurs from southern India, throughout south-east Asia and down to northern Australia. The species is classified as Least Concern (LC) according to the IUCN red list (IUCN – The IUCN red list of threatened species), but the status is outdated and requires substantial work (Webb *et al.* 2010). The saltwater crocodile usually inhabits freshwater ecosystems even though they can tolerate higher salinity. (Webb *et al.* 2010, Campbell *et al.* 2010). Commonly this species inhabits marshes, swamps, inland lakes and non-tidal parts of rivers but they also occur in tidal rivers and streams with higher salinity as well as the ocean. This species is threatened by habitat destruction, poaching and removal due to the fact that they prey on humans and livestock. Large crocodiles are potentially dangerous to humans (Martin 2008) and the conservation of this species is often controversial, resulting in high levels of human-wildlife conflict (Webb *et al.* 2010). Diminishing and threatened populations of the saltwater crocodile can be re-established by addressing the following criteria: Intact habitat, effective protection and tolerance of expanding crocodile population by those living in the area. These conditions are seldom met and without incentives a tolerance of increasing abundance of this species can be difficult to achieve. (Webb *et al.* 2010). Saltwater crocodiles can travel large distances across open ocean, however this behaviour is unusual (Campbell *et al.* 2010). Crocodiles up to a size of around 2 m have quite small home ranges. Individuals larger than this starts to move further and when reaching a length close to 3 m they usually travel far and without well-defined home ranges (Hutton & Woolhouse 1989). The exception is breeding females, who stay close to their nests. (Hutton & Woolhouse 1989). The nesting period of the saltwater crocodile is between November and March, which corresponds to the wet season (Webb *et al.* 1977).

The IUCN crocodile specialist group classified crocodilian species according to the quality and quantity of population survey data. The data could be classified as “good”, “adequate”, “poor” or “extremely poor”. For the saltwater crocodile, adequate data is available for parts of the range (i.e. Australia and Papau New Guinea) but large part of its range is still un-surveyed and therefore the saltwater crocodile data is classified as “poor” (Webb *et al.* 2010). In Sabah, the saltwater crocodile is considered common in the Kinabatangan River along with its associated wetlands, still the IUCN crocodilian specialist groups states that follow up surveys and monitoring of the saltwater crocodile population in the Kinabatangan River (as well as the rest of Sabah) should be of high priority (Ross 1998, Webb *et al.* 2010). The species is legally protected in the region (Groombridge 1982).

Method

Disturbances

River surveys to quantify human presence and disturbance was carried out over 2 months at four different sites along the Kinabatangan River in Borneo, Malaysia at four different time-shifts during day and night, 08.00 to 10.00, 13.00 to 15.00, 18.00 to 20.00 and 23.00 to 01.00 (table 1). River surveys at three different transects at one time-shift, 08.00 to 09.00 was used as well to quantify human disturbances (table 2). Each site was revisited three times for each separate time-shift and each transect was surveyed three times. Human activities was measured as presence or absence of people, the number of people operating in the area, the number of boats passing by, arriving at or leaving the area (motor and non-motor), the number of stationary boats in the area alongside with the amount of rubbish in the water. Presence and number of fishing equipment and people fishing was also measured, and the type of fishing equipment was noted. Hand binoculars was used to determine the presence and frequency of the different disturbance factors. The sites were either surveyed from a motor boat or from a jetty and the transects were surveyed using boat transportation with a small motor boat. The habitat in the area at the sites and along the transects were characterised according to how undisturbed or disturbed it is depending on the presence or absence of settlement and if the landscape was deforested or not. The four sites along the river were chosen to represent samples of disturbance of a shorter river stretch, and the sites locations were marked with a Garmin cs60 GPS and is shown in figure 1. These four sites are called site 1 – DG Jetty, site 2 – Batu Putih, site 3 – Kampung Monyet and site 4 – Koyah (table 1). A human disturbance index was created to quantify the presence/absence and intensity of human activities as well as characterising the habitat at the different sites and transects. The index is divided into two main parts, activities on the shore/close to the shore and activities in open water (i.e. boats, fishing equipment). An ordinal classification of the human disturbances with four variables on a four point scale, for each main part, was calculated for each area and transect (Appendix 1). The higher an area scores, the more disturbed it is. The proximity to the closest oil palm plantation from each site was measured using the GPS-data in Gamin Map Source version 6.13.17 and projecting it in Google Earth version 7.1.2.2041. All disturbance surveys were done between the 2nd of October and 30th of November 2014.

Night counts

The same transects was then used for doing night counts (i.e. inventories) of saltwater crocodiles (*Crocodylus porosus*) (table 2). These were done three times for each transect, starting at 20.00. Transect 1 was surveyed on the 31st of October and the 16th and 19th of November. Transect 2 was surveyed on the 11th, 18th and 23rd of November. Transect 3 was surveyed on the 6th, 17th and 20th of November. Head torches (LED Lenser H14 4 in 1 - 210 Lumens) were used to locate the crocodiles on the night counts and at least two observers conducted the survey at each time. The location where the crocodiles where seen was marked with Garmin cs60 GPS and the time noted. The crocodiles were assorted into five different size classes called 0, 1, 2, 3 and EO. The size classes used where the same as used earlier at research at the Danau Girang Field Centre (Luke Evans, personal communication). Size class 0 is crocodiles with a length of 0 to 50 cm, class 1 is crocodiles with a length of 50 cm to 1 m, class 2 is crocodiles with a length of 1 to 2 m and class 3 is crocodiles larger than 2 m. EO stands for Eyes Only and this class was used when a crocodile was spotted but its size could not be determined (Appendix 2). The size classes 0, 1, 2 and 3 each represent a life stage where class 0 is hatchlings, class 1 juveniles, class 2 sub-adults and class 3 adults (Gramentz 2008, Sah & Sturebring 1996, Hutton & Woolhouse 1989). A comment was made when the crocodiles' behaviour was “uncommon” for a night count occasion such as if it was resting on the riverbank or if it was spotted in the middle of the river. All night count surveys were carried out travelling upstream, to reduce crocodile disturbance, mostly noises and waves generated from the boat. The river's water level was measured every day with a laser range finder between 08.00 and 20.00. Sarkis-Goncalves *et al.* (2004) formulated an equation for calculating the true population number from night count surveys in caimans. They ended up with two equations slightly different depending on the observer. These equations were used to calculate two proposed numbers of the saltwater crocodile population along the whole surveyed area. The mean value of the total number of crocodiles seen over the whole survey area was used in the equation.

$$N^1 = 2.02711 + 1.09778 \times Nc^1$$

$$N^2 = 2.99757 + 1.0790 \times Nc^2$$

Where Nc was the mean number of the studied species observed during the night counts in the surveyed area and N is the estimated population number. The upraised numbers stands for the two different observers in the Sarkis-Goncalves *et al.* (2004) study.

Number of crocodiles at the sites

By choosing a river stretch of 4 km around each site and counting the number of crocodiles seen in these areas the number of crocodiles per site was determined. The disturbance measures at each site can be seen as a sample of the amount of disturbances in that 4 km area of the river. The 4 km stretch and the crocodiles within it were determined using the GPS-data in Garmin Map Source version 6.13.17 and measuring the length by projecting the GPS-points on satellite images in Google Earth version 7.1.2.2041.

Statistics and analysis

The abundance data along with the disturbance data were analysed fitting generalized linear mixed models using penalized quasi likelihood in R (R Core Team 2014). Number of boats passing the area, number of stationary boats in the area, number of people operating in the area, the amount of fishing equipment in the area and the amount of rubbish in the area was modelled as fixed factors, while the different sites was modelled as a random factor. The count data of the crocodiles in the area (both the total number and the number in the different size classes) as well as data of the proportion of crocodiles in the different size classes in the area was used as response factors in the models.

The number of class 3 crocodiles per km was also modelled as a response factor in a generalized linear mixed model with boats passing along the transect, amount of fishing and fishing equipment along the transect and the number of temporary settlements along the transect were modelled as fixed factors, the transects were modelled as random factor. When using number of crocodiles as response variable Poisson errors and log link-funcitions were used, when having proportions as response variable binary errors and logit link-function were used. When calculating proportions Eyes Only individuals were excluded.

One-way analysis of deviance from using generalized linear models was used to detect differences in the disturbance variables between the different sites and also between the different time-shifts within each site. Fisher's exact test was used to investigate if there were any differences in the proportion of small (class 0 and 1) and large (class 2 and 3) crocodiles between the different sites. Generalized linear models with analysis of deviance were used to investigate if there were any differences in the proportion of crocodiles between the different size classes and between transects. Linear regression was used to investigate if the mean number of crocodiles at the sites were correlated with how close each site was to an oil palm plantation. To analyse if water level had an effect on number of crocodiles seen at each survey occasion, number of class 3 crocodiles seen at each survey occasion and on the number of boats passing at each point-sample occasion Poisson regression was used, with a log link-function. To analyse if water level had an effect on the proportion of class 3 crocodiles logistic regression was used, with a logit link-fuction. All statistical analysis were carried out in R (R Core Team 2014). Maps detailing the location of the inventoried crocodiles and the location of the fishing equipment were made in Inkscape version 0.48.

