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DENSITY AND ABUNDANCE OF THE IRRAWADDY DOLPHIN, *ORCAELLA BREVIROSTRIS*, IN THE MAHAKAM RIVER OF EAST KALIMANTAN, INDONESIA: A COMPARISON OF SURVEY TECHNIQUES

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ABSTRACT. – On-going monitoring surveys are being conducted on a freshwater Irrawaddy dolphin population, locally referred to as the Pesut, inhabiting the Mahakam River in East Kalimantan, Indonesia. The aim of the study is to provide detailed information on the abundance, distribution, and ecology relevant to conservation of this population. This paper describes results from surveys in February 1999 - July 2000 that relate to population abundance estimates and compares different survey techniques. The primary goal of these investigations is to develop a conservation program for effective management of Indonesia's only freshwater dolphin population, which is considered to be critically endangered. In this study, both modified strip-transect and direct count survey-methods were employed. Total search effort in the Mahakam River amounted to 4260 km (397 hours). Results of eight sighting surveys indicate that the dolphins in the mainstream Mahakam range from 180 km above the mouth to 480 km upstream, seasonally inclusive of several tributaries and lakes. However, dolphins are reported to sporadically move as far down- and upstream as 80 km and 600 km, respectively. The distribution of the dolphins changes seasonally and is influenced by water levels and variation in prey availability. The middle Mahakam area (MMA) and tributaries between 180 km and 350 km upstream were identified as primary dolphin habitat, based on highest dolphin densities. Sighting rates calculated for medium water levels in the MMA in 1999 and 2000 are nearly similar (ca. 0.09 dolphins/ km, CV=25%, 49%). Highest sighting rate for the MMA was recorded at low water levels (0.142 dolphins/ km, CV=51%), indicating that dolphins are congregating in the main river in deeper waters. Lowest sighting rate was recorded at high water levels (0.035 dolphins/ km, CV=33%), suggesting that dolphins have moved upstream into the tributaries. Total mean abundance-estimates, based on density estimates and direct counts, were both 34 dolphins. However, the mean estimate based on density estimates exhibited more variation (CV=25%), than the mean direct count estimate with associated CV of 5%. Unless a modified density sampling technique has been developed that is appropriate to the river conditions and takes into account dolphins daily migrations between main river and tributaries, direct count studies seem a more useful tool for assessing abundance of this particular freshwater population.

KEY WORDS. – Freshwater dolphin, Irrawaddy dolphin, *Orcaella brevirostris*, Mahakam River, Indonesia, survey techniques, abundance, density estimates.

INTRODUCTION

River dolphins and porpoises are among the world's most threatened mammals. The habitats of these animals has been degraded by human activities, in some cases resulting in dramatic declines in their abundance and range (Reeves et al., 2000). In Indonesia, one facultative freshwater dolphin population of *Orcaella brevirostris*, or Irrawaddy dolphin (locally referred to as Pesut) inhabits the Mahakam River and associated lakes in East Kalimantan. The species is found in shallow, coastal waters of the tropical and subtropical Indo-Pacific and in the Mahakam, Ayeyarwady and Mekong river systems (Stacey & Arnold, 1999). The status of the Irrawaddy dolphin in the Mahakam River was changed from 'Data Deficient' to 'Critically Endangered' in the IUCN Red List of Threatened Animals in 2000 (Hilton-Taylor, 2000). The species is protected in Indonesia and has been adopted as a symbol of East Kalimantan.

Preliminary investigations on population abundance were made from late February 1997 to early April 1997 (Kreb, 1999). Thereafter, the current research project was undertaken, which began in February 1999 and will continue at least until November 2001. This paper describes research on dolphin abundance and an evaluation of the methods employed during surveys in February 1999 to July 2000.

Relatively few published studies exist on the Irawaddy dolphin population in the Mahakam River. Studies so far have focused on their distribution and daily movement patterns in Semayang-Melintang Lakes and, in the region connecting the Pela and Melintang tributaries (Priyono, 1994), and on bio-acoustics (Kamminga et al., 1983). Earlier reports on their abundance were given by the Indonesian Directorate General of Forest Protection and Nature Conservation, which reported the existence of a population of 100-150 individuals for Semayang Lake, Pela River, and adjacent Mahakam River (Hardjasasmita, 1978) and an estimate of 68 individuals by Priyono (1994). However, no methods were presented about how both estimates were derived and these estimates may be merely guesses. A preliminary survey conducted by the author together with the East Kalimantan Nature Conservation Department reported that encounter rates in the middle Mahakam segment were 0.06 dolphins per linear kilometre in 1997 (Kreb, 1999).

MATERIAL AND METHODS

Study area

The Mahakam River is one of the major river systems of Kalimantan and runs from 118° east to 113° west and between 1° north and 1° south (Fig 1). The climate is characterised by two different seasons, namely dry (from July-October, southeast monsoon) and wet season (November-June, northwest monsoon) (MacKinnon, 1997). However, dry and wet periods alternate during the wet season as well. The Mahakam River is the main transport system in the central part of East-Kalimantan. The river measures about 800 km from its origin in the Müller Mountains to the river mouth. The Semayang and Melintang Lakes are 10,300 hectares and 8,900 hectares, respectively (MacKinnon et al., 1997). Average widths of the river in the upper segment (from Long Bagun to Muara Benangak), middle segment (Muara Benangak to Muara Kaman) and lower segment (Muara Kaman to Samarinda), are 160 m, 200 m and 390 m, respectively, determined from visual estimates (see Survey methods). Highest mean transparency measured in the main river at low water levels is 24 cm (range 10-35 cm). Mean depths in the upper, middle, and lower segments, and in Semayang and Melintang Lakes were 10 m, 15 m, 12 m, 1.1 m and 1.3 m respectively. Differences in the water levels of the main river between high and low water conditions range as much as 10 m in 'normal years' (during extreme drought a maximum difference of 20 m may be recorded), whereas the maximum difference in lakes is ca. 5 m. Water levels rise vertically and only slightly horizontally. Large passenger boats are able to navigate up to Long Iram (ca. 427 km upstream). These boats of maximum 800 hp are only able to move as far upstream as Long Bagun (ca. 560 km upstream) at high water levels. Rapids begin upstream of Long Bagun, which are only navigable by large motorised canoes (minimum 40 hp). These rapids limit dolphins from ranging further upstream.