Table 1. *Description and location of the four survey sites.*

Site	Description	Coordinates
1 – Danau Girang Jetty	Jetty for the Danau girang field station. Lies in lot 6 of the LKWS. 520 m to closest oil palm plantation.	5 25.068 N 118 02.001 E
2 – Batu Putih	Village just outside of the LKWS. Tourist facilities, jetty, high density of settlements, mosque, road (13) just by the village, bridge (road) over the river. 210 m to closest oil palm plantation.	5 24.522 N 117 57.082 E
3 – Kampung Monyet (translates to Monkey Village)	Undisturbed site, no settlements or roads. Lies in lot 6 of the LKWS. 1076 m to closest oil palm plantation.	5 24.311 N 118 00.228 E
4 - Koyah	No settlements or roads. Lies in lot 6 of the LKWS. 360 m to closest oil palm plantation.	5 24.408 N 118 04.998 E

Table 2. *Description of the transects. Both disturbance surveys and night count surveys were done along these transects.*

Transect number	Between	Length (km)
1	Danau Girang and Kampung Monyet	6.2
2	Danau Girang and Koyah	8.1
3	Kampung monyet and Batu Putih	11.4

Results

A total of 88 observations of crocodiles were done during the nine surveys. 80 % of the crocodiles spotted and determined to class at the night count surveys were immature (class 2 and under) and 20 % were adults (class 3) (figure 2). 10.2 % of the observations were hatchlings, 36.3 % were juveniles, 20.5 % were sub-adults, 17 % were adults and 16 % could not be determined and were classified as Eyes Only (figure 3). From Sarkis-Goncalves *et al.* (2004) equations the proposed numbers of the crocodile population in the area was 34 or 35 crocodiles.

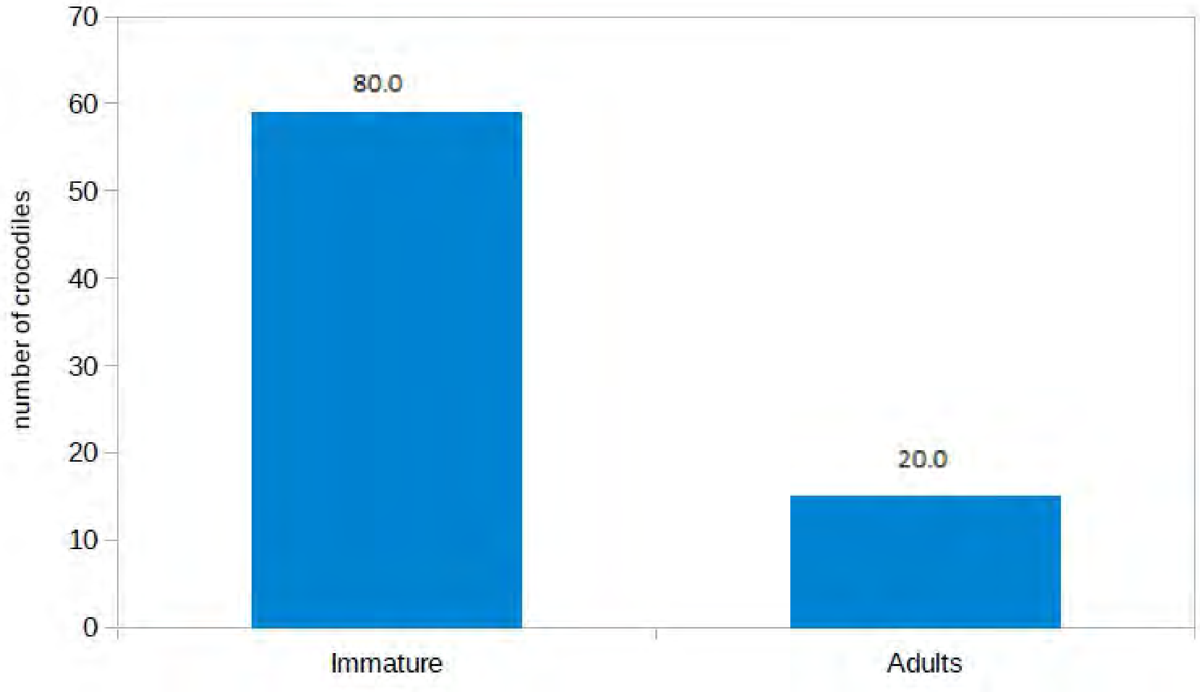

Figure 2. *Number of immature and adult crocodiles seen at the night counts. Percentage of the total number seen is given above each bar.*

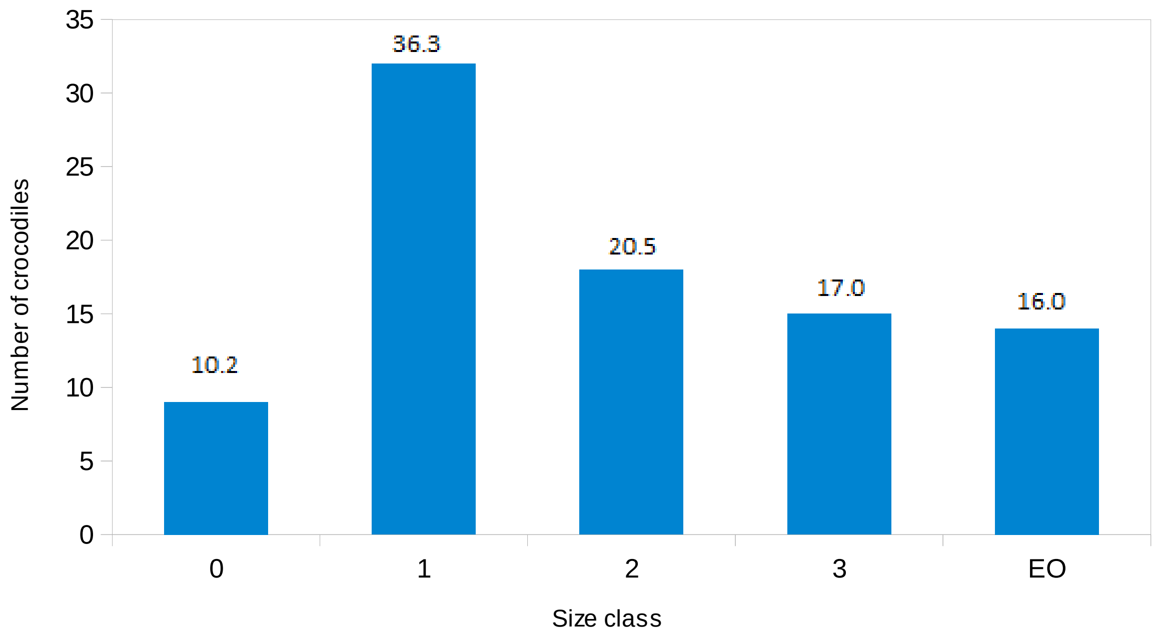

Figure 3. *Number of crocodiles in the different size classes seen at the night counts. Percentage of the total number seen is given above each bar.*

Disturbance index

Site 2 (the village Batu Putih) had the highest disturbance index score followed by site 1 (Danau Girang Jetty), site 4 and site 3 which had the lowest score as well as the same score. Batu Putih and the Danau Girang Jetty both have permanent settlements and boats arrives and leaves these areas on a daily basis. People live and operate in these areas which results in higher scores. Batu Putih scored higher than the Danau Girang Jetty mainly because more people operate in the area close to the river and because a higher number of boats are seen here (table 3, table 4). The amount of rubbish seen in the river was not correlated to the water level. Transect number 3 (between KM and BP) has the highest disturbance score and the other two had almost an equal score (table 3, table 5).

Table 3. *Disturbance index for the four sites and three transects. Lowest possible score: 8. Highest possible score: 32.*

Site/Transect	**Disturbance index**
Danau Girang Jetty (DG)	16.4
Batu Putih (BP)	22.5
Kampung Monyet (KM)	10.8
Koyah	10.8
1 – DG to KM	17
2 – DG to Koyah	16.7
3 – KM to BP	24.3

Table 4. *Disturbance index for the four sites with the score of each separate factor shown.*

Disturbance index								
Site/variable	SA	SB	SC	SD	WA	WB	WC	WD
Danau Girang Jetty	2	3	3	1	1	3.3	1.1	2
Batu Putih	4	4	4	1.2	2.2	3.4	1.3	2.5
Kampung Monyet	1	2	1	1.1	1	1.7	1.1	2
Koyah	1	2	1	1	1	1.4	1.2	2.3

Table 5. *Disturbance index for the three transects with the score of each separate factor shown.*

Disturbance index								
Transect/variable	SA	SB	SC	SD	WA	WB	WC	WD
1- DG to KM	2	3	3	1.3	1	1.7	1.7	3.3
2 – DG to Koyah	2	3	3	1	1.3	1.7	2	2.7
3 – KM to BP	4	4	4	1.3	2	3	3	3

Difference in disturbance regimes along the surveyed area

The number of boats passing by the areas at daytime, the number of stationary boats at the sites at daytime and the number of people operating in the areas at daytime was different for the four sites (p-values: <0.005 for all three disturbances). The amount of rubbish seen, the amount of fishing and fishing equipment and the number of people swimming at daytime was not shown to be significantly different between the sites. The mean number of boats passing by the areas during daytime was high for site 2, a bit less for site 1 and only any single boat at site 3 and 4 (figure 4). The mean number of stationary boats in the area at daytime was highest for site 2 and second highest for site 1, at site 3 and 4 no stationary boats were seen (figure 5). The same pattern was found for the number of people operating at the sites at day time (figure 6). The number of boats passing by the area differed for the different time-shifts at site 1 and 2 (p-values: < 0.005 for both sites). The number of people operating in the area differed for the different time-shifts at site 1 and

2 (p-values: < 0.05 for both sites). The number of boats passing and the number of people operating the area were not shown to be different between the time-shifts for site 3 and 4. The number of stationary boats in the area was not shown to be different between the time-shifts for any of the sites. The number of boats passing by the areas were not shown to be correlated with water level.

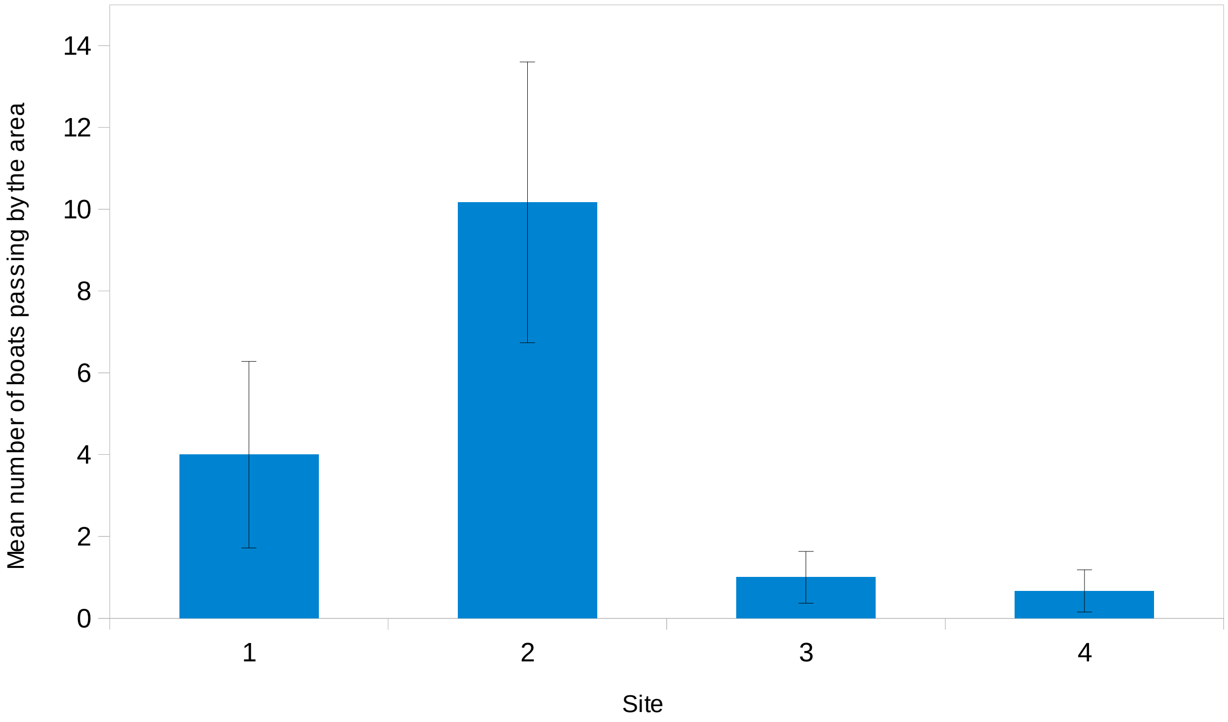

Figure 4. *Mean number of boats passing by the areas at each site. Standard deviation is shown as black bars.*

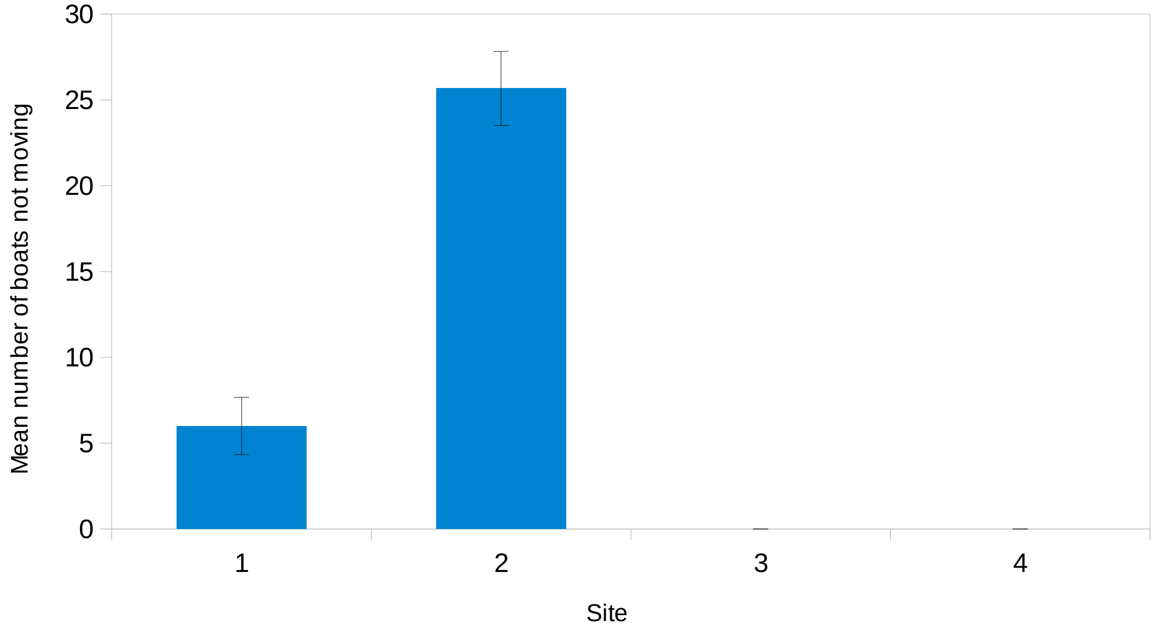

Figure 5. *Mean number of stationary boats at each site. Standard deviation shown as black bars.*

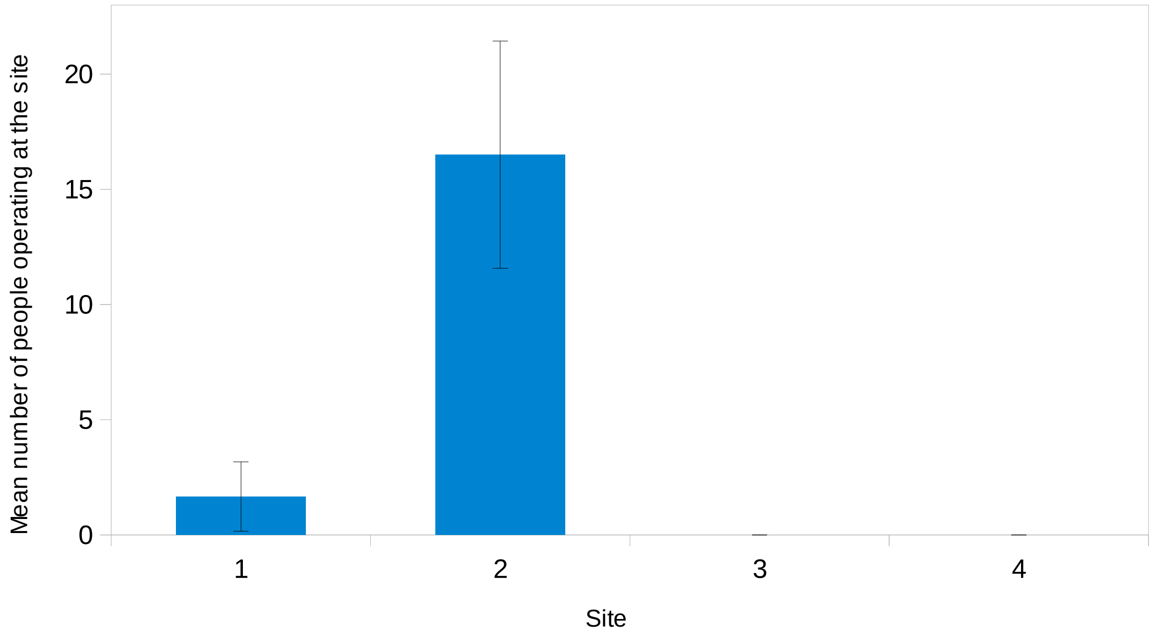

Figure 6. *Mean number of people operating in the areas at each site. Standard deviation shown as black bars.*

Differences in the number of crocodiles between the sites

The mean number of crocodiles seen at the survey sites was relatively similar between the site 1, 2 and 3 with between 3 and 4 crocodiles seen at each survey. The number was slightly higher at site 4 (figure 7). The number of crocodiles could not be shown to be different between the sites.