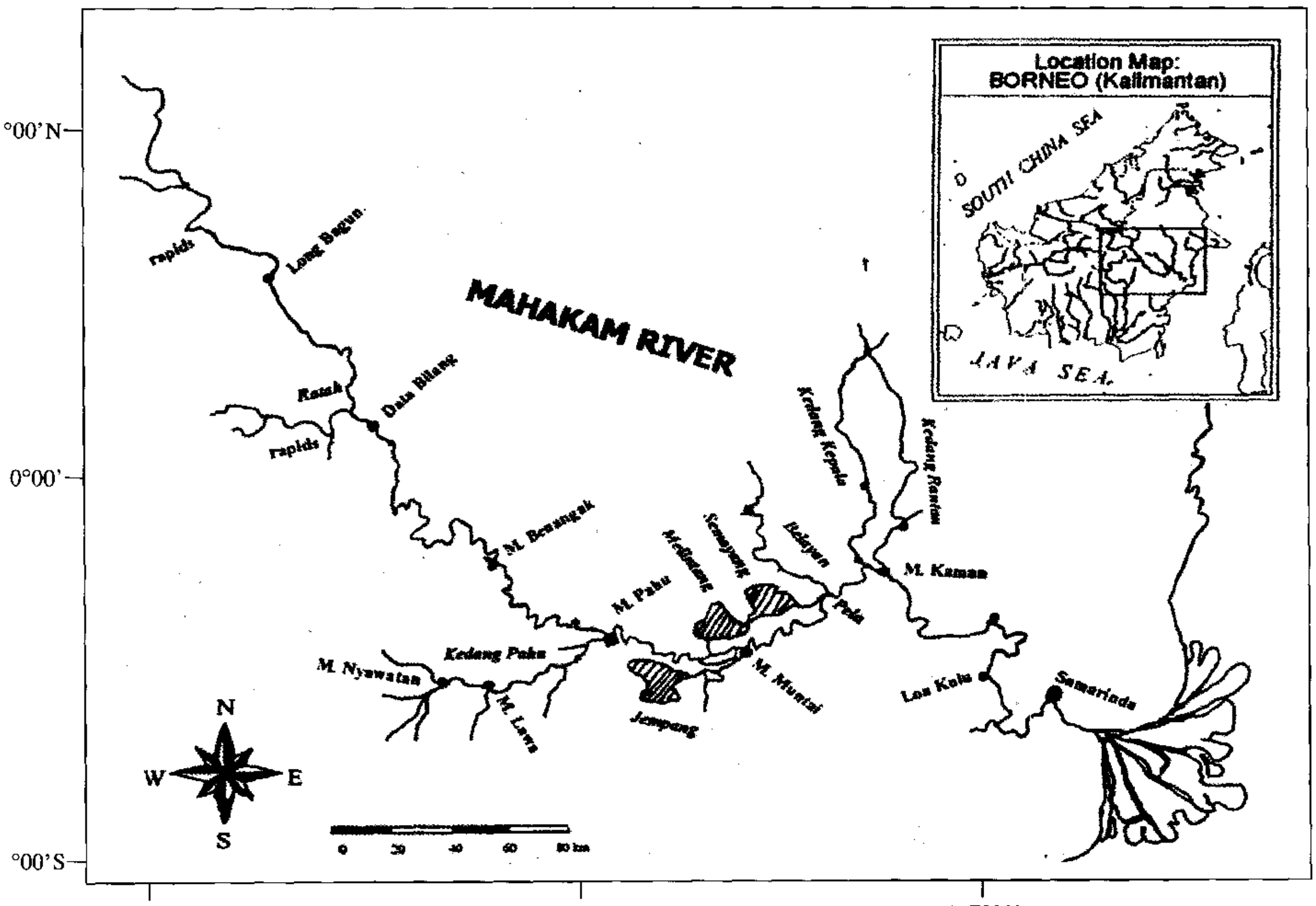

Fig. 1. Map of the Mahakam River, East Kalimantan, Indonesia. Names of places that begin with Muara, meaning confluence area, are abbreviated with M.

Coal mining, gold digging and logging activities pollute waters throughout the Mahakam. Fisheries in the middle segment of the Mahakam River and Semayang, Melintang, and Jempang Lakes are intensive, with an annual catch of 25,000 to 35,000 metric tons since 1970 (MacKinnon et al., 1997).

Field methods

Survey area. – Three surveys covering the entire study area were conducted in 1999 at low, medium and high water levels and one survey at medium water levels in 2000. Each one took about 4 weeks. Survey coverage included Ratah, Kedang Pahu, Belayan, Kedang Kepala, Kedang Rantau tributaries, Semayang and Melintang Lakes, as well as connecting tributaries, Pela and Jempang, part of the delta area, and minor tributaries (Fig. 1).

It was not possible to survey representative transects and extrapolate because of the unpredictable variation of dolphin densities. Therefore, the entire range of dolphins in the Mahakam was surveyed. Ranges for different seasons were identified during preliminary surveys and from interviewing fishermen about the dolphins' occurrence and their prey. To study the relation between fish- and dolphin migrations, interviews were held at different locations along the river to identify seasonal fish abundance for 25 species including those suspected or known to be preyed upon by dolphins. Generally, dolphins did not frequent upstream areas of tributaries, where there was no more connection with freshwater swamp lakes that replenish the river with fish. If during the survey, the water conditions were such that no dolphins were expected to occur in a particular area of a tributary and interviews with fishermen confirmed their absence for that period, the area was not surveyed. Water conditions in upstream areas of some tributaries connected with freshwater swamp-lake habitat, which did not favour dolphin occurrence during particular seasons were flooding, heavy currents in combination with lots of floating tree trunks, aquatic weeds and a high acidity. Also, decreasing water levels caused the dolphins to move downstream in the tributaries together with their prey. During one of the four intensive surveys conducted in May/ June 2001 at medium, decreasing water levels, areas that didn't seem likely to be visited by the dolphins at that particular water level condition were nevertheless visited to check if this was true. Indeed no dolphins were found in these areas, which represented upstream areas of particular tributaries.