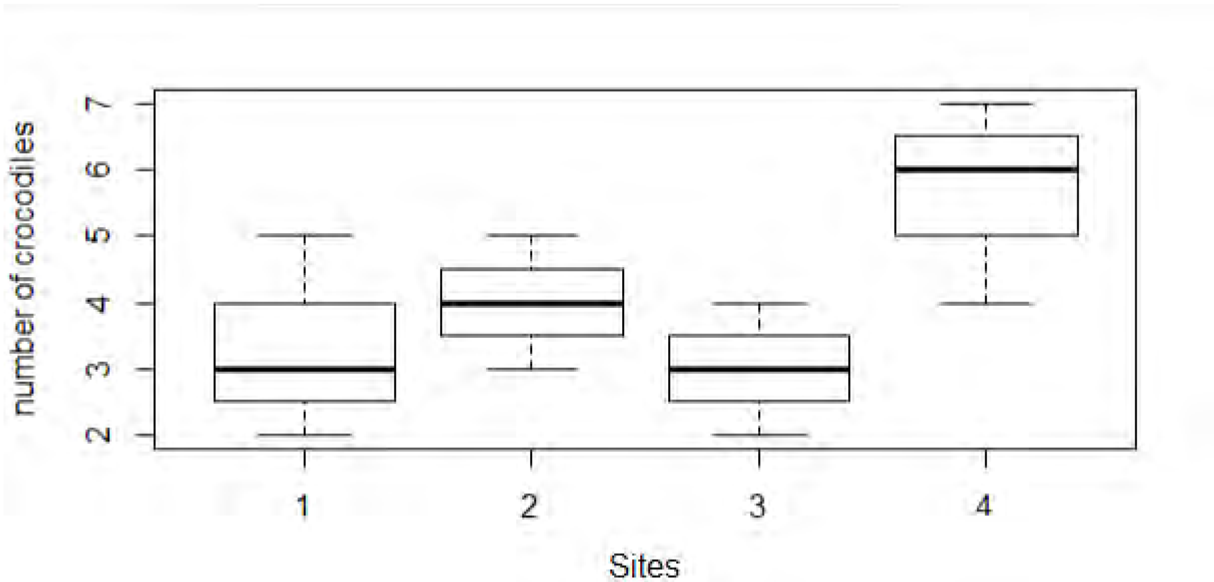

Figure 7. Boxplot of the number of crocodiles seen at the different sites.

Number of crocodiles and human disturbances

The number of crocodiles in an area significantly differed depending on the number of boats passing by that area, the number of boats at shore in the area and the number of people operating in the area (p-values: < 0.05 for all three disturbances), although the estimated coefficients were very small. The number of class 3 crocodiles in an area differed depending on the number of boats passing by the area, the number of stationary boats in the area and the amount of fishing equipment in the area (p-values: < 0.05 for all three disturbances). The proportion of class 3 crocodiles in an area differed depending on the number of stationary boats in the area and the amount of fishing equipment in the area (p-values: < 0.05 for both disturbances). The proportion of class 2 and 3 crocodiles together in an area differed depending on the number of boats passing by the area and the number of stationary boats in the area (p-values: < 0.05 for both disturbances). The number of class 3 crocodiles per kilometre is dependent on the number of temporary settlements along a transect (p-value: < 0.05). Neither the proportion of small (class 0 and 1) nor the proportion of big (class 2 and 3) crocodiles could be shown to differ between the three transects. Then number of crocodiles at each site were not correlated with how close it is to an oil palm plantation.

Night counts

The total number of crocodiles and the number of class 3 crocodiles seen at the night count surveys could not be shown to be correlated with water level. The proportion of class 3 crocodiles spotted at the night counts is correlated with water level (p-value: < 0.05). The mean number of crocodiles per kilometre were very similar for all the three transects (table 6). Table 6 shows the total number of crocodiles as well as the number of crocodiles per kilometer seen at each survey-time. Table 7 shows the mean number of crocodiles per kilometre in the different size classes.

Table 6. *Total number of crocodiles and the number of crocodiles per km seen at the different survey occasions. The mean number of crocodiles and mean number of crocodiles per km seen at the surveys.*

Transect number	Date	Total number of crocodiles	Number of crocodiles/km
1	31st of October 2014	7	1.1
1	16th of November 2014	10	1.6
1	19th of November 2014	7	1.1
Mean for transect 1		**8**	**1.3**
2	11th of November 2014	8	1.0
2	18th of November 2014	10	1.2
2	23rd of November 2014	6	0.7
Mean for transect 2		**8**	**1.0**
3	6th of November 2014	7	0.6
3	17th of November 2014	17	1.5
3	20th of Novmber 2014	16	1.4
Mean for transect 3		**13.3**	**1.2**

Table 7. *Mean number of crocodiles in each class per km.*

Transect/Class	0	1	2	3	EO
1	0.16	0.32	0.16	0.38	0.27
2	0.12	0.29	0.21	0.21	0.16
3	0.09	0.56	0.29	0.09	0.15

Distribution of crocodiles in the surveyed areas of the river

The distribution and size classes of the crocodiles spotted at the night count surveys are shown in figures: 8 to 16. At an approximately 2.5 km stretch of the river around site 3 no crocodiles were observed during any of the survey occasions. In the same 2.5 km stretch five, of a total of eight, fish traps where seen during the disturbance surveys of the transects (figure 17). On three other stretches, longer than 500 m, no crocodiles where seen during any of the surveys, these stretches are 700 m outside Batu Putih, 1.5 km on transect 2 upstream Danau Girang and 700 m on transect 2 closer to Koyah (Figure 12 to 17).

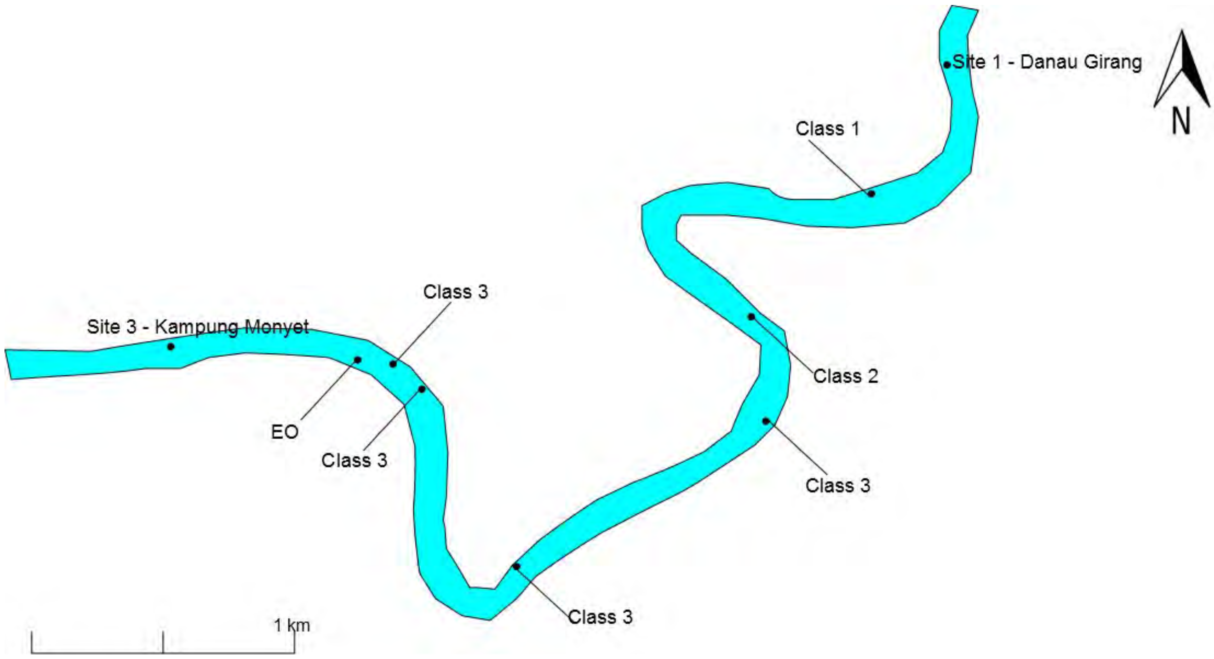

Figure 8. *Crocodile positions and determined size classes from the first survey of transect 1 (Danau Girang to Kampung Monyet) (31st of October 2014).*

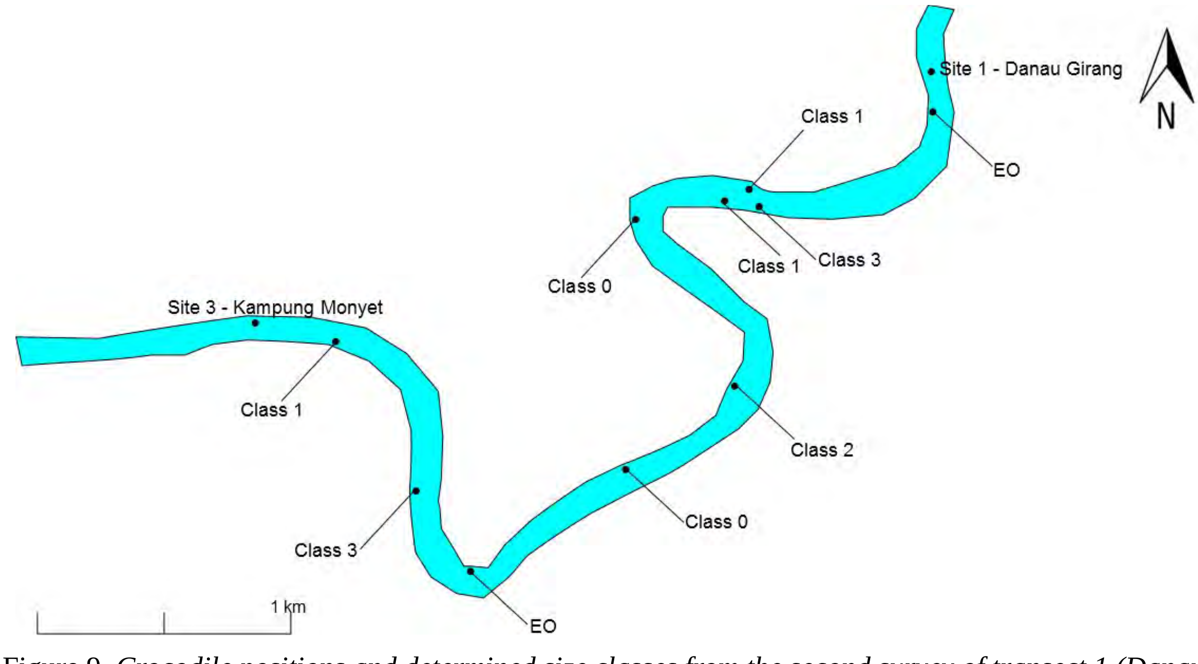

Figure 9. *Crocodile positions and determined size classes from the second survey of transect 1 (Danau Girang to Kampung Monyet) (16th of November 2014).*

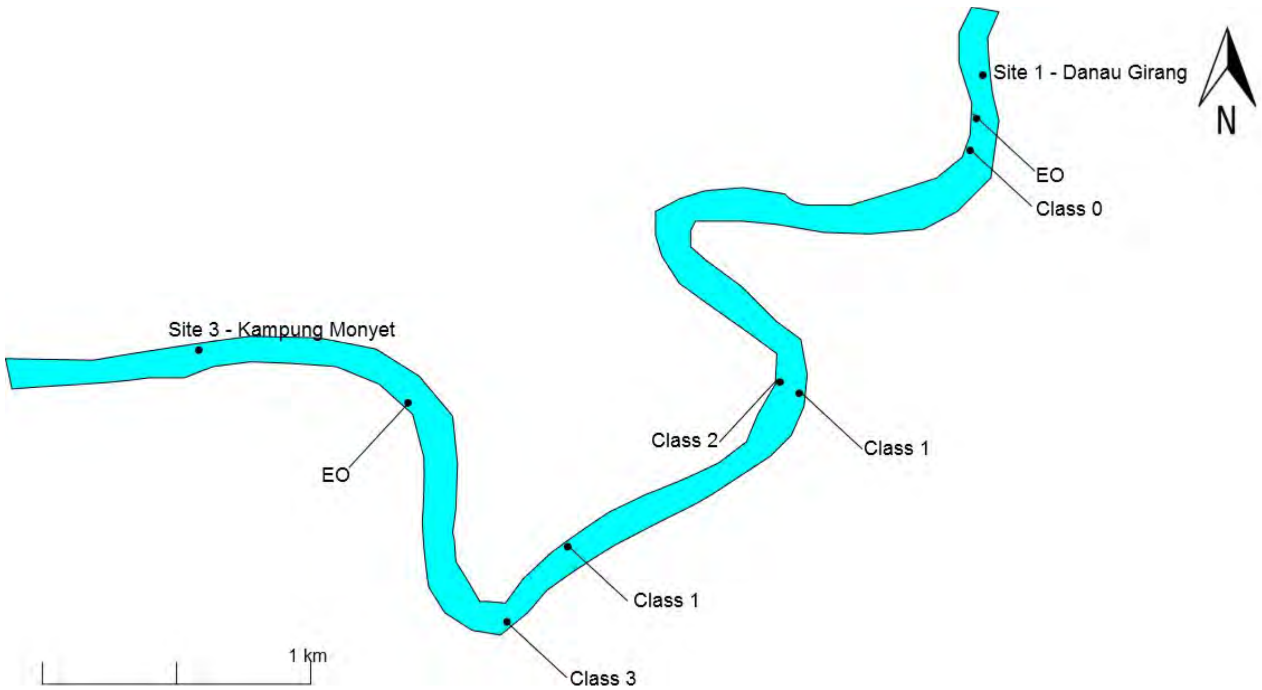

Figure 10. *Crocodile positions and determined size classes from the third survey of transect 1 (Danau Girang to Kampung Monyet) (19th of November 2014).*

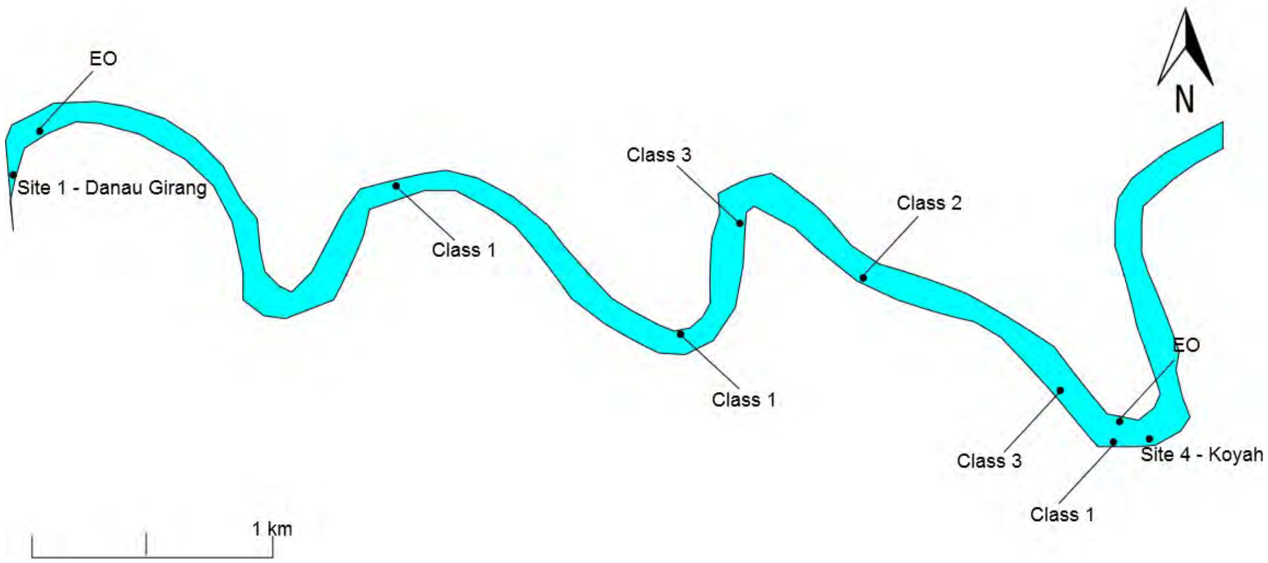

Figure 11. *Crocodile positions and determined size classes from the first survey of transect 2 (Danau Girang to Koyah) (11th of November 2014).*