Seventeen transect lines were surveyed in different habitats. Table 1 presents only those transects on which at least one sighting was made during one or more seasons. Each transect could be finished within one day. Eight transects were in the main river (ca. 66 km), two were in the lakes (ca. 48 km), five were in four middle segment tributaries (ca. 50 km), and two were in upper segment tributaries (ca. 32 km). In addition to transects, narrow tributaries that become accessible during high water levels for boats and potentially for dolphins were also surveyed.

Survey methods. – Modified strip-transect surveys were conducted, using the width of the river as the strip width for each transect within the identified dolphin distribution area. Modification thus included that strip width was not calculated as a function of perpendicular sighting distance because this distance was not a function of detection probability but of dolphins preferred distribution along the width of the river due to restrictions imposed by river width (see Results, Detection probability). Line-transect surveys were only conducted in Semayang and Melintang Lakes. Parallel line-transects were spaced at 1.5 km apart. Transect lines in the lakes were systematically designed to cover the entire survey area and no prior assumptions were made regarding dolphin distribution.

Within the dolphin distribution area, the vessel always travelled in the central part of the river, even in river bends, which was possible because the main river was deep enough to do so. Only in areas where width of river was less than 100m, such as in some tributaries, was the boatsman free to travel near the riverbank. The widest arms of the delta area (width = >400 m) were surveyed following a zigzag pattern.

Various environmental random samples, such as depth, clarity, pH and surface flow rate were taken on average five times a day at 3-5 spots along the width of the river, but only depth and clarity samples were analysed at the time of writing and presented in the survey area text. Depth was measured by lowering a rope with attached weight and markings every meter to the bottom of the river. Transparency was measured using a Secchi disk. When taking the depth and clarity measurements, the boat would drift with the flow so that the rope would be hanging in a straight line.

The river was scanned from an elevated platform (eye-height ca. 3 meters above water level) on top of a motorised boat (12 hp) moving at a speed of ca. 10 km/ hr in the central part of the river, covering an average distance of 50 km per day. The observation team consisted of at three observers, who rotated at 30-minute intervals. The first observer scanned the river continuously with 7x50 binoculars. The second observer searched for dolphins with naked eyes and recorded search effort and geographical data every 15 minutes by aid of a GPS. At the same time, environmental data were recorded, such as rain, wind, sun glare, fog conditions, cloud coverage and the extent to which floating tree logs and water weeds impaired sighting ability. Survey effort was suspended when sighting conditions were such that they impaired sighting efficiency due to heavy rainfall and fog. Sun glare was never so bad that survey effort had to be ended and was anticipated by using a good binocular, head protection and sunglasses. The front observers alternated scanning with binoculars every 15 minutes to keep concentration high. During the first survey, a rear observer was present during the entire survey in primary dolphin habitat. All dolphins that were sighted by this observer involved groups that were located in or just after a river bend. Therefore, during the next surveys a rear observer was only present during and after river bends and confluence areas to allow the third observer at the rear to regain concentration for the next turn at the front observers' position.

Upon sighting dolphins, linear sighting distance and position of the first sighted dolphin along the width of the river was recorded (for calculation of relative perpendicular sighting distances). Dolphin positions were recorded in one of the following three categories. The central part was defined as the nearest area on each side of the transect line that occupies 25% of half the river width. On each side of the transect line, the area in between centre and shore occupied 50% of half the river width. The shore area was defined as an area of 25% on each side of the transect line nearest to the shore. Distance to the dolphins was estimated visually by the observer. A bridge of known distance that crossed the river in Samarinda, was taken as a reference for further distance estimations. During the survey, each fifteen minutes, the river width was estimated and agreed upon by all observers so that distance estimations became more standardised. In addition, observers now and then referred to floating objects in the river and tried to standardise their estimation. During sightings, for between one half-hour and one hour, dolphins were counted, identified and their group composition was recorded (see Group size and sighting definition). The upper picture in Fig. 2 (a) portrays two adults and one calf in the centre. Because of the group's tight formation calves may easily remain undetected. Therefore observation time was rather long to allow for most accurate group size estimation. By aid of binoculars and naked eye alone observers tried to look for identifiable marks on the dolphin's body and dorsal fins and drawings were made of the marks. Also, photographs and video footage were taken for identifying individual dolphins, but these analyses are not yet complete. The picture in the centre of Fig. 2 (b) shows a typical slow surfacing pattern, which enables observers to notice and photograph natural markings on the dolphin's body. General and individual behaviours were recorded in combination with group- dive and surfacing times. Group diving times were collected during 14 sightings and were recorded for ca. 30 minutes from the start of a dolphin's dive and the surfacing of the next dolphin. However, time gaps of less than 3 seconds were ignored to reduce a bias towards short dive time intervals and were included in the duration of group-surfacing, i.e. the time a group is available on the surface for observation. The picture below in Fig. 2 (c) shows a dolphin surfacing after a deep dive, producing a loud blow. Also during a 'normal' dive and surfacing pattern, the dolphins regularly produce blows, facilitating detection. Finally after all observations were made, the same kinds of samples were taken as those during search effort.

Double counting. – By the aid of identification of individual dolphins, I attempted to prevent double counting of dolphins on the same transects. Additionally, for the direct count analysis, I tried to reduce double counting of the same group or subgroup (in the case of an aggregation of dolphin groups) encountered on different transects. The following assumptions were made when determining if groups were similar: 1) minimally one individual of the (sub) group was re- identified. 2) similar age-classes. 3) similar (sub) group sizes, i.e., within the range of minimum and maximum group size estimates, as the earlier encountered group. 4) time elapsed between both encounters and distance between both locations should be in accordance with dolphins' movements (mean speed is < 6 km/ hr). 5) absence or presence of dolphins that are easily recognisable by naked eye in only one of both groups did not favour similarity. 6) in case of any uncertainty, a non-conservative approach was preferred and groups were considered to be different.