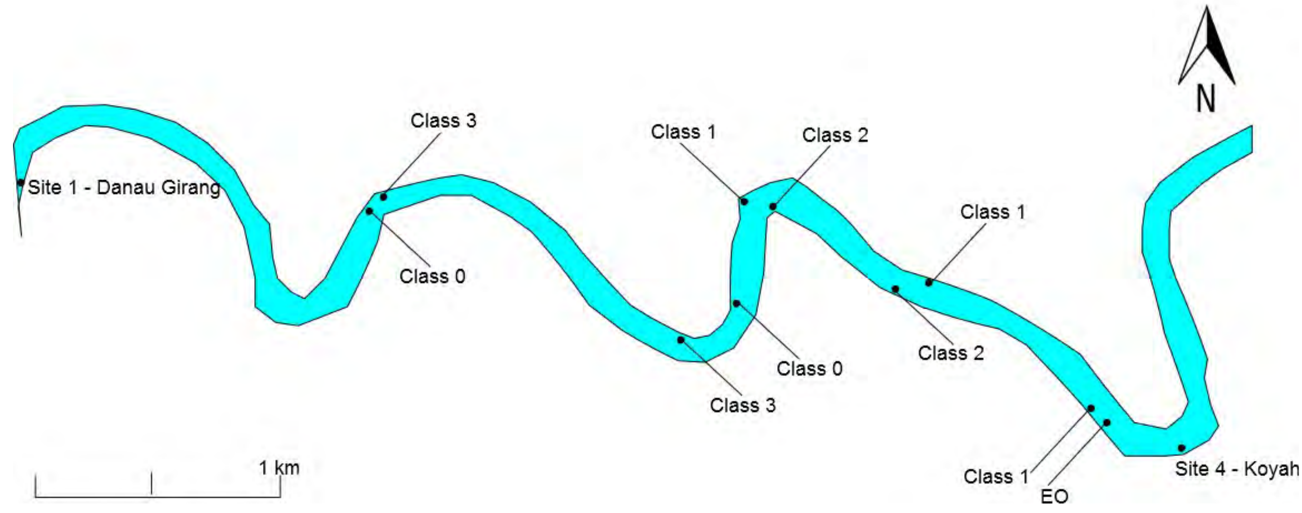

Figure 12. *Crocodile positions and determined size classes from the second survey of transect 2 (Danau Girang to Koyah) (18th of November 2014).*

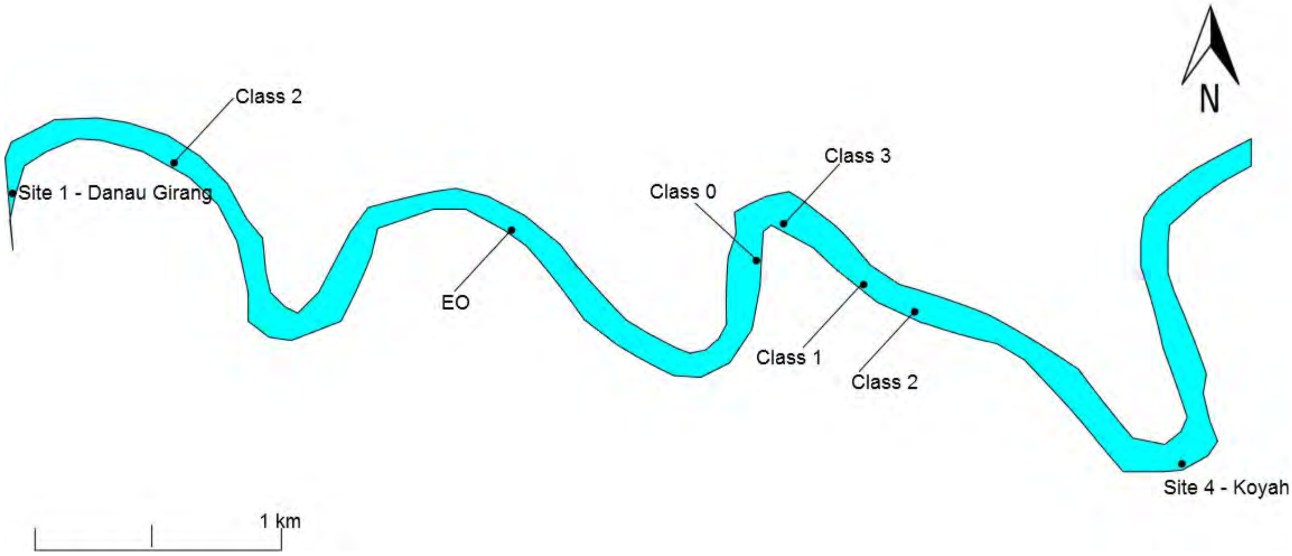

Figure 13. *Crocodile positions and determined size classes from the third survey of transect 2 (Danau Girang to Koyah) (23rd of November 2014).*

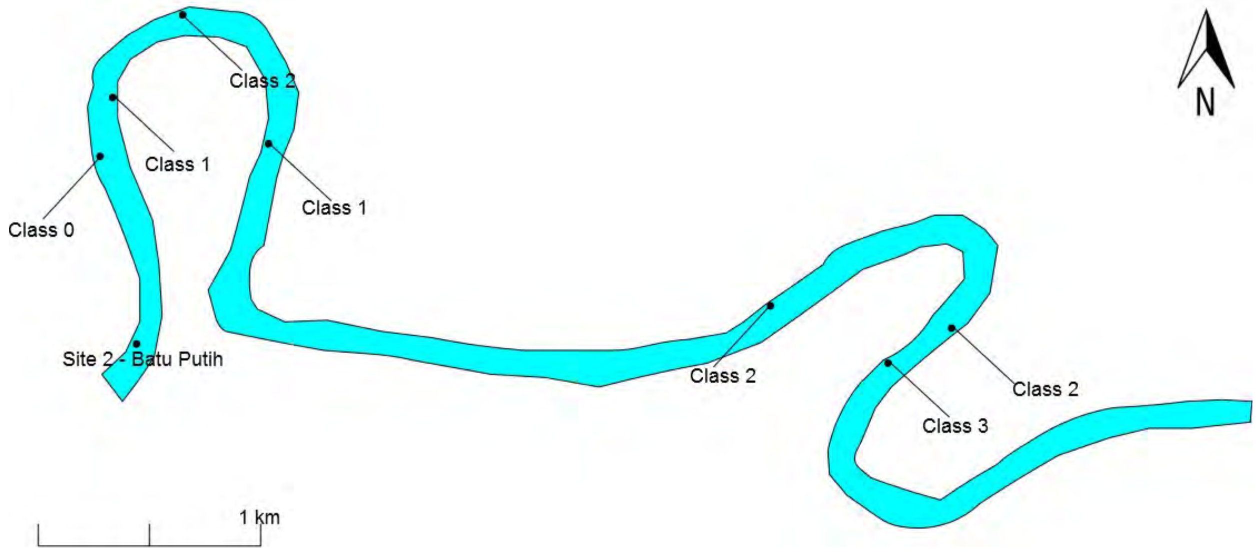

Figure 14. *Crocodile positions and determined size classes from the first survey of transect 3 (Kampung Monyet to Batu Putih) (6th of November 2014).*

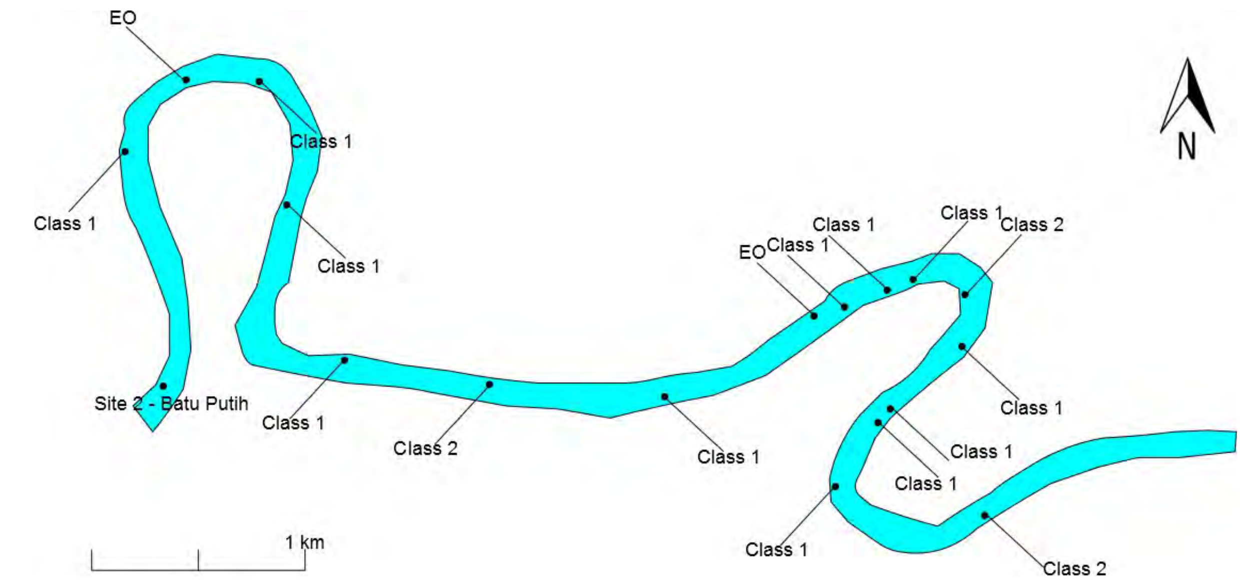

Figure 15. *Crocodile positions and determined size classes from the second survey of transect 3 (between Kampung Monyet and Batu Putih) (17th of November 2014).*