Preliminary analysis of studies of dolphins that were followed in one confluence area during three periods for on

Fig. 2a. Two adults and one calf in the center swimming in tight formation.

Fig. 2b. Typical slow surfacing pattern enabling the observers to take notice of natural markings on the dolphin's body and dorsal fin by aid of the naked eye and binoculars.

Fig. 2c. A dolphin surfacing after a deep dive, producing a loud blow. Also during a 'normal' dive and surfacing pattern, the dolphins regularly produce blows, facilitating detection.

average six consecutive days, revealed that group composition during these days was relatively stable. That is to say, close interactions among different groups never exceeded one hour, which is the time that is spent observing the dolphins during surveys, which aim to identify total abundance of the population. Opposite to the problem of double counting is the problem of dolphins that moved in one direction at night whereas the survey team would move in the other direction and thus miss a sighting. However, replicates of surveys may account for this problem.

Group size and sighting definition. – For the calculation of sighting rates, mean group sizes are multiplied by number of sightings and divided per linear kilometre of river surveyed. To this aim it is necessary to determine what constitutes a sighting or group. Within this study, dolphins that are leaving the initial observed group of dolphins, i.e. moving outside the visibility of the observers (ca. 400 meters), which remain close to the initially sighted group during the observation period (on average one hour), are considered to belong to another group and constitute a new sighting. On the other hand, new dolphins that join the initial group are included in the group size estimate unless they move away from the initially sighted group within the observation period. Although for the new group no sighting distance data are available, the approach of defining group size as described above is preferred for the density and abundance estimates because the chance of a sighting of a group, whose composition remains the same during the observation period, is higher than the chance of encountering an opportunistic aggregation of different dolphin groups. The decision to separate dolphin groups because of their non- or short-duration interaction also makes comparisons of mean group sizes and number of sightings more meaningful among different surveys.

Of the 58 sightings and groups of dolphins in total that were used to calculate the abundance and density estimates presented here, three sightings involved dependent sightings of groups that only interacted for a brief time during the observation period. Therefore, they were treated as three different sightings. The following example is given to elucidate what constitutes a dependent sighting: After an initial sighting was made of 3 individuals, which were followed downstream, another group of 9 dolphins was encountered. However, the initial group of 3 dolphins moved downstream away from the new group. While continuing observation on the group of 9 dolphins, another group of 3 dolphins from upstream joined the group for a moment and then moved into a small tributary, whereas the group of 9 dolphins moved upstream. So, instead of considering this as one sighting with 15 dolphins, I consider this as 3 different sightings and groups.

The size of the group upon initial sighting includes all dolphins visible to the observers using a best, minimum and maximum estimate. Final decision about the group size estimation was taken by the primary researcher. In most cases at least one-half hour was needed to get a good count (depending on the group size), carefully looking for natural markings to identify individuals and determine if two surfacings were made by the same dolphin.

Availability bias and perception bias. – To account for undetected dolphins due to the dolphins' submergence within the observers' visibility field (availability bias) and reducing observers' perception bias (those dolphins that surface in the visual range, but are still missed by all observers), a rear observer was present (see Survey methods). An attempt was made to reduce perception bias by suspending survey effort when sighting conditions were such that they impaired sighting efficiency, due to heavy rainfall and fog. Sun glare was anticipated by using a good binocular, head protection and sunglasses. Finally, scanning bouts with binoculars were rather short, i.e. 15 minutes, to keep concentration high. For comparison of increased sighting efficiency, two additional seasonal surveys (besides the four focal seasonal surveys described in this paper) of higher observer' intensity were conducted. Each of these surveys covered the same transects in primary dolphin habitat and one observer was added to the observer team that now consisted of 4 observers (two front observers, one rear observer and one observer stand-by).

Analysis methods

Mean sighting frequencies were calculated per transect, habitat segment and water level condition (Table 1). Mean number of sightings and sighting rates were calculated as the mean number of sightings and sighting rates of upstream and downstream surveys per transect and water level condition. Except for one segment representing a line transect in a lake, all transects were replicated per water level condition. For the lake transect that was only surveyed once, the number of sightings recorded were taken as the mean in order to be comparable with the other mean number of sightings, assuming that a replicate survey in the same period conducted in this lake would yield the same results.

For the calculation of mean dolphin densities, the mean river width per segment was taken as the mean strip width. Abundance estimates were calculated for each transect as a product of dolphin densities and total transect area completed. Estimates per transect were summed to get total abundance per water level condition.

To check for the variation in abundance estimates derived from different surveys, the coefficient of variation was calculated directly from the variance of each seasonal estimate in relation to their mean. Because of the assumption that all groups within the strip width would be detected by either front or rear observers (see Analysis, Detection probability), the fact that there was no group size bias detected, and the entire possible range of dolphins was covered for each survey (except for high water levels), no other components were included in the calculation of CV. Although a considerable variation in group-size was found among different surveys, this is more likely to reflect a biological variation than a size bias related to detection probability. Therefore, instead of calculating the variance of numbers of sightings and group sizes, the CV was directly applied to the abundance estimates. The estimates of the high water level survey were excluded because several transects were not completed. In addition, CVs were calculated per habitat segment, i.e. for the middle-river segment and two tributaries per water level condition to check for the variation of sighting rates among different transects (see formula below). Of the other habitat segments only one transect was completed per water level condition and these segments represented secondary habitat, in which only during specific seasons dolphins were sighted. Therefore, no CVs for seasonal abundance estimate were calculated, but the CV for the middle- river segment may be used as an indication of seasonal variation. Lastly, CVs were calculated for different river segments for the mean abundance estimates of surveys that were both conducted at medium water levels in 1999 and 2000:

$$R_i = \frac{g.n}{L}$$

$$D_i = \frac{R_i}{W_i}$$

$$N = \Sigma\,(D_i.\ A_i)$$

$$S(R_i) = \sqrt{\Sigma \frac{(r_j - R_i)^2}{(x_j - 1)}}$$

$$CV = \frac{S.100}{R_i}$$

Where g = mean group size
R_i = mean sighting rate per river segment;
r_j = mean sighting rate per transect
i = river segment;
j = transect
n = number of sightings;
L = length of transect completed
D = mean dolphin density;
W = mean strip width
N = total abundance within survey area;
A = total transect area
S = standard deviation;
x_j = number of transects completed
CV = coefficient of variation

All sightings are included in the analysis of sighting rates, density- and abundance estimates based on density sampling techniques, except for double counts within one transect and off effort sightings. For direct counts, double sightings on different transects per one-way survey were excluded. In case uncertainty existed about whether two groups consisted of the same dolphins, a non-conservative approach was chosen and these numbers were added in total count. The sightings made by the rear observer are included in total abundance estimate calculations of both survey methods. The percentage of sightings made by front and rear observers are presented in Table 2. Sightings made in one tributary of the upper river segment involved one group of 5 dolphins whose movements were restricted in an area of ca. 1 km by two rapids. Sightings made during medium- and high water levels in 1999 are off-effort sightings by other persons than the survey team. The survey team was not able to move upstream of the rapids because of heavy currents due to recent rainfall. However, according to different people in this area, the dolphins have moved upstream of the rapids since October 1998 during a big flood. Because of the overall low sample size these sightings are included in the abundance estimates and because they were confirmed during the next surveys.

Correction factors to account for undetected dolphins have been left out because there is a lack of a detailed dive time study. Therefore, it is tentatively assumed that all dolphins will be sighted by front or rear observers within the primary dolphin habitat (middle river-segment, mean width = 200m, SD = 54), upper river segment (mean width = 161m, SD = 48), and tributaries (max width of 150m). Because linear sighting distances only start decreasing after 400m with 100%, and the survey boat always travelled in the central part of the river, these sighting distances are within the above-mentioned width ranges (see Results). Linear sighting distances of rear sightings and of sightings made in narrow tributaries with many river bends where the average distance between two bends < 400 m were excluded from analysis. Sighting distances of dolphins in river bends are most likely to be restricted as maximal sighting distance is dependent on the distance of two river bends, whereas the sighting distances made by the rear observer may be influenced by the boat's engine while passing by.

Detection probability. – Sighting probability was investigated for the following variables: 1) Firstly, linear sighting distances were plotted against the number of sightings made (Fig. 3) and tested with chi-squared statistics to investigate if there are significant differences in detection probability of dolphins within the strip width. 2) Relative perpendicular sighting distances were expressed in percentages over three categories in relation to the number of sightings. 3) In addition, the correlation between linear sighting distances and group sizes was investigated and the correlation was measured with the coefficient of determination (r^2) (Fig. 4). 4) Group dive times were plotted against group size and the Spearman Rank correlation coefficient (r_s) was calculated (Fig. 5).

I preferred to calculate relative perpendicular sighting distances (PSD) because of biases related to the calculation of absolute PSD such as variation in river width between different river segments, and the fact that the vessel cannot maintain a straight course in river bends, leading to biases in calculation of PSDs, whereas many sightings are associated with river bends. In addition, the dolphins restricted and preferred distribution along the width of the river causes both relative and absolute PSD to be of little value to define strip widths as they do not reflect observers' sighting abilities. Therefore, I did not calculate the probability density function at zero perpendicular distance f(0).

RESULTS

Density and abundance estimates

Total search effort in the Mahakam River amounted to 4260 km (397 hours). Actual sightings in the main river segment were confined between Muara Kaman (ca.180 km upstream) and Muara Benangak (ca.375 km upstream) including tributary Belayan (1 km upstream), tributary Kedang Pahu (max. 80 km upstream), tributary Ratah (480 km upstream main river and 20 km upstream the tributary past a rapid) lake effluent Pela and Lake Semayang (Fig. 1). However, depending on water level conditions, the dolphins may move as far downstream in the main river until Loa Kulu (80 km upstream of mouth), whereas their uppermost distribution is limited by the high rapids past Long Bagun (560 km upstream of mouth).

Sighting rates for each transect and river segment in which dolphins were sighted are in Table 1. Dolphins were sighted in 6 different habitat segments: middle-river segment (MR, mean width = 200m, SD = 54); narrow middle-river tributary connected with confluence area with highest dolphin densities ($MRT_{1.1}$, mean width = 43m, SD = 13); middle-river tributary in swamp lake area ($MRT_{2.1}$, mean width = 81m, SD = 13); very narrow upper segment ($MRT_{1.2}$, mean width = 34m, SD = 14) of the middle river tributary ($MRT_{1.1}$), which falls dry in dry season; upper-river tributary with rapids and rock bottom substrate (URT_1, mean width = 75m, SD = 11); Lake Semayang, surrounded by freshwater swamp forest habitat (LS).

Mean sighting rates for medium water levels in 1999 and 2000 are nearly similar in the MR segment (0.092 dolphins/ km and 0.096 dolphins/ km with CVs of 25% and 49%). The maximum mean sighting rate for the MR segment was recorded at low water levels (0.142 dolphins/ km, CV = 33%), whereas lowest mean sighting rate in this segment was recorded at high water levels (0.035 dolphins/ km, CV = 51%), indicating that dolphins have moved upstream in the tributaries. Also, the dolphins' seasonal movements followed changing water levels and seasonal variations in prey availability. Mean sighting rate and mean abundance of the combined medium water level surveys is 0.09 dolphins/ km and 19 dolphins (CV = 35%) in the entire MR segment and 0.134 dolphins/ km and 10 dolphins (CV = 97%) in the $MRT_{1.1}$ segment. No significant differences in mean abundance of dolphins were found between the average abundance of dolphins per transect in the MR segment (mean width = 200 m) and the transect in the $MRT_{1.1}$ segment (mean width = 43m) ($c^2 = 0.77$, d.f. = 1, $p > 0.05$). Mean abundance in the $URT_{1.1}$ segment at medium water levels is 4 dolphins (CV = 40%). Total mean abundance estimate of three completed (medium water levels 1999 and 2000 and low water level 1999) and replicated (up-and downstream) surveys based on density estimates (calculated from strip-transects) and direct counts are both 34 dolphins (with respective CVs of 25% and 5%).