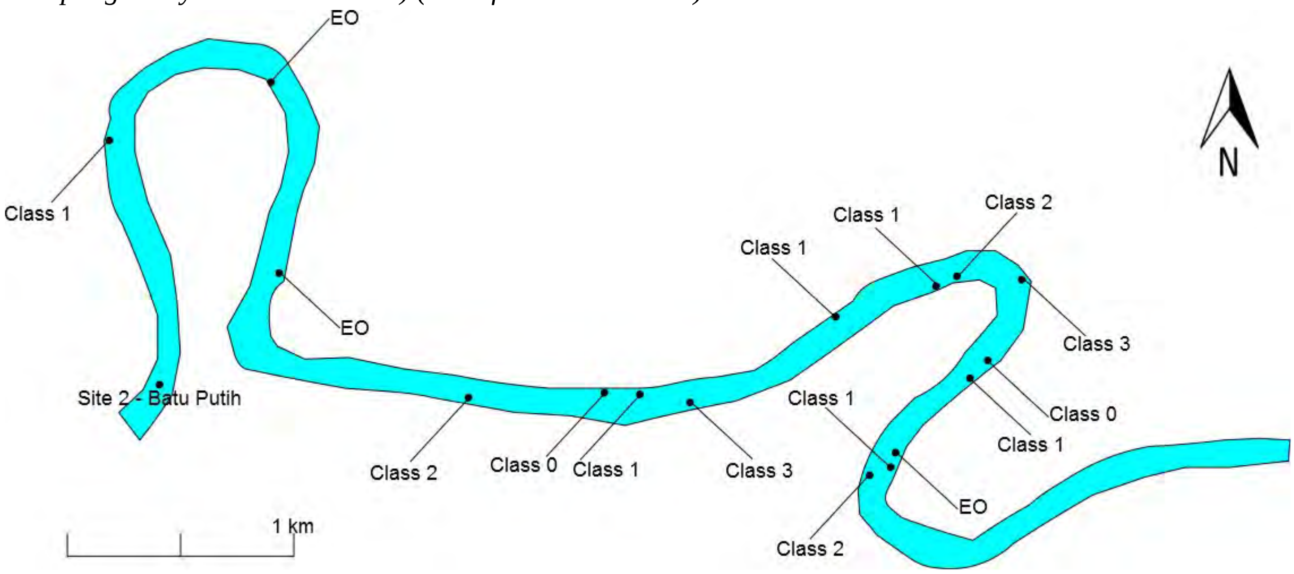

Figure 16. *Crocodile positions and determined size classes from the third survey of transect 3 (Kampung Monyet to Batu Putih) (20th of November 2014).*

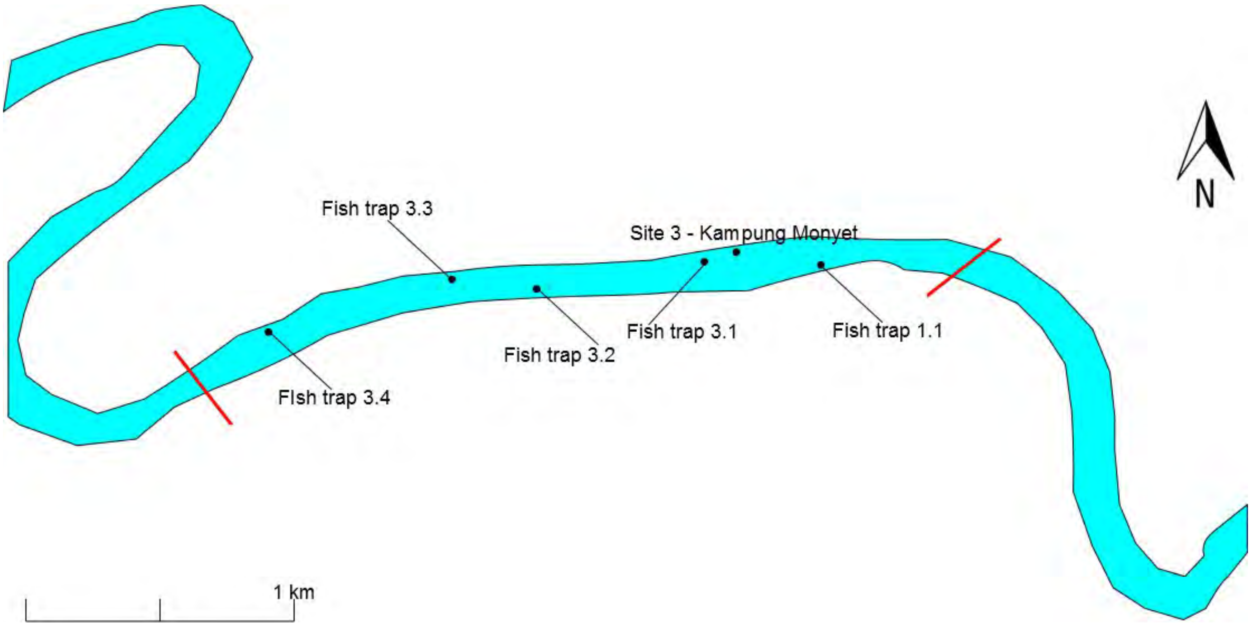

Figure 17. *The red lines mark the 2.5 km stretch of the surveyed area where no crocodiles where observed during any of the night counts and where five of the total of eight fish traps where seen during the survey of the transects at day time. The first number stands for on what transect the fish trap was seen on and the second number stands for the order the traps were seen in.*

Discussion

Disturbance index

Batu Putih, which is the biggest place for living in this area of the Kinabatangan River studied scored the highest disturbance index, this is expected since the area comprises of several types of commercial facilities and settlements for living. Danau Girang Jetty scored second highest and this is also a place were people live permanently. The other two sites (site 3 and 4) scored lower, which might be because none of these two places have permanent settlements and boats that go by these places do that on the way to somewhere else. Some fishing do occur in these areas but not more than at the two other sites. The results of the disturbance index are expected and relatively well represent the different amount of disturbance in these places.

Transect 3 had the highest score, mainly because more temporary settlements were seen in this area and because the habitat is more disturbed. This is probably because this transect is the closest to Batu Putih. The temporary settlements were mainly for tourists and more than one eco-tourism establishment are currently placed in and around Batu Putih.

Disturbance at the sites

The four sites differed in the amount of boats passing by, the number of stationary boats and the number of people operating in the areas, so the frequency and type of disturbances were different at different sites along the Kinabatangan River. At both site 1 and 2 the number of boats passing and the number of people operating in the area was significantly different for the different time shifts. More boats and people were active during day time at these sites, which is expected. At site 3 and 4 there was no significant difference between the time differences and the disturbance here is hence more even as well as lower compared to site 1 and 2.

Differences in number of crocodiles between the sites

When looking at the results from the night counts it seems that the saltwater crocodiles are present all along the three transects. Some spots have a higher number of crocodiles seen, some lower and some none but altogether they are relatively evenly spread. In the area adjacent to Batu Putih (700 m from the jetty) no crocodiles were observed under any of the three surveys. This suggests that crocodiles stay away from humans, at least up to a certain range. The crocodiles do not seem to be excessively attracted to humans, since there is a lack of crocodiles in close proximity to Batu Putih, nor to be too disturbed by them, since the number of crocodiles could not be shown to differ between the sites, even though the sites had very different disturbance rates. On the other hand the results from the generalized linear mixed model shows that the number of crocodiles in an area might be affected by number of boats passing by, number of stationary boats and number of people operating in the area and crocodiles in the Kinabatangan River might therefore be sensitive to human activities. This is thus not the only factors that can be used to explain the number of crocodiles in an area of the river. Since the coefficients in the model were very small and since the statistical power of the model were low it can not safely be concluded that these factors affect the number of crocodiles in an area. It has been shown that many crocodilians are relatively robust to change in their environment and to human disturbance as long as some essentials are met, these include for example the amount of prey and the volume and the quality of the water body (Webb *et al.* 2010). It might be the case that the number of crocodiles are dependent on the measured disturbance factors but not as much as it is dependent on some other variable or variables, as for example amount of prey in the area. The similar abundance and numbers of crocodiles between the areas may also show that the human activities are not very disturbing. The presence of legal protection of the species, the LKWS and the fairly low amount of people permanently living along this river stretch seems to be favourable for the saltwater crocodile population.