Mean group sizes of dolphins observed at medium, high and low water levels in 1999 and medium water levels in 2000 are 3.2 dolphins (median = 3; range = 1-7; SD = 2.1), 2.6 dolphins (median = 1; range = 1-6; SD = 2.3), 3.8 dolphins (median = 3; range = 1-8; SD = 2.3) and 5.7 dolphins (median = 5; range = 3-10; SD = 2.4) respectively.

Detection probability. – When calculating the percentages of initial sightings in relation to relative perpendicular sighting distances (position along the width of the river), I found that the number of initial sightings peaked near the shore (45% of total n = 49), but not significantly ($c^2 = 2.9$, df = 2, $p>0.05$). The remaining sightings were nearly equally spread over the two other segments, i.e. the centre area of the river (29%) and the area in between centre and shore (26%). On the other hand, the number of sightings (total n = 33) were found to decrease sharply with 100% only after 400m linear sighting distance (Fig. 3). No significant variation was found among the sighting distances inside of 400 m ($c^2 = 5.3$, df = 5, $p>0.05$). Because the maximum mean river width for one of the transects (MR_1) within dolphin distribution area is 238 m (range = 120 m – 400 m, SD = 62 m), there is no apparent bias towards undetected dolphins near the shore, because maximum sighting distances are greater than one-half the survey strip. Therefore, I assumed that the probability of sighting dolphins was uniform throughout the survey trip.

Because I found no distinct decrease of sightings in relation to perpendicular sighting distances, linear sighting distances (n = 35) were plotted against group size to see if there is any detection bias for any group size (Fig. 4). No significant correlation was found between the two variables ($r = 0.132$, df = 33, $p > 0.05$) and only 1.7 % of the variation in group-sizes is accounted for by variation in linear sighting distances ($r^2 = 0.017$).

Dolphin group dive data were collected only during 14 sightings. However, results presented in Fig. 5 seem to indicate that group dive times are negatively related with group size, i.e. small groups have longer mean group dives per sighting than large groups ($r_s = 0.665$; $p < 0.01$; n = 14).

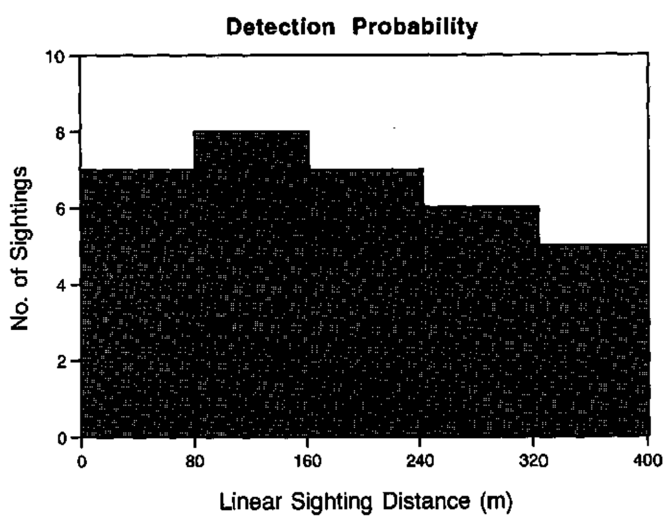

Fig. 3. Histogram showing the frequency of sightings per linear sighting distance category.

Table 1. Sighting rates, density and abundance estimates for each transect where dolphins were sighted. This table only presents those transects on which during one or more season at least one sighting was made. Each transect was replicated for each water level condition and number of sightings in this table represent the means of the replicated surveys. Symbols used: $MR_{1,2,3}$ = middle river segment = Muara Kaman – Muara Benangak; $MRT_{1.1,1.2}$ = Kedang Pahu tributary; $MRT_{1.1}$ = Muara Pahu – Muara Lawa; $MRT_{1.2}$ =Muara Lawa – Nyawatan; $MRT_{2.1}$ = Belayan tributary = Muara Belayan until Tuana Tuha; URT_1 = Ratah tributary = Muara Ratah – rapids; LS = Lake Semayang; n = mean number of sightings per replicated transect ; R = mean sighting rate; D = mean density; N = total abundance; ; g = average group size per water level; i = habitat stratum; W = mean strip width; L = transect length; - = no data available because of non-surveyed area; # = no density calculated because of unknown strip width; CV = coefficient of variation.

HABITAT	Transect	(Km)	(Km)	Medium Water Levels '99 mean g = 3.2 dolphins				High Water Levels '99 mean g = 2.6 dolphins				Low Water Levels '99 mean g = 3.8 dolphins				Medium Water Levels 2000 mean g = 5.7 dolphins			
				mean n	mean R_i	mean D_i	N_i	mean n	mean R_i	mean D_i	N_i	mean n	mean R_i	mean D_i	N_i	mean n	mean R_i	mean D_i	N_i
MAIN RIVER	$MR_{1,2,3}$	0.200	207	6	0.092	0.2	19.2	2.5	0.035	0.18	6.5	7	0.142	0.71	26.6	3.5	0.096	0.48	19.9
	MR_1	0.200	69	2	0.092	0.46	6.4	1	0.038	0.19	2.6	2	0.110	0.55	7.6	0.5	0.041	0.20	2.9
	MR_2	0.200	69	1.5	0.069	0.34	4.8	0.5	0.019	0.09	1.3	3	0.165	0.83	11.4	1.5	0.123	0.61	8.6
	MR_3	0.200	69	2.5	0.115	0.46	8	1	0.052	0.26	2.6	2	0.152	0.76	7.6	1.5	0.123	0.61	8.6
TRIBUTARY	$MRT_{1.1}$	0.043	76	1	0.042	0.98	3.2	0	0	0	0	0	0	0	0	3	0.225	5.23	17.1
	$MRT_{1.2}$	0.034	30	—	—	—	—	1	0.086	2.5	2.6	—	—	—	—	0	0	0	0
	$MRT_{2.1}$	0.081	45	0	0	0	0	—	—	—	—	1	0.084	1.03	3.8	0	0	0	0
	URT_1	0.075	33	1	0.1	1.3	3.2	1	0.08	1.1	2.6	1	0.12	1.6	3.8	1	0.172	2.29	5.7
LAKE	LS	—	52	0	0	0	0	1	0.05	#	2.6	—	—	—	—	—	—	—	—
	N (strip)			8			25.5	5.5			14.3	9			34.7	7.5			42.7
	$CV(R_{(MR)})$						25%				51%				33%				49%
	N (count)						34				18				32				35

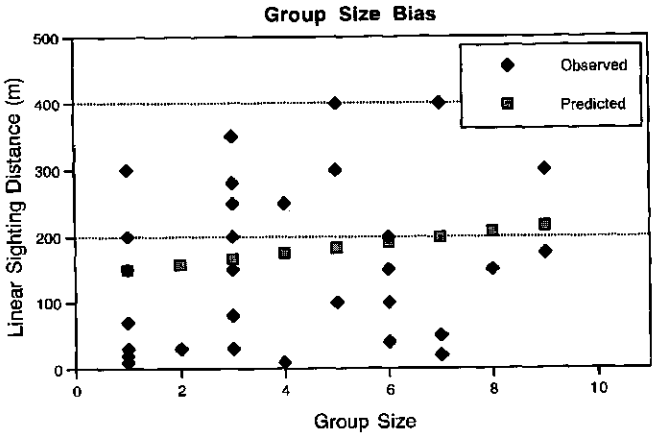

Fig. 4. Scatter plot of linear sighting distances and group size indicating probability of any detection bias related to group size.

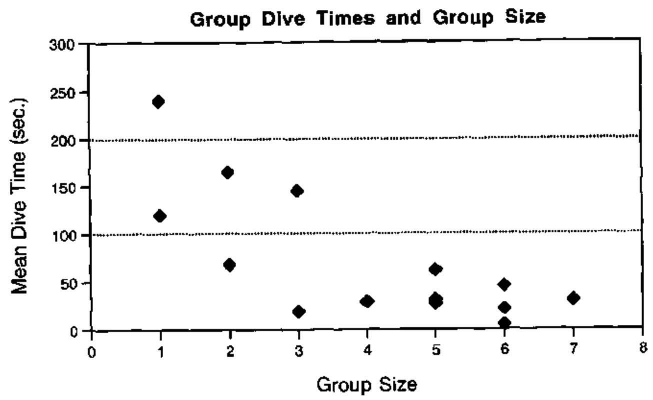

Fig. 5. Scatter plot showing a negative relation between group size and mean group dive times.

Mean of all average group dive times per sighting is 72.0 sec (median = 38.3; SD = 69.2; range = 5-240). Mean time that a group of dolphins is visible per surfacing (time between first dolphin's surfacing and last dolphin's diving allowing for maximum interval of 3 sec.) is only 2.5 seconds (2-6 sec). Although a lower detection probability is expected for dolphins with a small group size due to longer dive times, no detection bias was found for any given group size in relation to sighting distance as stated earlier (Fig. 4). Additionally, single dolphins were frequently observed: 29% of all on effort sightings (n = 49) constitute single dolphins.

The percentage of sightings during the four surveys covering the entire dolphin distribution range, made by an observer at the front of the boat using binoculars was on average 63 % and that by a front observer without binocular was 31% (total n = 52). On average, during each survey 6 % of all sightings were missed by the front observers, being observed only by the rear observer (Table 2). During two additional one-way surveys at medium to decreasing water levels conducted in the middle-river segment (MR) whereby three transects were completed, observer efficiency was increased from three to four observers (data not presented in table). During each of these surveys, three sightings were made, all by the front observers.

DISCUSSION

Two different methods, strip-transects and direct counts, were employed to estimate abundance for the Mahakam dolphin population. In this study, a modified form of strip-transect surveys was used. Instead of determining the effective strip width based on perpendicular sighting distances, the average entire river width was estimated per segment and used as strip width for density calculation. Two things were evident: 1) Dolphin positions along the width of the river at initial sighting peaked near the shore, (although not significantly) and 2) Linear sighting distances start decreasing slightly after 166 m and number of sightings made at 400 m linear distance have not yet dropped to half the number of sightings at 166 m (62%), but dropped to zero beyond 400 m. Because the maximum river width in the dolphin distribution area is 400 m (with strip width as follows 200 m), it seems reasonable to assume that sighting detection probability is not limited by strip width, but is more likely to be influenced by dolphin availability bias and observer perception bias. Also, river width in the Mahakam does not change much throughout seasons and floods almost only vertically instead of horizontally, in contrast to rivers like the Amazon. Sighting distances and river width estimations are visually estimated and are therefore likely to be biased. However, attempts were made to make distance estimations more standardised among the observers of the survey team and among different survey teams (see Survey methods).

When comparing total abundance estimates that are calculated on the basis of density estimates calculated from strip-transects and those estimates based on direct counts, I found that the latter analysis method produced more consistent results for the three completed surveys (medium water levels in 1999 and 2000 and low water levels in 1999). Total mean abundance-estimates, based on density estimates

Table 2. Observer perception bias (% sightings made per observer category); n = number of sightings.