Even though it could be shown that the number of boats passing by, the number of stationary boats and the number of people operating in the area had an affect on the number of crocodiles the data set were relatively small and so were the number of crocodile inventories. With more data the results could be more robust and accurate. Extensive inventories and thorough monitoring of the saltwater crocodile in the Kinabatangan River could give fairly accurate knowledge of the population status and which factors that decides the number of crocodiles in an area. Still, the results indicate that crocodiles are affected by human disturbances. How disturbances affect crocodiles are difficult to understand (Gramentz 2008). Adult crocodiles seems to be more sensitive to fishing and fishing equipment since the proportion of class 3 was shown to be significantly determined by the amount of fish and fishing equipment. Larger crocodiles also seem to be more sensitive to disturbance from boats since the proportion of class 3 crocodiles was also explained by number of stationary boats, and the proportion of class 2 and 3 crocodiles together was explained by number of boats passing and the number of stationary boats. This might be because larger crocodiles are more wary (Webb & Messel 1979, Grant & Lewis 2010) and therefore avoid these activities more.

Number and distribution of crocodiles

The saltwater crocodile seems to be relatively evenly distributed in the part of the Kinabatangan River surveyed during this study. Since the species is legally protected, is relatively robust to changes and disturbances in its environment and since the amount of disturbances is generally low it seems that the saltwater crocodile population in the studied area of the Kinabatangan River has good prospects for the future. At some stretches along the surveyed part of the river there were no crocodiles seen during any of the inventories. These stretches are an approximatley 700 m stretch just beside Batu Putih, a 2.5 km stretch around site 3 (figure 19), a 1.5 km stretch on transect 3 (downstream DGFC) where a temporary fishing camp was seen during the study period and a 700 m stretch also on transect 3 closer to Sungai Koyah. The longest stretch without any spotted crocodiles, the 2.5 km stretch around site 3, were thus the stretch where most (as well as almost all) fish traps were seen. These traps were permanent during the time of the study. The proportion of class 3 crocodiles could be explained by the amount of fishing equipment and thus it might be the case that crocodiles are affected by this. Maybe due to frequent boat traffic close to the traps and maybe due to less prey in the areas where fishing is common. Since larger crocodiles demand higher levels of prey and since their diet consists to a larger extent of fish (Wallace and Leslie 2008) fishing might have a larger effect on crocodiles in later life stages. No class 3 crocodiles were seen outside of the LKWS or outside of protected areas all together (LKWS and VFR:s), this together with the above discussed reasons for the distribution of class 3 crocodiles might indicate that adult crocodiles are more sensitive, wary and/or demanding when it comes to disturbance regimes and habitat quality. The distribution of class 0 and 1 crocodiles might be due to the spatial location of appropriate shoreline vegetation.

Sources of bias

The number of crocodiles seen on the night count surveys were not correlated with water level, which otherwise is a common bias for these type of surveys (Hutton & Woolhouse 1989, Sarkis-Goncalves *et al.* 2004). The proportion of class 3 crocodiles seen at the night counts were correlated with water level. This suggests that water level effects the accuracy of the survey and that the results might be biased towards a larger proportion of class 3 crocodiles when the water level is higher. Other factors such as water temperature and moon phases that in previous studies have been shown to have an effect was not measured in this study and can not be analysed. Lack of experience in these type of surveys for the observers might also have an effect. The disturbance factors that were measured should generally not be biased due to easiness of counting these factors. Amount of fishing equipment might be underestimated due to difficulties to detect them (some traps might have been totally submerged and therefore missed and fishing lines were generally hard to spot).

Montague (1983) and Webb & Messel (1979) showed that there was an increase in the distance from the boat when the individuals submerged/fled with increasing body size. Big crocodiles might be more wary to light sources and boats and therefore submerge earlier than smaller crocodiles. This suggests that most of the Eyes Only observations could be larger class crocodiles.

Night counts

During the night counts 80 % of the spotted (and size class determined) crocodiles were immature and 20 % were adults. This is fairly consistent with other studies (Gramentz 2008, Sah & Stuebing 1996). On the other hand the percentage of crocodiles in the different size classes differ from other studies (Gramentz 2008, Sah & Stuebing 1996) with higher proportion bigger size crocodiles and a lower proportion class 0 crocodiles. This might be the result of a number of factors. As a suggestion it might indicate a difference in population structure. It might also be the case that bigger crocodiles are easier to spot and many smaller individuals are hiding in the shoreline vegetation and are therefore missed. It is possibly that the number of hatchlings were very low during the time of the study since nesting season starts around the beginning of November (Webb *et al.* 1977) and very few new crocodiles have had time to hatch. It might also be the case that the area has few suitable nesting areas and that results in low number of hatchlings in this part of the river. Most hatchlings do not move far from there nesting site (Hutton & Woolhouse 1989) and if there are very few nests in close proximity to the surveyed area few hatchlings will be observed. In a study by Montague (1983), between 0.18 and 2.23 crocodiles per kilometre were seen. The number of crocodiles per kilometre in this study falls within that span and suggests that the number in this study likely. The 1.2 crocodiles per kilometer in this study is also significantly higher than the densities of saltwater crocodiles in Sabah proposed by Cox J and Whitaker R in the early 1980's, density figures from those surveys where 0.05 crocodiles per kilometer (Whitaker & Whitaker 1989).

The estimated population size in the surveyed area is 34 or 35 individuals, which also implies that the population in the area is viable and that the population has increased in size since the surveys by Cox J and Whitaker R in the 1980's (Whitaker & Whitaker 1989).

Habitat
A lot of the land around Batu Putih is agricultural land, plantations and infrastructure (figure 1). Since the crocodiles seems to avoid being in close proximity to Batu Putih it might be because the habitat does not have a good enough quality. Although 700 m lack of crocodiles observation in three different survey occasions might be to little to draw any conclusions about this. Since the habitat around the surveyed area to a relatively big proportion is protected and the density of humans in the area is low together with the fact that hunting is forbidden provides a good habitat for the saltwater crocodile.

Conclusions and future directions
The human activities in the area of the Kinabatangan River surveyed do not seem to have a major effect on the crocodile population in the area. This study shows that close and extensive monitoring is needed to draw fully reliable conclusions, this is in agreement with Webb *et al.* (2010). However it also shows that disturbances such as fishing, boat traffic and human altered habitat might have an effect on the saltwater crocodiles in this area. Hence, higher amount of disturbances and increased exploitation of the area around the Kinabatangan River in the future might lead to diminishing populations of the saltwater crocodile. Therefore, knowledge of the species' ability to handle disturbances and continuous monitoring of the population is necessary. This, together with preserved surrounding habitat and further protection of the species will most likely sustain the saltwater crocodile population in the Kinabatangan River.

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Appendix 1

Protocol for disturbance index assessment

Shore

A Habitat - *how disturbed is the shore habitat in the area*

1. Undisturbed/natural habitat
2. Small degree of disturbance
3. Mosaic/patchy - patches with very disturbed areas mixed with undisturbed patches
4. Urban/high degree of disturbance

B Presence of humans in area

1. Total absence
2. Few people visit area; no regular visits, no settlements or economic activities
3. Regular presence, both tourists and local visit the area regularly, economic activities might be present or only few but constant settlement
4. Constant high presence of people, lots of settlement

C Presence of settlements

1. No settlements
2. Temporary settlements
3. Few constant settlements
4. Many constant settlements

D Presence of fishing/other economic activities

1. No fishing
2. Occasional fishing, few people fishing
3. Regular fishing but not every day
4. Fishing every day, many people fishing

Water

A Intensity/presence of boats without motor (how many boats are passing by the area and how often during a day)

1. No boats
2. Few boats, no regular visits
3. Frequent/regular boat traffic
4. Constant, high presence of boats

B Intensity/presence of boats with motor

1. No boats
2. Few boats, no regular "visits"
3. Frequent/regular boat traffic
4. Constant, high presence of boats

C Intensity/presence of fishing equipment (i.e. traps, nets)

1. No equipment
2. Low abundance of fishing equipment, only a few nets/other equipment
3. Medium abundance of fishing equipment
4. High abundance of fishing equipment

D Presence of visible rubbish in the river

1. No rubbish
2. Small amounts of rubbish (1 to 15)
3. Medium amounts of rubbish (16 to 50)
4. *High amounts of rubbish (>50)*

Appendix 2.

Protocol for night counts

			CLASS						
Date	Transect	GPS	0	1	2	3	EO	Time	Comment