Observer/Survey period	n	Front observer		Rear observer
		+ binocular	-binocular	
Surveys Feb/ March '99	14	50 %	36 %	14 %
Surveys May '99	8	50 %	38 %	12 %
Survey Oct '99	15	77 %	23 %	0 %
Survey May/June 2000	15	75 %	25 %	0 %
Total / Average	**52**	**63%**	**31%**	**6 %**

and direct counts, were both 34 dolphins. However, the mean estimate based on density estimates exhibited more variation (CV of 25%), than the mean direct count estimate with associated CV of 5%. The higher variation among abundance estimates based on density estimates may arise from the fact that the abundance estimates for different segments, i.e. main river and tributaries, were added together to derive total abundance, whereas dolphins daily migrate between these areas. This problem does not exist for direct count estimates as these daily migrations are taken into account and double counts avoided (see Survey methods). No CVs of total abundance estimates per season were calculated because of the fact that segments other than middle-river segment consisted only of one transect. However, a seasonal CV for abundance was given in the middle-river segment for three completed transects.

The highest sighting rate for the middle- river segment (0.142 dolphins/ km) was recorded at low water levels, indicating that dolphins are congregating in deeper waters of the main river. The lowest sighting rate (0.035 dolphins/ km) was recorded at high water levels, indicating that dolphins have moved upstream and into the tributaries. This movement pattern was also confirmed through interviews with local fishermen and coincides with fish-migration at first flooding. At high water levels, only two sightings were recorded in tributaries. However, this is probably not a representative figure, because three other middle-segment tributaries and the narrow upstream areas beyond tributary 1.2 (Kedang Pahu) were not surveyed. During the low water survey no dolphins were found to occur in the upper river segment, although during a prolonged dry season (more than 3 months) dolphins are said to move to the upper river segment as far as Long Bagun (560 km upstream), as currents are less strong than during the other water conditions in this segment. However, the absence of observations in the upper river segment is not representative of the dry season's low water levels, because of the short duration of the dry season. Also water levels had for a week increased rapidly in the upper segment, due to heavy rainfall. However, data were not included in the high water level category, as this category became of a prolonged period of high water levels and did not extend to the other river segments.

The highest sighting rate recorded during low water levels for the middle Mahakam segment (0.14 dolphins/ km) is similar to sighting rates recorded for Irrawaddy dolphins in a segment of the Ayeyarwady River between Bhamo and Mandalay (0.16 dolphins/ km) (Smith & Hobbs, 2002). Average sighting rates during medium water levels in 1999 and 2000 were 0.09 dolphins/ km and similar to encounter rates recorded during a preliminary survey in 1997 in the same river segment and season (0.06 dolphins/ km) (Kreb, 1999). Compared to other freshwater dolphin species, rates are much lower than those recorded for *Inia geoffrensis* and *Sotalia fluviatilis* in segments of main channel of Amazon River (0.43 – 0.60 and 0.41 dolphins/ km, respectively) (Vidal et al., 1997; Martin & da Silva, 2000), and those recorded for *Platanista gangetica*, varying from 0.2 – 1.36 dolphins/ km (Smith, 2000; Smith et al., 2001). Total abundance estimates in this study of 35-42 dolphins are of the same order of magnitude as those for *Lipotes vexillifer*, of which the 'best guess' of current population size is a few tens of animals (Reeves et al., 2000).

No significant differences were found between the mean abundance of dolphins at medium water levels (when there are no seasonal dolphin migrations) in two different transects (main river and tributary) within the primary dolphin habitat of different mean width (200 m and 43 m) (c^2 =0.77, d.f. = 1, $p > 0.05$). However, when comparing densities, a conclusion may be drawn for example that dolphin densities are higher in a narrow river segment than in a wider river segment, whereas sighting rates and abundance are nearly similar in the two segments. For that reason these densities should not be used for comparison between different river segments or with other studies. Instead, sighting rates and direct counts give a much more useful comparison.

The following data are in favour of the reliability of the abundance estimates presented here: 1) The dolphin availability bias and observer perception bias seem low, and missed sightings by the front observers are partially anticipated for by using a rear observer. Moreover, in spite of a lower detection probability of dolphins with a small group size due to longer dive times, single dolphins were frequently observed (29% of all on effort sightings ($n = 49$) constitute single dolphins). In addition, no correlation was found between group size and linear sighting distance and number of sightings only drop sharply beyond 400 m. 2) There seems to be no bias towards undetected dolphins near the shore because most sightings (78%) were made at linear sighting distances (≥ 166 m) that cover the distance from centre to shore in primary dolphin habitat (mean distance is 200 m). In addition, initial dolphin sightings even peaked near the shore. 3) There is a high similarity of direct count abundance estimates during different surveys (CV =5%).

However, with regard to direct counts a potential bias exists with regard to the estimation of best group size estimates. For this reason, absolute counts in the true sense of the word are not possible. The low number of observers may cause an underestimation of numbers and the fact that rear observers were only present in and after river bends and confluence areas, assuming that most dolphins in straight river stretches would be sighted by the front observers. On the other hand, the detection probability analyses plus the two repeated surveys in 2000 and 2001 with increased numbers of observers in the middle river segment suggest that this factor is not likely to influence the estimates significantly. However, the number of sightings was low during these last surveys as only three transects were covered and not the entire river stretch. So, the surveys with an added observer cannot really be compared in terms of the percentage of sightings that are missed by front observers and observed by rear observer due to unequal sample size.

Recommendations for future studies are to conduct at least a yearly extensive and intensive monitoring survey during the dry season, covering the entire dolphin distribution range with a standard number of observers, i.e. two front observers, one rear observer and one observer at rest for 30 minutes in between 1,5 hours observing bouts. Photo-identification may also be a valuable tool to determine total abundance. Unfortunately, data collection and analyses are not yet complete at time of writing. Also, a detailed dive time study is required to address the dolphin availability bias more properly and the need to include a correction factor. In conclusion, I would say that for assessing abundance of the dolphin population in the Mahakam, both density-sampling techniques and direct-counts seem appropriate and yield numbers of the same order of magnitude. Nevertheless, the direct counts of different surveys exhibit less variation. A simple direct count also was suggested as the most appropriate method for assessing populations of obligate river dolphins (Smith & Reeves, 2000). However, recommendations for future studies in the Mahakam also include to develop a modified density sampling technique that is appropriate to the river conditions and takes into account the dolphins daily movements between the main river and tributaries.

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